# November 5, 2018 Update: MAPMT ADC fitting

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November 5, 2018

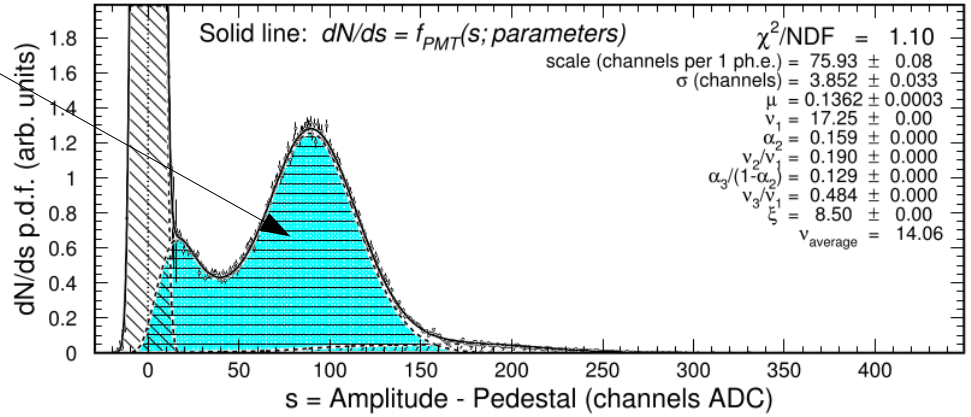
# Overview

- The ADC spectra of the Hamamatsu 12700 MAPMTs are fitted using a model derived by Pavel Degtyarenko
- The form of the model we chose to use has 9 free parameters (= long computation time)
- Found that at least 3 parameters can be fixed without sacrificing fit quality to greatly improve computation time
- Ensured that the fit algorithm works across various settings and modules independently

# Adc Model

## Characteristic fit of the ADC spectrum from CLAS12

Single photoelectron contribution in blue




(c) Hamamatsu H12700 MAPMT GA0133, HV = 1050 V.

$$f(a;\mathbf{d}) = \sum_{n=0}^{\infty} \left\{ G(a,n;\sigma_{\text{eff}}) \left[ e^{-\mu} q_0(n) + \sum_{m=1}^{\infty} P(m;\mu) T(n,m;\mathbf{t}) \right] \right\}.$$

Sum over the number of photoelectrons produced at the first stage of the PMT

Sum over the number of photoelectrons produced at the later stages of the PMT

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# Adc Model cont.

$$\nu_{cL} = \sum_{u=1}^{L} \nu_u i_u$$

$$P(n;\nu) \equiv \frac{\nu^n e^{-\nu}}{n!}$$

$$\sum_{u=1}^{L} \alpha_u = 1,$$

$$T(n,m;\mathbf{t}) = \sum_{\substack{i_1+i_2+i_3=m \\ i_1,i_2,i_3\geq 0}} \frac{m!}{i_1!\, i_2!\, i_3!} \alpha_1^{i_1} \alpha_2^{i_2} \alpha_3^{i_3} P(n;\nu_c),$$

$$f(a;\mathbf{d}) = \sum_{n=0}^{\infty} \left\{ G(a,n;\sigma_{\mathrm{eff}}) \left[ e^{-\mu} q_0(n) + \sum_{m=1}^{\infty} P(m;\mu) T(n,m;\mathbf{t}) \right] \right\}.$$

Sum over the number of photoelectrons produced at the first stage of the PMT

Sum over the number of photoelectrons produced at the later stages of the PMT

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"...wherein the corresponding partial gains, or average multiplicities of the Poissonian components are $\nu_1$, ..., $\nu_L$, their relative contributions to the SPE function are $\alpha_1$, ..., $\alpha_L$..."

# Adc Model cont.

List of PMT model fit parameters.

| Name | Limits | | Brief description |
|---|---|---|---|
| $scale$ | >0 | – | Average amplitude of SPE signals (channels ADC) |
| $\sigma$ | >0 | – | Standard deviation of the pedestal fit (channels ADC) |
| $\mu$ | >0 | – | Average multiplicity of photoelectrons |
| $\nu_1$ | >0 | – | Average multiplicity of the first gain component in (26) |
| $\alpha_2$ | [0, 1] | – | Portion of second gain component in (26) |
| $\nu_2/\nu_1$ | [0, 1] | – | Relative multiplicity of the second gain component in (26) |
| $\alpha_3/(1-\alpha_2)$ | [0, 1] | – | Relative portion of third gain component in (26) |
| $\nu_3/\nu_1$ | [0, 1] | – | Relative multiplicity of the third gain component in (26) |
| $\xi$ | >1 | – | Average multiplicity at the second dynode |

- 9 free parameters
- 20-30 hours to fit a single run (192 channels)
- by fixing 3 of the parameters ($\xi$, $\nu_2$, $\nu_3$) $\rightarrow$ 3.5-4.5 hours (192 channels)

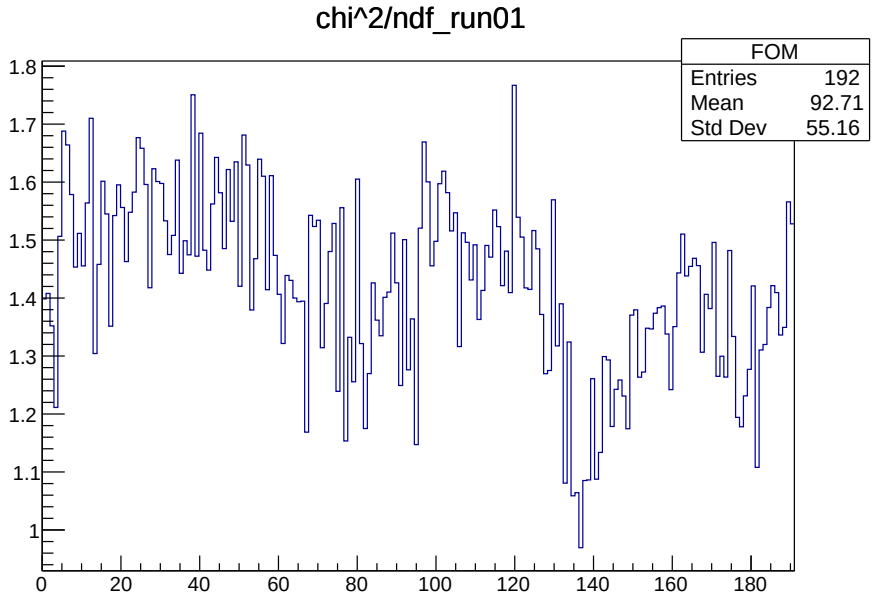
# MAPMT ADC fitting with fixed parameters

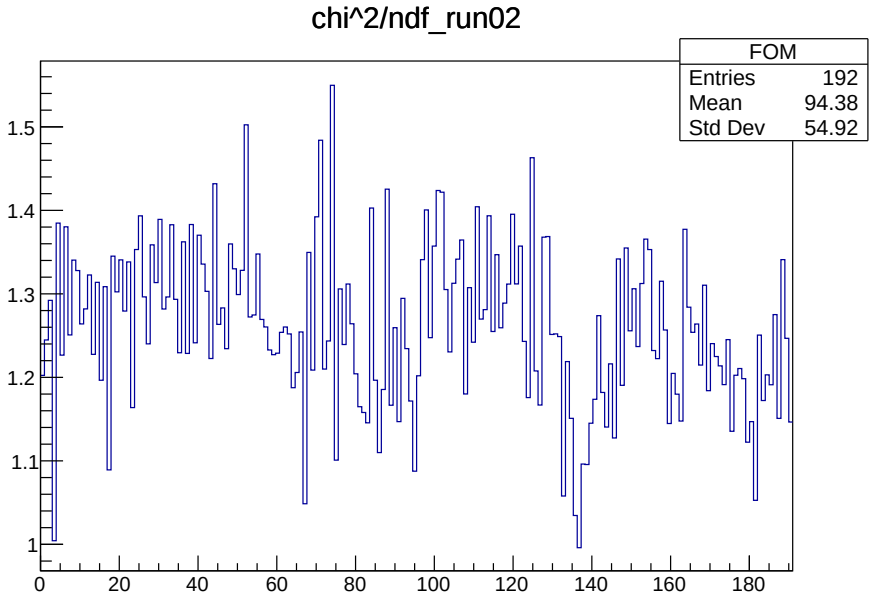
- Question from last time: Are these fixed parameters global to all MAPMTS and run conditions?
- Findings:
  - Fixing $\xi$, $\nu_2$, and $\nu_3$ yielded a $\chi^2/NDF \approx 1-2$ for 9 run conditions (with a different module than the one used to determine the fixed values).
  - $\chi^2/NDF \approx 1-2$ is around the same for the examples provided in Pavel's NIM paper.
  - $\sigma$ may be able to be fixed for each combination of gain and HV
- runs shown, using a randomly selected module (module 075) run(hv,gain); 1(1100,32), 2(1100,64), 3(1100,128), 13(1075,32), 14(1075,64), 15(1075,128), 25(1000,32), 26(1000,64), and 27(1000,128)

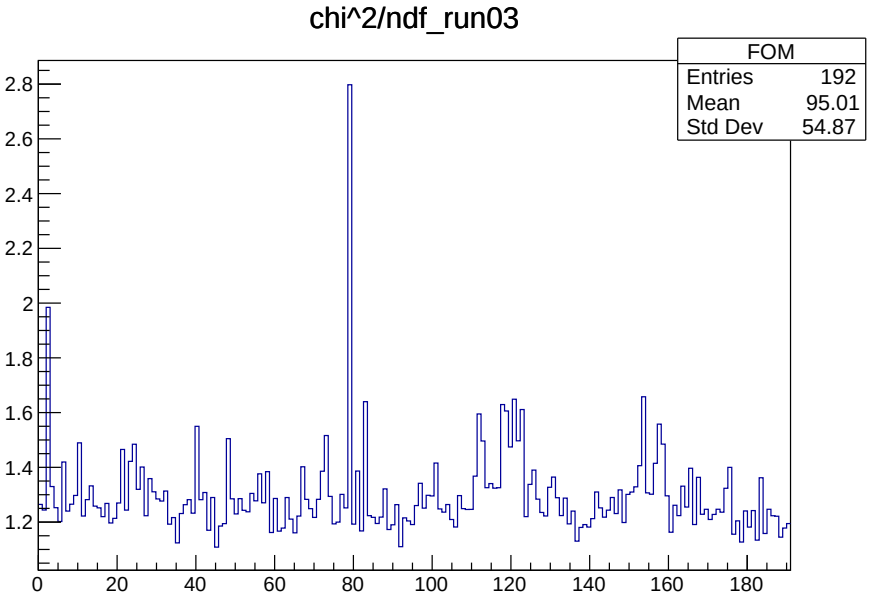
# Reference Slide: Run settings for each module (presented runs highlighted)

