

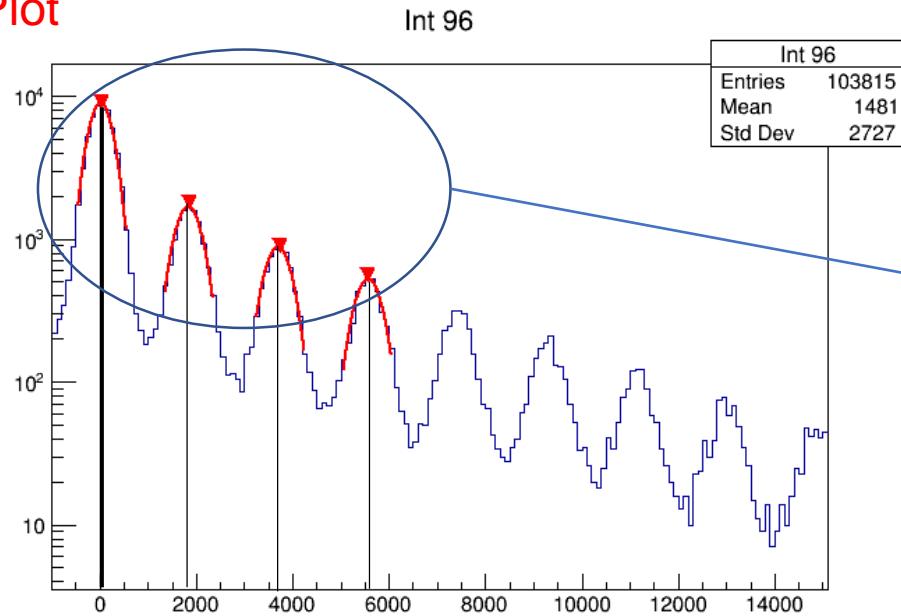
ProtoDUNE Photon Detection
SensL Stability
June 2019

Chris Macias & Maria Manrique
Indiana University

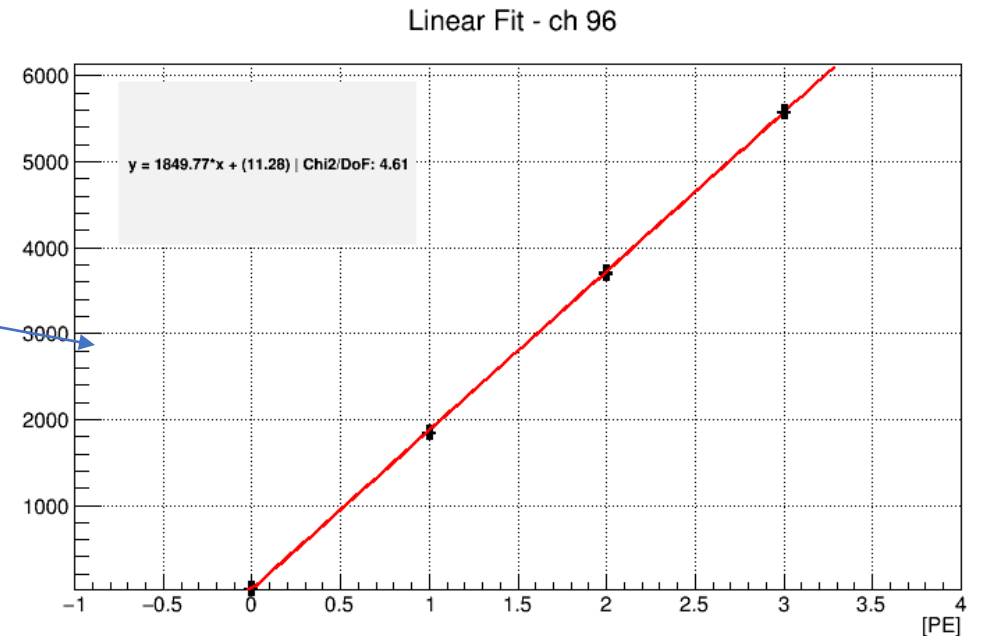
ProtoDUNE PD Update, June 2019

APA3 SensL ADC/Avalanche - Example

Possible TDR
Plot

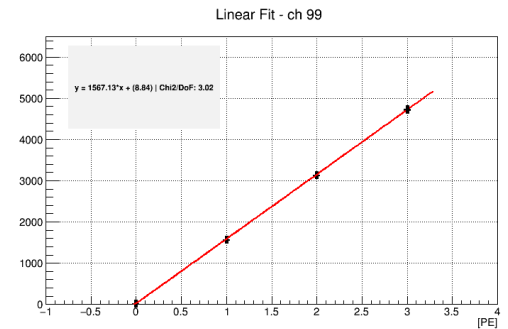
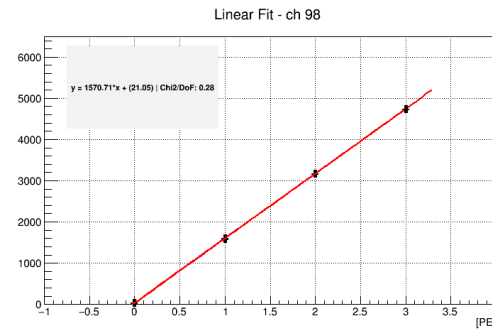
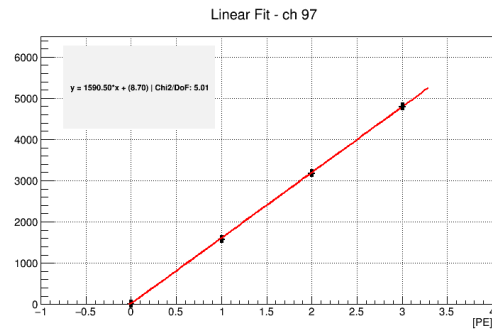
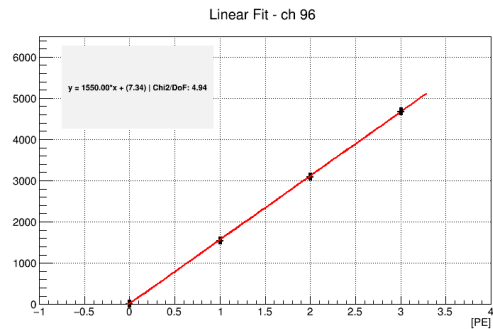
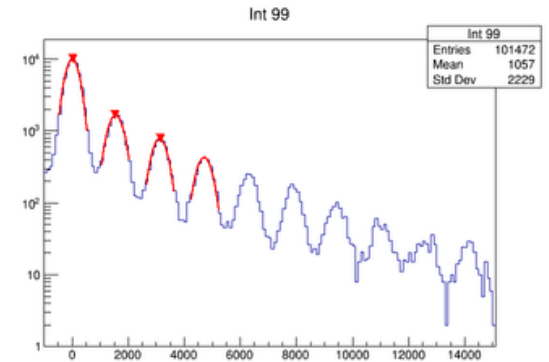
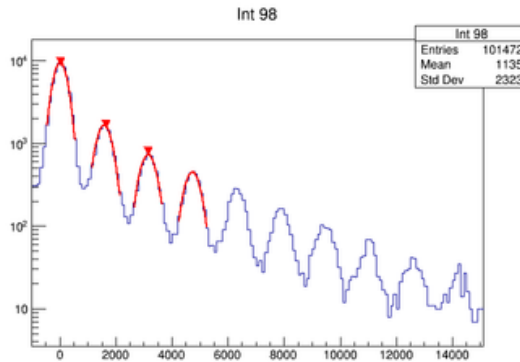
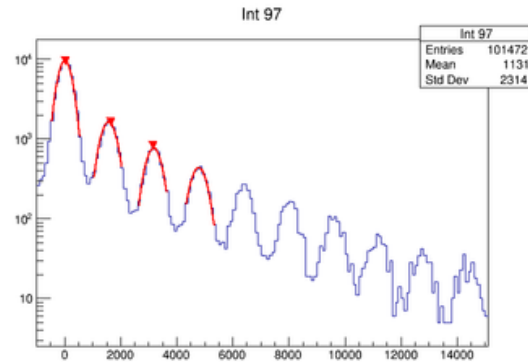
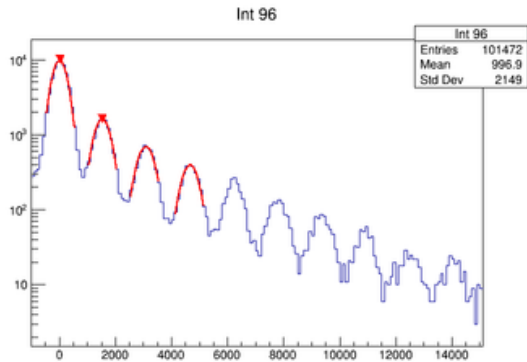


