

ProtoDUNE Light Attenuation in the presence of dopants

Kyle Spurgeon - XX Septmeber, 2020

- Recap how the attenuation study is performed
- Present updated results
- Look at waveform components of results
- Brief dive into how light attributes change over ProtoDUNE run conditions

Attenuation Analysis

- Look at light incident vs distance from PDS
- Provide an avenue to Rayleigh Scattering Lengths
- Will present current results from data for all 3 epochs (Pure LAr, +N, +N+Xe)
- Still need to complete MC generation for comparisons

Attenuation Analysis

How To


Entire PD Channel Map



APA- Face A



APA- Face B

 = Readout end

| USDaS | | | | | | |
|----------------|-----------|--------|-------|-------|--------|----|
| PD Module | HB | SSP | SSPch | DAQch | OptDet | |
| 002-0047-FL34 | Hamamatsu | SSP503 | 0-3 | 216 | 219 | 41 |
| 002-0008-IU54 | Hamamatsu | SSP503 | 4-7 | 220 | 223 | 43 |
| 002-0058-FL24 | Hamamatsu | SSP503 | 8-11 | 224 | 227 | 45 |
| 002-0063-IU19 | Hamamatsu | SSP504 | 0-3 | 228 | 231 | 47 |
| 003-0026-FL07* | SensL-C1 | SSP501 | 0-3 | 192 | 195 | 49 |
| 002-0014-IU26 | Hamamatsu | SSP504 | 4-7 | 232 | 235 | 51 |
| 003-0024-FL33 | SensL-C1 | SSP501 | 4-7 | 196 | 199 | 53 |
| 003-0004-IU48 | SensL-C1 | SSP501 | 8-11 | 200 | 203 | 55 |
| 002-0041-FL36 | Hamamatsu | SSP504 | 8-11 | 236 | 239 | 57 |
| 002-0036-IU47 | SensL-C1 | SSP502 | 0-3 | 204 | 207 | 59 |

| MSDaS | | | | | | |
|---------------|-----------|--------|-------|-------|--------|----|
| PD Module | HB | SSP | SSPch | DAQch | OptDet | |
| 002-0002-FL22 | Hamamatsu | SSP601 | 0-3 | 240 | 243 | 21 |
| 002-0054-IU22 | Hamamatsu | SSP601 | 4-7 | 244 | 247 | 23 |
| 002-0059-FL08 | Hamamatsu | SSP601 | 8-11 | 248 | 251 | 25 |
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| 002-0060-FL39 | Hamamatsu | SSP602 | 4-7 | 256 | 259 | 29 |
| ARAPUCA-2 | Hamamatsu | SSP603 | 0-3 | 264 | 267 | 31 |
| | | SSP603 | 4-7 | 268 | 271 | |
| | | SSP603 | 8-11 | 272 | 275 | |
| 002-0055-FL40 | Hamamatsu | SSP602 | 8-11 | 260 | 263 | 33 |
| 002-0013-IU01 | Hamamatsu | SSP604 | 0-3 | 276 | 279 | 35 |
| 002-0011-FL15 | Hamamatsu | SSP604 | 4-7 | 280 | 283 | 37 |
| 002-0031-IU02 | Hamamatsu | SSP604 | 8-11 | 284 | 287 | 39 |

| DSDaS | | | | | | |
|-----------------|----------|--------|-------|-------|--------|----|
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| 001-0003-FL01 | SensL-C1 | SSP401 | 0-3 | 144 | 147 | 1 |
| 002-0044-IU50 | SensL-C1 | SSP401 | 4-7 | 148 | 151 | 3 |
| 002-0039-FL29 | SensL-A1 | SSP401 | 8-11 | 152 | 155 | 5 |
| 003-0002-IU27 | SensL-C1 | SSP402 | 0-3 | 156 | 159 | 7 |
| 002-0025-FL25 | SensL-C1 | SSP402 | 4-7 | 160 | 163 | 9 |
| 003-0011-IU37 | SensL-C1 | SSP402 | 8-11 | 164 | 167 | 11 |
| 003-0048-FL42 | SensL-C1 | SSP403 | 0-3 | 168 | 171 | 13 |
| 002-0023-IU53 | SensL-C1 | SSP403 | 4-7 | 172 | 175 | 15 |
| 002-0038-IU35 | SensL-C1 | SSP403 | 8-11 | 176 | 179 | 17 |
| 002-0040-FLP06* | SensL-C1 | SSP404 | 0-3 | 180 | 183 | 19 |

***Modified SSP**

| SSP_Serial# | | |
|-------------|-------|-------|
| USDaS | MSDaS | DSDaS |
| 127 | 131 | 120 |
| 125 | 130 | 119 |
| 132 | 129 | 118 |
| 121 | 128 | 117 |
| | | |
| USRaS | MSRaS | DSRaS |
| 123 | 113 | 109 |
| 116 | 112 | 108 |
| 115 | 111 | 107 |
| 114 | 102 | 106 |



Start with all beam-left photon detectors
 Beam-left chosen due to (then unknown) bias of CRTs

Attenuation Analysis

How To

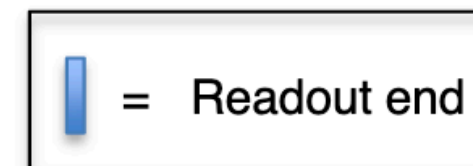
Entire PD Channel Map



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= Readout end

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| | | SSP603 | 8-11 | 272 | 275 | |
| 002-0055-FL40 | Hamamatsu | SSP602 | 8-11 | 260 | 263 | 33 |
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| 002-0031-IU02 | Hamamatsu | SSP604 | 8-11 | 284 | 287 | 39 |

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|-----------------|----------|--------|-------|-------|--------|----|
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| 002-0044-IU50 | SensL-C1 | SSP401 | 4-7 | 148 | 151 | 3 |
| 002-0039-FL29 | SensL-A1 | SSP401 | 8-11 | 152 | 155 | 5 |
| 003-0002-IU27 | SensL-C1 | SSP402 | 0-3 | 156 | 159 | 7 |
| 002-0025-FL25 | SensL-C1 | SSP402 | 4-7 | 160 | 163 | 9 |
| 003-0011-IU37 | SensL-C1 | SSP402 | 8-11 | 164 | 167 | 11 |
| 003-0048-FL42 | SensL-C1 | SSP403 | 0-3 | 168 | 171 | 13 |
| 002-0023-IU53 | SensL-C1 | SSP403 | 4-7 | 172 | 175 | 15 |
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| USDaS | MSDaS | DSDaS |
| 127 | 131 | 120 |
| 125 | 130 | 119 |
| 132 | 129 | 118 |
| 121 | 128 | 117 |
| 123 | 113 | 109 |
| 116 | 112 | 108 |
| 115 | 111 | 107 |
| 114 | 102 | 106 |



Separate technology types (double shift/ararpuca and chip type)

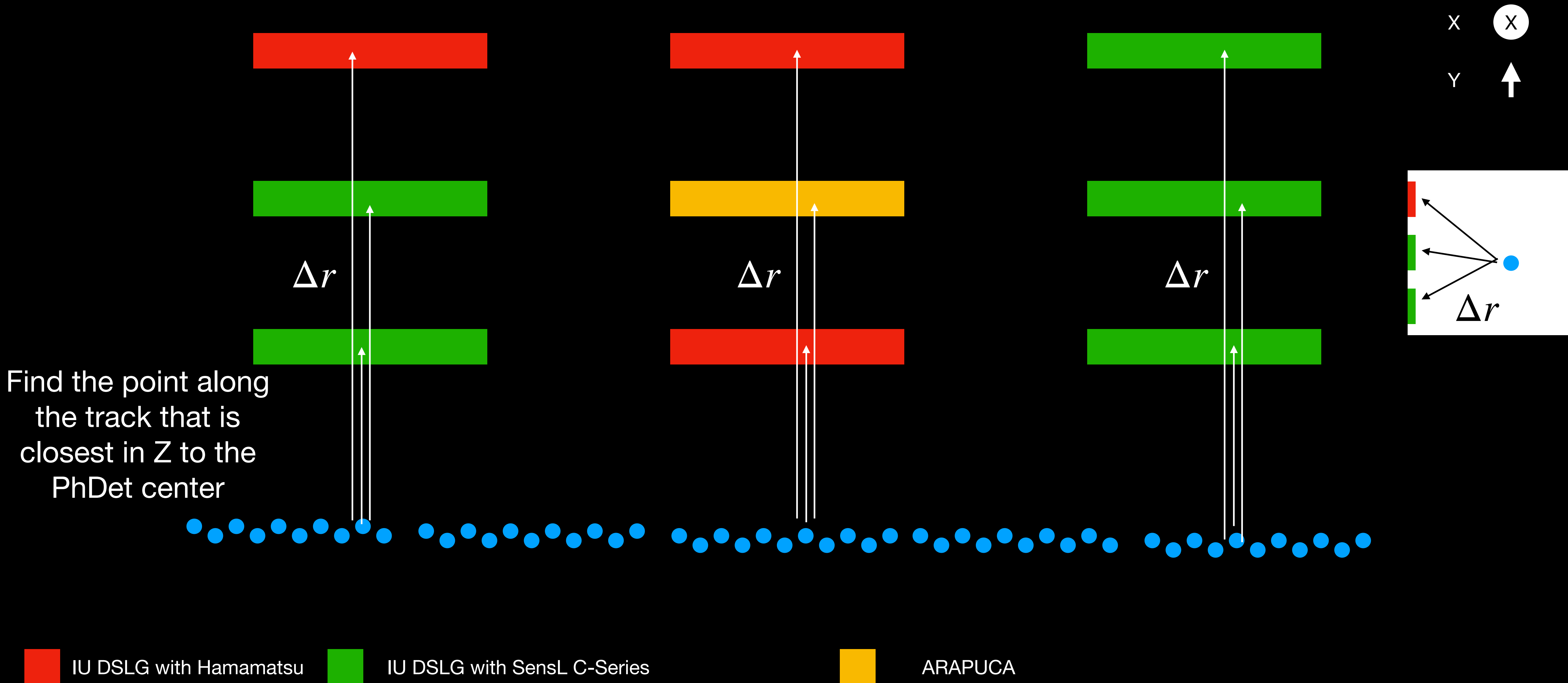
So one track contributes:

7 data points to the “SensL” graph

7 Data point to the “Hamamatsu” graph

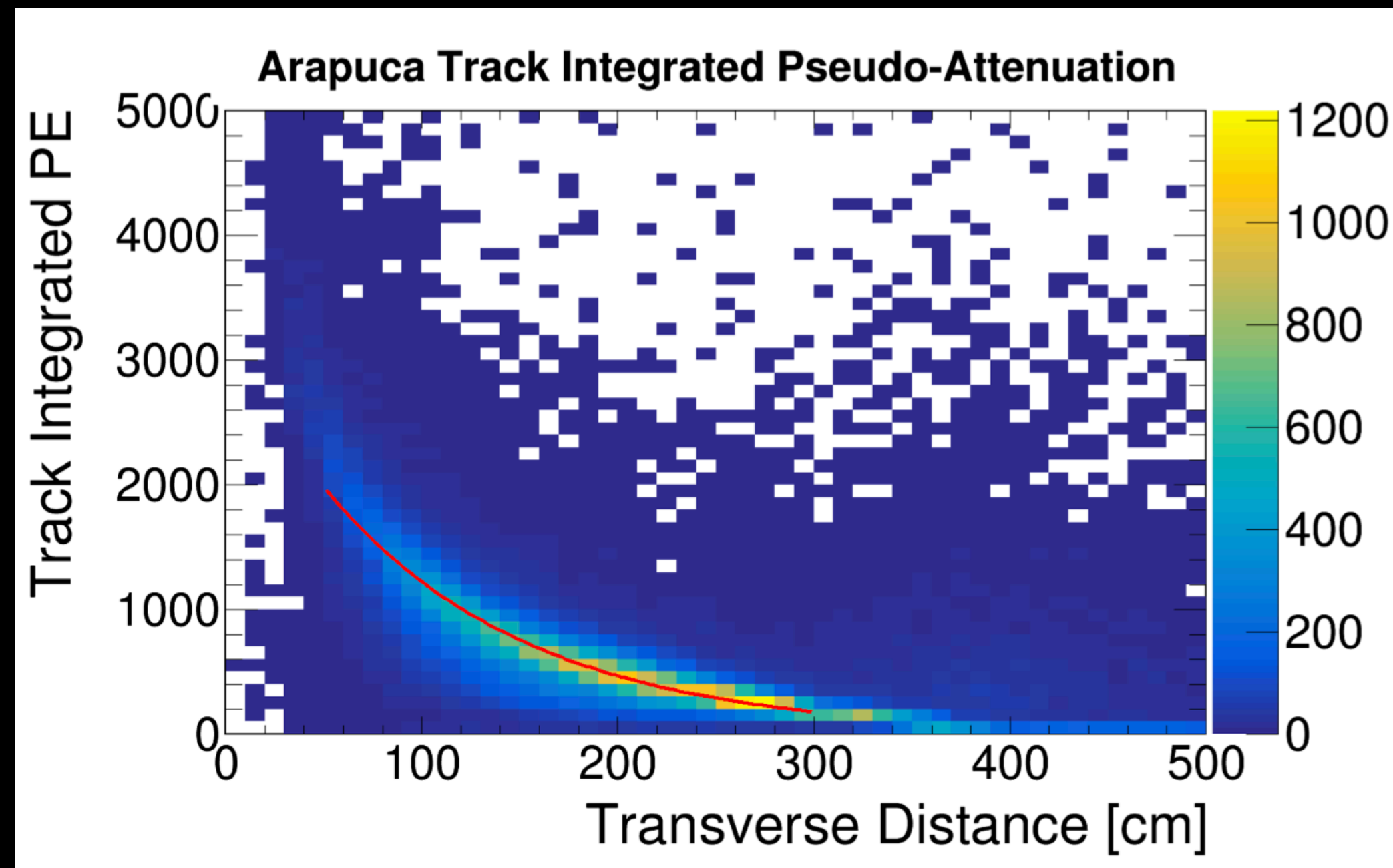
1 data point to the ARAPUCA graph

Distance Calculation



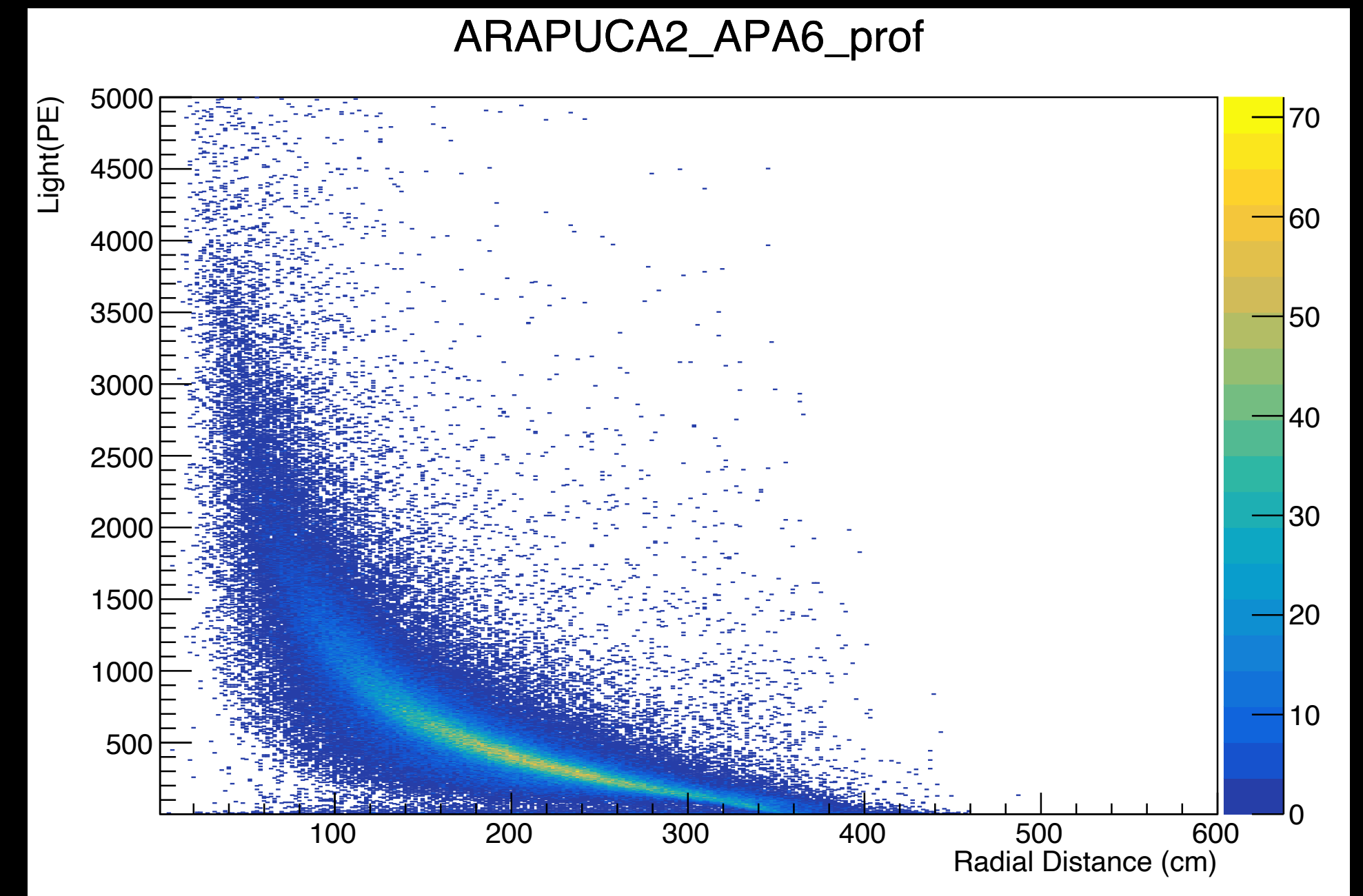
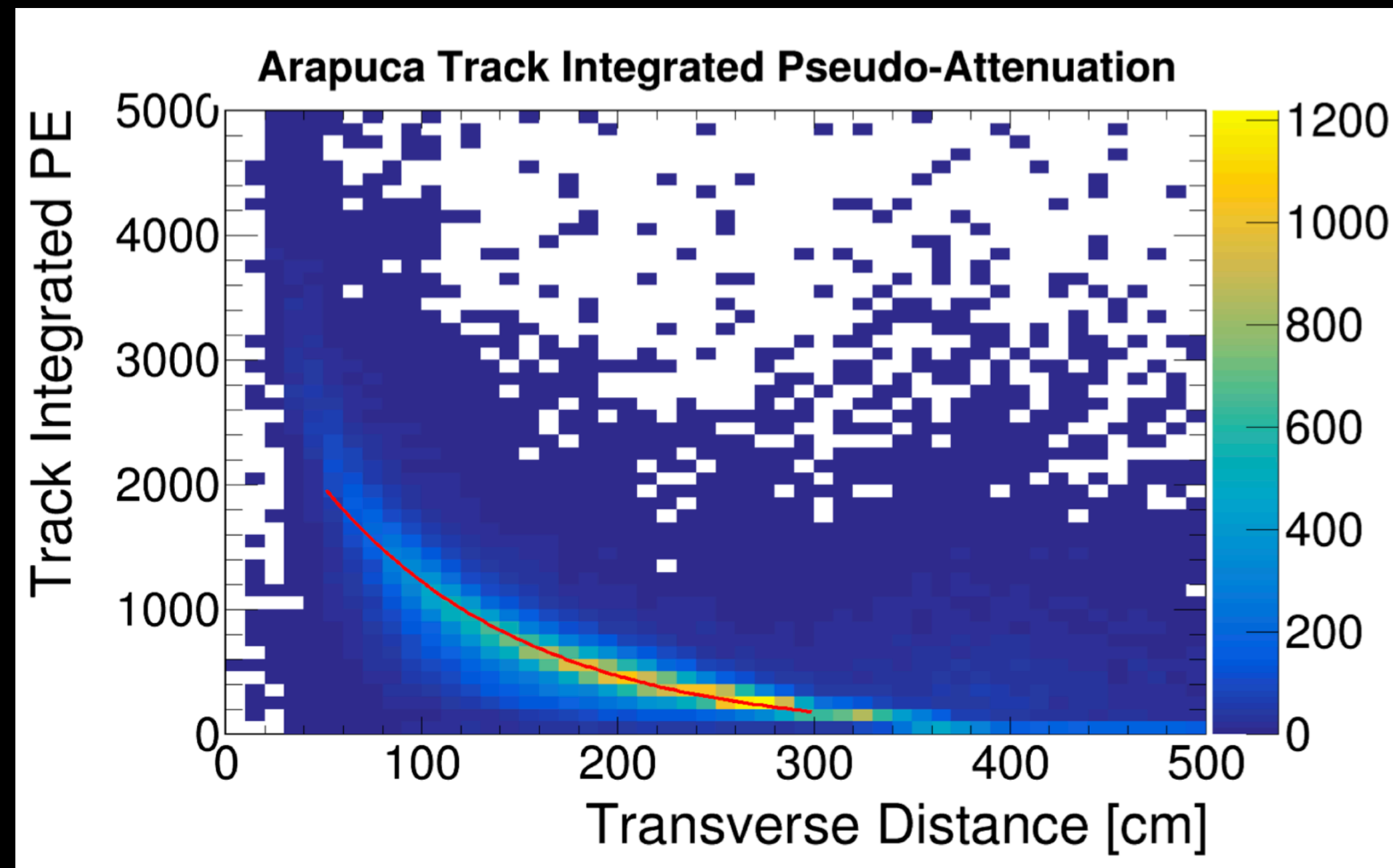
Previous Results

- Bryan Ramson performed this on the LAr data
 - See [here](#) for his talk from LIDINE 2019



Current Results

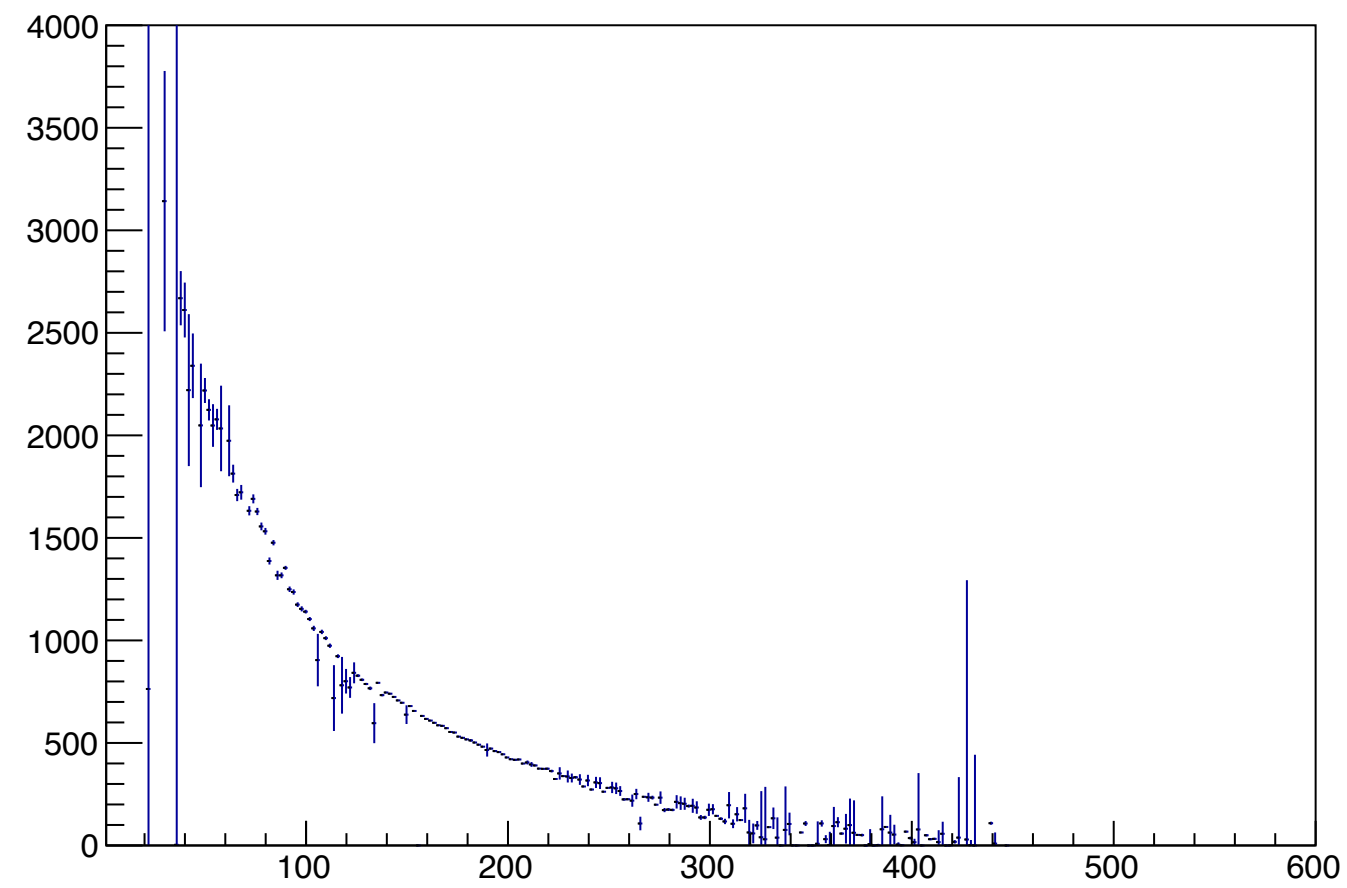
- New analysis makes use of better CRT-CTB matching to get a cleaner sample



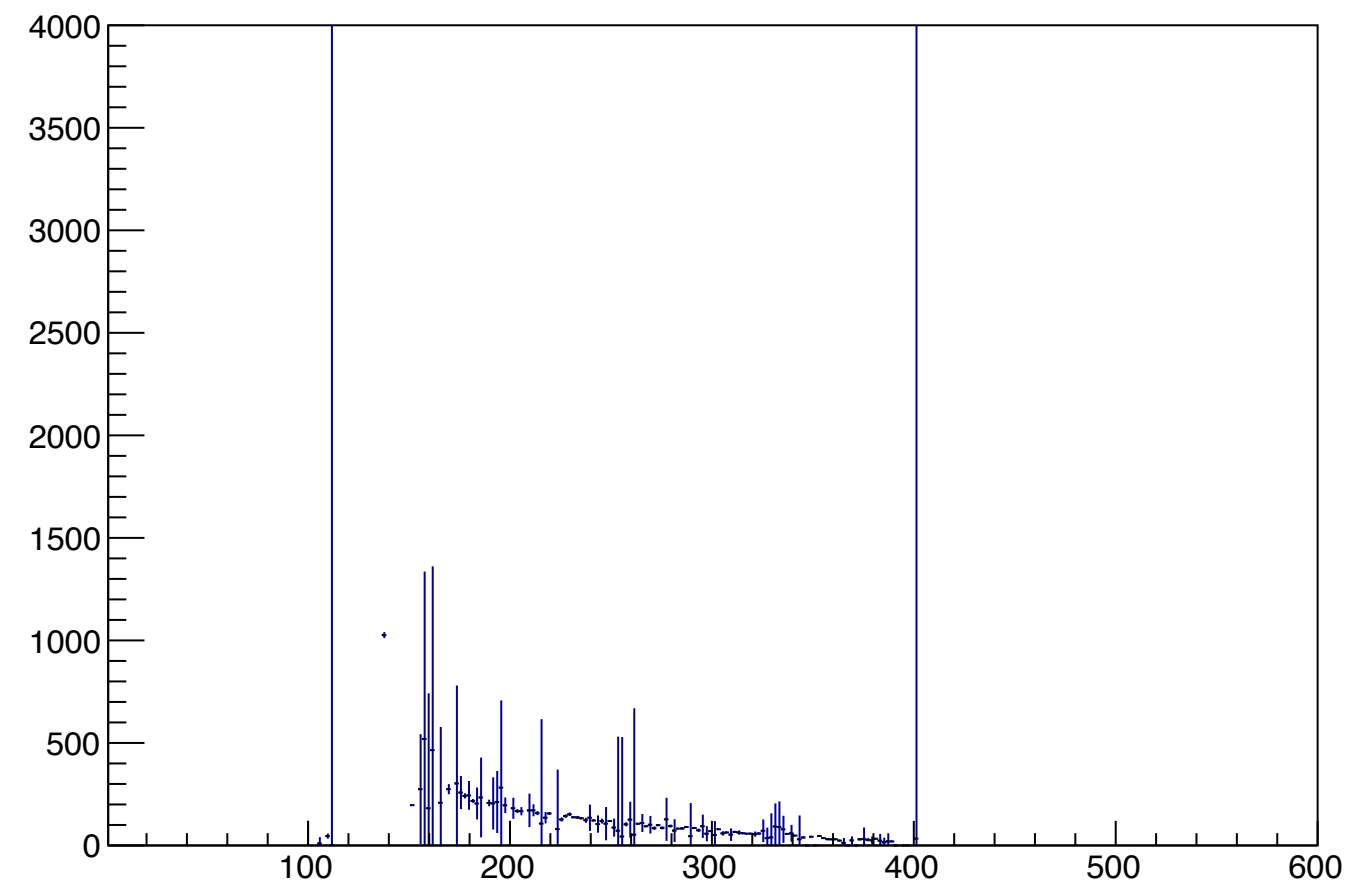
Current Results

ARAPUCA

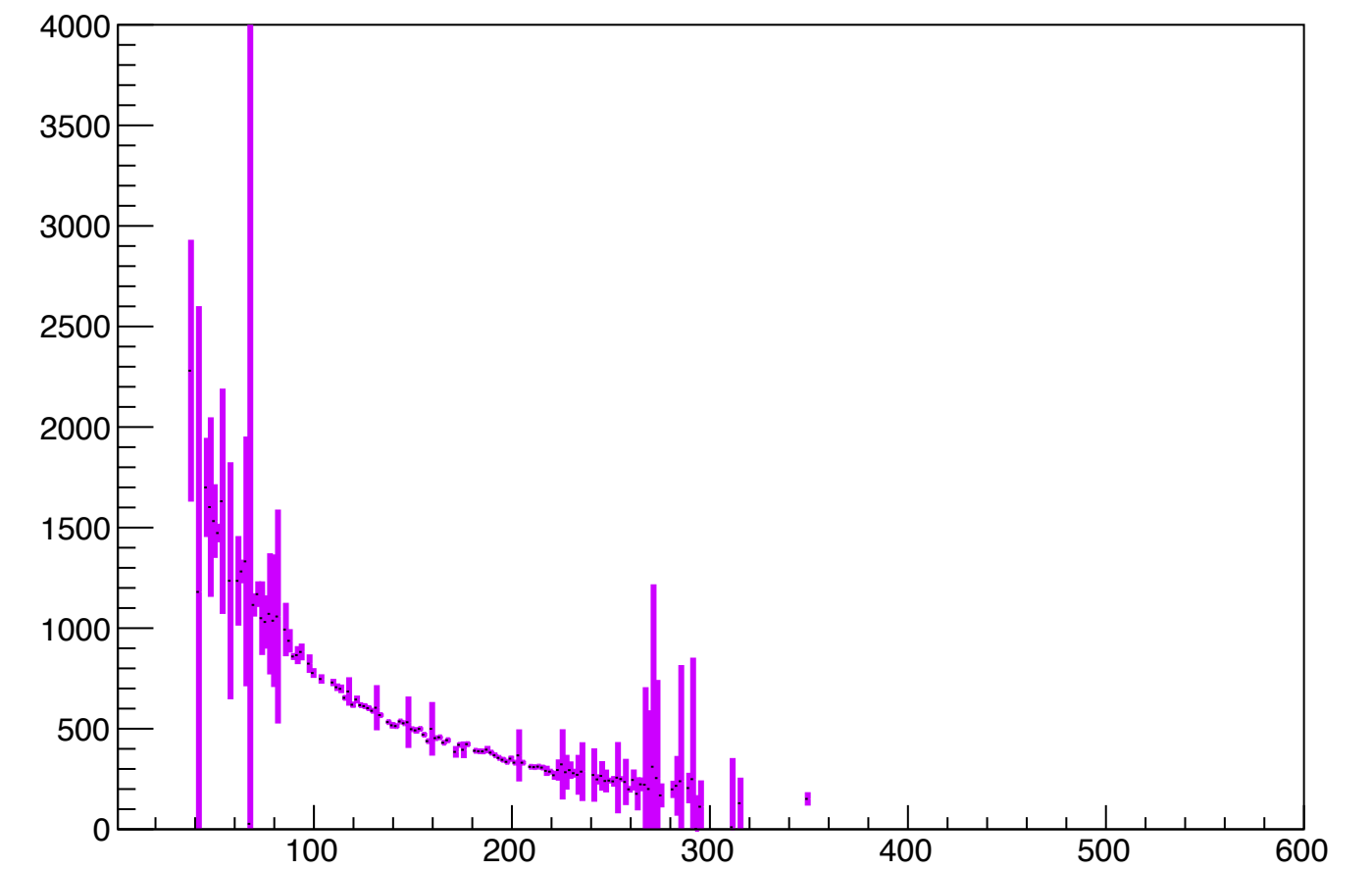
ARAPUCA2_APA6_prof



ARAPUCA2_APA6_prof



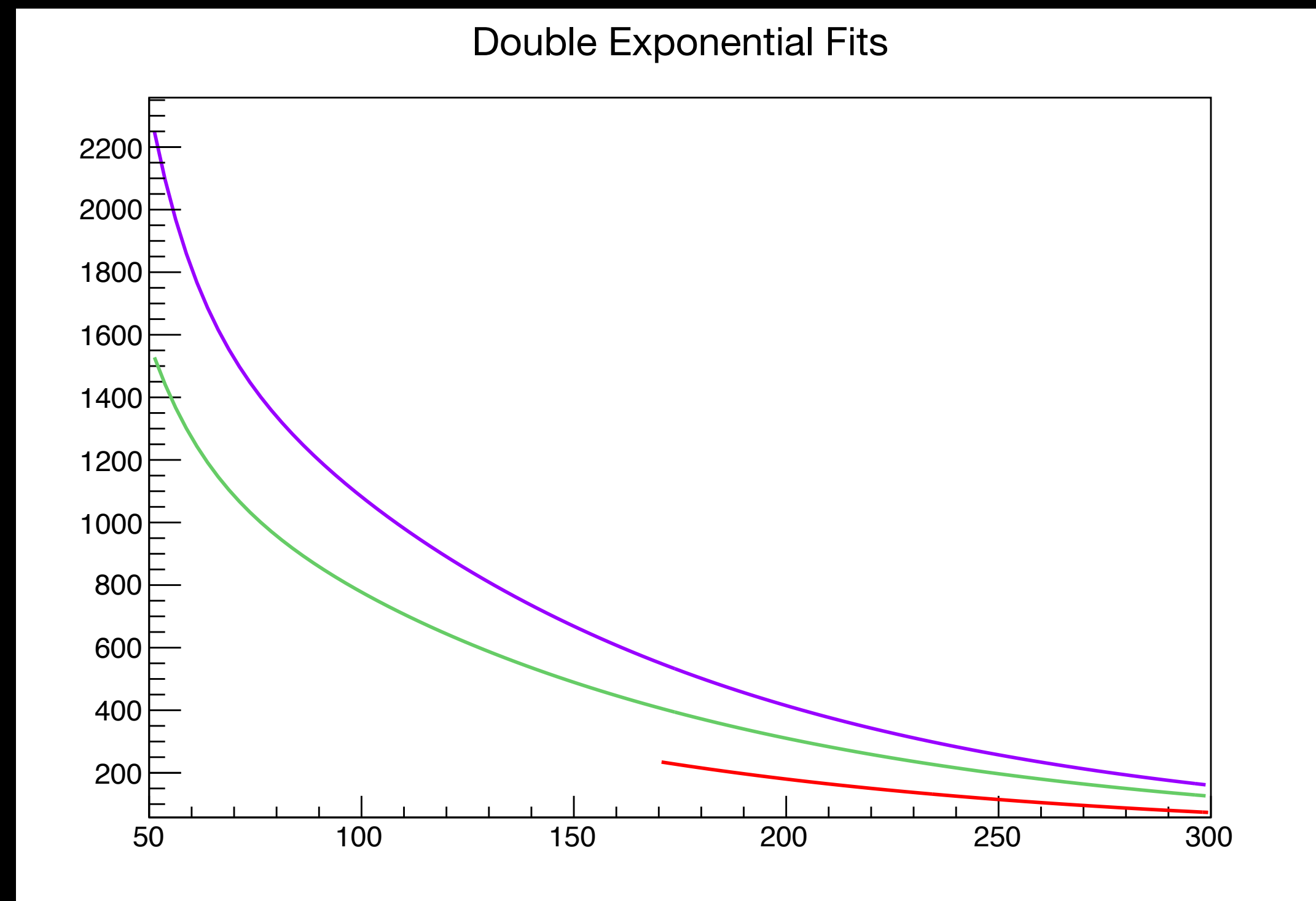
ARAPUCA2_APA6_prof



Current Results

ARAPUCA

- Fit all attenuation curves to double exponentials
 - best model for now
- Not including numbers here
 - no physical meaning for now