1 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 32 THR 25 run
2 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 64 THR 25 run
3 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 128 THR 25 run
4 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 32 THR 50 run
5 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 64 THR 50 run
6 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 128 THR 50 run
7 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 32 THR 100 run
8 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 64 THR 100 run
9 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 128 THR 100 run
10 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 32 THR 200 run
11 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 64 THR 200 run
12 W 6 X 200 Y 25 HV 1100 GMODE 0 GAIN 128 THR 200 run
13 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 32 THR 25 run
14 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 64 THR 25 run
15 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 128 THR 25 run
16 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 32 THR 50 run
17 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 64 THR 50 run
18 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 128 THR 50 run
19 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 32 THR 100 run
20 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 64 THR 100 run
21 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 128 THR 100 run
22 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 32 THR 200 run
23 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 64 THR 200 run
24 W 6 X 200 Y 25 HV 1075 GMODE 0 GAIN 128 THR 200 run
25 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 32 THR 25 run
26 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 64 THR 25 run
27 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 128 THR 25 run
28 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 32 THR 50 run
29 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 64 THR 50 run
30 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 128 THR 50 run
31 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 32 THR 100 run
32 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 64 THR 100 run
33 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 128 THR 100 run
34 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 32 THR 200 run
35 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 64 THR 200 run
36 W 6 X 200 Y 25 HV 1000 GMODE 0 GAIN 128 THR 200 run
37 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 32 THR 25 run
38 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 64 THR 25 run
39 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 128 THR 25 run
40 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 32 THR 50 run
41 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 64 THR 50 run
42 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 128 THR 50 run
43 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 32 THR 100 run
44 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 64 THR 100 run
45 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 128 THR 100 run
46 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 32 THR 200 run
47 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 64 THR 200 run
48 W 4 X 200 Y 25 HV 1100 GMODE 0 GAIN 128 THR 200 run
49 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 32 THR 25 run
50 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 64 THR 25 run
51 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 128 THR 25 run
52 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 32 THR 50 run
53 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 64 THR 50 run
54 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 128 THR 50 run
55 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 32 THR 100 run
56 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 64 THR 100 run
57 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 128 THR 100 run
58 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 32 THR 200 run
59 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 64 THR 200 run
60 W 4 X 200 Y 25 HV 1075 GMODE 0 GAIN 128 THR 200 run
61 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 32 THR 25 run
62 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 64 THR 25 run
63 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 128 THR 25 run
64 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 32 THR 50 run
65 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 64 THR 50 run
66 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 128 THR 50 run
67 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 32 THR 100 run
68 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 64 THR 100 run
69 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 128 THR 100 run
70 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 32 THR 200 run
71 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 64 THR 200 run
72 W 4 X 200 Y 25 HV 1000 GMODE 0 GAIN 128 THR 200 run

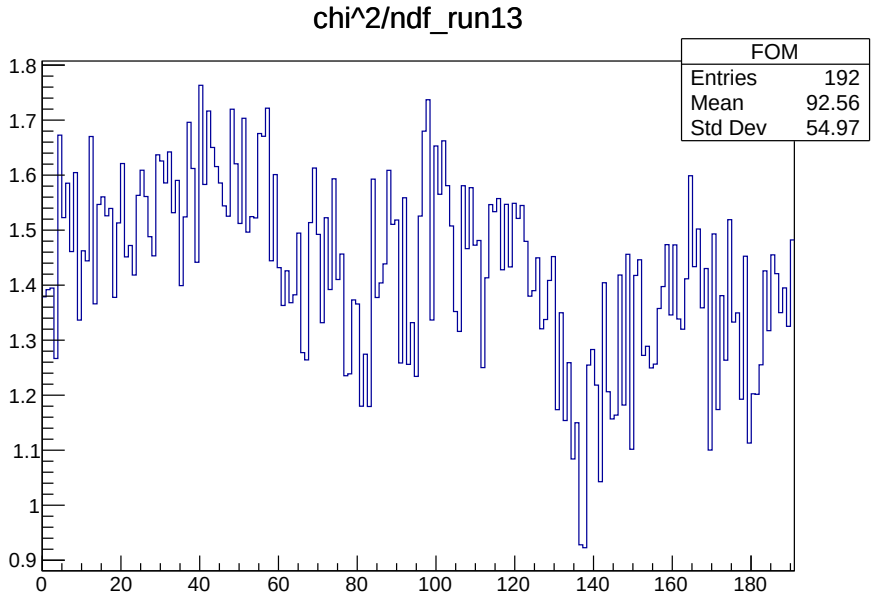
# $\chi^2$/NDF for runs 01, 02, and 03 (HV=1100)

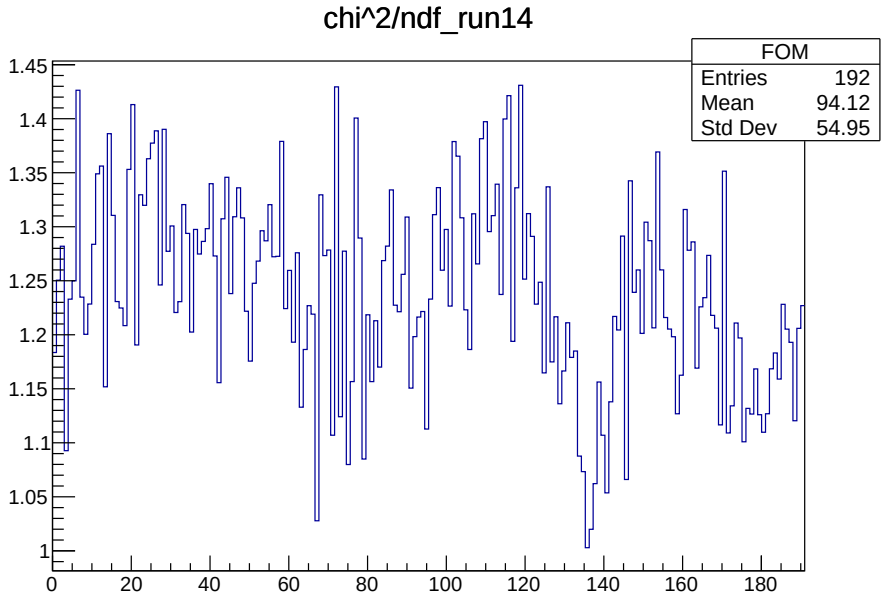


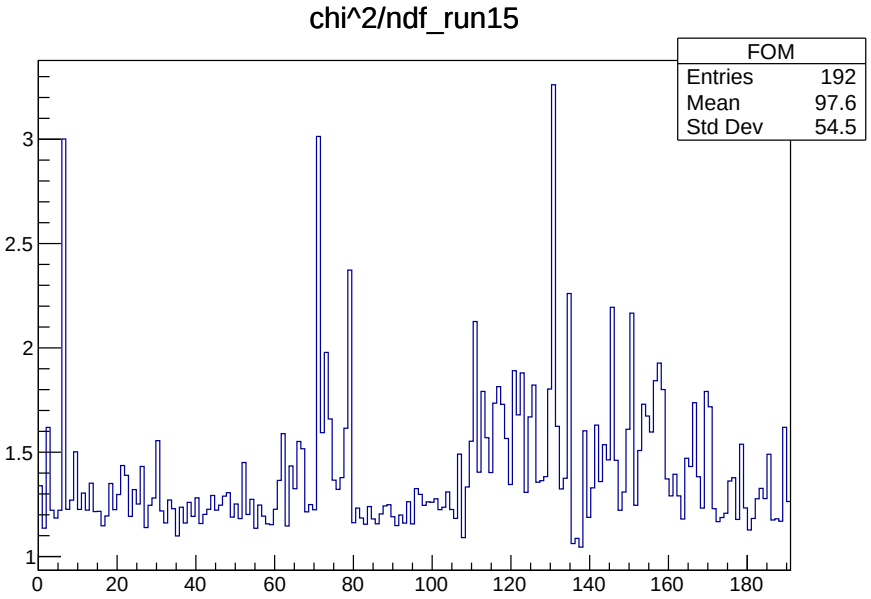



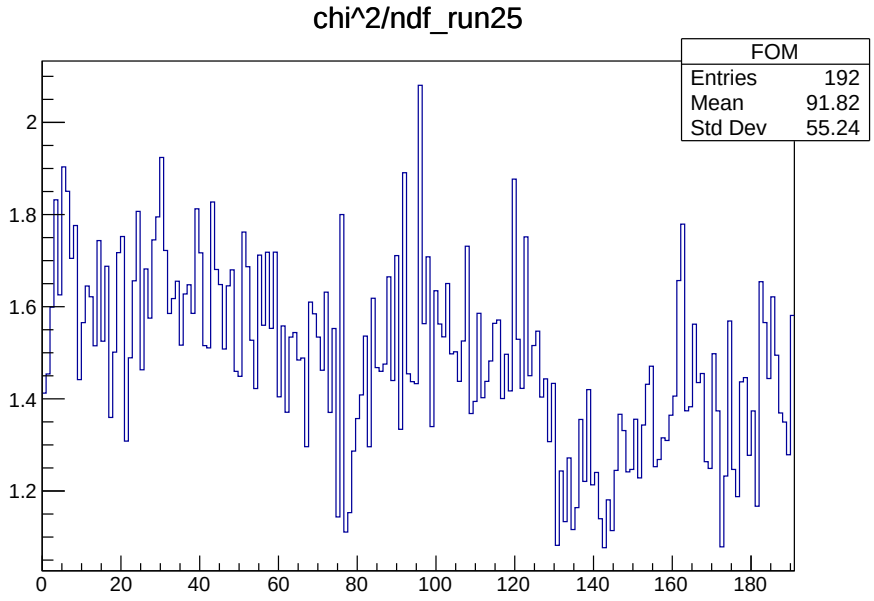
# $\chi^2$/NDF for runs 13, 14, and 15 (HV = 1075)