Possible TDR
Plot

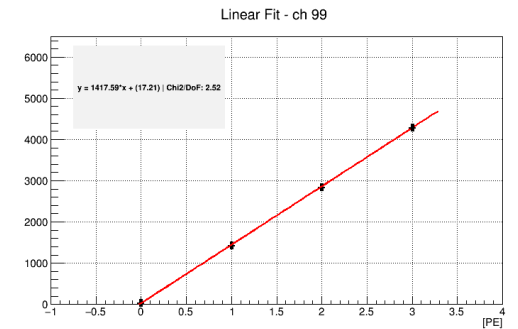
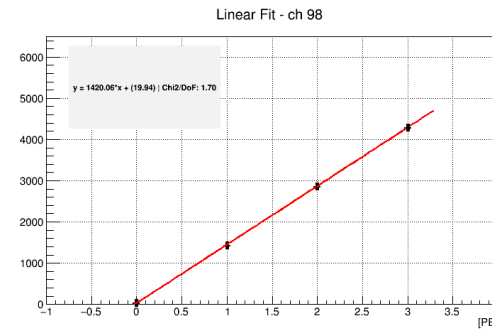
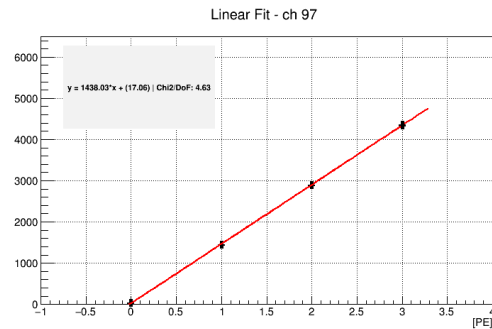
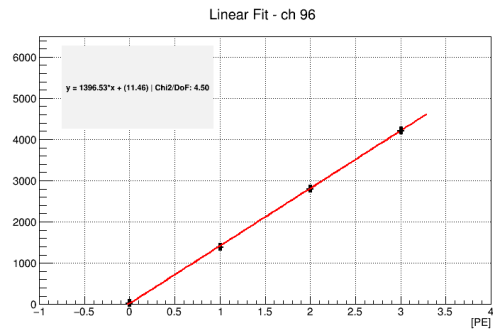
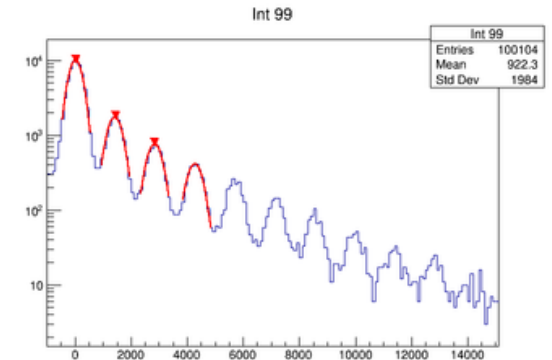
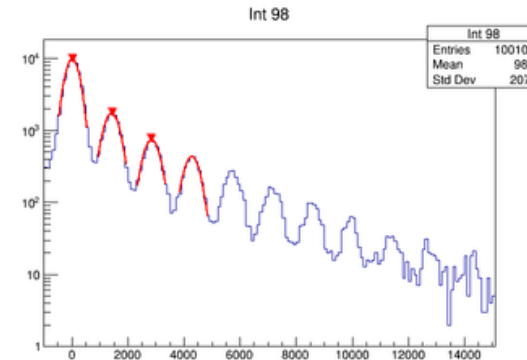
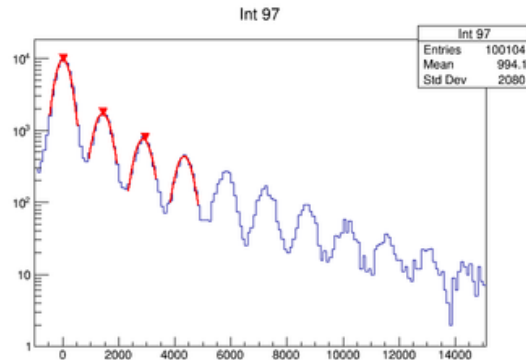
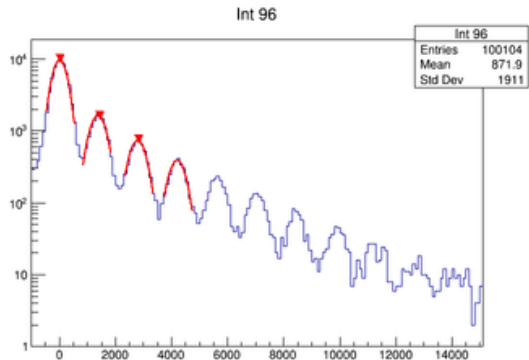