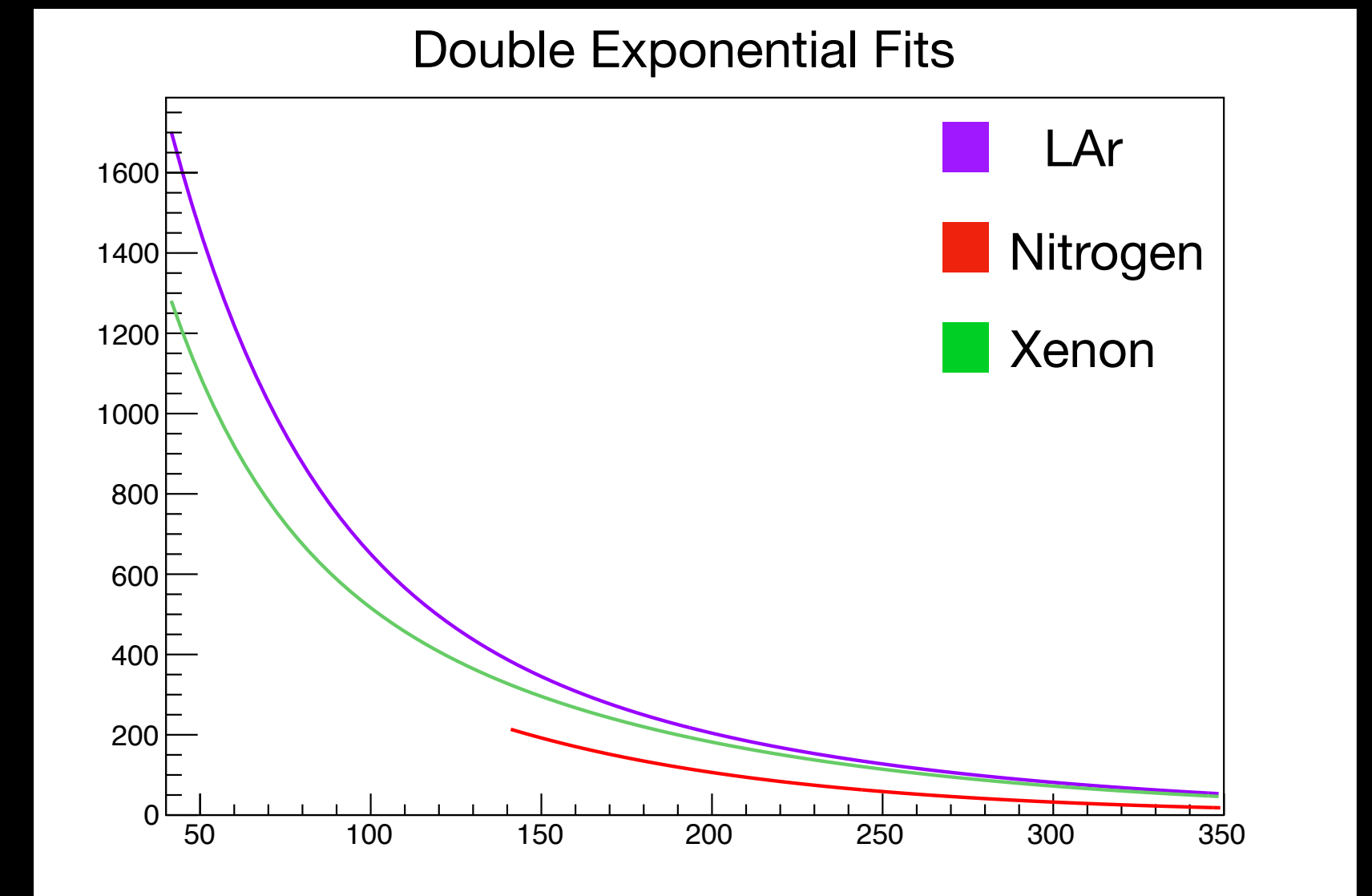
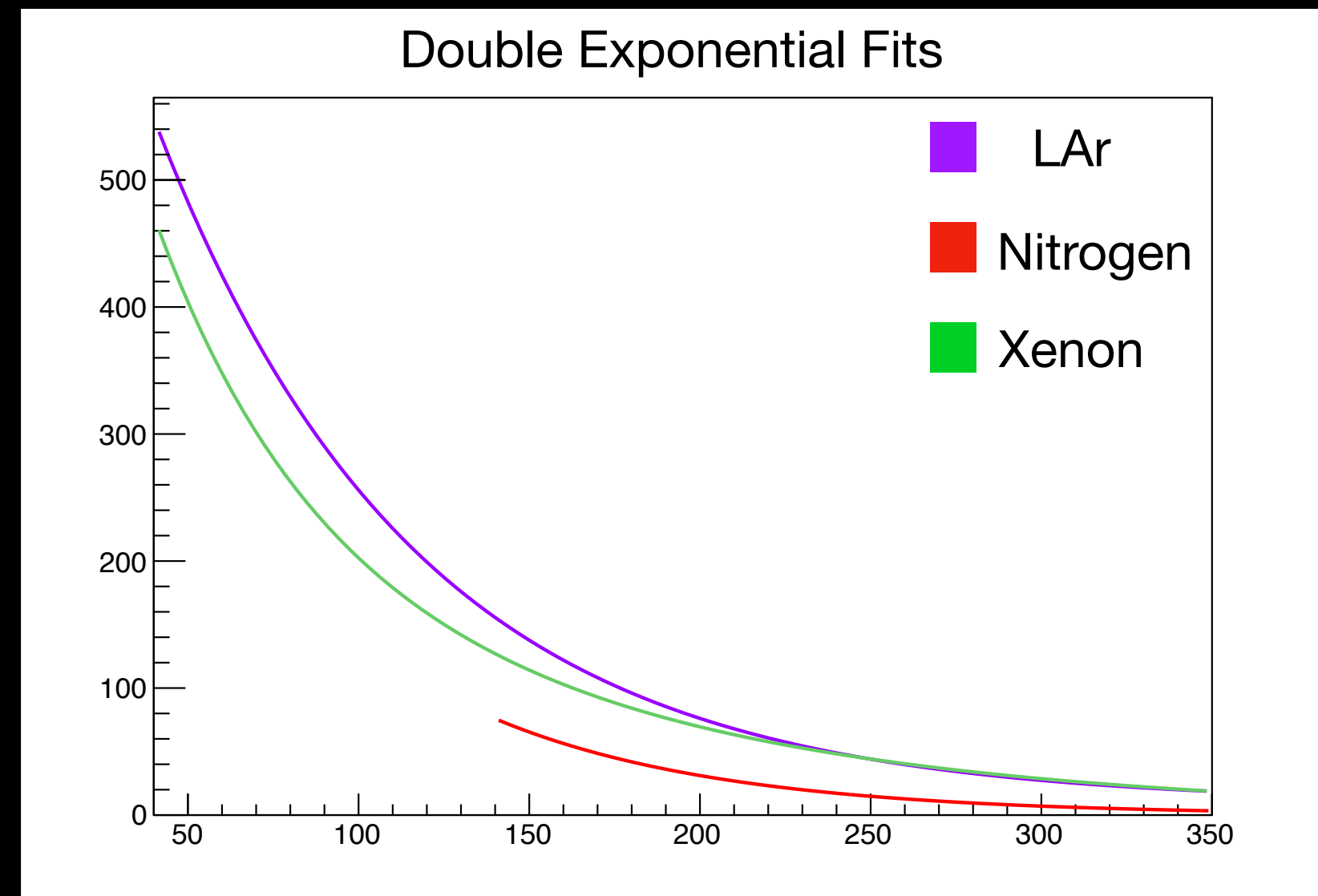


- LAr
- Nitrogen
- Xenon

Current Results

DSL

- Fit all attenuation curves to double exponentials
 - best model for now
- Not including numbers here
 - no physical meaning for now



More to come on this - I have a talk in the CM (Thursday sometime - not sure what meeting?)