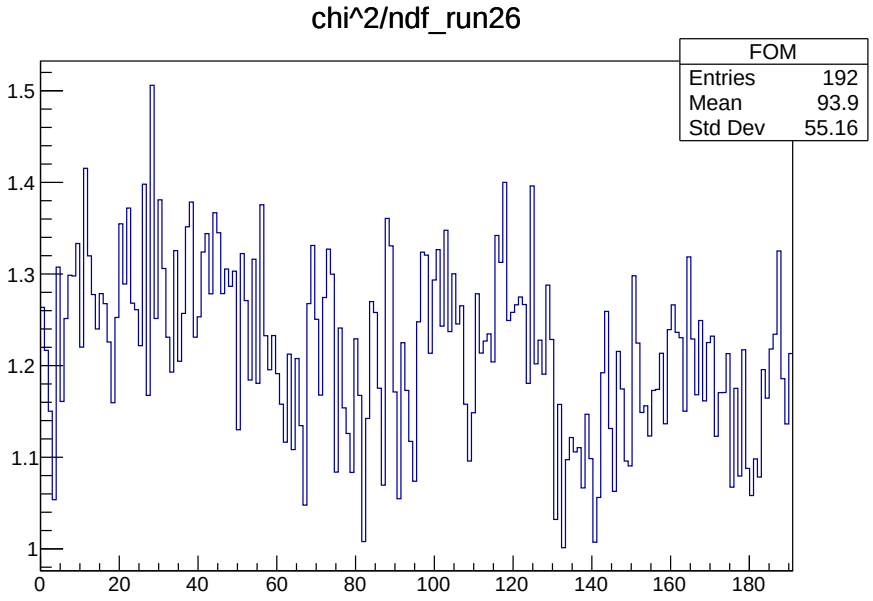


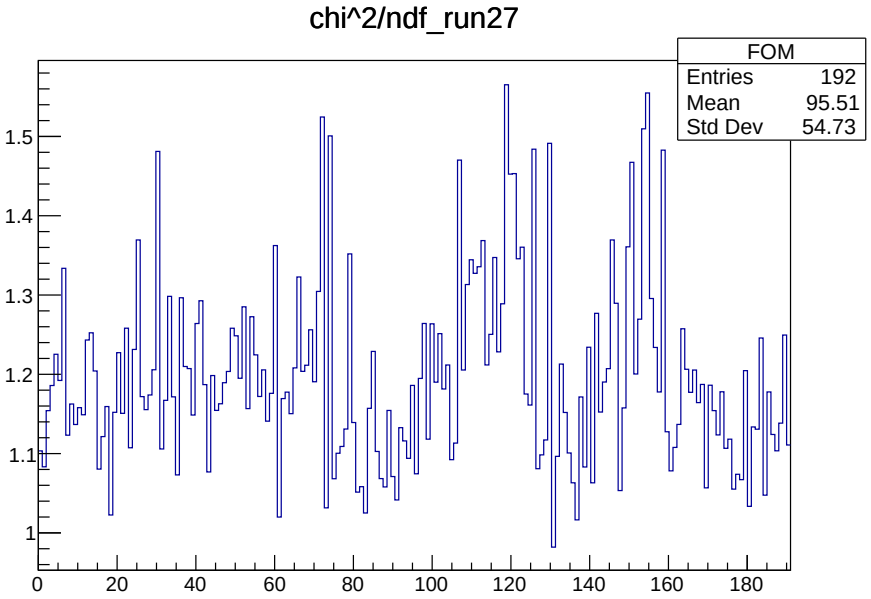



# $\chi^2$/NDF for run 25, 26, and 27 (HV = 1000)



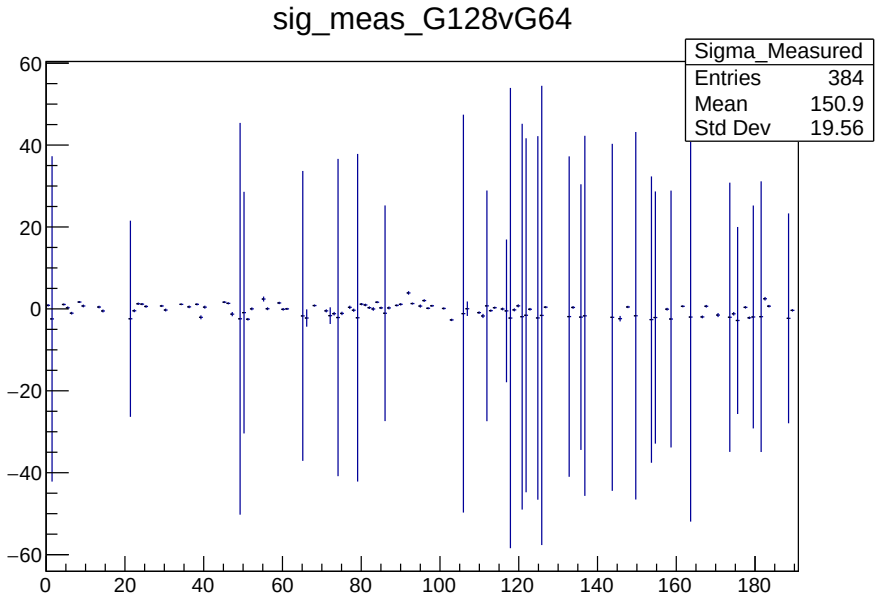



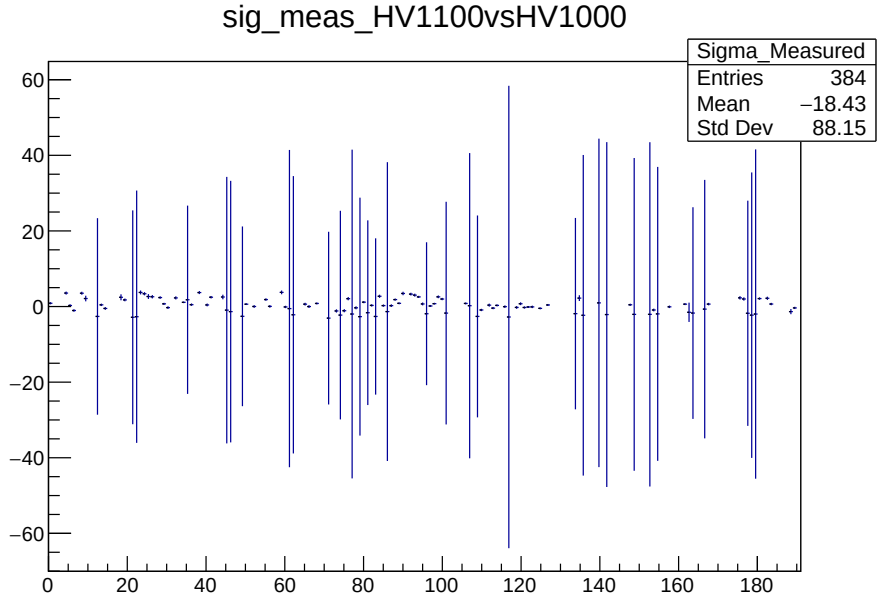



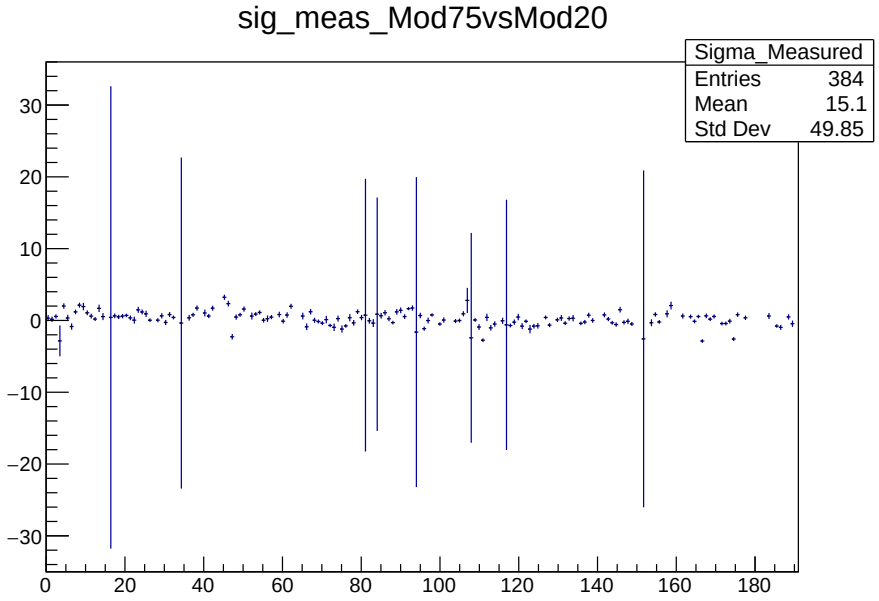
# Summary

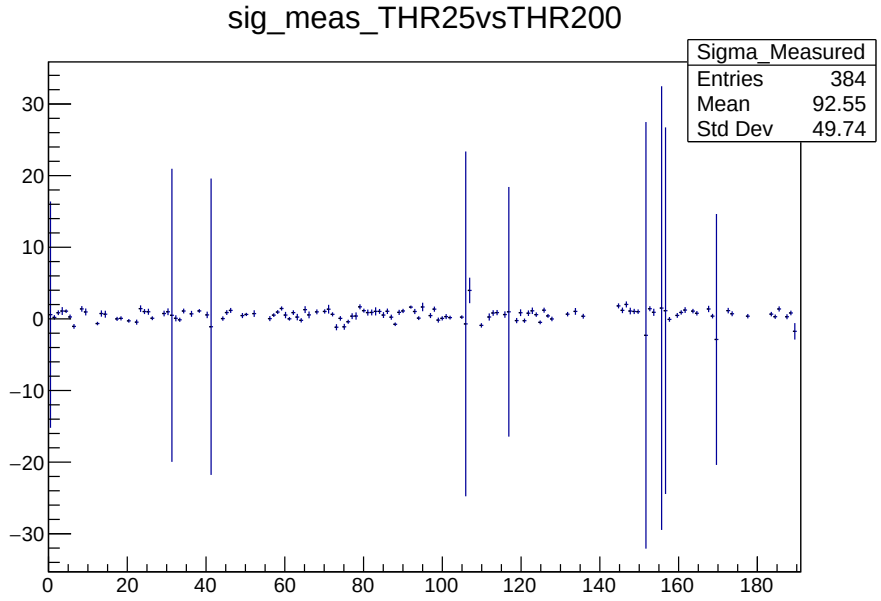
- Fits are stable with fixed parameters across various high voltage and gain settings, as well as different modules
- The fitter will be ready to run over all of the tested modules this week
- Determination of pixel efficiency for each setting will then follow