- Fit the first 4 Avalanche peaks with a gaussian, using TF1 fit.
 - Fit range - [Peak-500, Peak+500]
- Linear Fit, via TF1 fit, using
 - mean of each peak
 - sigma as error

SensL's- ADC/Avalanche @ 26.0



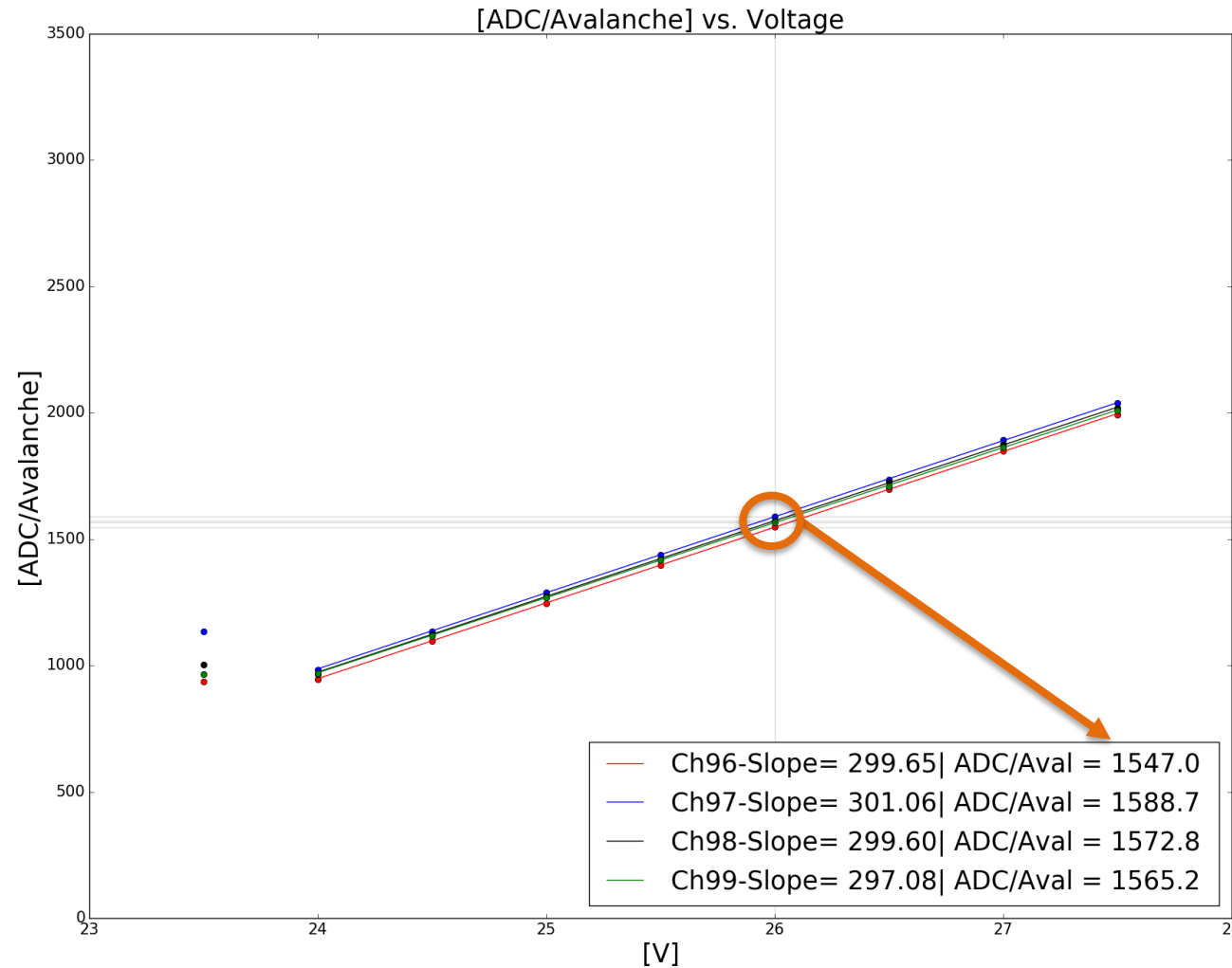
SensL's- ADC/Avalanche @ 25.5



SensL's- ADC/Avalanche vs. Voltage

Consistent Slopes!