Still need MC

Doping vs. Time in ProtoDUNE

Look at amplitude and integral of avg waveforms

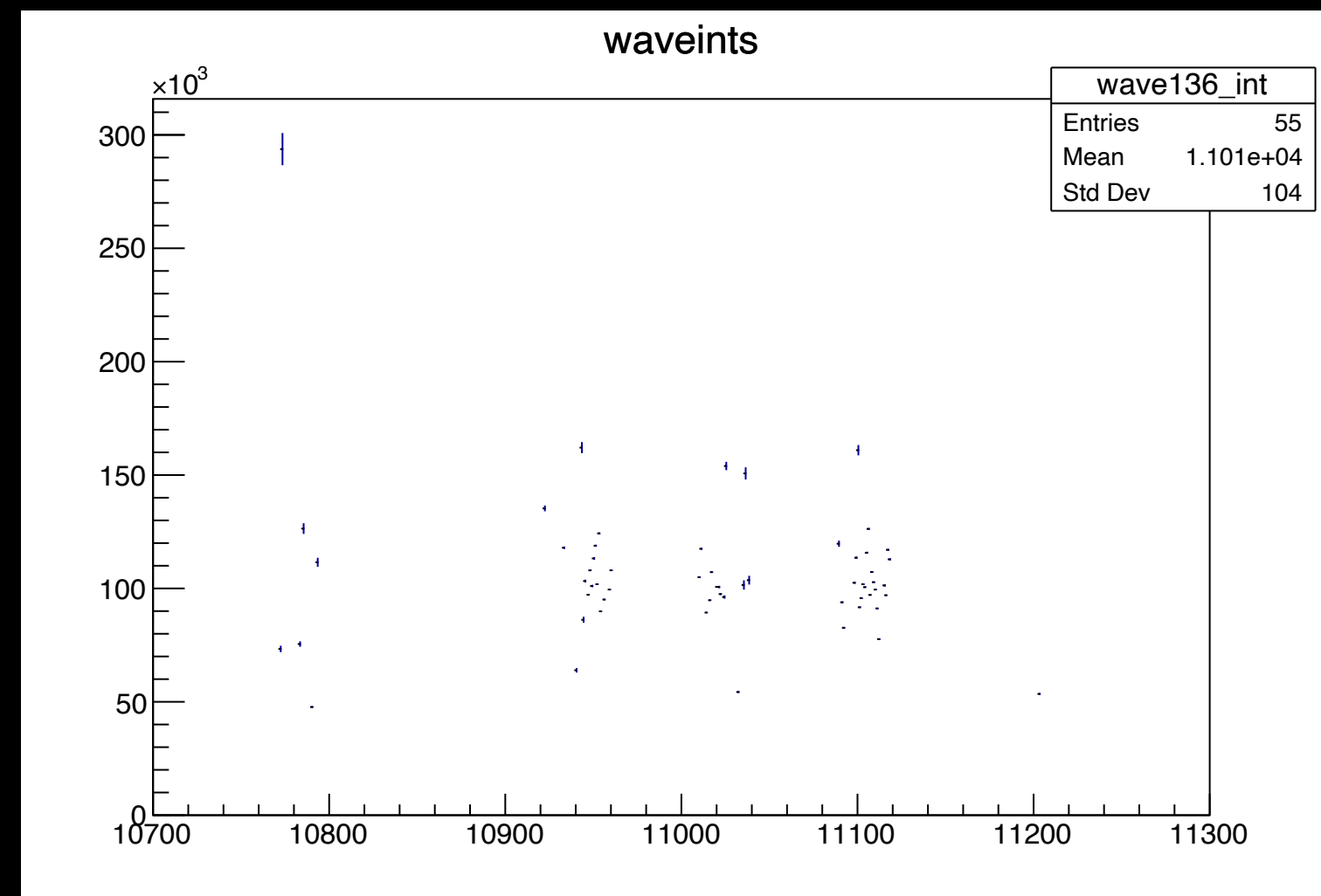
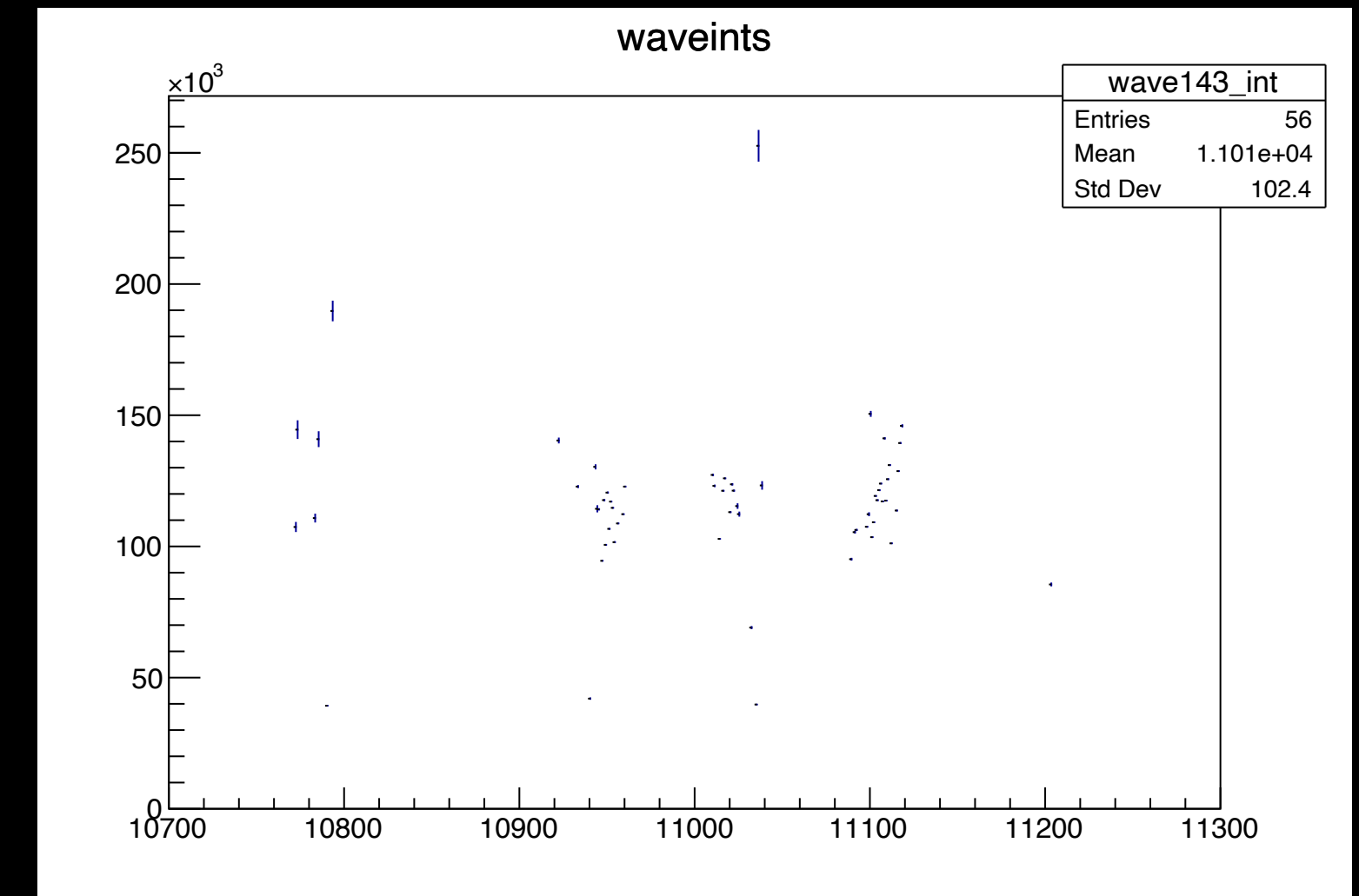
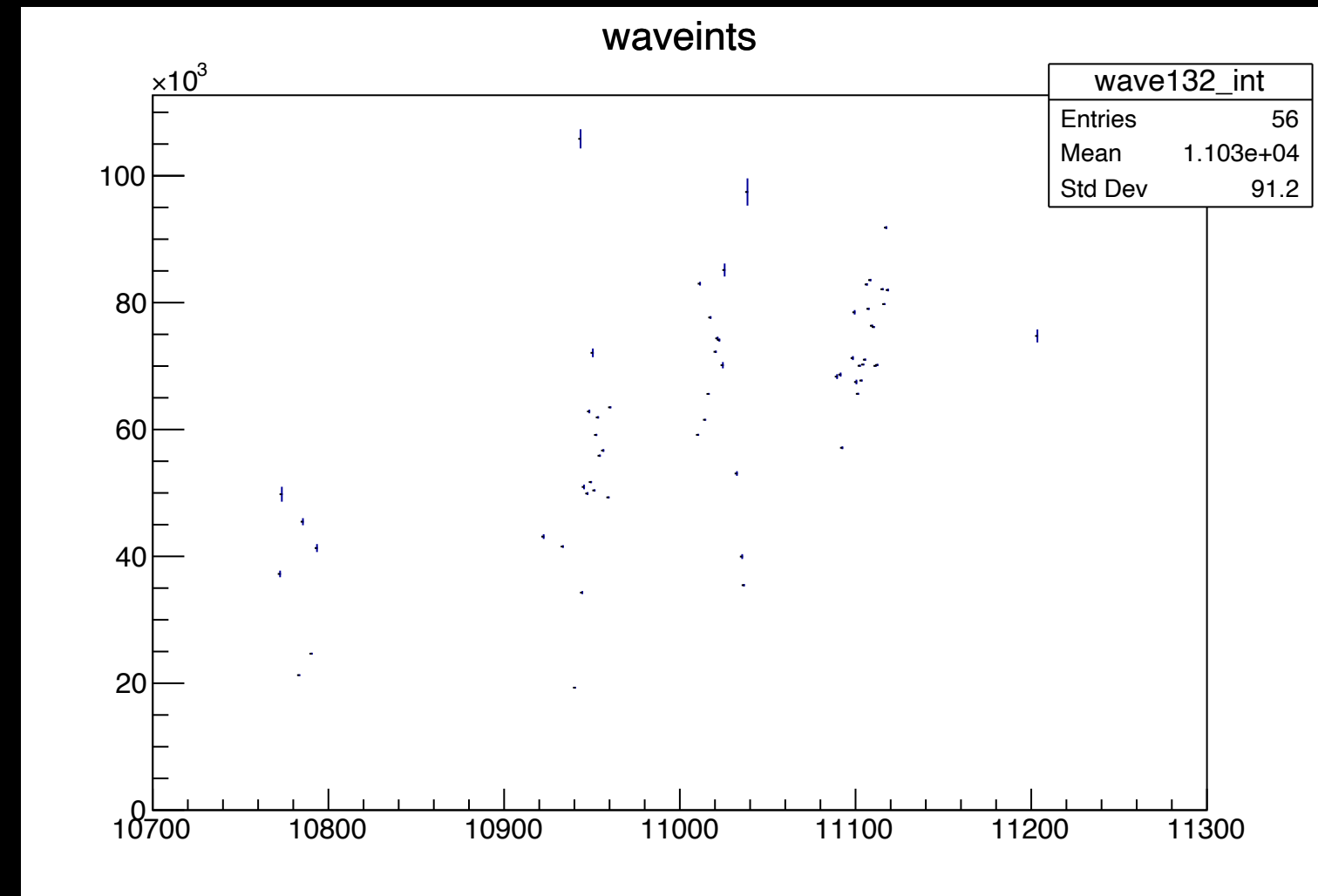
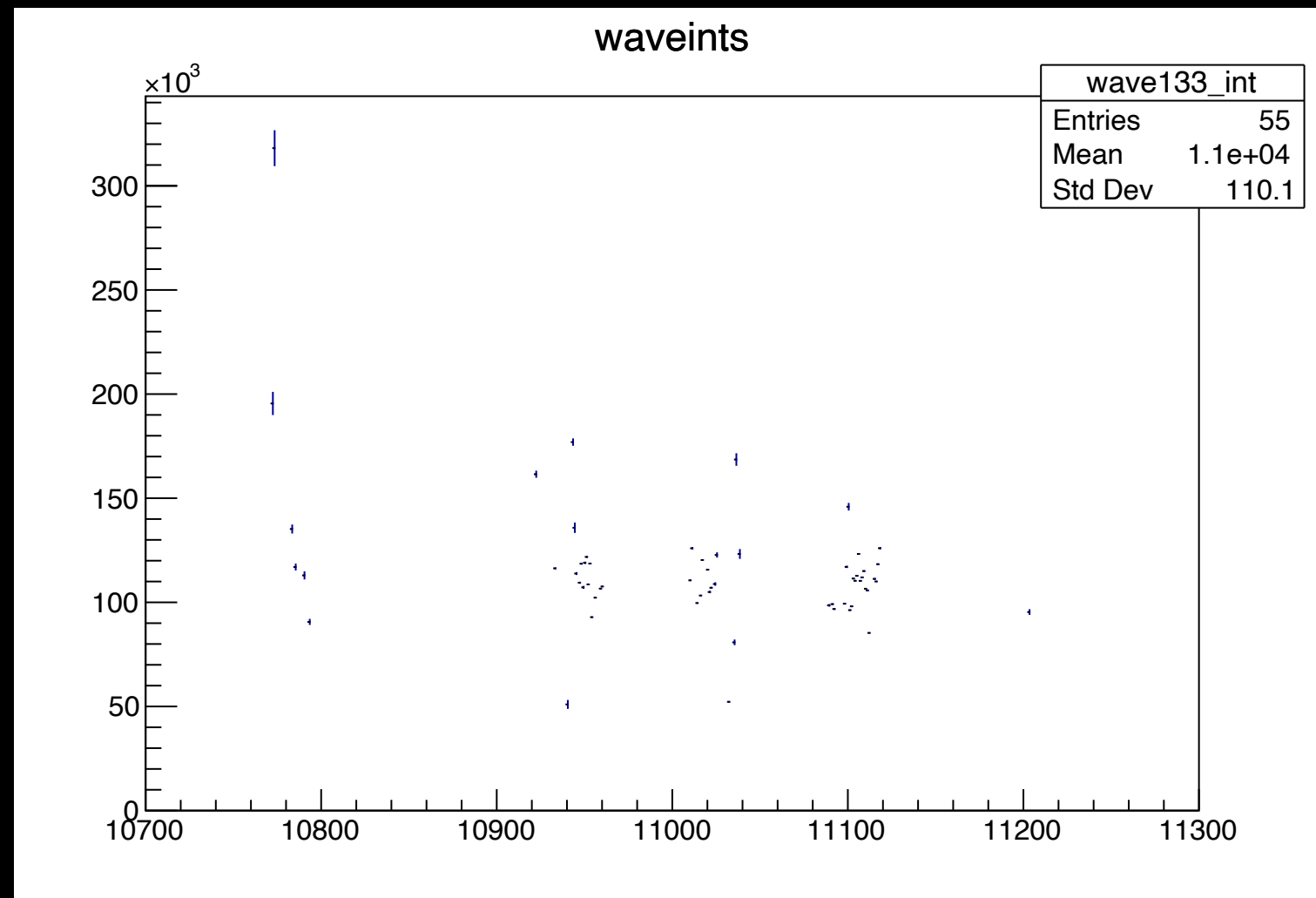
- Processing Procedure
 - Decode/reconstruct data
 - Sort by channel
 - Clean Saturated events and events with pre-trigger activity
 - Average remaining waveforms
 - Get metrics from these avg waveforms
- CHANNEL BY CHANNEL AS OF NOT - not per module

Just finished (pre)processing this morning - preliminary

ARAPUCA in APA 3

Individual Channels

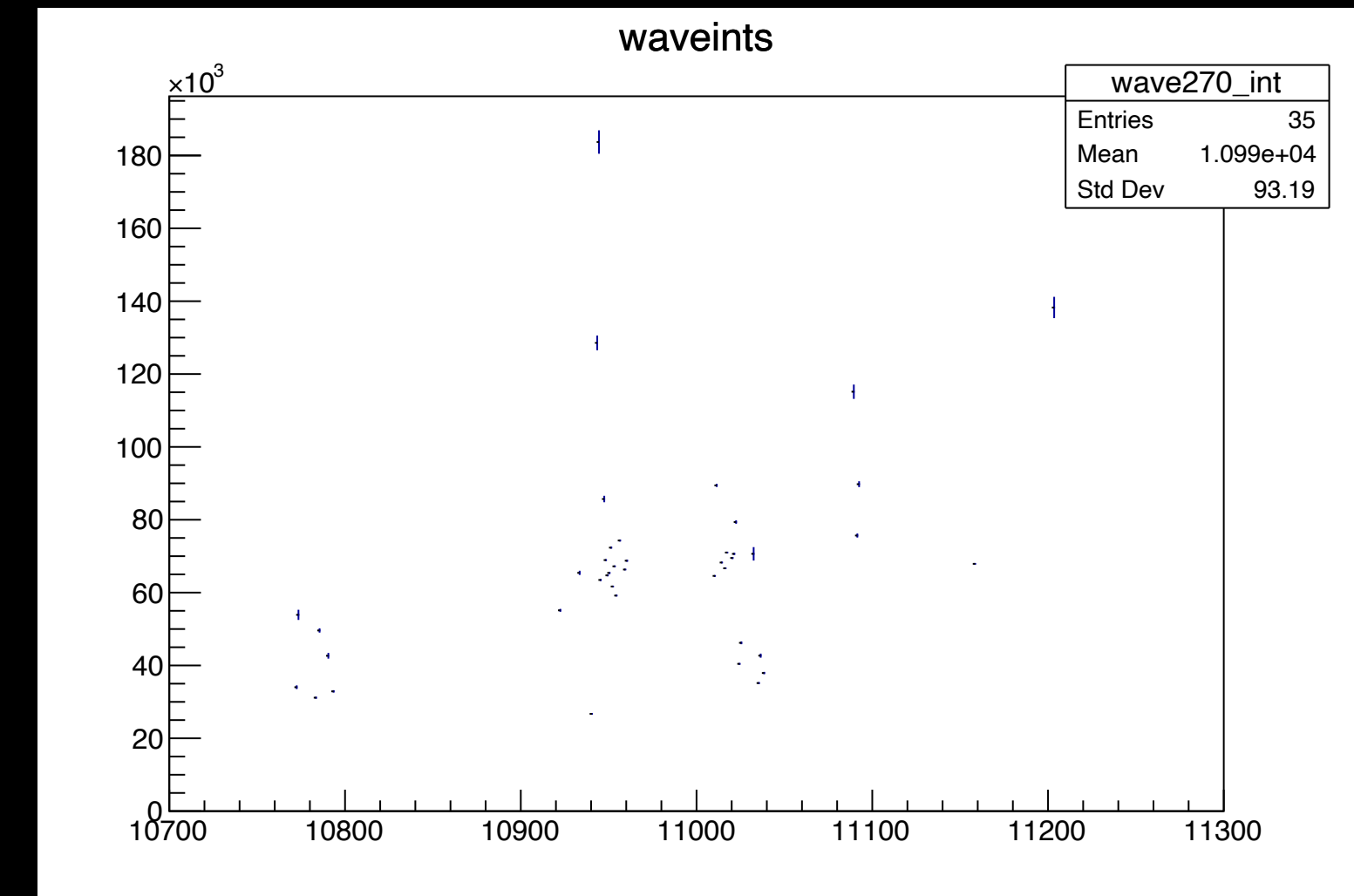
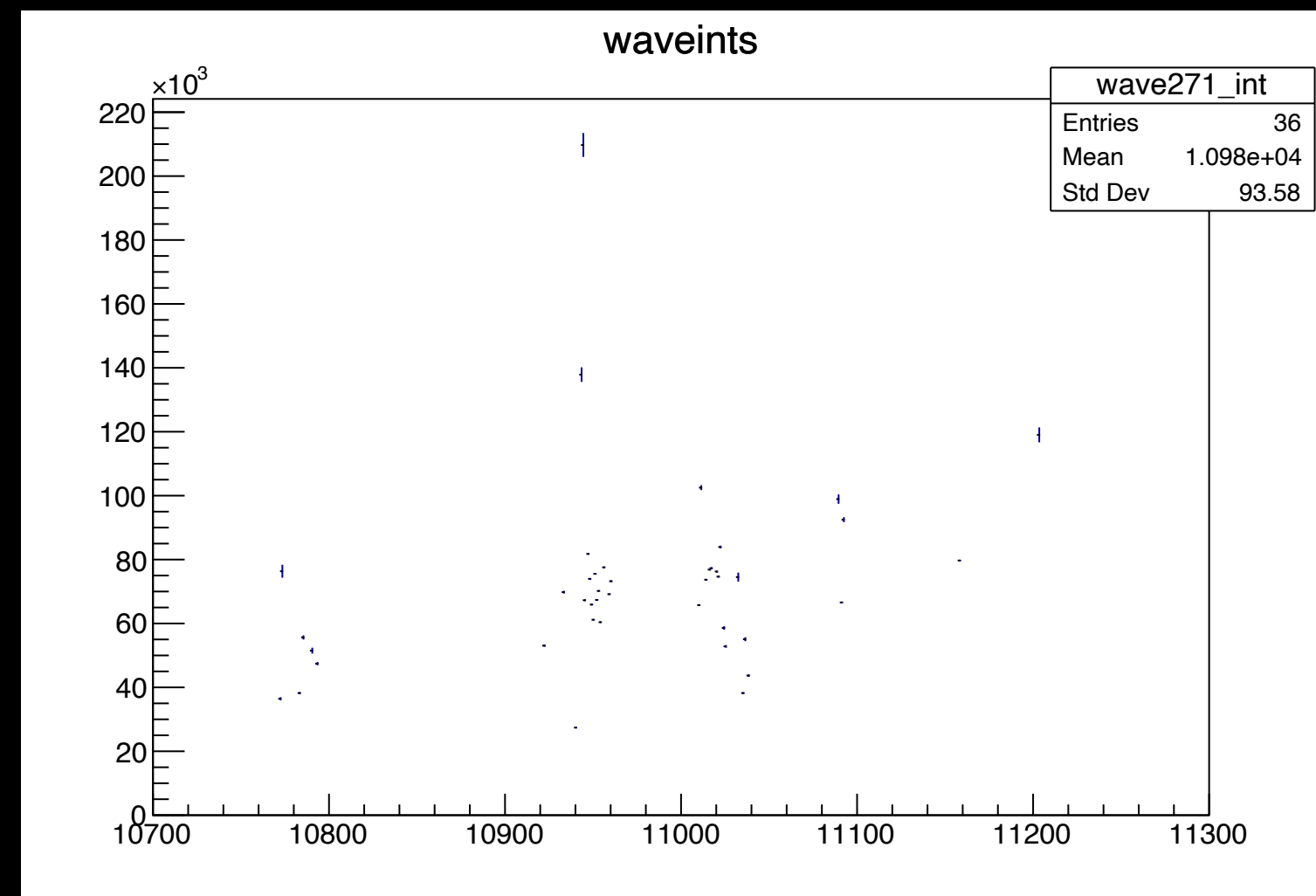
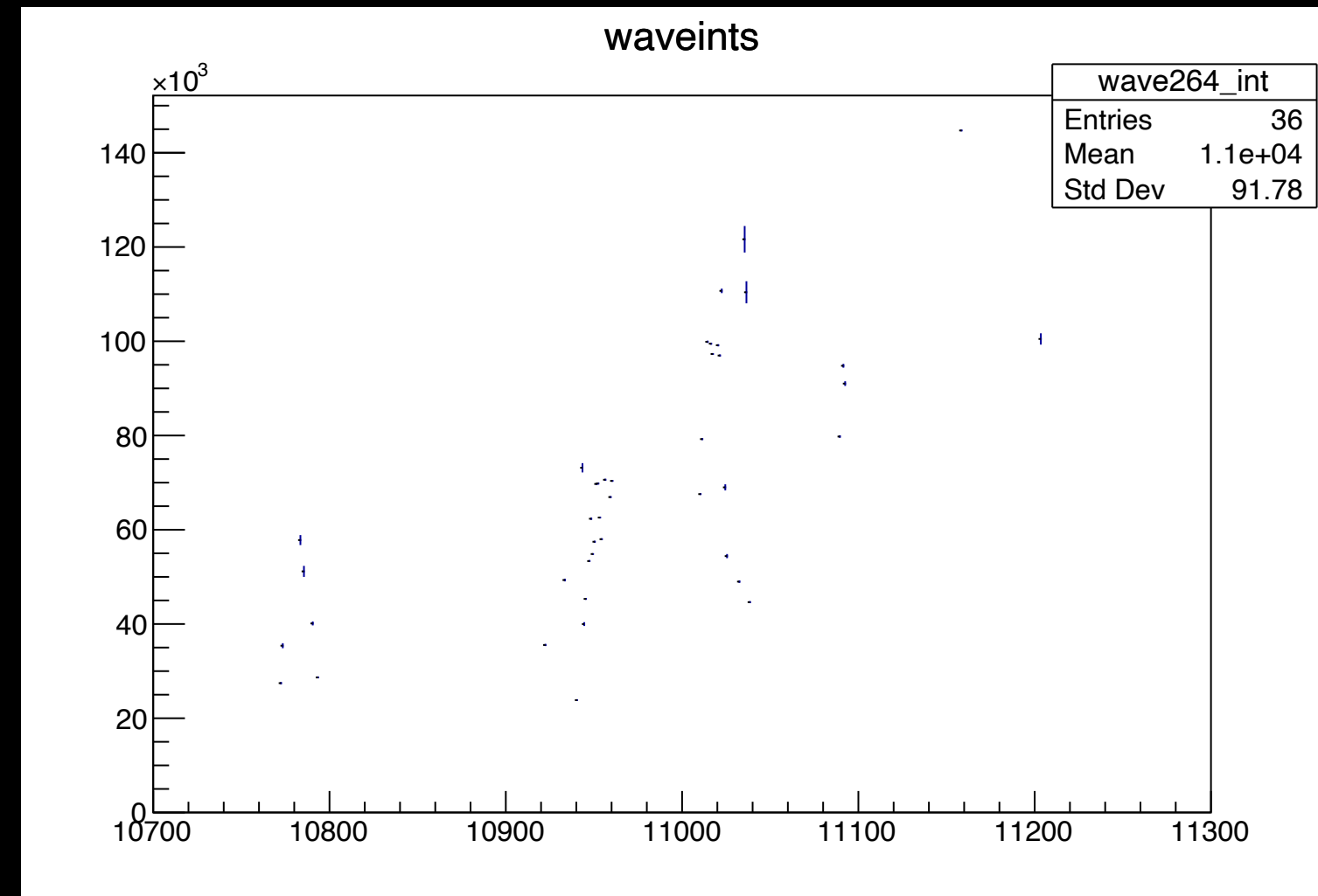
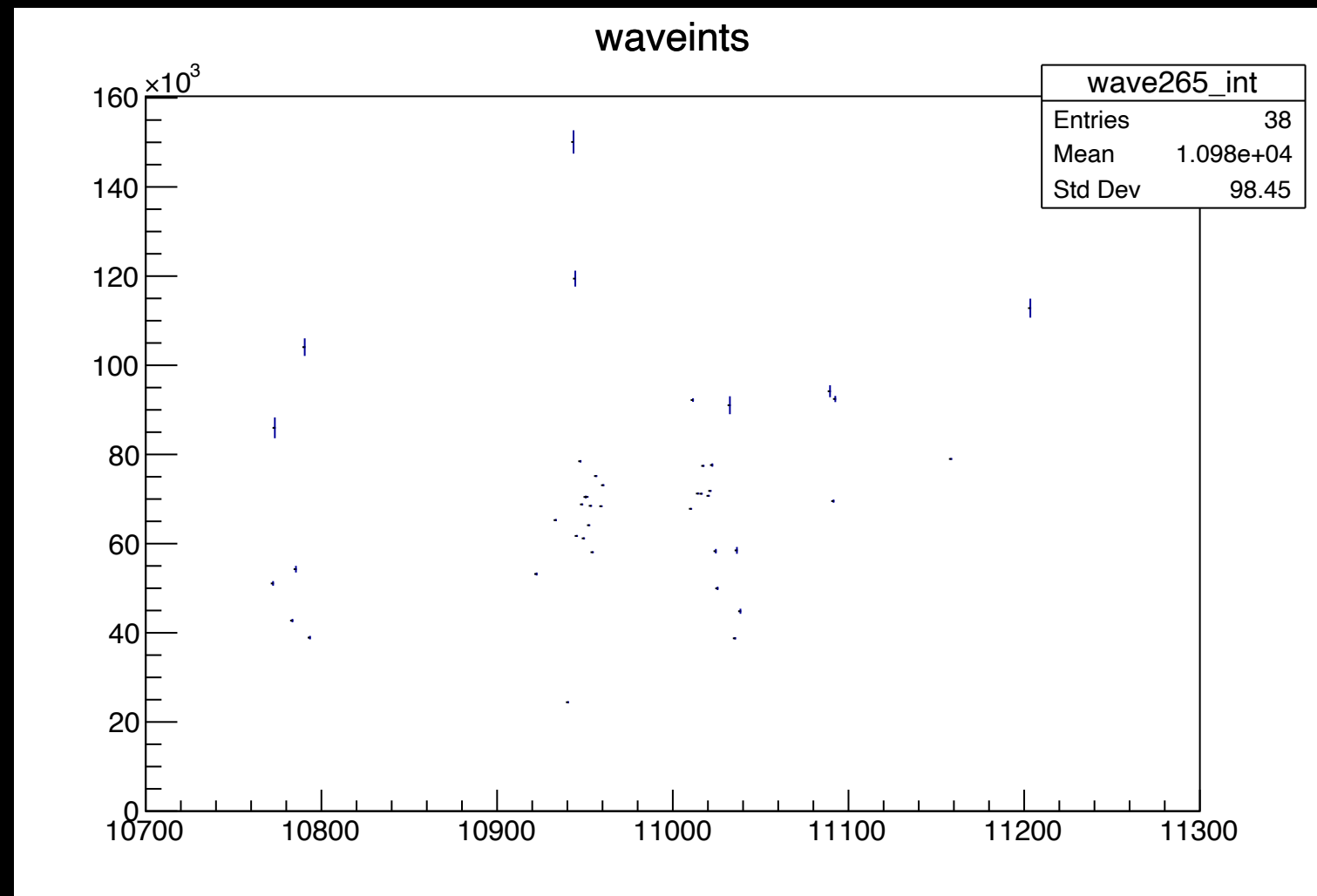
Stats boxes are in the way. Sorry!
4 of 12 channels at random