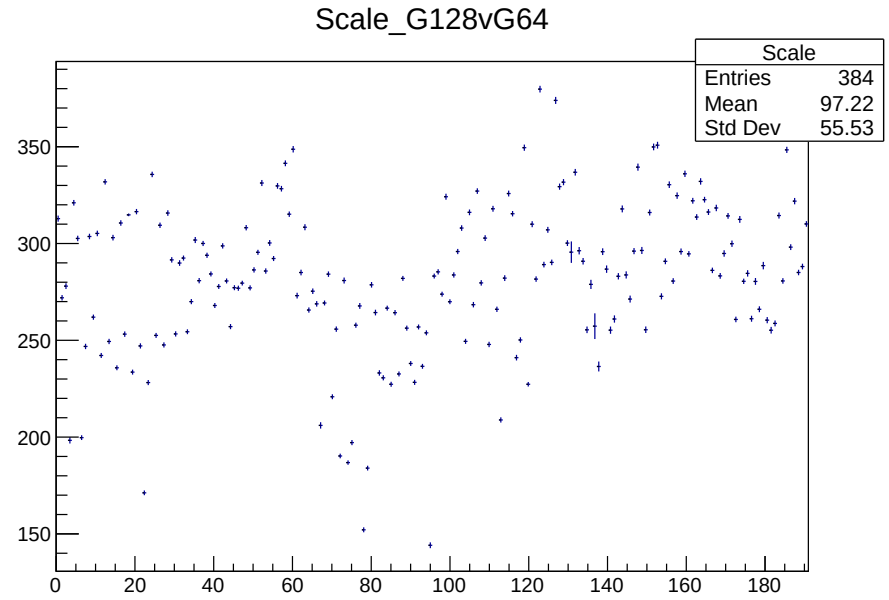
Backup slides

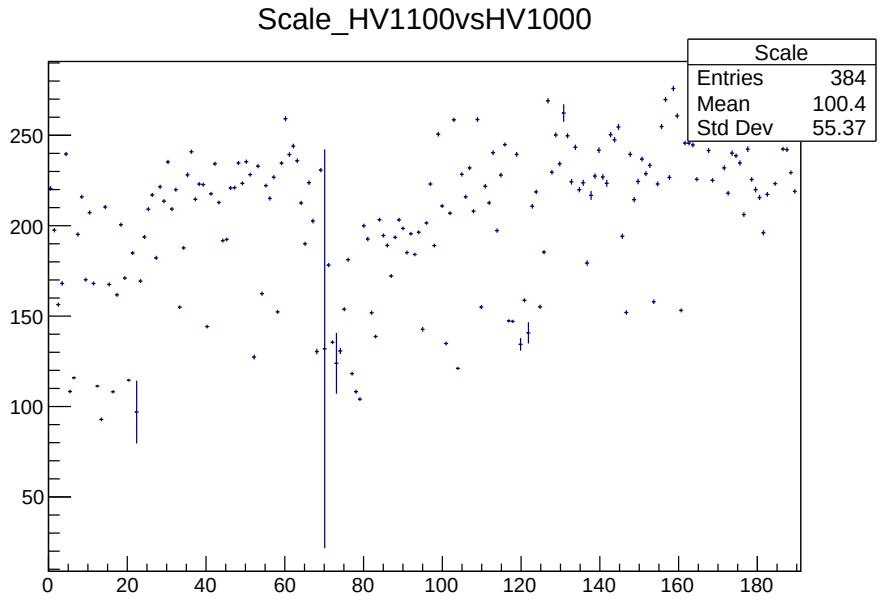

sig_meas_G128vG64
Sigma_Measured
Entries 384
Mean 150.9
Std Dev 19.56

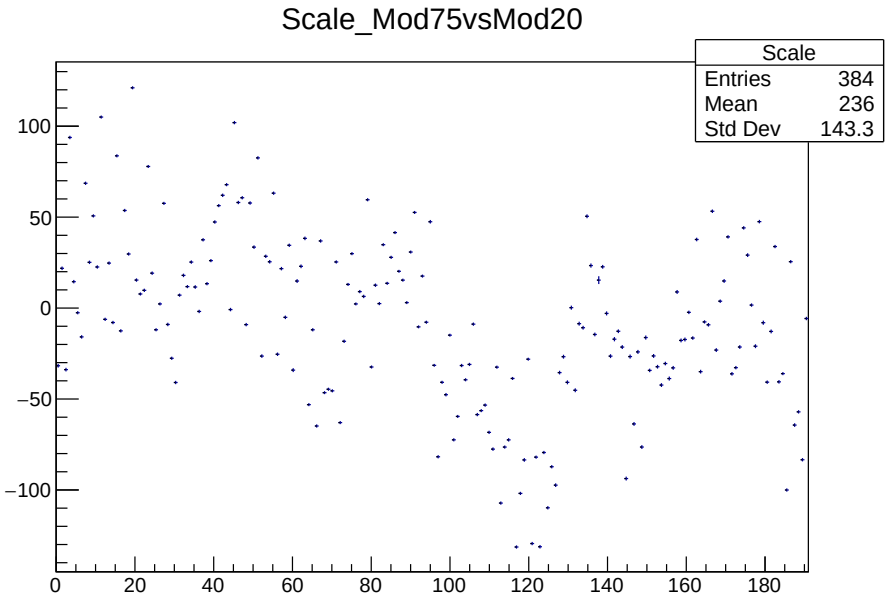

sig_meas_HV1100vsHV1000
Sigma_Measured
Entries 384
Mean −18.43
Std Dev 88.15


sig_meas_Mod75vsMod20
Sigma_Measured
Entries 384
Mean 15.1
Std Dev 49.85


sig_meas_THR25vsTHR200
Sigma_Measured
Entries 384
Mean 92.55
Std Dev 49.74


Scale_G128vG64
Scale
Entries 384
Mean 97.22
Std Dev 55.53


Scale_HV1100vsHV1000
Scale
Entries 384
Mean 100.4
Std Dev 55.37


Scale_Mod75vsMod20
Scale
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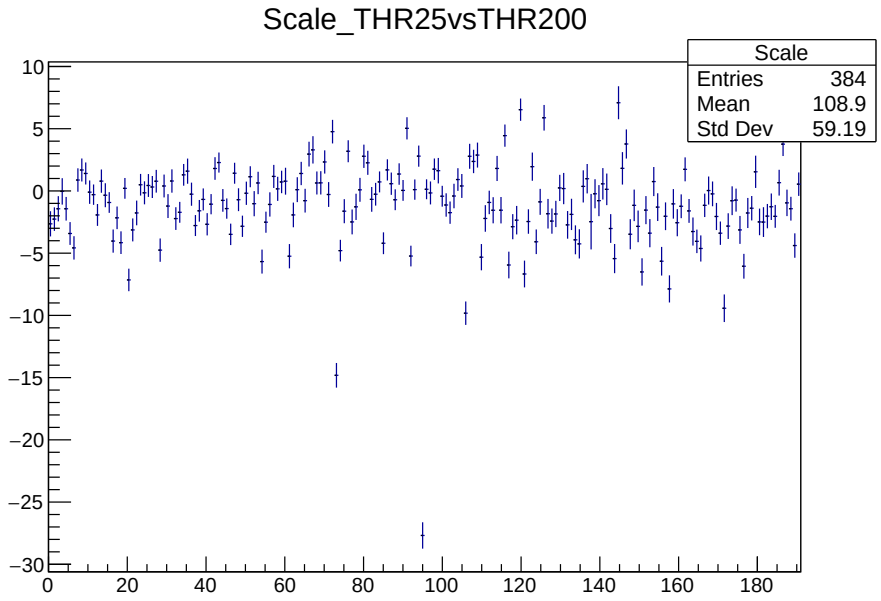
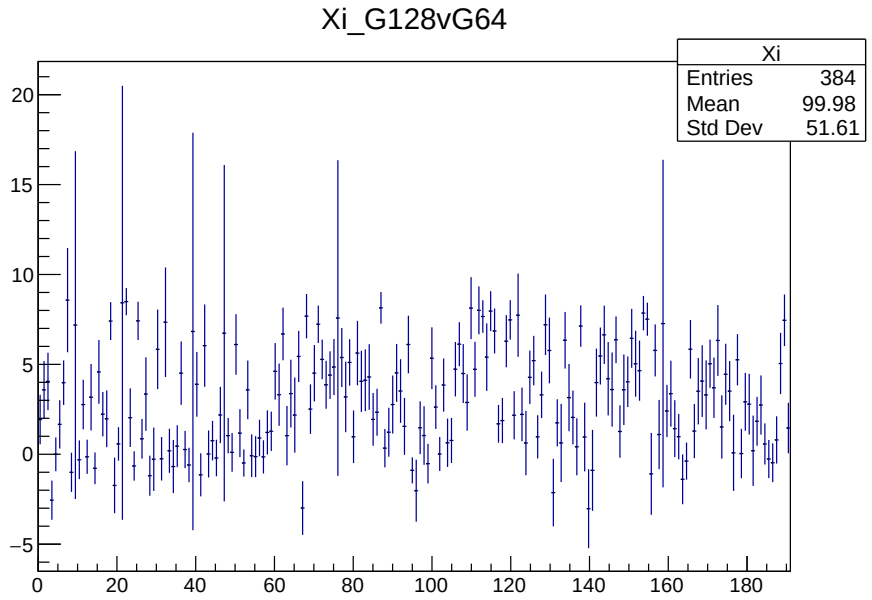
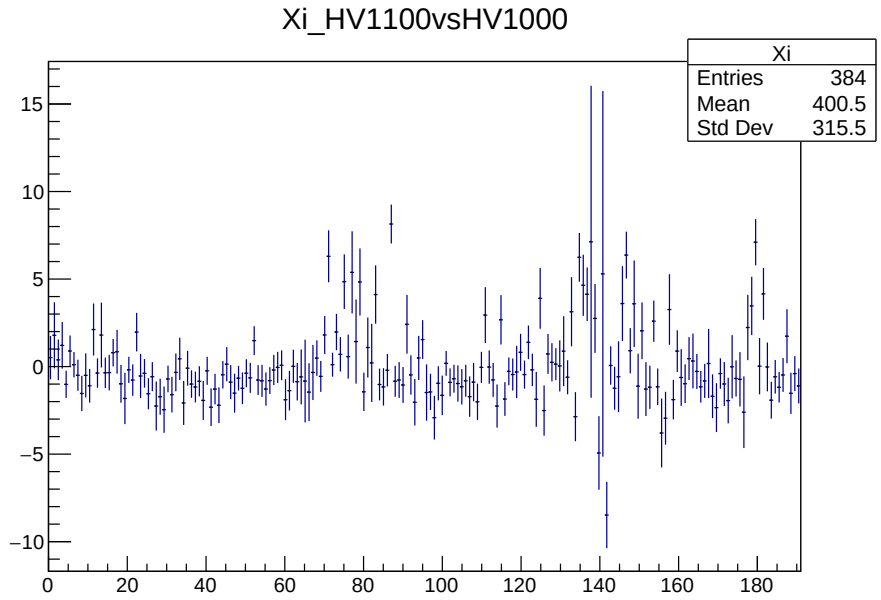
Mean 236
Std Dev 143.3