Possible TDR Plot ->

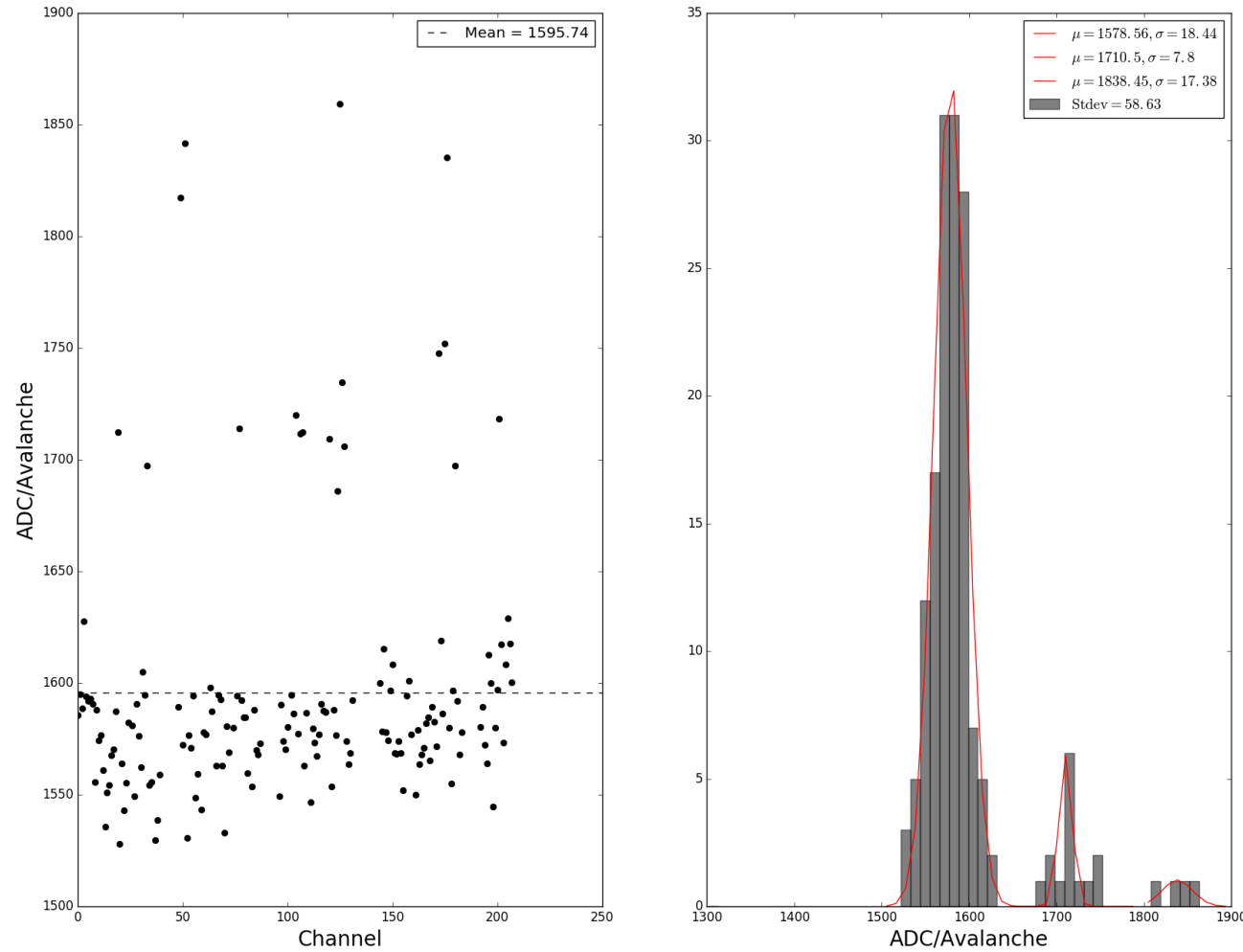


Determination of ADC/Avalanche Constant @ Nominal Voltage

SensL's- ADC/Avalanche via Gain Fit

Possible TDR
Plot ->

SensL Calibration:
ADC/Avalanche via Gain Fit



Channel Map- ADC/Avalanche

*Modified SSP



| USDaS | | | |
|----------------|---------------|-----------|--------|
| PD Module | ADC/Avalanche | OpChannel | OptDet |
| 002-0047-FL34 | | 216-219 | 41 |
| 002-0008-IU54 | | 220-223 | 43 |
| 002-0058-FL24 | | 224-227 | 45 |
| 002-0063-IU19 | | 228-231 | 47 |
| 003-0026-FL07* | | 192-195 | 49 |
| 002-0014-IU26 | | 232-235 | 51 |
| 003-0024-FL33 | | 196-199 | 53 |
| 003-0004-IU48 | | 200-203 | 55 |
| 002-0041-FL36 | | 236-239 | 57 |
| 002-0036-IU47 | | 204-207 | 59 |

| MSDaS | | | |
|---------------|---------------|-----------|--------|
| PD Module | ADC/Avalanche | OpChannel | OptDet |
| 002-0002-FL22 | | 240-243 | 21 |
| 002-0054-IU22 | | 244-247 | 23 |
| 002-0059-FL08 | | 248-251 | 25 |
| 002-0020-IU09 | | 252-255 | 27 |
| 002-0060-FL39 | | 256-259 | 29 |
| ARAPUCA-2 | | 264-267 | 31 |
| | | 268-271 | |
| | | 272-275 | |
| 002-0055-FL40 | | 260-263 | 33 |
| 002-0013-IU01 | | 276-279 | 35 |
| 002-0011-FL15 | | 280-283 | 37 |
| 002-0031-IU02 | | 284-287 | 39 |

| DSDaS | | | |
|-----------------|---------------------------------|-----------|--------|
| PD Module | ADC/Avalanche | OpChannel | OptDet |
| 001-0003-FL01 | 1600.09,1578.4,1615.34,1578.02 | 144-147 | 1 |
| 002-0044-IU50 | 1574.26,1596.53,1608.19,1568.61 | 148-151 | 3 |
| 002-0039-FL29 | 1568.17,1573.99,1568.68,1551.96 | 152-155 | 5 |
| 003-0002-IU27 | -,1594.35,1601.11,1577 | 156-159 | 7 |
| 002-0025-FL25 | -,1550.02,1578.9,1563.75 | 160-163 | 9 |
| 003-0011-IU37 | 1568.08,1570.87,1581.89,1584.56 | 164-167 | 11 |
| 003-0048-FL42 | 1565.42,1589.2,1582.63,1571.7 | 168-171 | 13 |
| 002-0023-IU53 | 1747.53,1618.93,1586.41,1751.84 | 172-175 | 15 |
| 002-0038-IU35 | 1835.31,1579.94,1555,1596.82 | 176-179 | 17 |
| 002-0040-FLP06* | 1697.18,1591.97,1568.05,1578.05 | 180-183 | 19 |

| USRaS | | | |
|---------------|---------------------------------|-----------|--------|
| PD Module | ADC/Avalanche | OpChannel | OptDet |
| 003-0031-IU20 | 1549.35,1590.3,1574.06,1570.38 | 96-99 | 40 |
| 002-0055-FL03 | 1580.5,-,1594.68,1586.22 | 100-103 | 42 |
| 002-0020-IU31 | 1720.03,1577.49,1711.62,1712.25 | 104-107 | 44 |
| ARAPUCA-1 | | | 46 |
| 002-0042-IU52 | 1562.98,1586.57,-,1546.62 | 108-111 | 48 |
| 002-0056-FL30 | 1579.77,1573.27,1567.41,1576.85 | 112-115 | 50 |
| 002-0047-IU17 | 1590.74,1587.57,1587.14,- | 116-119 | 52 |
| 002-0054-FL38 | 1709.4,1553.58,1588.15,1576.56 | 120-123 | 54 |
| 001-0039-IU51 | 1685.94,1859.2,1734.66,1705.93 | 124-127 | 56 |
| 003-0015-FL04 | 1573.91,1563.66,1568.62,1592.2 | 128-131 | 58 |