ARAPUCA in APA 6

Individual Channels

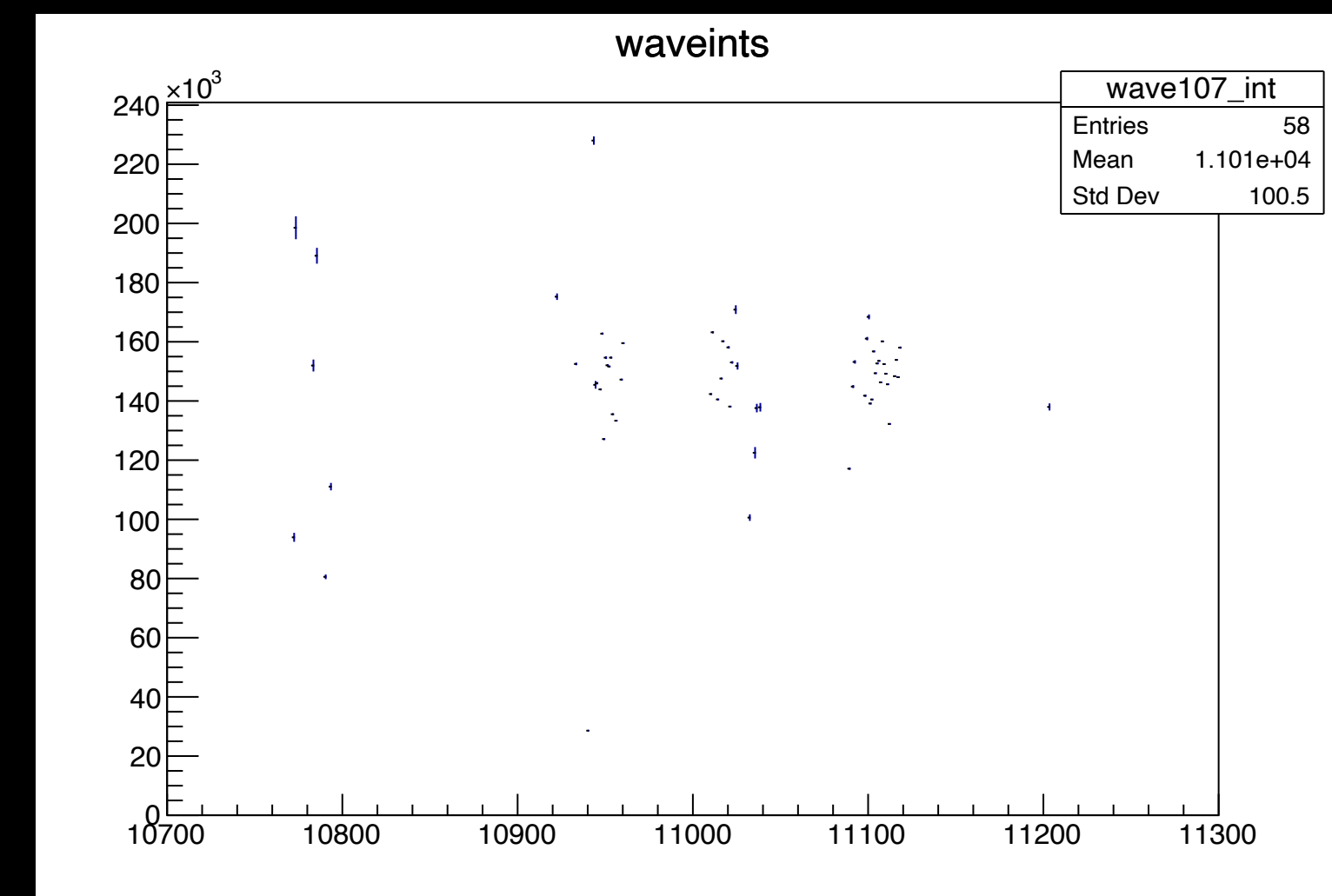
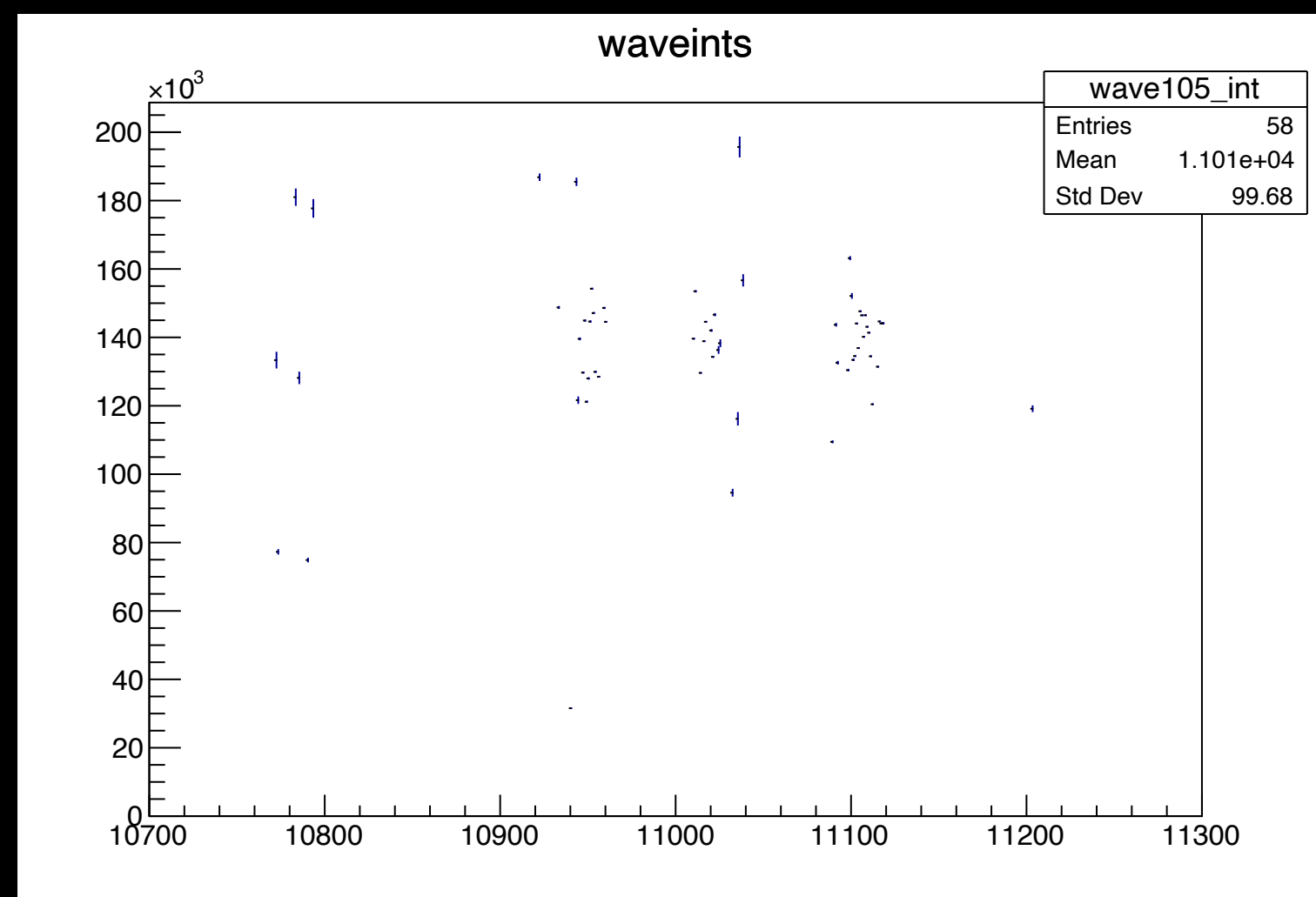
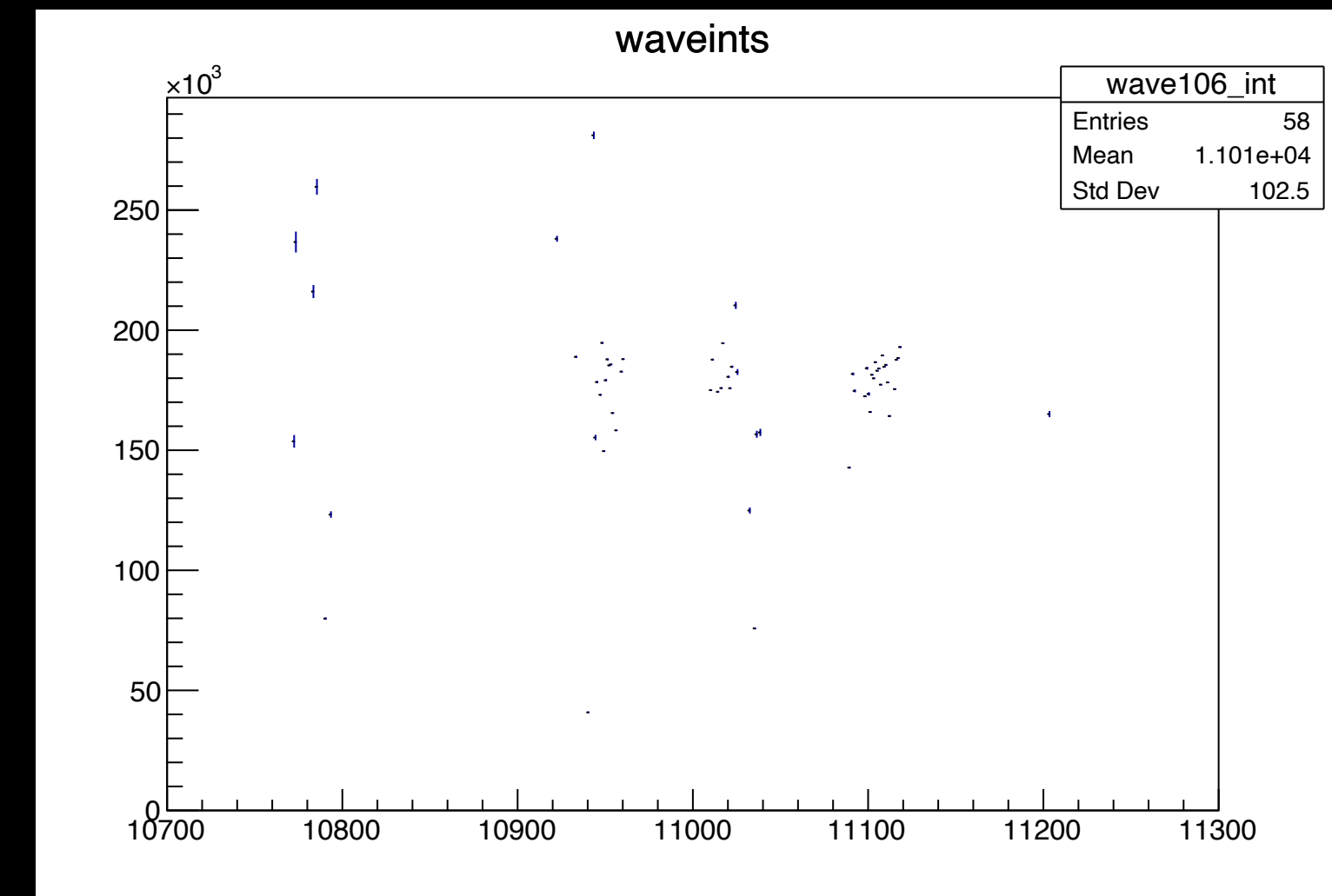
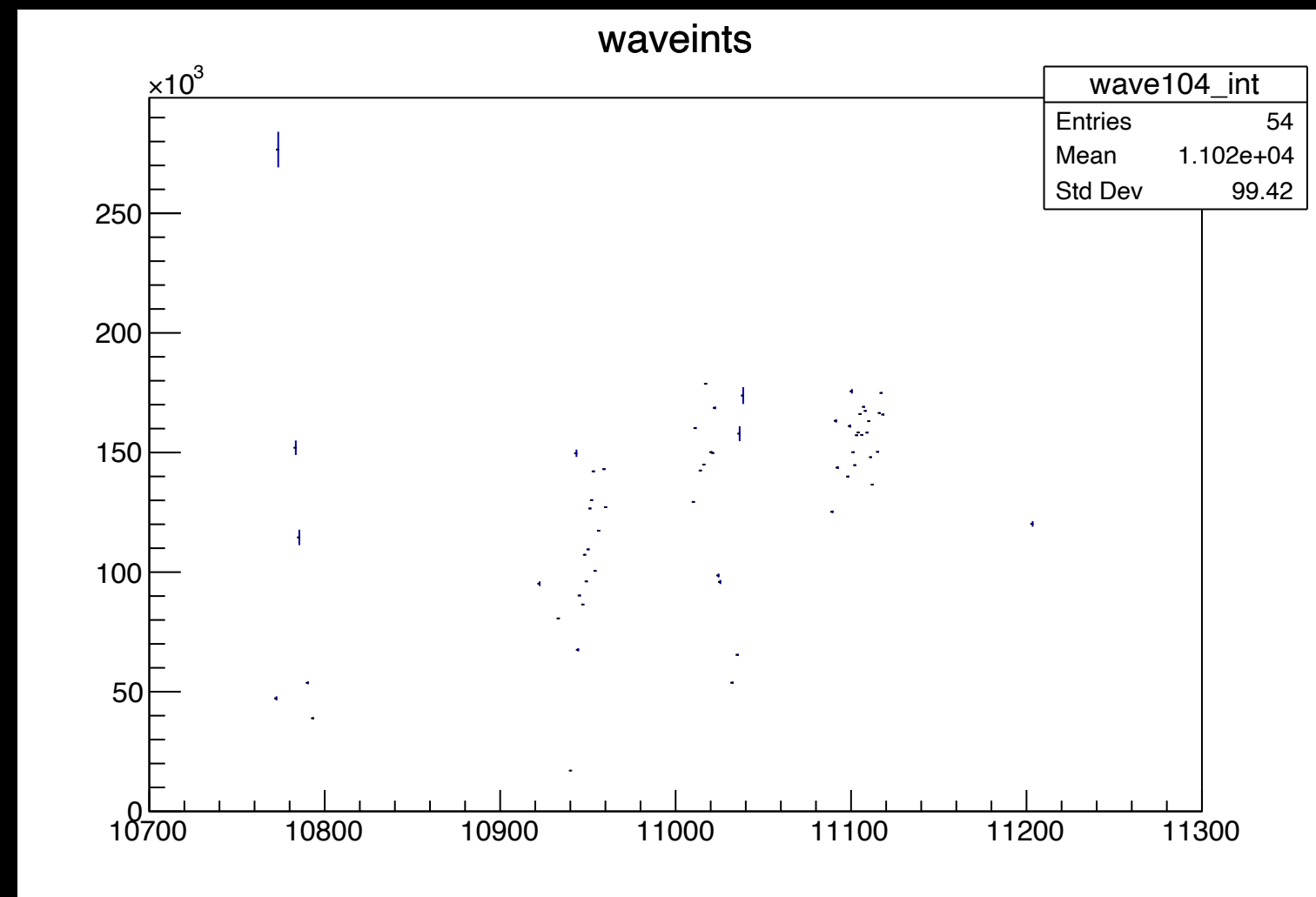
Stats boxes are in the way. Sorry!
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IU Bar in APA 3