Scale_THR25vsTHR200
Scale
Entries 384
Mean 108.9
Std Dev 59.19


Xi_G128vG64
Xi
Entries 384
Mean 99.98
Std Dev 51.61


Xi_HV1100vsHV1000
Xi
Entries 384
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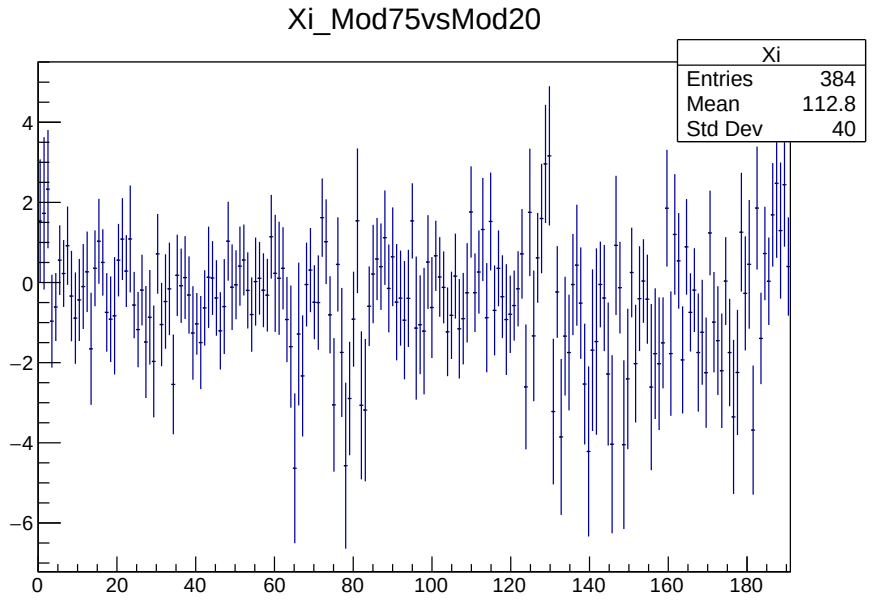
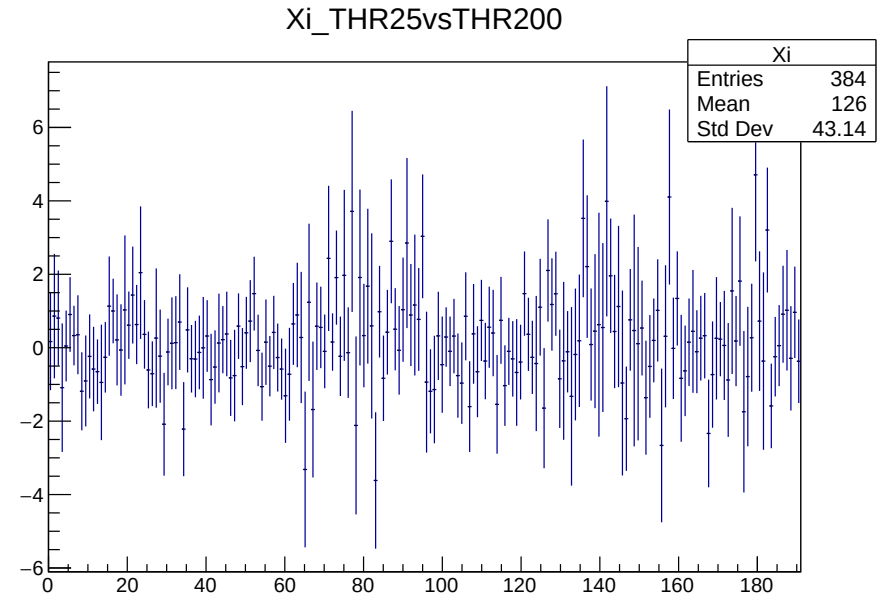
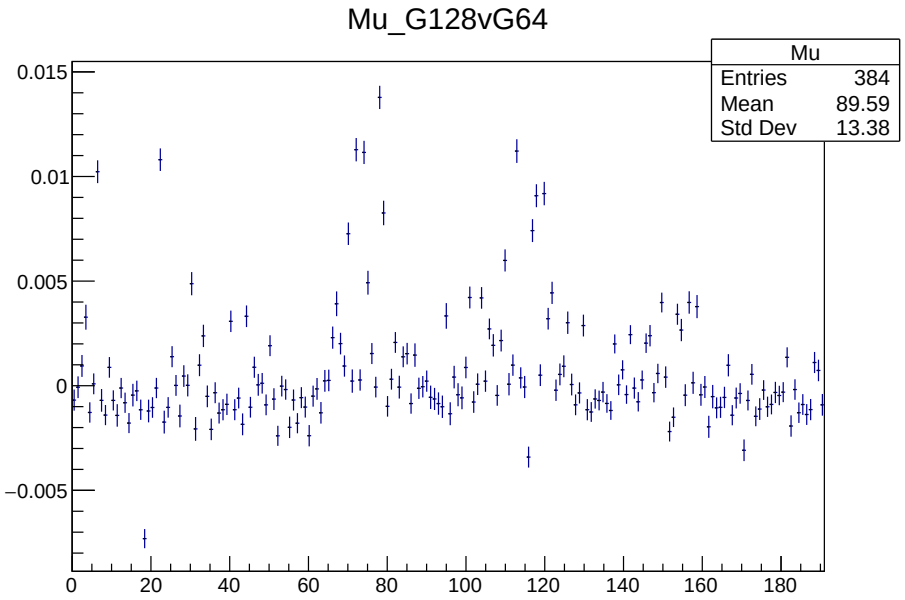
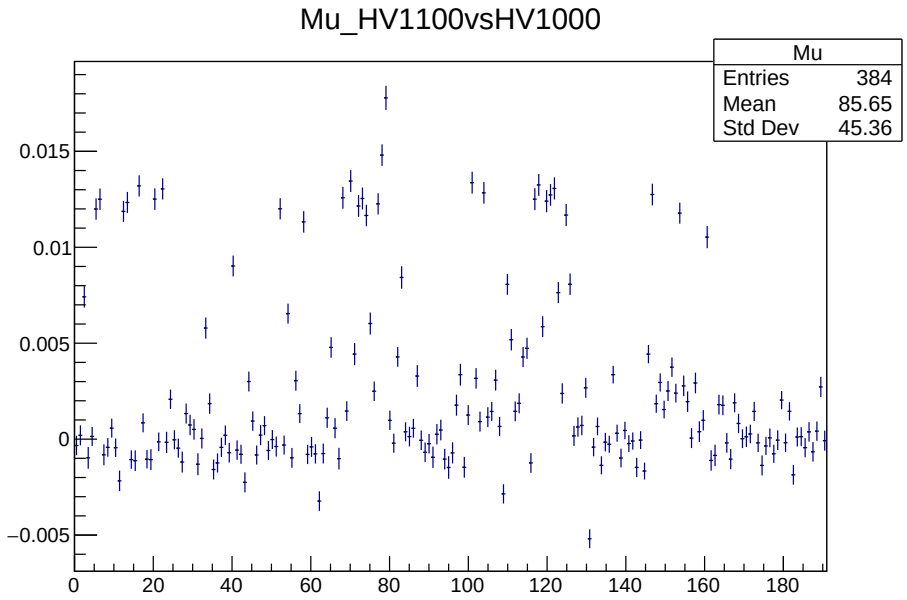
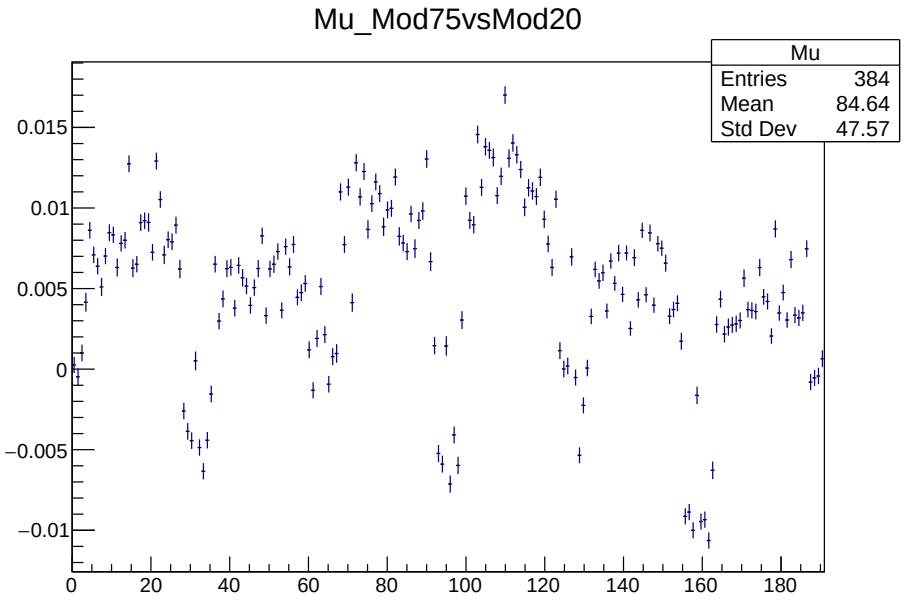
Std Dev 315.5