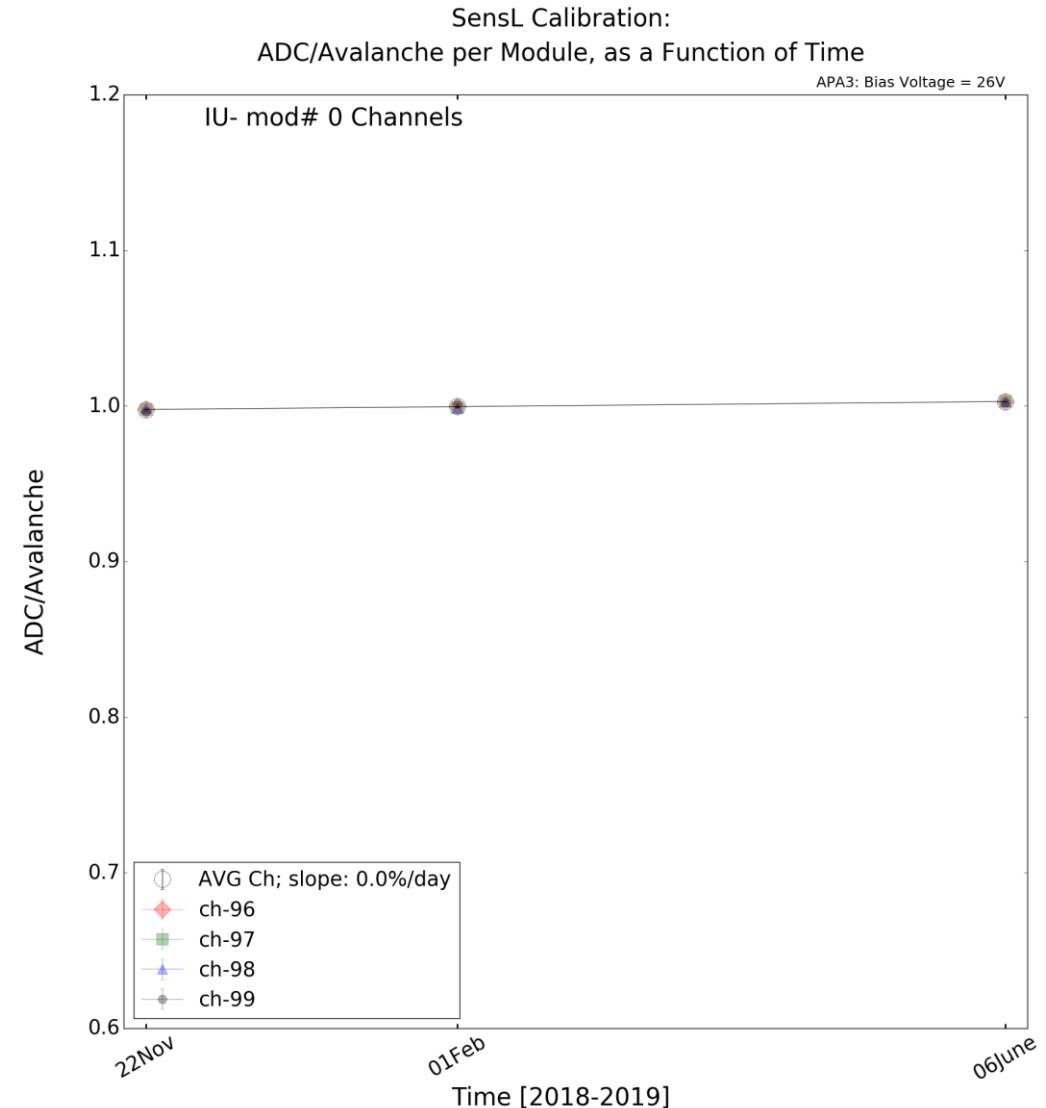
| MSRaS | | | |
|---------------|---------------------------------|-----------|--------|
| PD Module | ADC/Avalanche | OpChannel | OptDet |
| 002-0049-IU16 | 1589.4,1817.46,1572.45,1841.61 | 48-51 | 20 |
| 001-0054-FL18 | 1530.65,1576.78,1571.13,1594.26 | 52-55 | 22 |
| 002-0035-IU13 | 1548.57,1559.18,-,1543.5 | 56-59 | 24 |
| 002-0006-FL14 | 1577.9,1577.07,-,1597.91 | 60-63 | 26 |
| 001-0044-IU18 | 1587.24,-,1563,1594.78 | 64-67 | 28 |
| 002-0012-FL19 | 1592.74,1563.09,1533.01,1580.67 | 68-71 | 30 |
| 002-0027-IU12 | 1569.16,-,1579.86,- | 72-75 | 32 |
| 002-0015-FL21 | 1594.44,1714.15,1592.27,1584.65 | 76-79 | 34 |
| 001-0052-IU14 | 1584.55,1559.67,-,1553.73 | 80-83 | 36 |
| 003-0025-FL06 | 1587.9,1570.09,1567.89,1573 | 84-87 | 38 |

| DSRaS | | | |
|--------------------|---------------------------------|-----------|--------|
| PD Module | ADC/Avalanche | OpChannel | OptDet |
| 403-003-0063-IU28 | 1585.75,1595.02,1588.62,1627.83 | 0-3 | 0 |
| 403-003-0041-FL9 | 1594.07,1591.99,1593.12,1590.6 | 4-7 | 2 |
| 403-002-0001-IU15 | 1555.83,1588.16,1574.33,1576.55 | 8-11 | 4 |
| 403-003-0054-FLP12 | 1561.16,1535.62,1551.06,1554.26 | 12-15 | 6 |
| 403-001-0006-IU49 | 1567.53,1570.21,1587.21,1712.37 | 16-19 | 8 |
| 403-003-0064-FLP13 | 1528,1564.09,1542.86,1555.29 | 20-23 | 10 |
| 403-001-0061-IU04 | 1582.26,-,1580.84,1549.25 | 24-27 | 12 |
| 403-001-0042-FLP4 | 1590.8,1576.32,1562.32,1605 | 28-31 | 14 |
| 403-001-0025-IU21 | 1594.64,1697.21,1554.42,1555.76 | 32-35 | 16 |
| 403-003-0020-FL5 | -,1529.56,1538.75,1558.99 | 36-39 | 18 |