Individual Channels

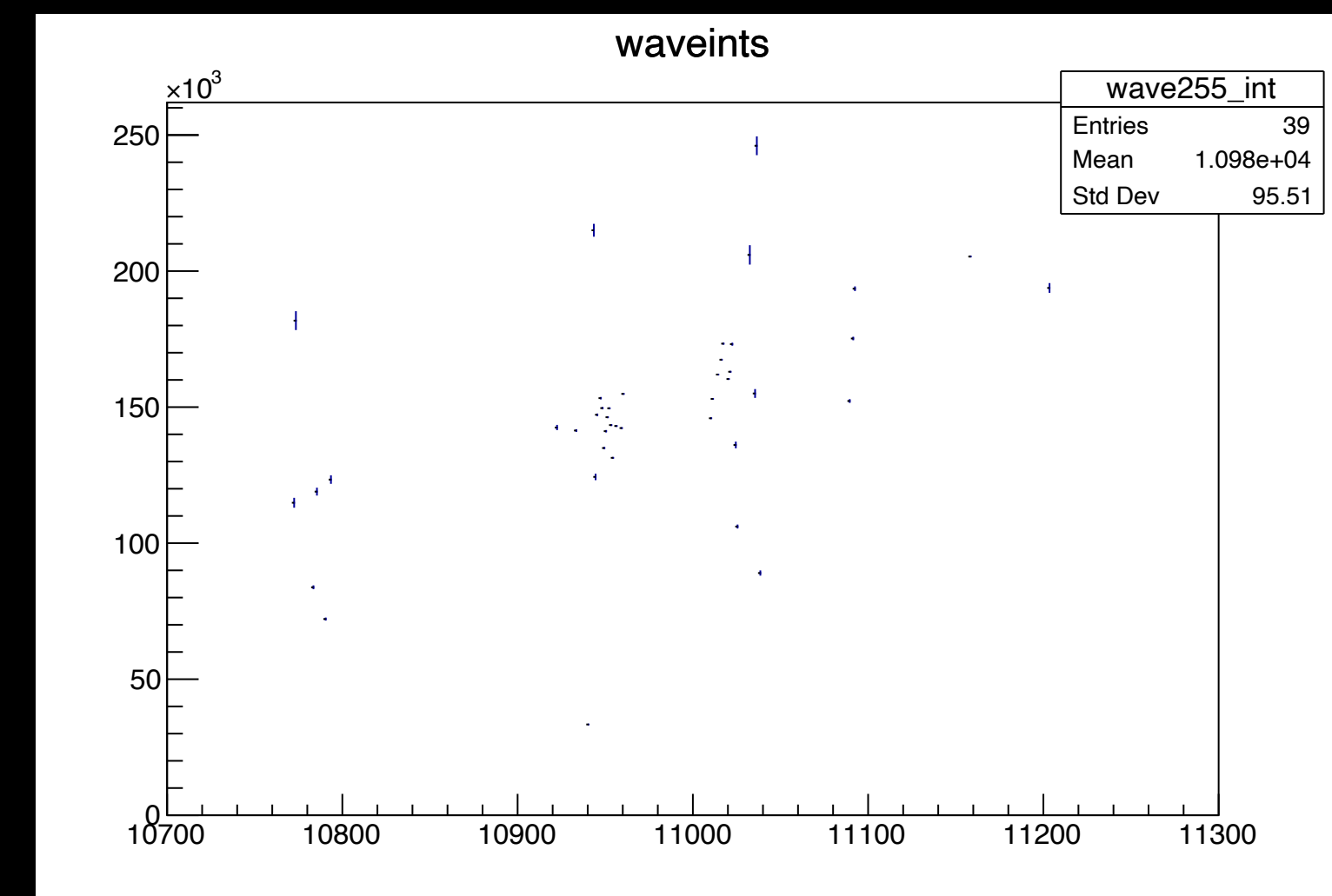
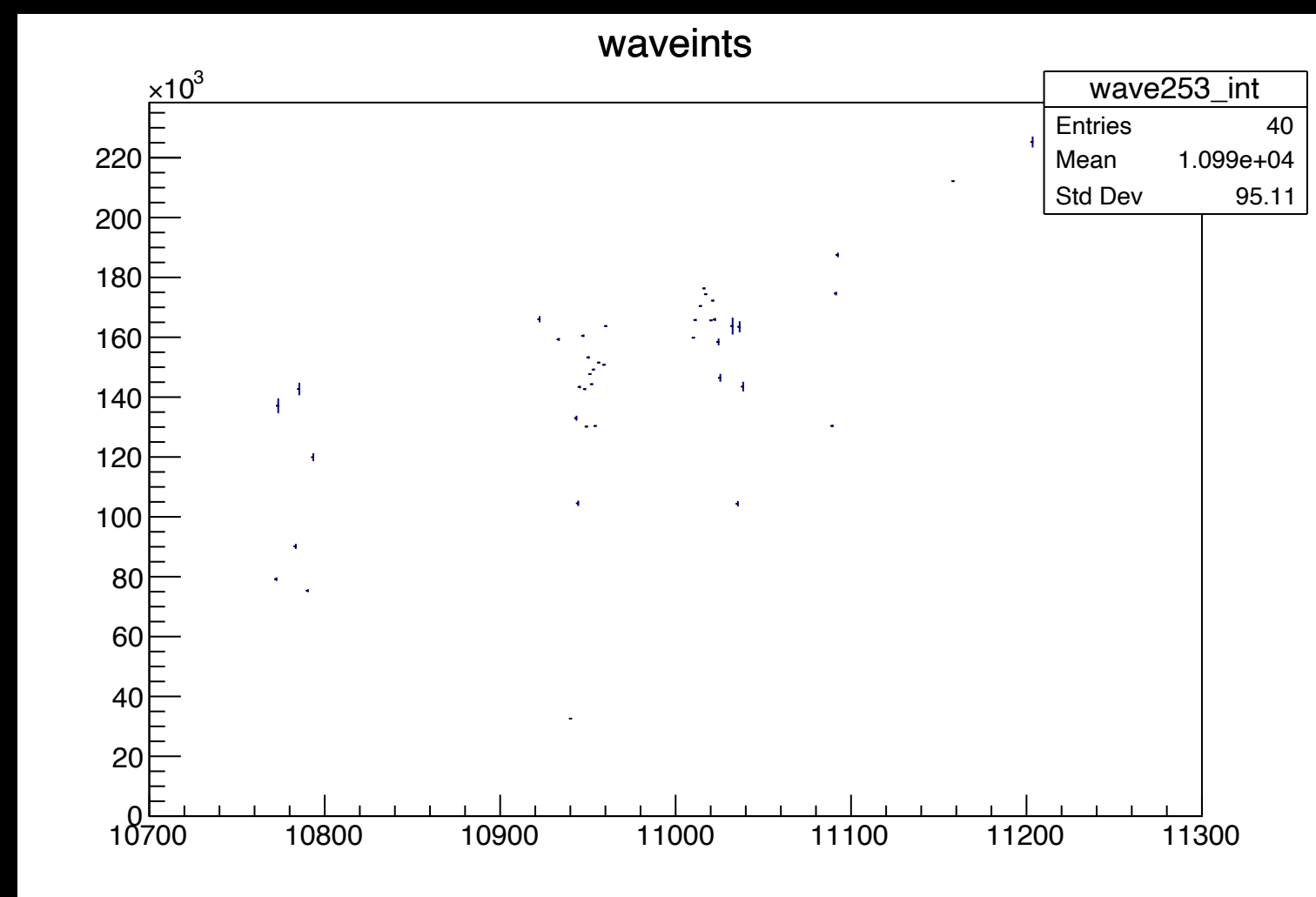
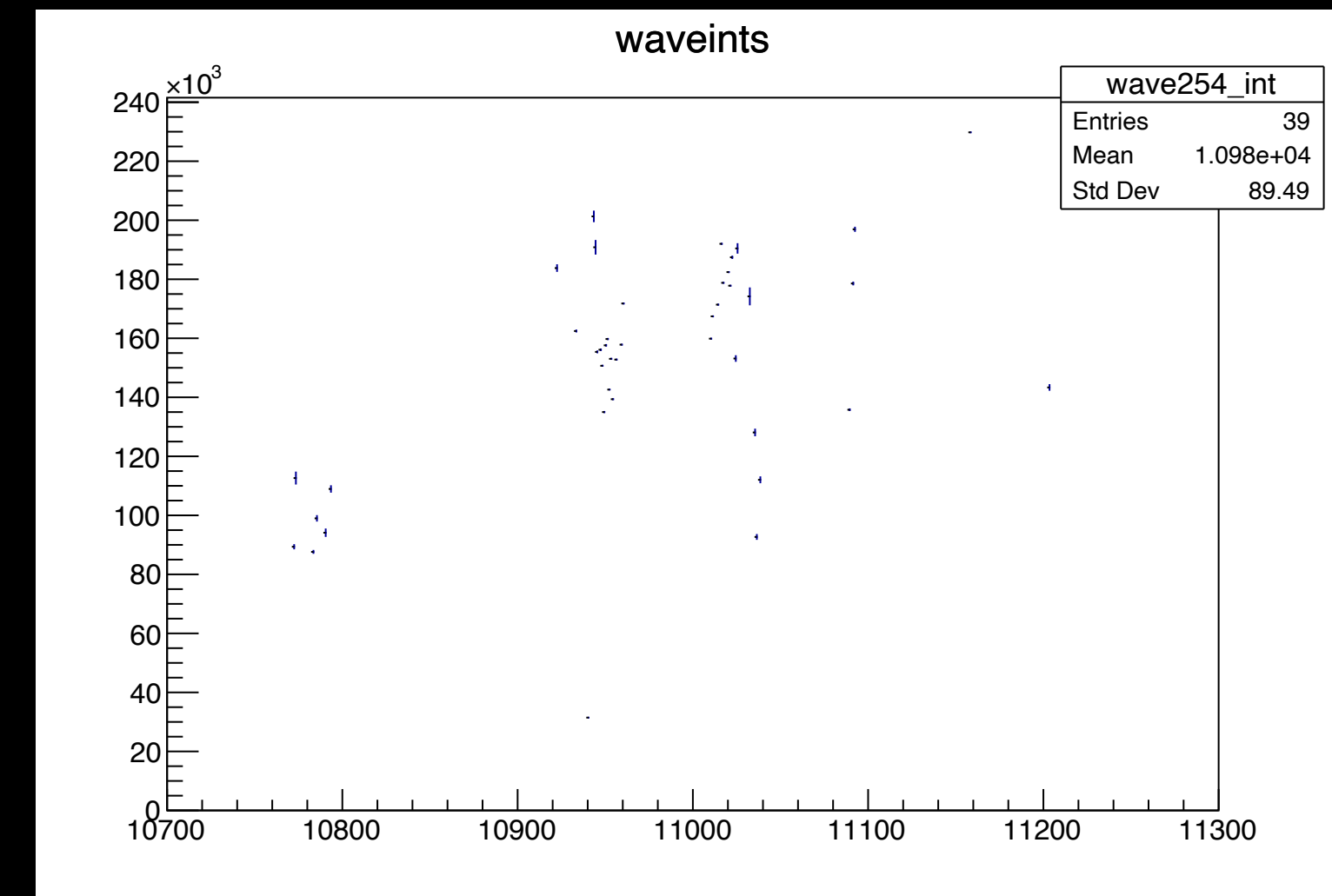
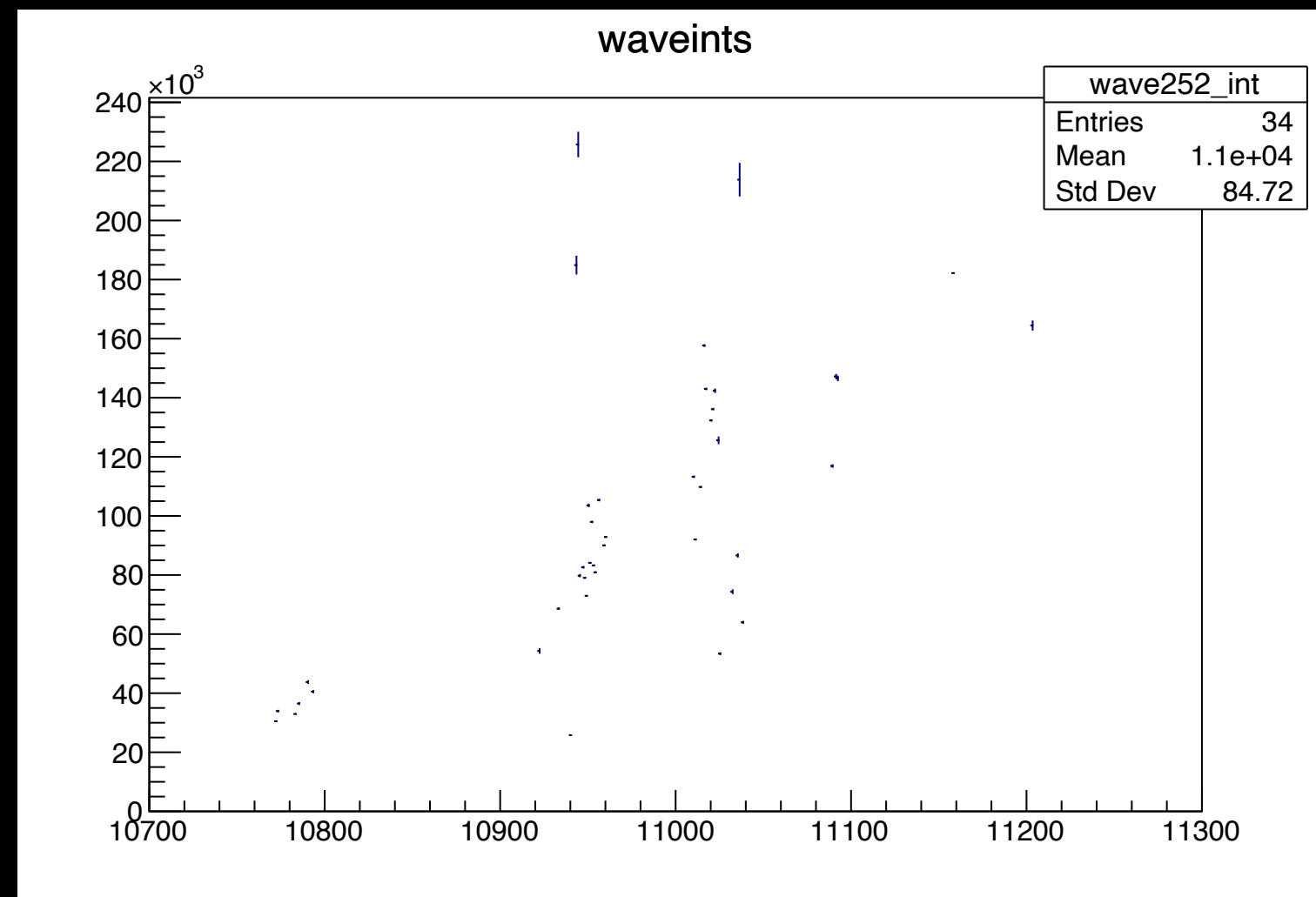
Stats boxes are in the way. Sorry!