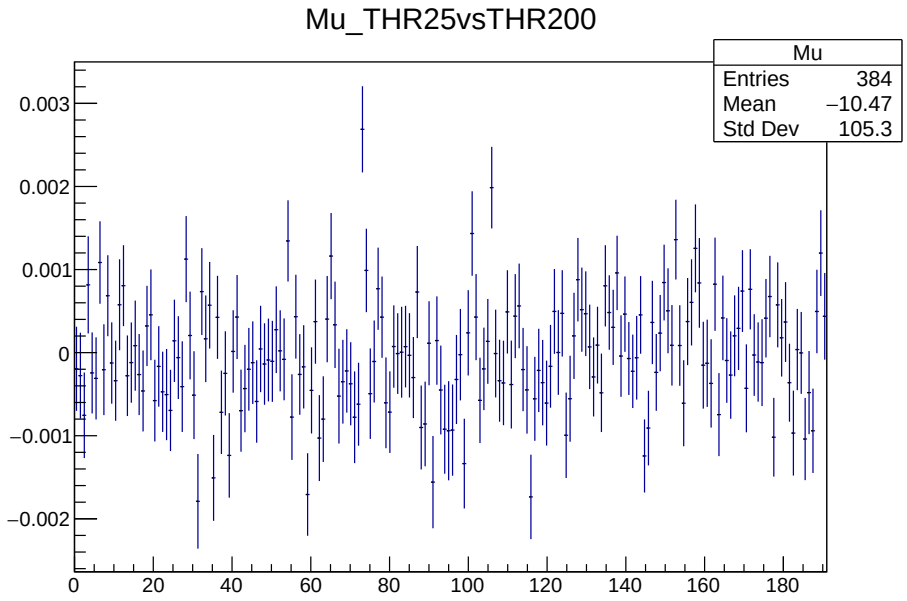

Xi_Mod75vsMod20
Xi
Entries 384
Mean 112.8
Std Dev 40

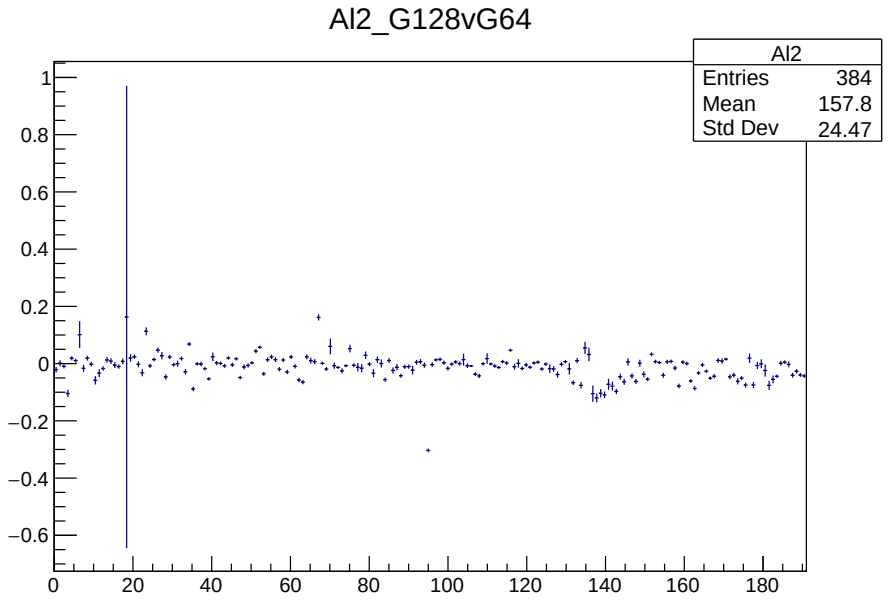

Xi_THR25vsTHR200
Xi
Entries 384
Mean 126
Std Dev 43.14

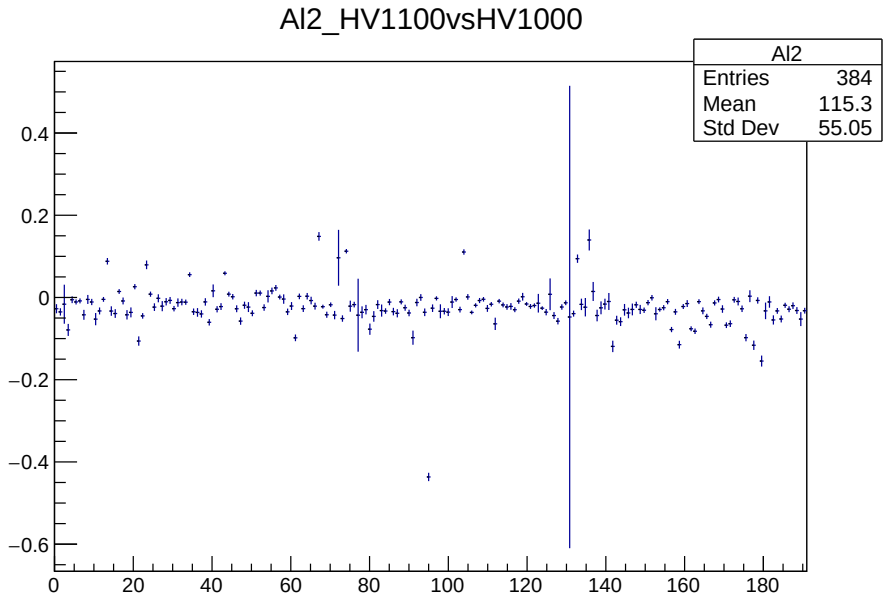

Mu_G128vG64
Mu
Entries 384
Mean 89.59
Std Dev 13.38

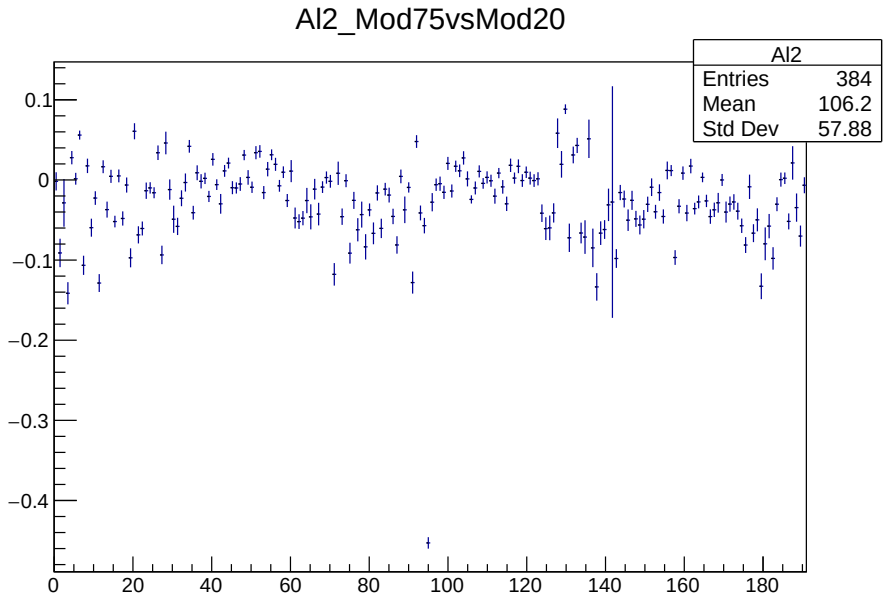

Mu_HV1100vsHV1000
Mu
Entries 384
Mean 85.65
Std Dev 45.36

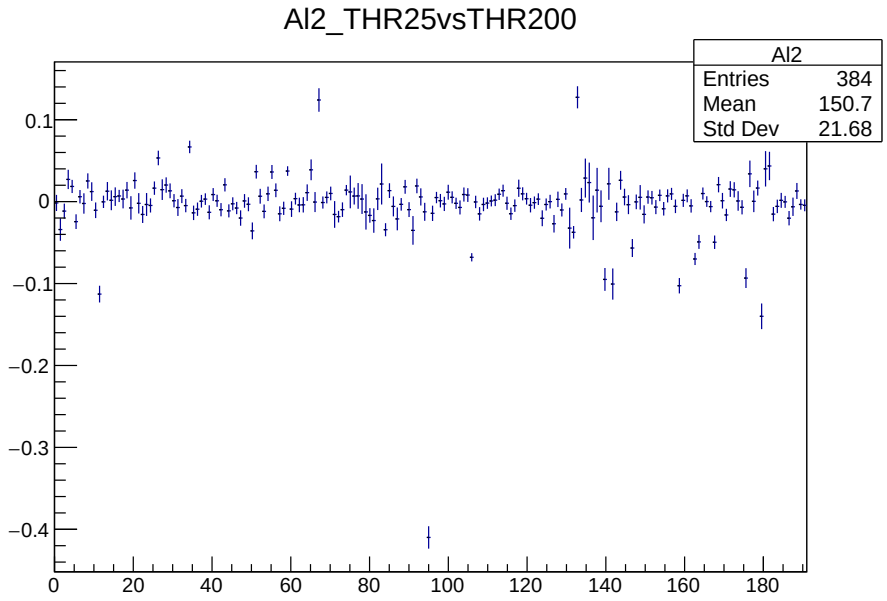

Mu_Mod75vsMod20
Mu
Entries 384
Mean 84.64
Std Dev 47.57

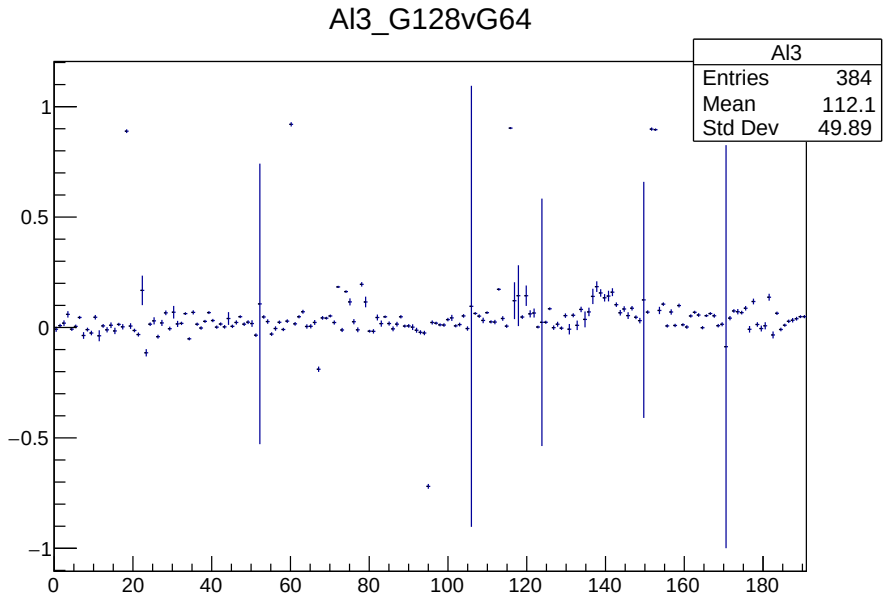

Mu_THR25vsTHR200
Mu
Entries 384
Mean −10.47
Std Dev 105.3

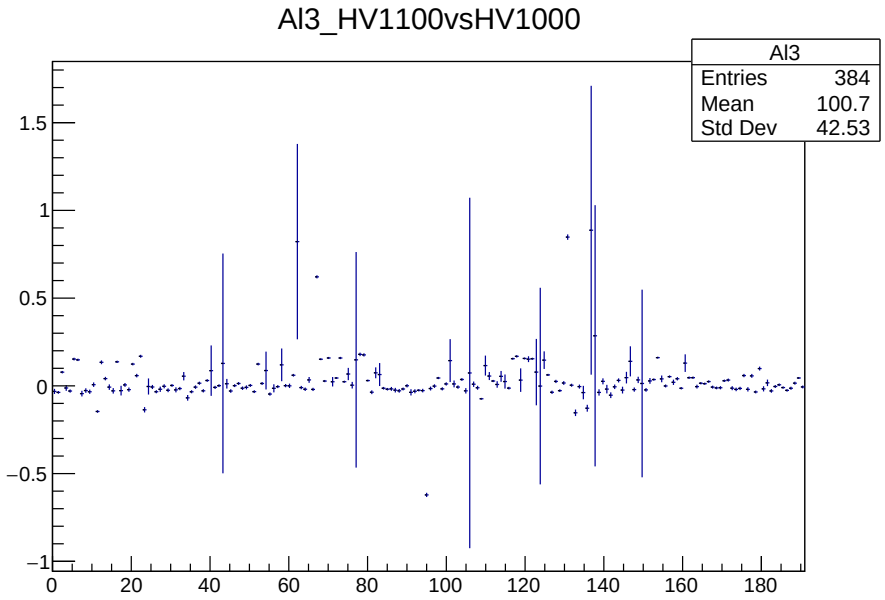

Al2_G128vG64
Al2
Entries 384
Mean 157.8
Std Dev 24.47

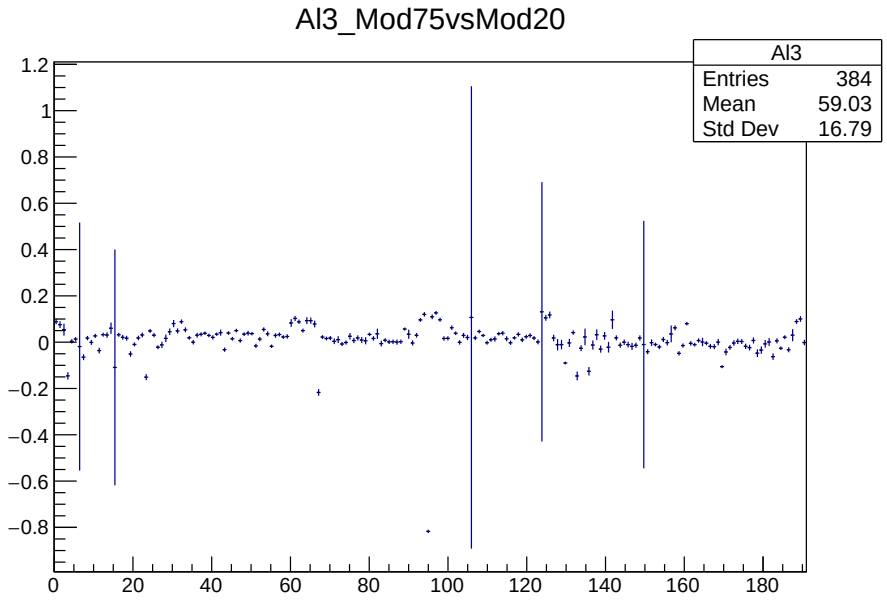

Al2_HV1100vsHV1000
Al2
Entries 384
Mean 115.3
Std Dev 55.05