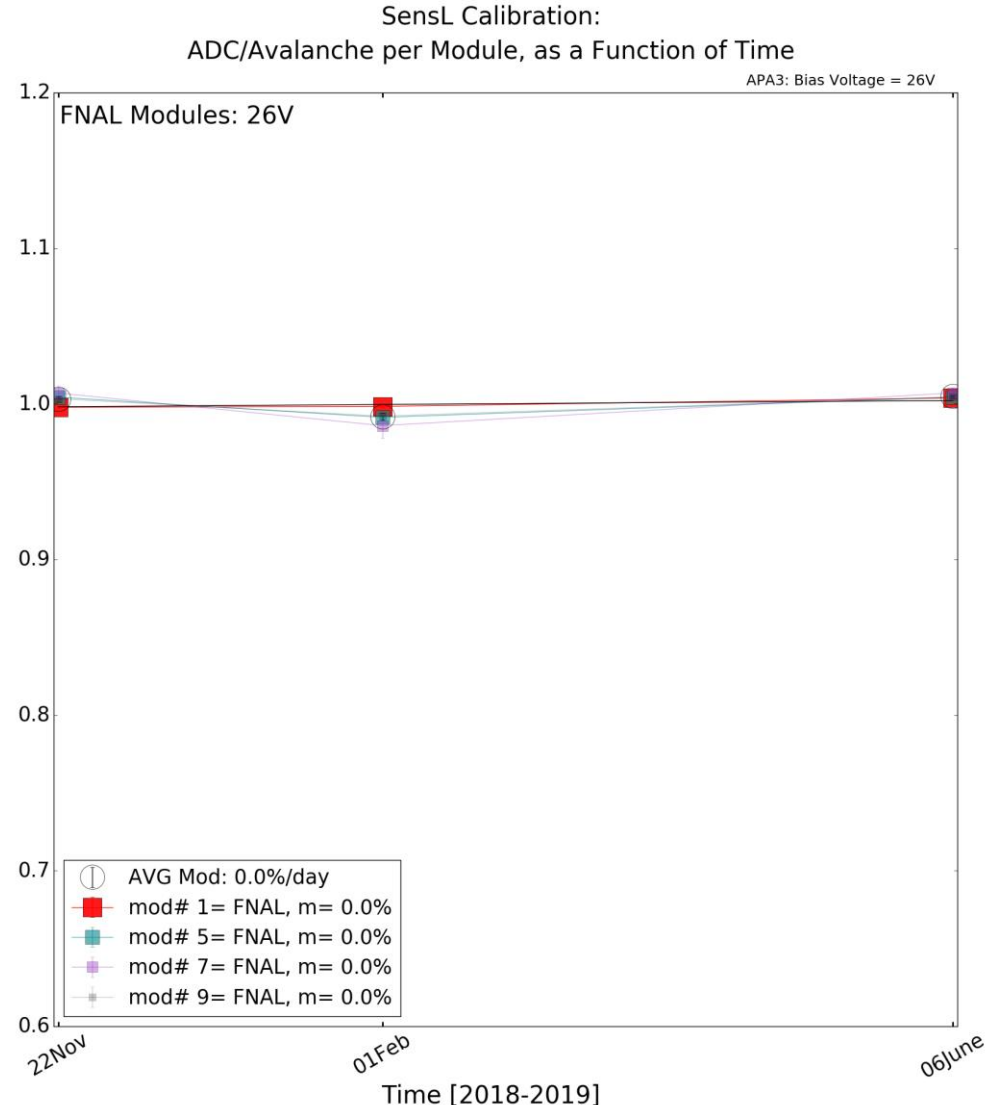
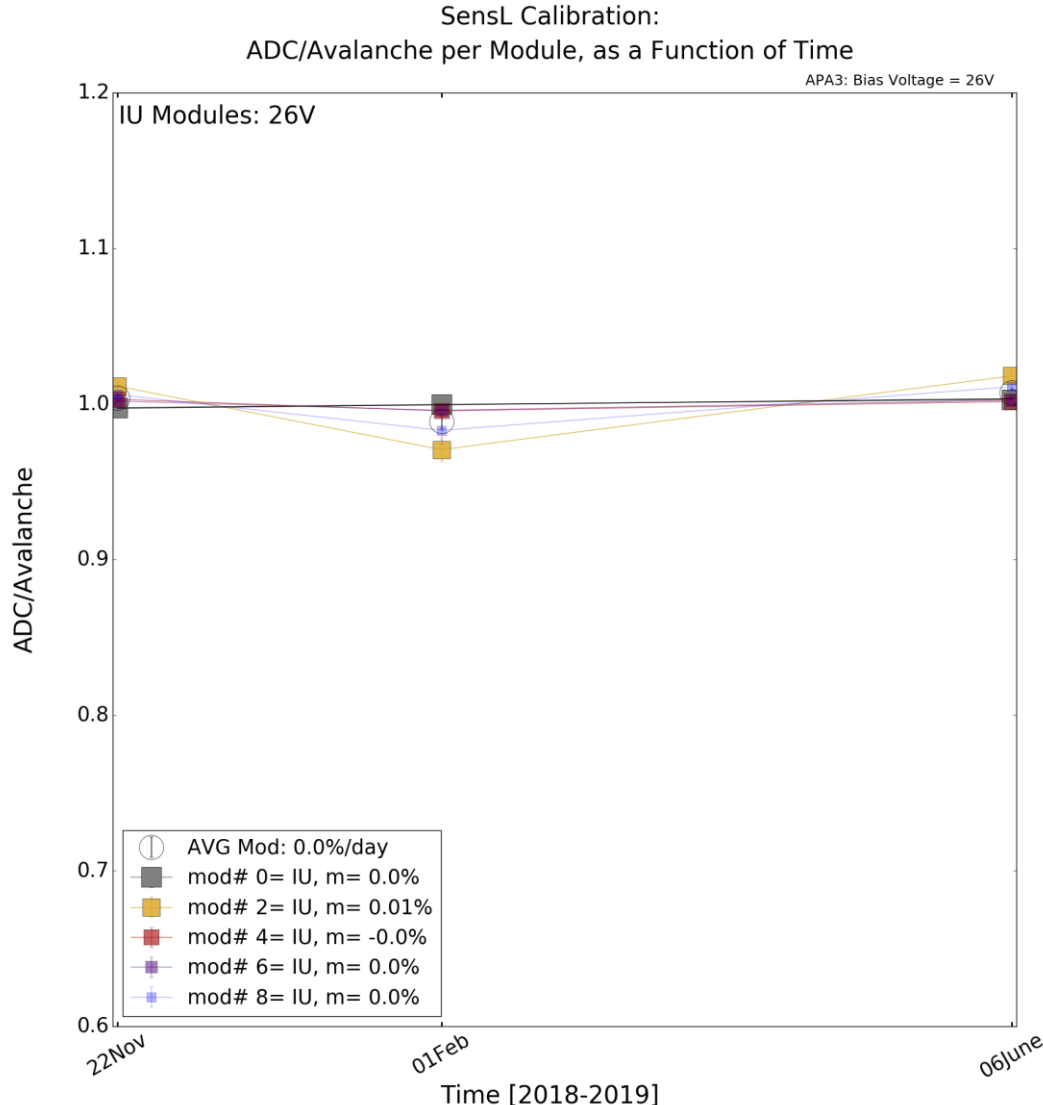
SensL Calibration Stability