IU Bar in APA 6

Individual Channels

Stats boxes are in the way. Sorry!



IU Bars in ProtoDUNE

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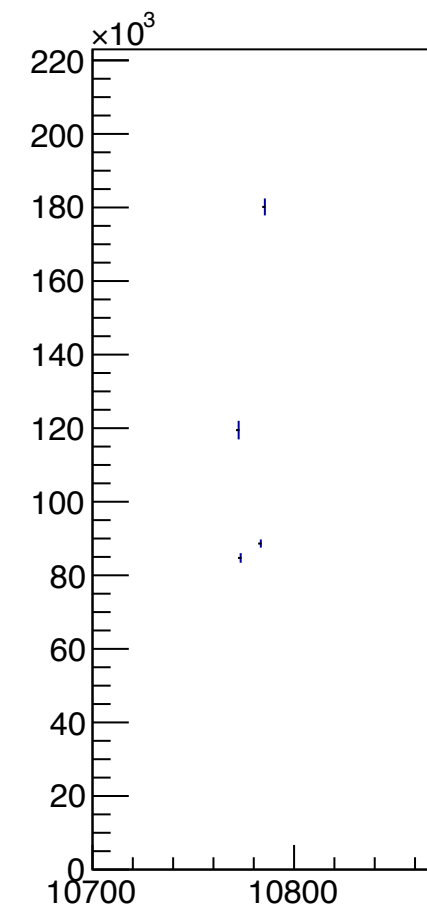
Individual

One channel from each of these bars

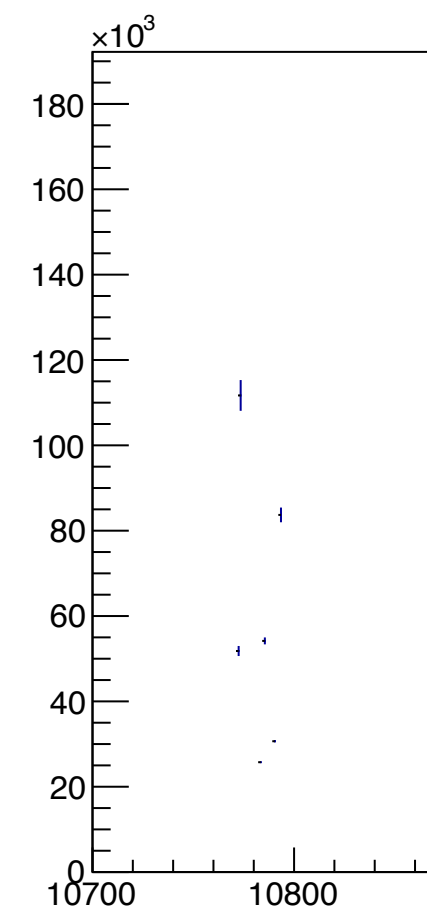
Entire PD Channel Map

- APA- Face A
- ⊗ APA- Face B

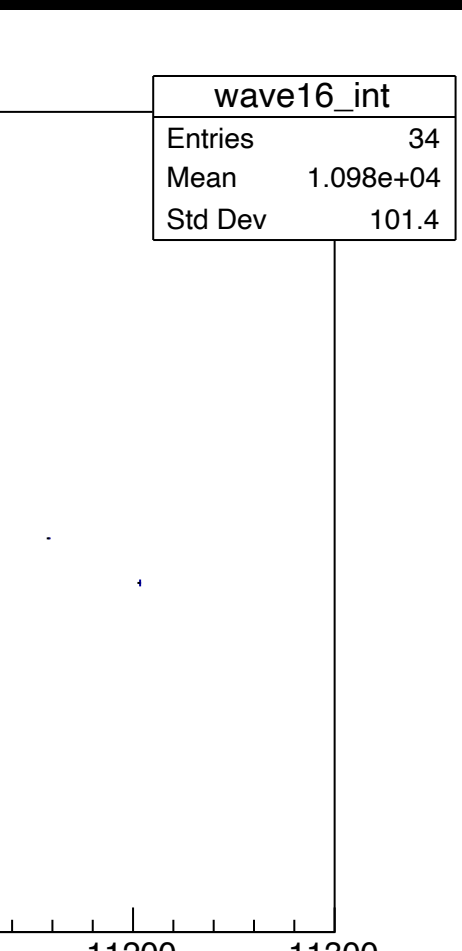
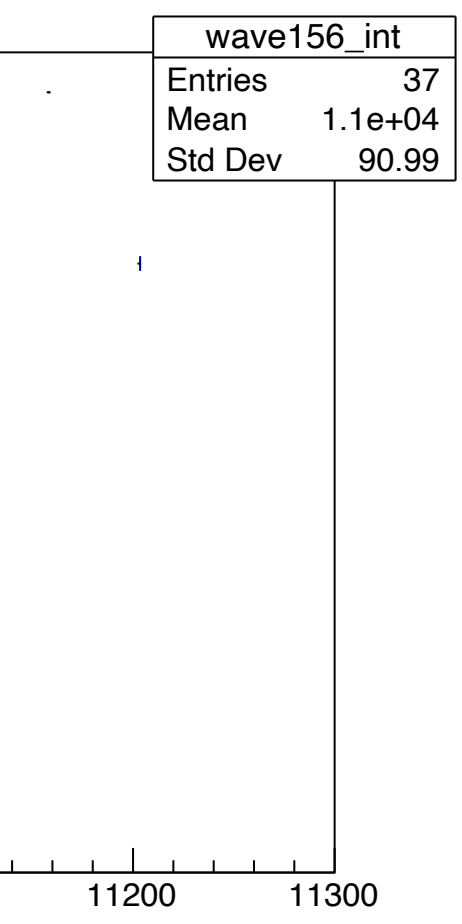
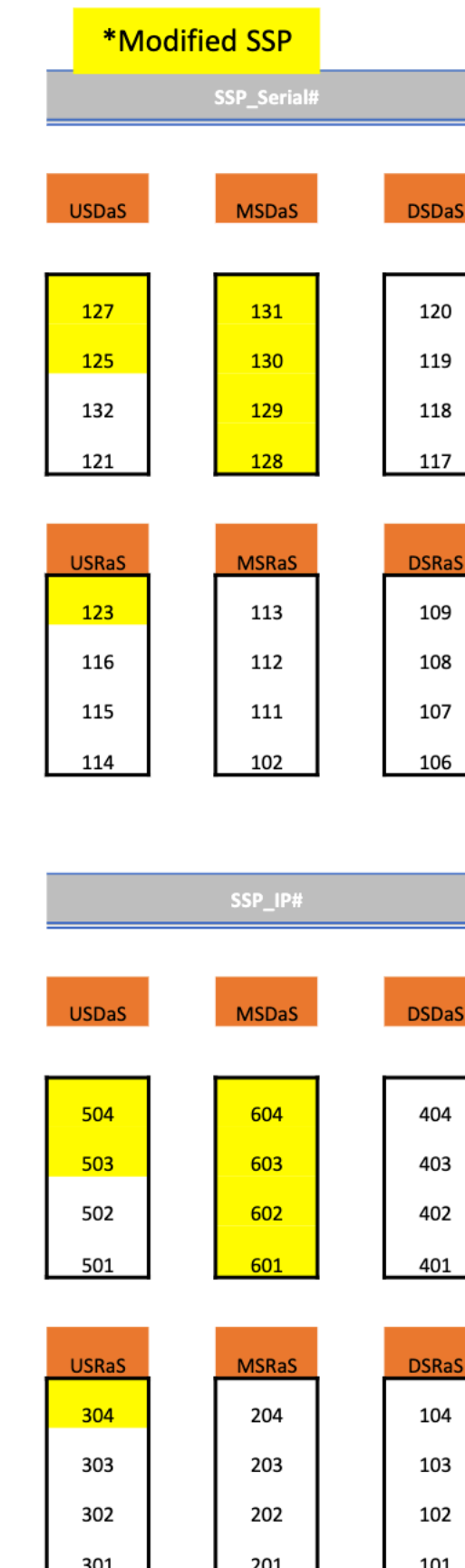
▮ = Readout end