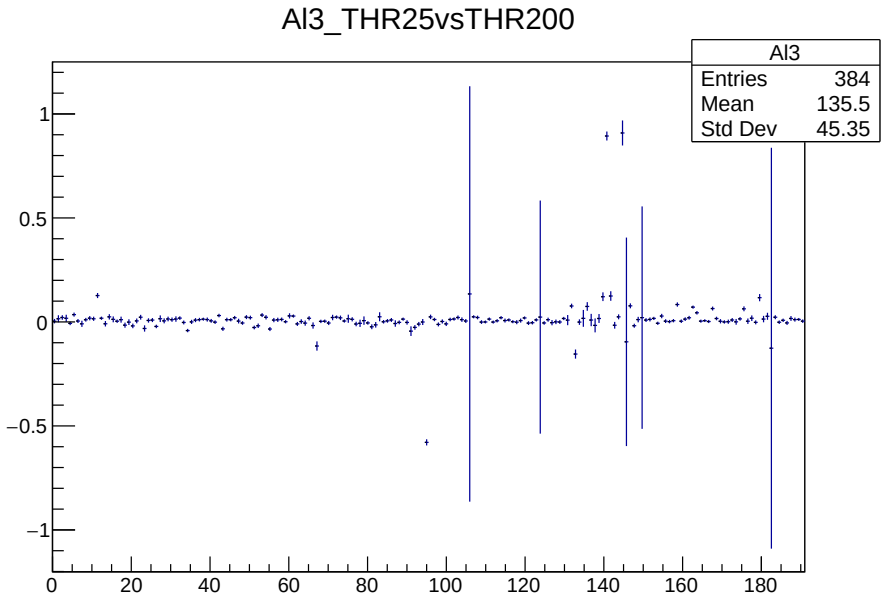

Al2_Mod75vsMod20
Al2
Entries 384
Mean 106.2
Std Dev 57.88

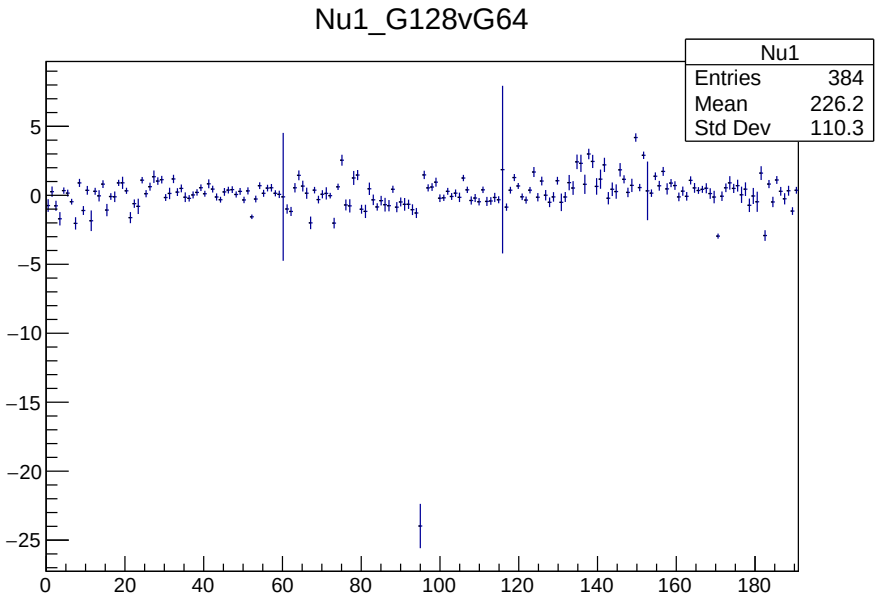

Al2_THR25vsTHR200
Al2
Entries 384
Mean 150.7
Std Dev 21.68

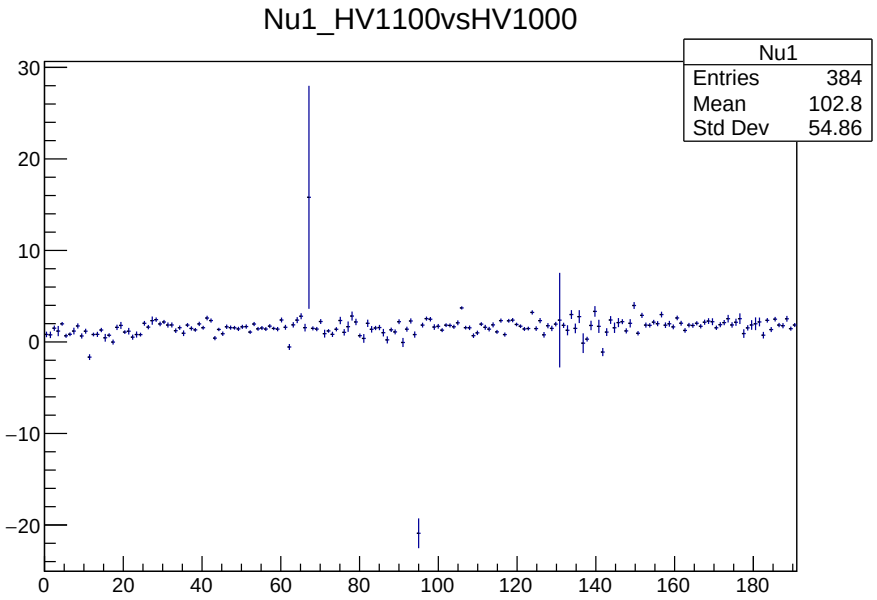

Al3_G128vG64
Al3
Entries 384
Mean 112.1
Std Dev 49.89

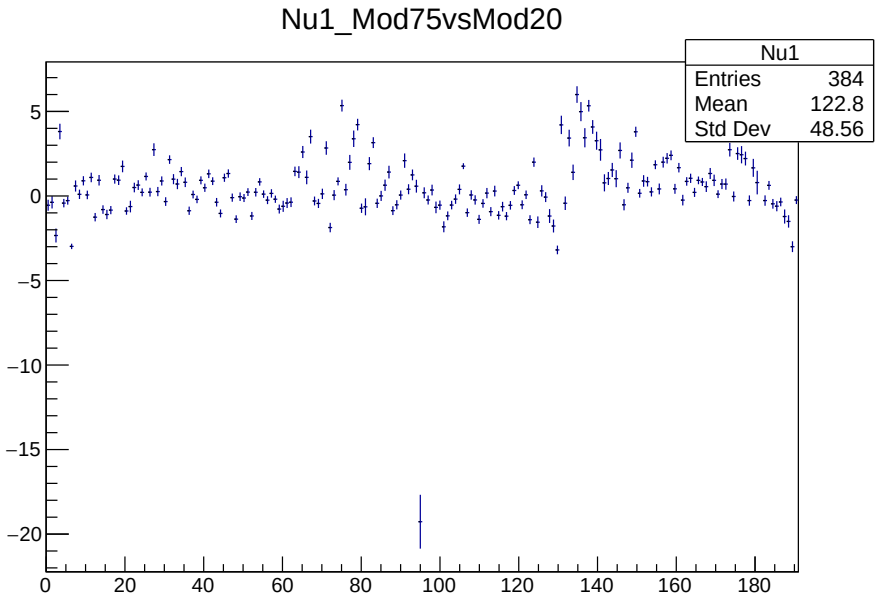

Al3_HV1100vsHV1000
Al3
Entries 384
Mean 100.7
Std Dev 42.53

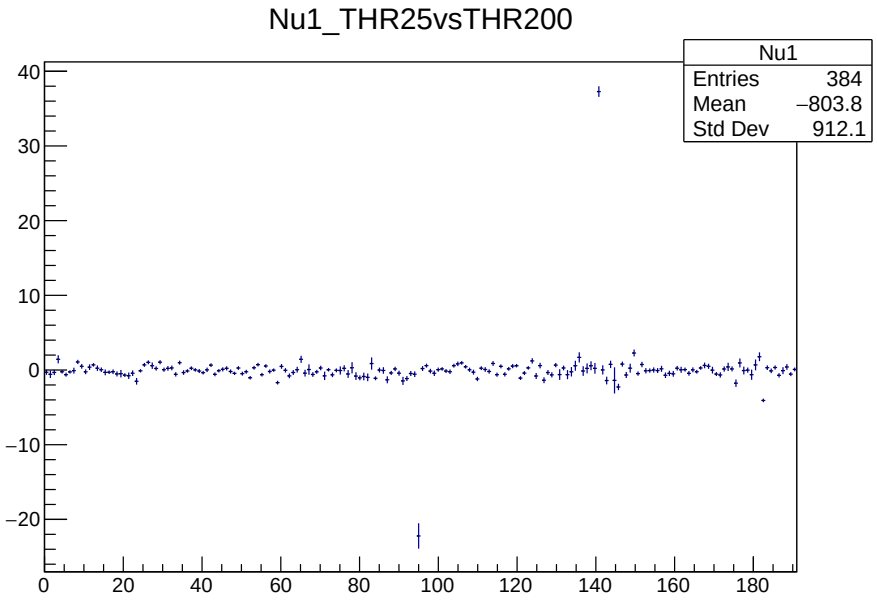

Al3_Mod75vsMod20
Al3
Entries 384
Mean 59.03
Std Dev 16.79

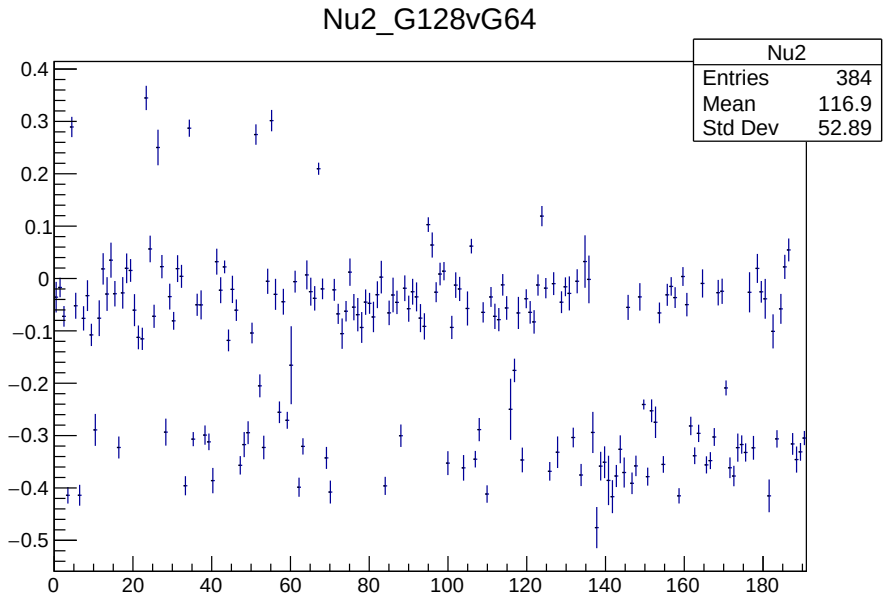

Al3_THR25vsTHR200
Al3
Entries 384
Mean 135.5
Std Dev 45.35

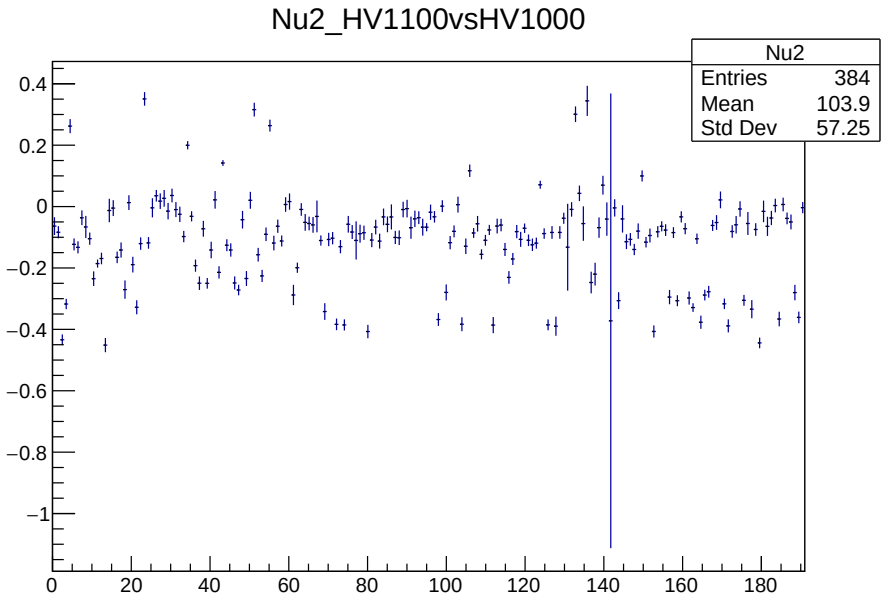

Nu1_G128vG64
Nu1
Entries 384
Mean 226.2
Std Dev 110.3

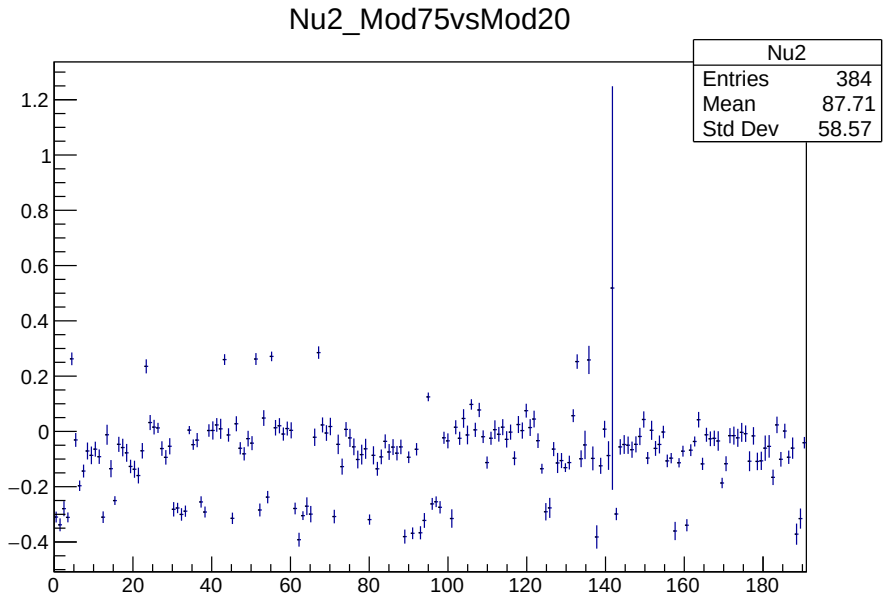

Nu1_HV1100vsHV1000
Nu1
Entries 384
Mean 102.8
Std Dev 54.86