APA3 SensL ADC/Avalanche Stability @ Nom. - Example

- ADC/Avalanche per Channel
- Runs 5933, 6626, 8185
 - Bias Voltage= 26 V
 - All viable LEDs
 - Scanning Pulse Heights within run
- Normalization
 - Mean(ADC/Avalanche) per channel
- $\langle \text{Channel} \rangle$ value
 - Mean(channels)
 - Statistical error = $\text{RMS}(\text{chs})/\text{sqrt}(N)$
- Linear regression
 - Measure any channel degradation [% / day]



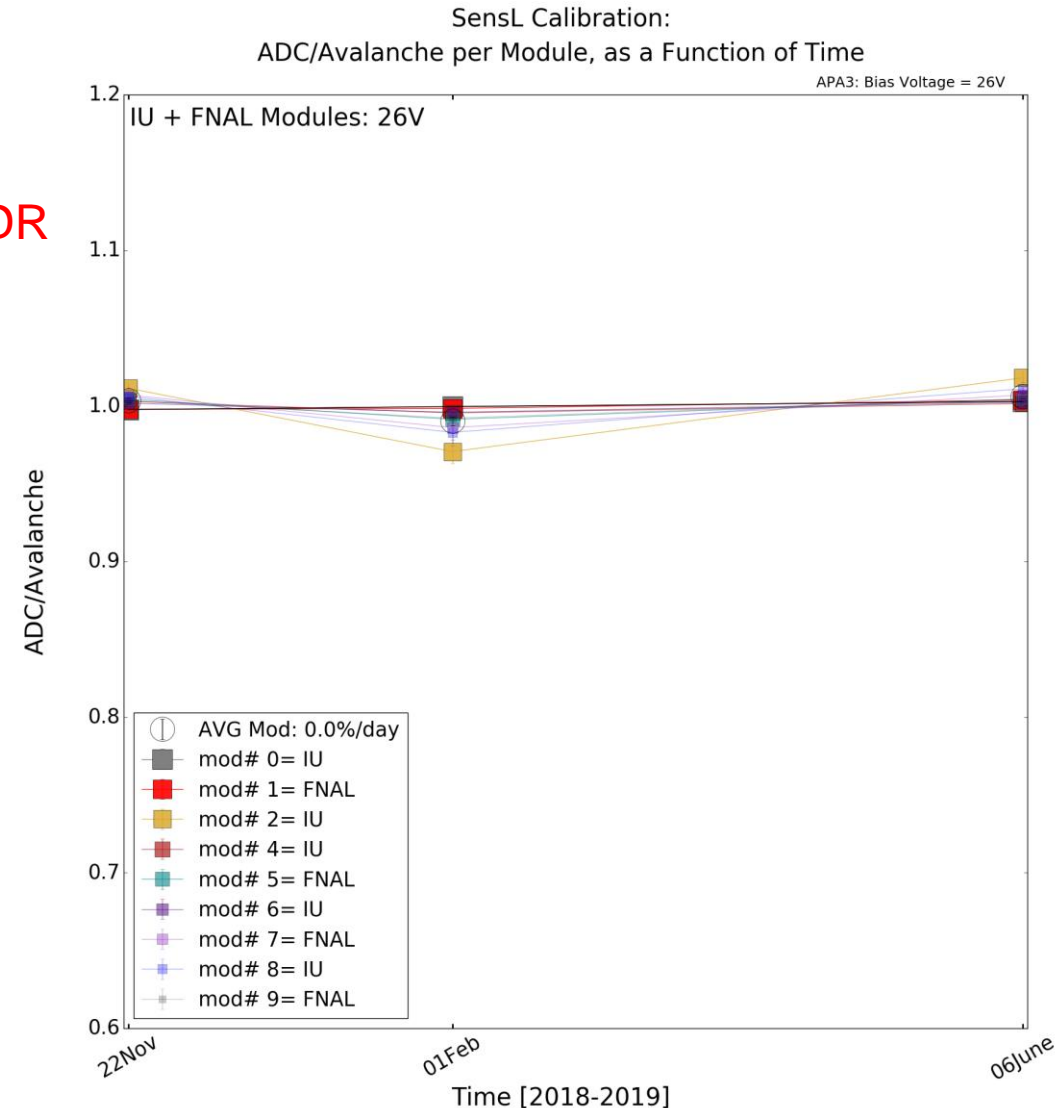
APA3 SensL ADC/Avalanche Stability @ Nom. - Module Comparison



APA3 SensL ADC/Avalanche Stability @ Nom. - Summary

- ADC/Avalanche per Module
- Runs 5933, 6626, 8185
 - Bias Voltage= 26 V
 - All viable LEDs
 - Scanning Pulse Heights within run
- Normalization
 - Mean(ADC/Avalanche) per channel
- $\langle \text{Module} \rangle$ value
 - Mean(modules)
 - Statistical error = $\text{RMS}(\text{mods})/\sqrt{N}$
- Linear regression
 - Measure any module degradation [% / day]