BEAM →



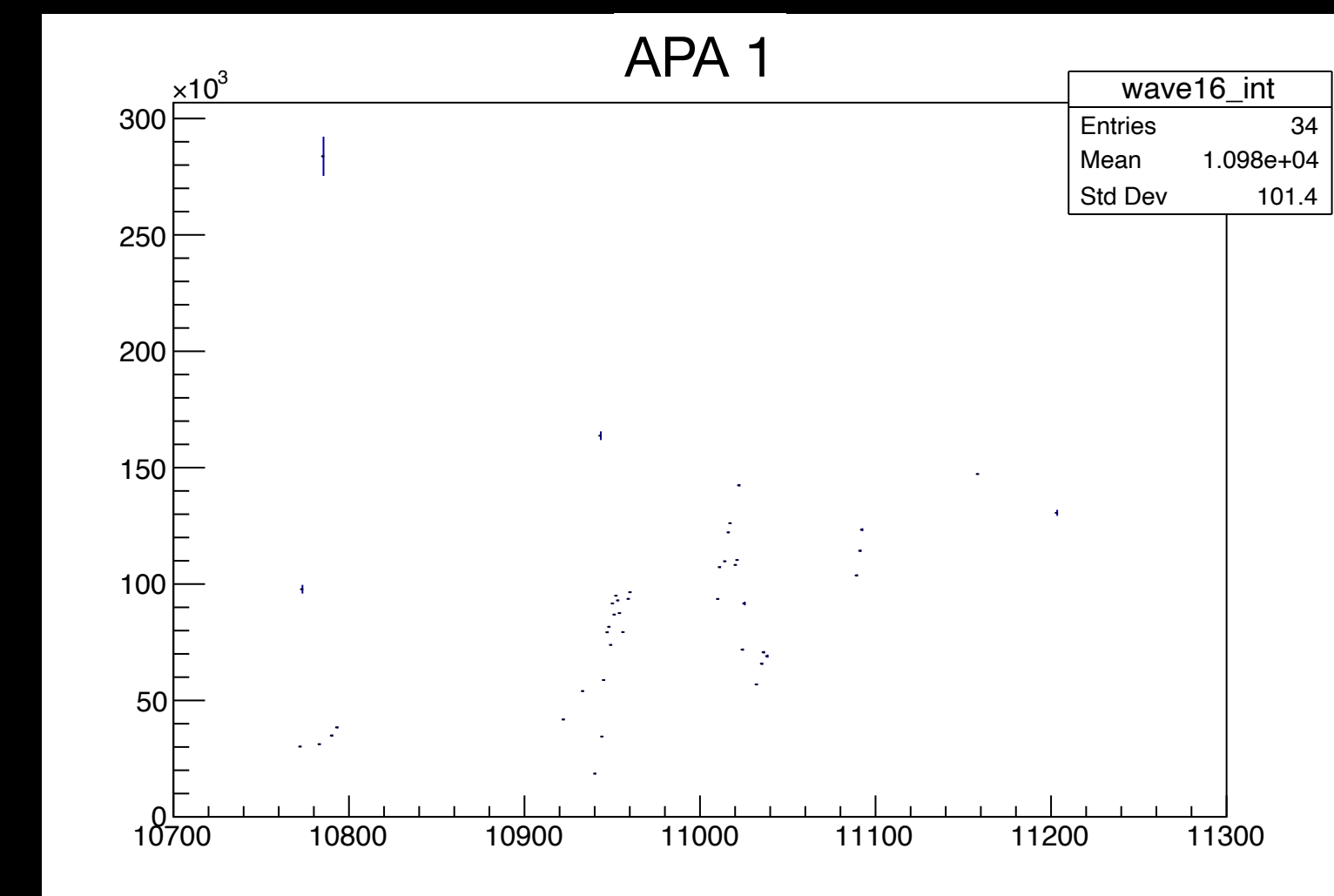
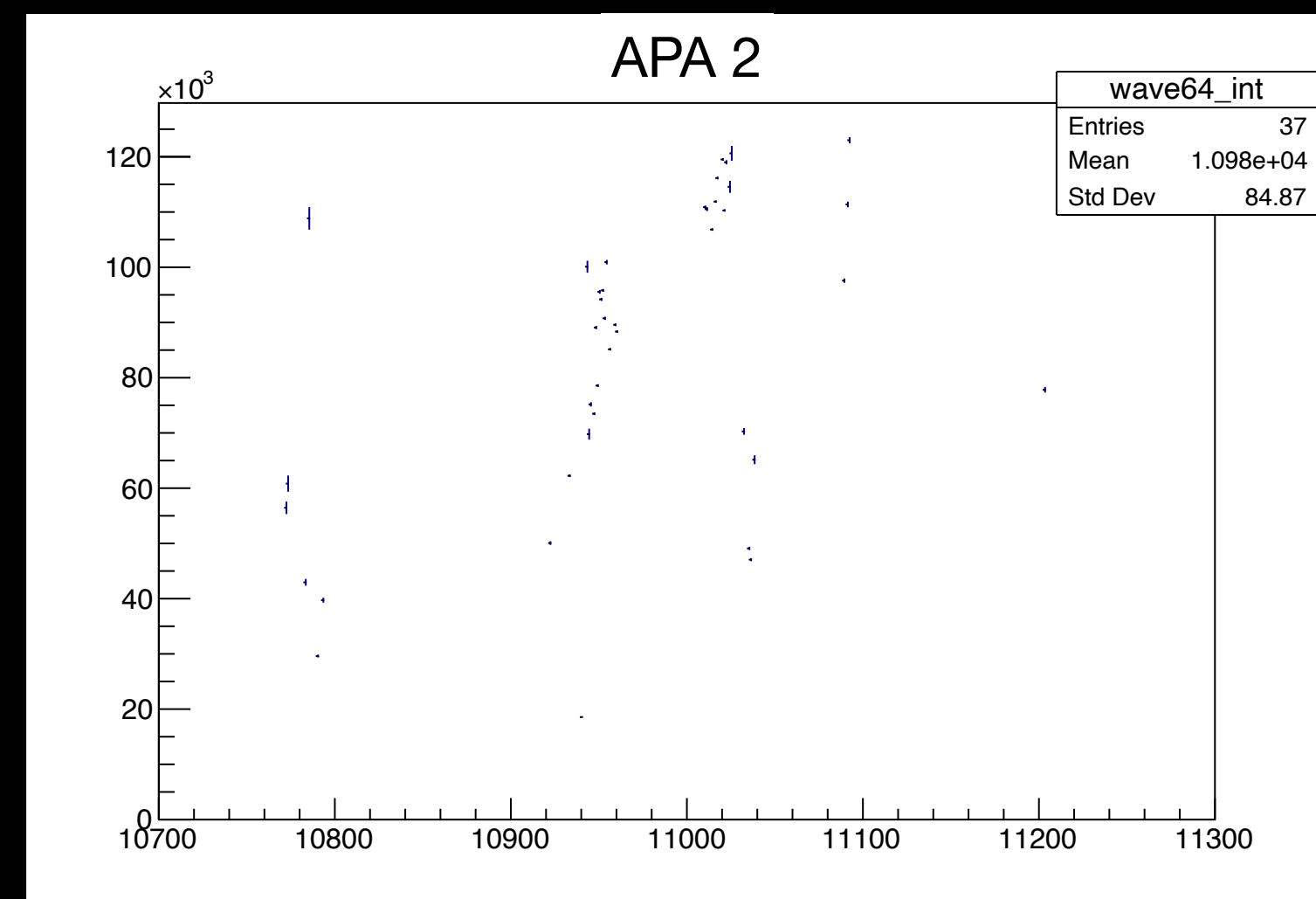
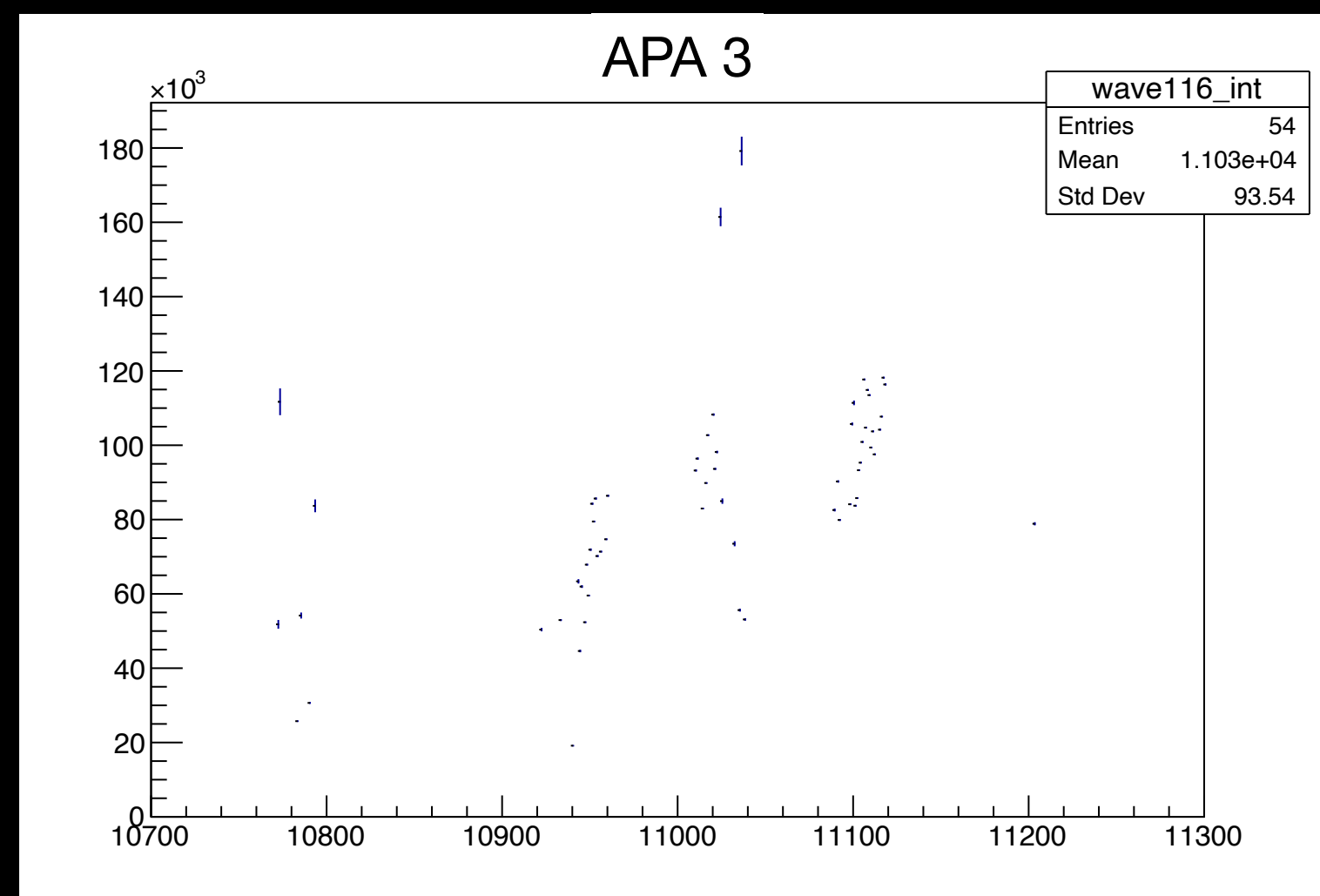
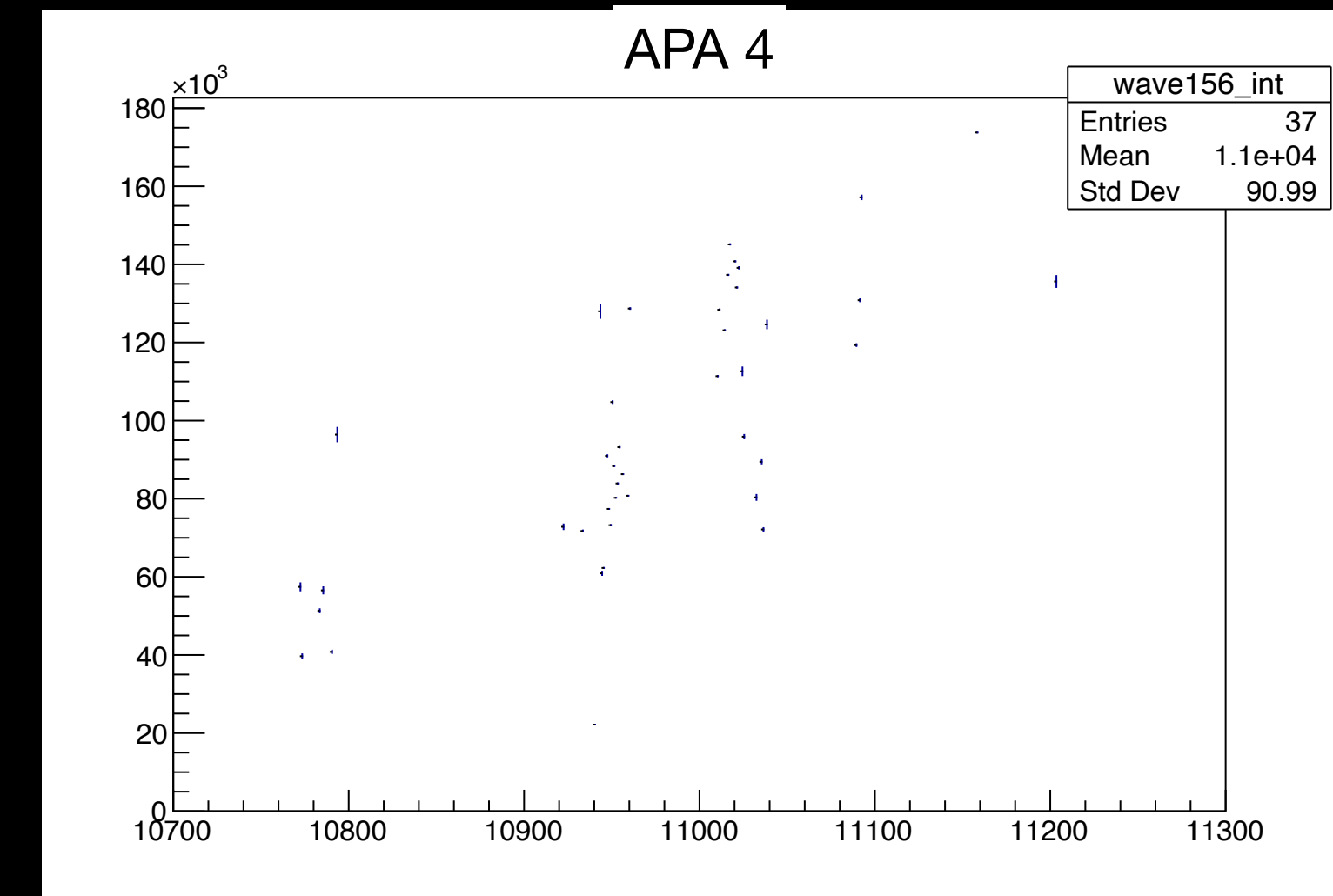
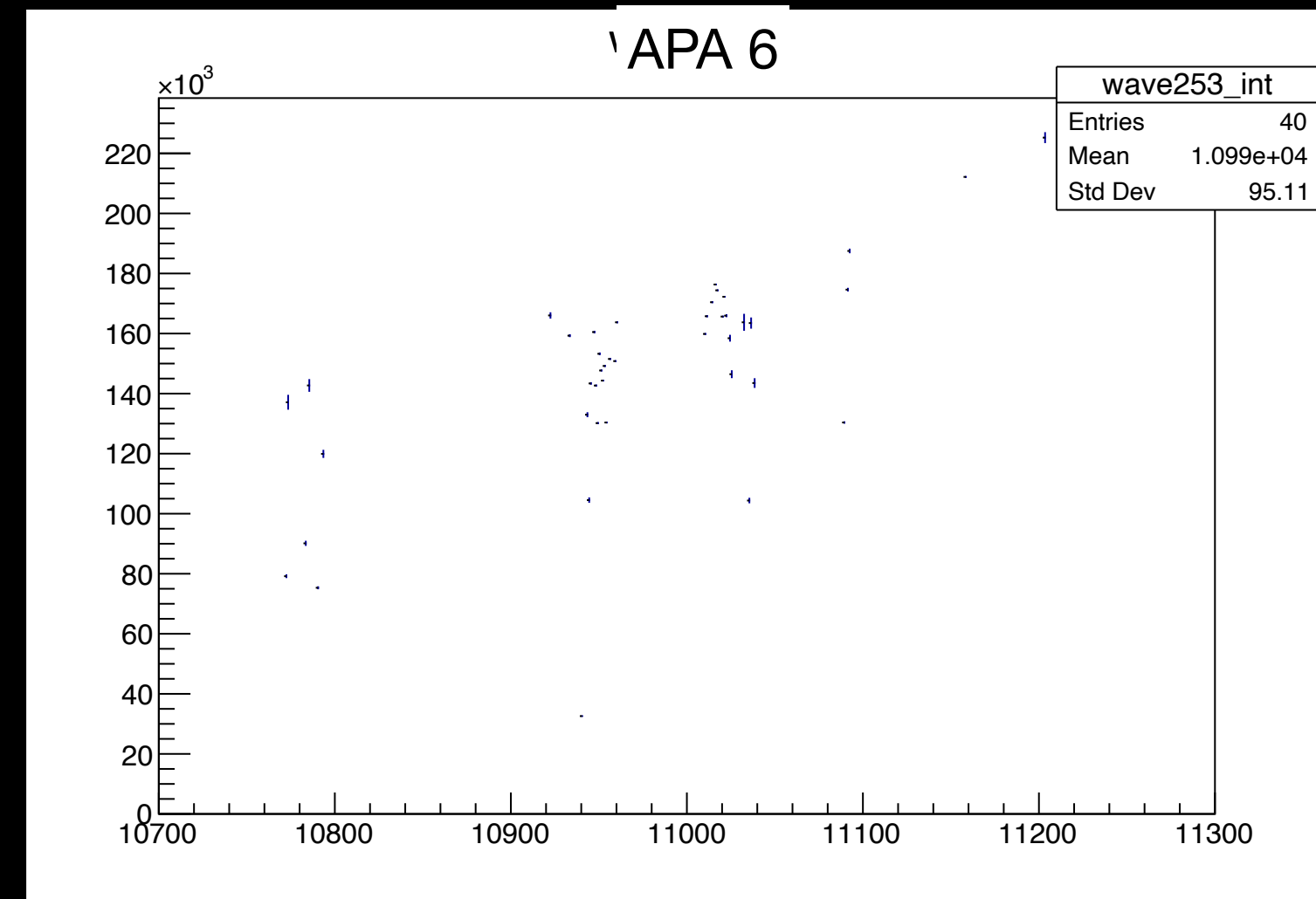
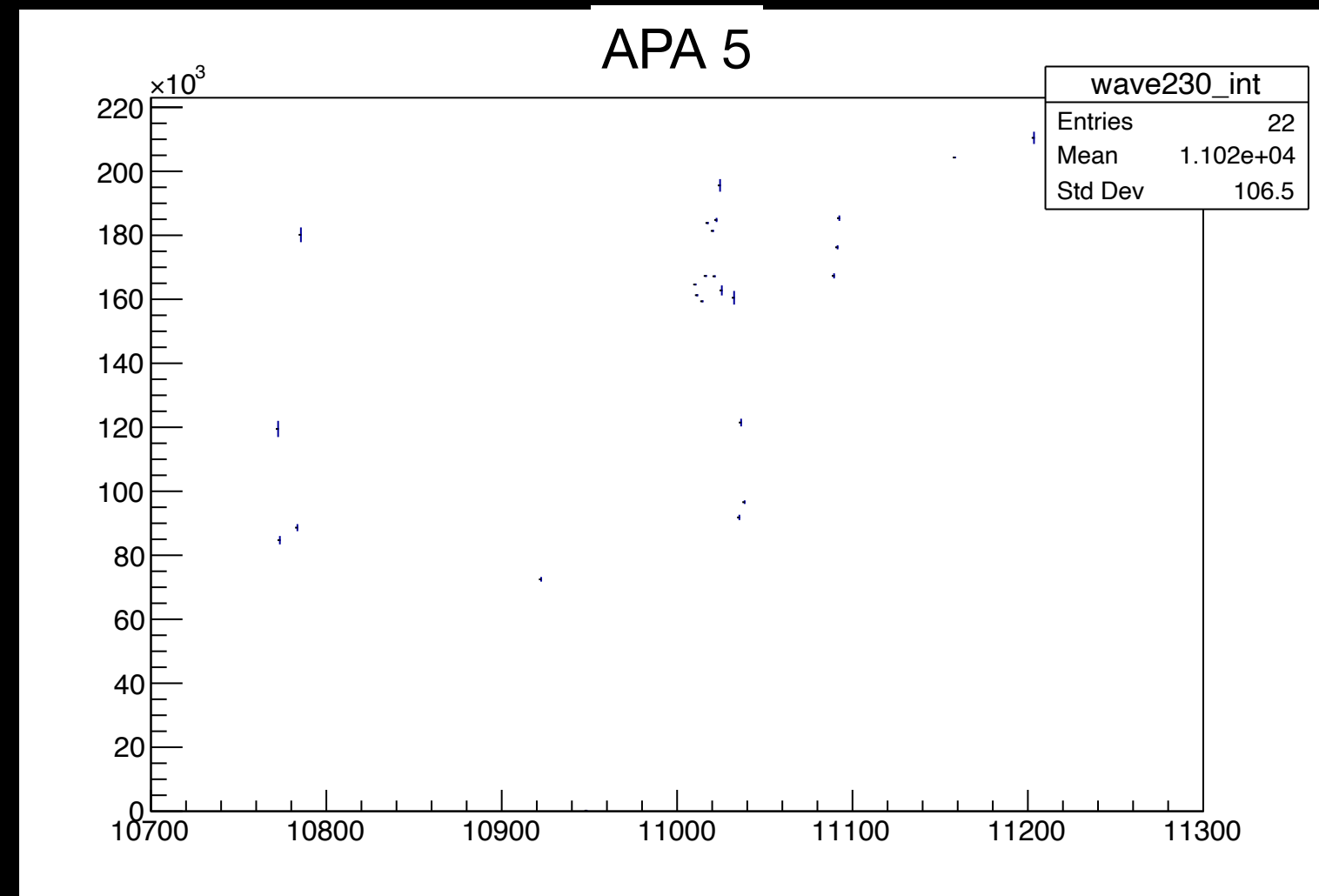
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| 003-0031-IU20 | SensL-A1 | SSP301 | 0-3 | 96 | 99 | 40 | 002-0049-IU16 | SensL-A1 | SSP201 | 0-3 | 48 | 51 | 20 | 403-003-0063-IU28 | SensL-A1 | SSP101 | 0-3 | 0 | 3 | 0 |
| 002-0055-FL03 | SensL-A1 | SSP301 | 4-7 | 100 | 103 | 42 | 001-0054-FL18 | SensL-A1 | SSP201 | 4-7 | 52 | 55 | 22 | 403-003-0041-FL9 | SensL-A1 | SSP101 | 4-7 | 4 | 7 | 2 |
| 002-0020-IU31 | SensL-A1 | SSP301 | 8-11 | 104 | 107 | 44 | 002-0035-IU13 | SensL-A1 | SSP201 | 8-11 | 56 | 59 | 24 | 403-002-0001-IU15 | SensL-A1 | SSP101 | 8-11 | 8 | 11 | 4 |
| ARAPUCA-1 | Hamamatsu | SSP304 | 0-3 | 132 | 135 | 46 | 002-0006-FL14 | SensL-A1 | SSP202 | 0-3 | 60 | 63 | 26 | 403-003-0054-FLP12 | SensL-A1 | SSP102 | 0-3 | 12 | 15 | 6 |
| 002-0042-IU52 | SensL-A1 | SSP302 | 4-7 | 136 | 139 | 46 | 001-0044-IU18 | SensL-A1 | SSP202 | 4-7 | 64 | 67 | 28 | 403-001-0006-IU49 | SensL-A1 | SSP102 | 4-7 | 16 | 19 | 8 |
| 002-0056-FL30 | SensL-A1 | SSP302 | 8-11 | 140 | 143 | 46 | 002-0012-FL19 | SensL-A1 | SSP202 | 8-11 | 68 | 71 | 30 | 403-003-0064-FLP13 | SensL-A1 | SSP102 | 8-11 | 20 | 23 | 10 |
| 002-0047-IU17 | SensL-A1 | SSP302 | 0-3 | 116 | 119 | 52 | 002-0027-IU12 | SensL-A1 | SSP203 | 0-3 | 72 | 75 | 32 | 403-001-0061-IU04 | SensL-A1 | SSP103 | 0-3 | 24 | 27 | 12 |
| 002-0054-FL38 | SensL-A1 | SSP303 | 4-7 | 112 | 115 | 50 | 002-0015-FL21 | SensL-A1 | SSP203 | 4-7 | 76 | 79 | 34 | 403-001-0042-FLP4 | SensL-A1 | SSP103 | 4-7 | 28 | 31 | 14 |
| 002-0039-IU51 | SensL-A1 | SSP303 | 8-11 | 124 | 127 | 56 | 001-0052-IU14 | SensL-A1 | SSP203 | 8-11 | 80 | 83 | 36 | 403-001-0025-IU21 | SensL-A1 | SSP103 | 8-11 | 32 | 35 | 16 |
| 003-0015-FL04 | SensL-C1 | SSP303 | 0-3 | 128 | 131 | 58 | 003-0025-FL06 | SensL-A1 | SSP204 | 0-3 | 84 | 87 | 38 | 403-003-0020-FL5 | SensL-A1 | SSP104 | 0-3 | 36 | 39 | 18 |



IU Bars in ProtoDUNE

Individual Channels

Stats boxes are in the way. Sorry!



- Seems like the ARAPUCA in APA3 doesn't see much increase in light
 - Have been seeing this effect since I started this analysis
 - Was the main holdup - trying to get agreement with other results
- ARAPUCA in APA 6 does see a substantial increase
- IU Double shift light guides consistently see a fairly substantial increase in light
 - Fairly uniform effect across detector at a first look
- Remember - These are all channel by channel

- More processing needed
- Need to combine for module to module comparison
- Some formatting issues for sure - again, just finished processing this morning
 - Would like to get processing procedure a little more streamlined
- Deconvolution procedure in place - will process this next week and look at those metrics as well
 - Will probably do this on a small subset of the data to save time/memory