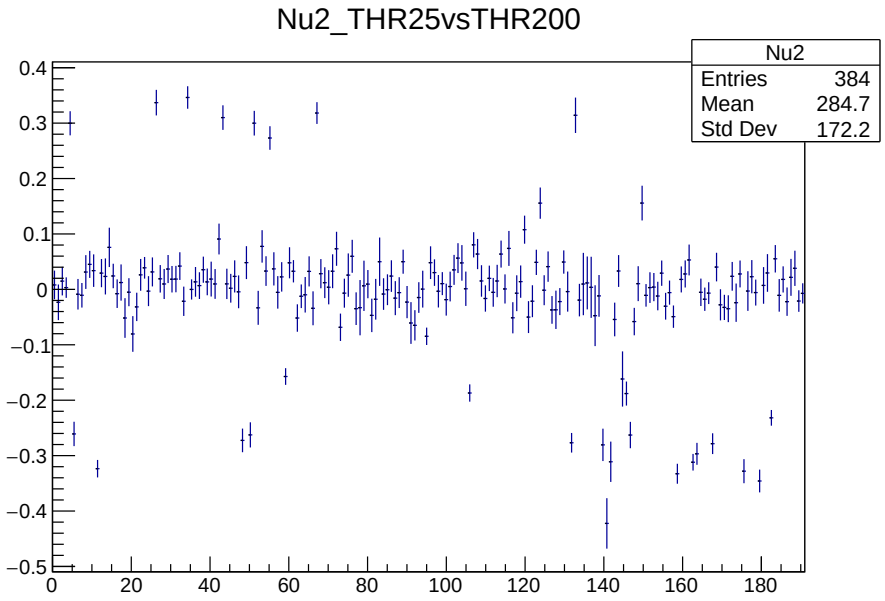

Nu1_Mod75vsMod20
Nu1
Entries 384
Mean 122.8
Std Dev 48.56

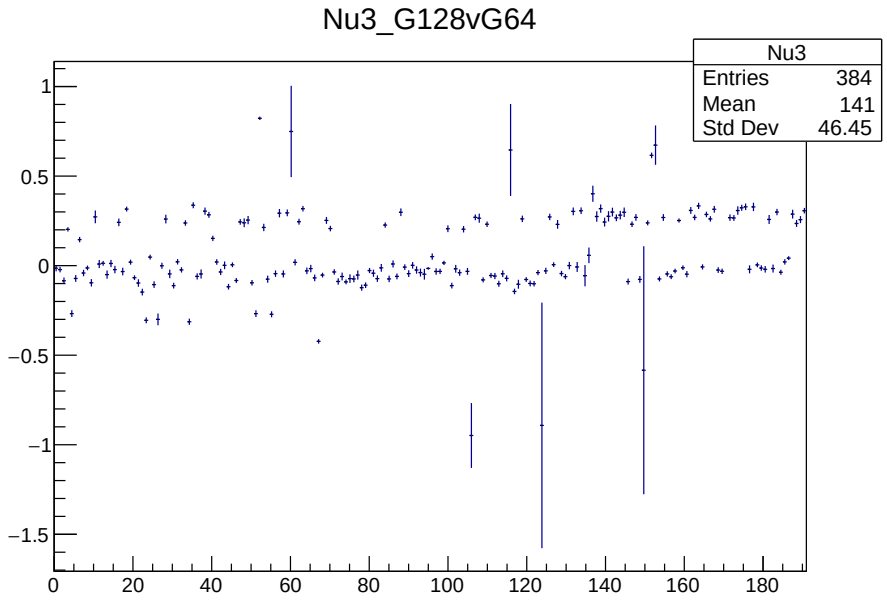

Nu1_THR25vsTHR200
Nu1
Entries 384
Mean −803.8
Std Dev 912.1

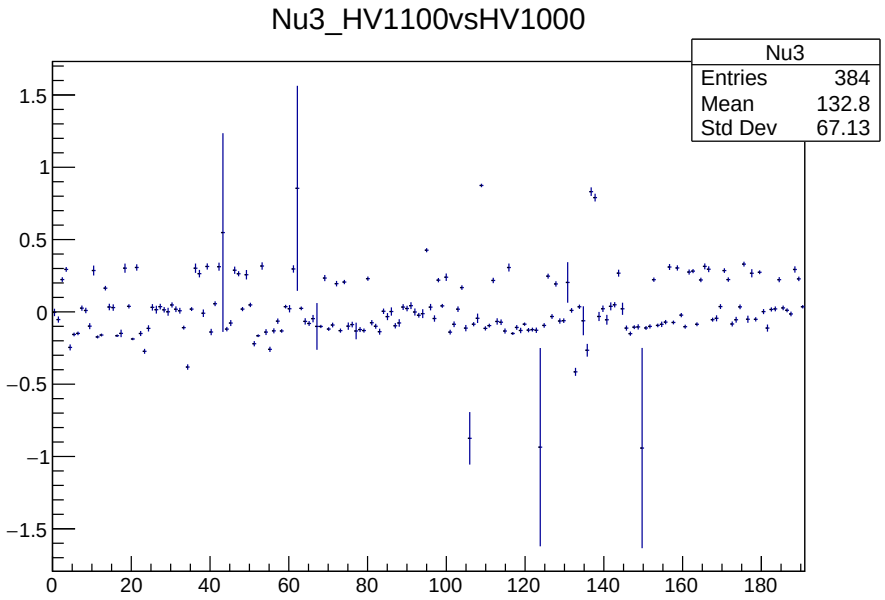

Nu2_G128vG64
Nu2
Entries 384
Mean 116.9
Std Dev 52.89

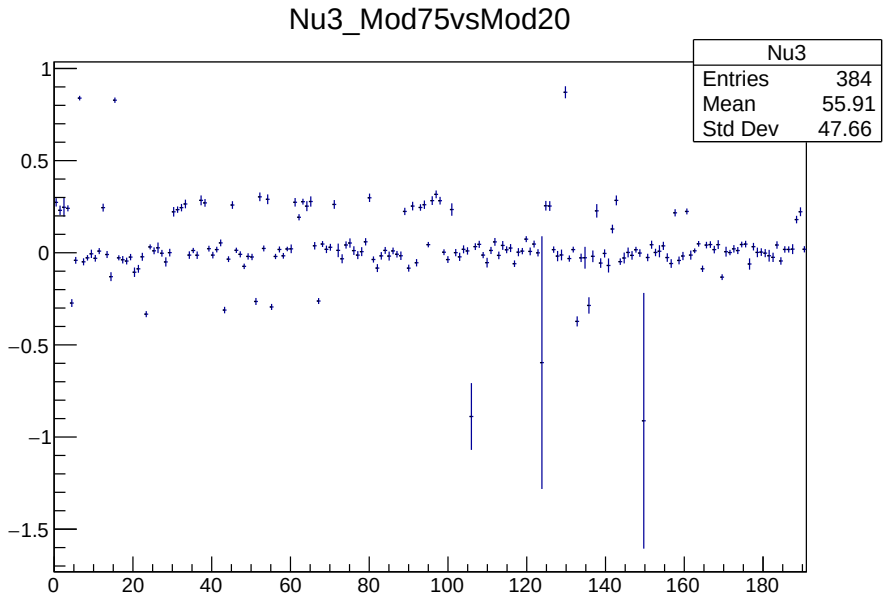

Nu2_HV1100vsHV1000
Nu2
Entries 384
Mean 103.9
Std Dev 57.25

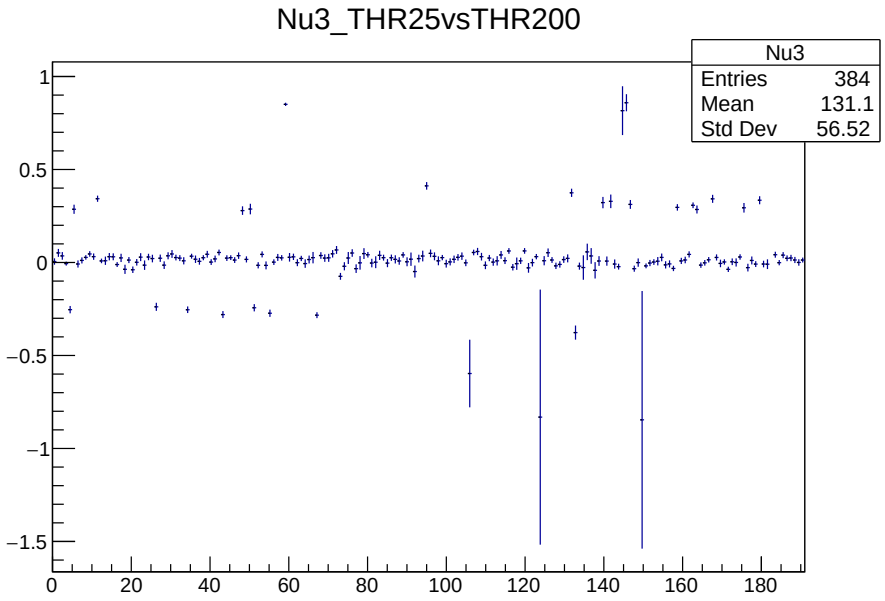

Nu2_Mod75vsMod20
Nu2
Entries 384
Mean 87.71
Std Dev 58.57


Nu2_THR25vsTHR200
Nu2
Entries 384
Mean 284.7
Std Dev 172.2


Nu3_G128vG64
Nu3
Entries 384
Mean 141
Std Dev 46.45


Nu3_HV1100vsHV1000
Nu3
Entries 384
Mean 132.8
Std Dev 67.13


Nu3_Mod75vsMod20
Nu3
Entries 384
Mean 55.91
Std Dev 47.66


Nu3_THR25vsTHR200
Nu3
Entries 384
Mean 131.1
Std Dev 56.52