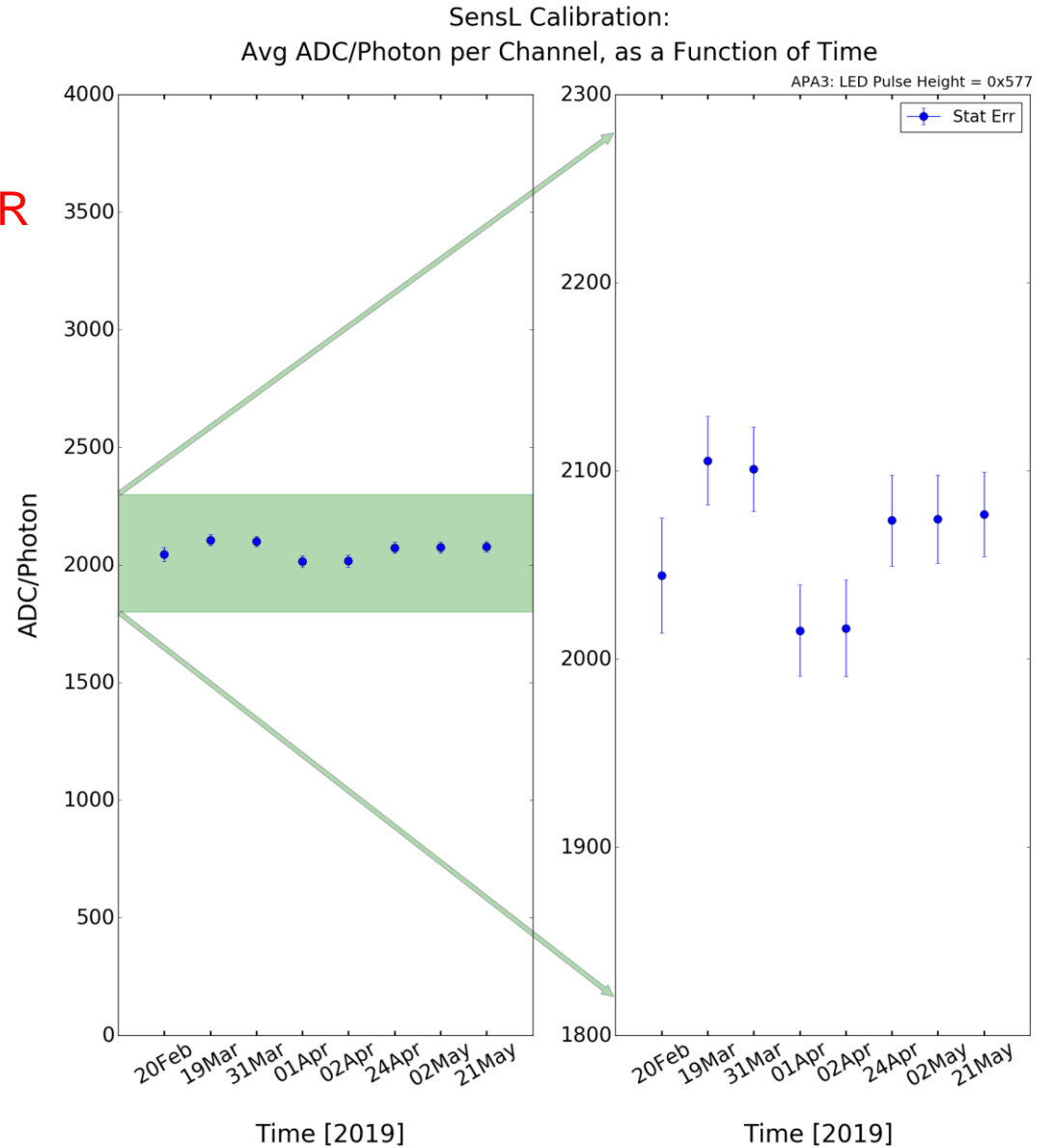
Possible TDR
Plot ->



APA3 SensL ADC/Photon Stability

- $\langle \text{ADC/Photon} \rangle$ per Channel
 - IU + FNAL modules
- Runs 6848, 7224, 7447, 7461, 7475, 7651, 7726, 7944
 - Stability Run
 - Pulse Peak Height = '0x577'
 - All viable LEDs on
- ADC/Photon value
 - Mean(channels)
- Statistical error
 - $\text{RMS}(\text{channels})/\sqrt{N}$

Possible TDR
Plot ->



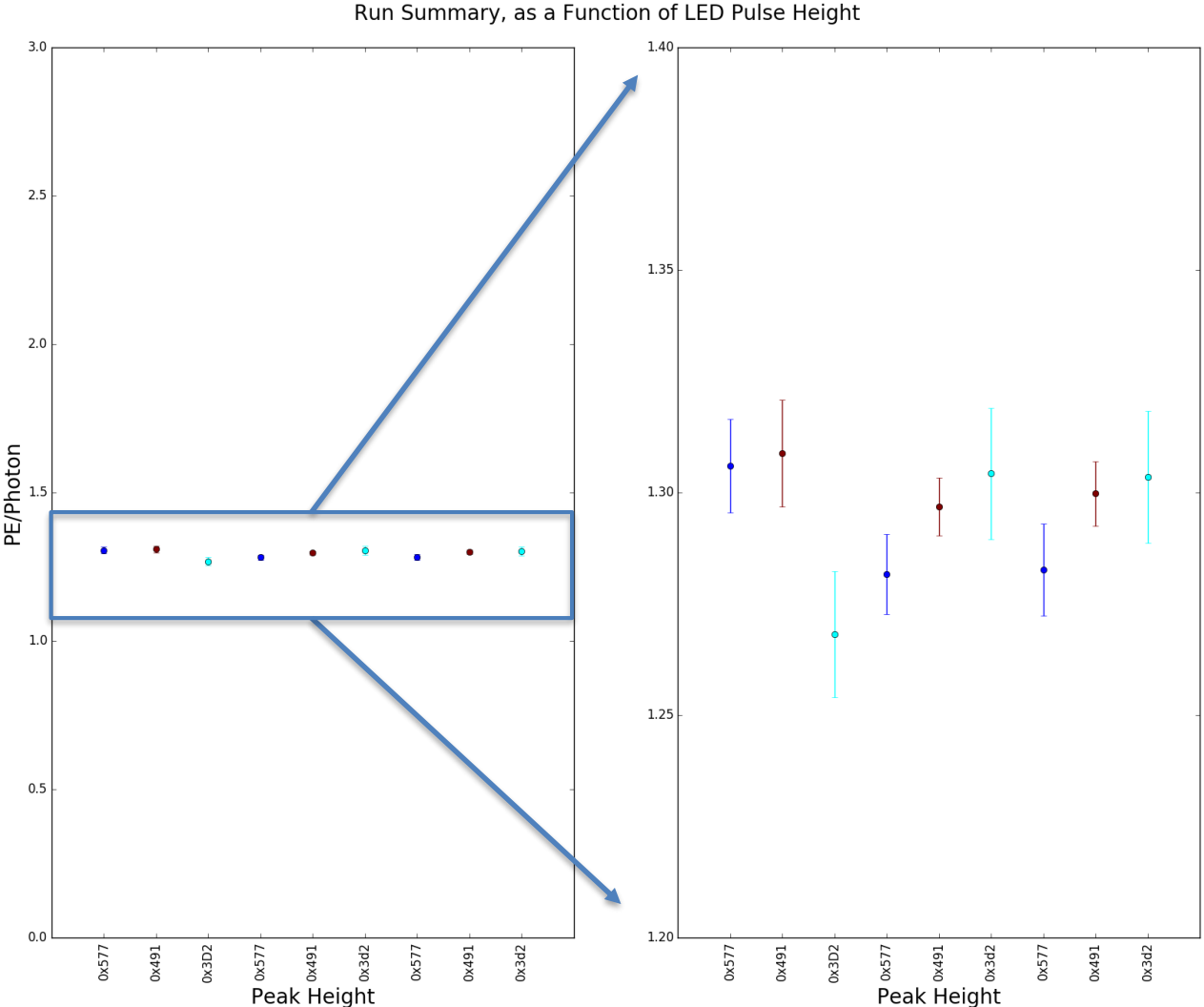
APA3 SensL PE/Photon- as a Function of LED Pulse Height

- Best Peak heights for consistent calibration measurements

- '0x577'
- '0x491'
- '0x3D2'

- Preliminary

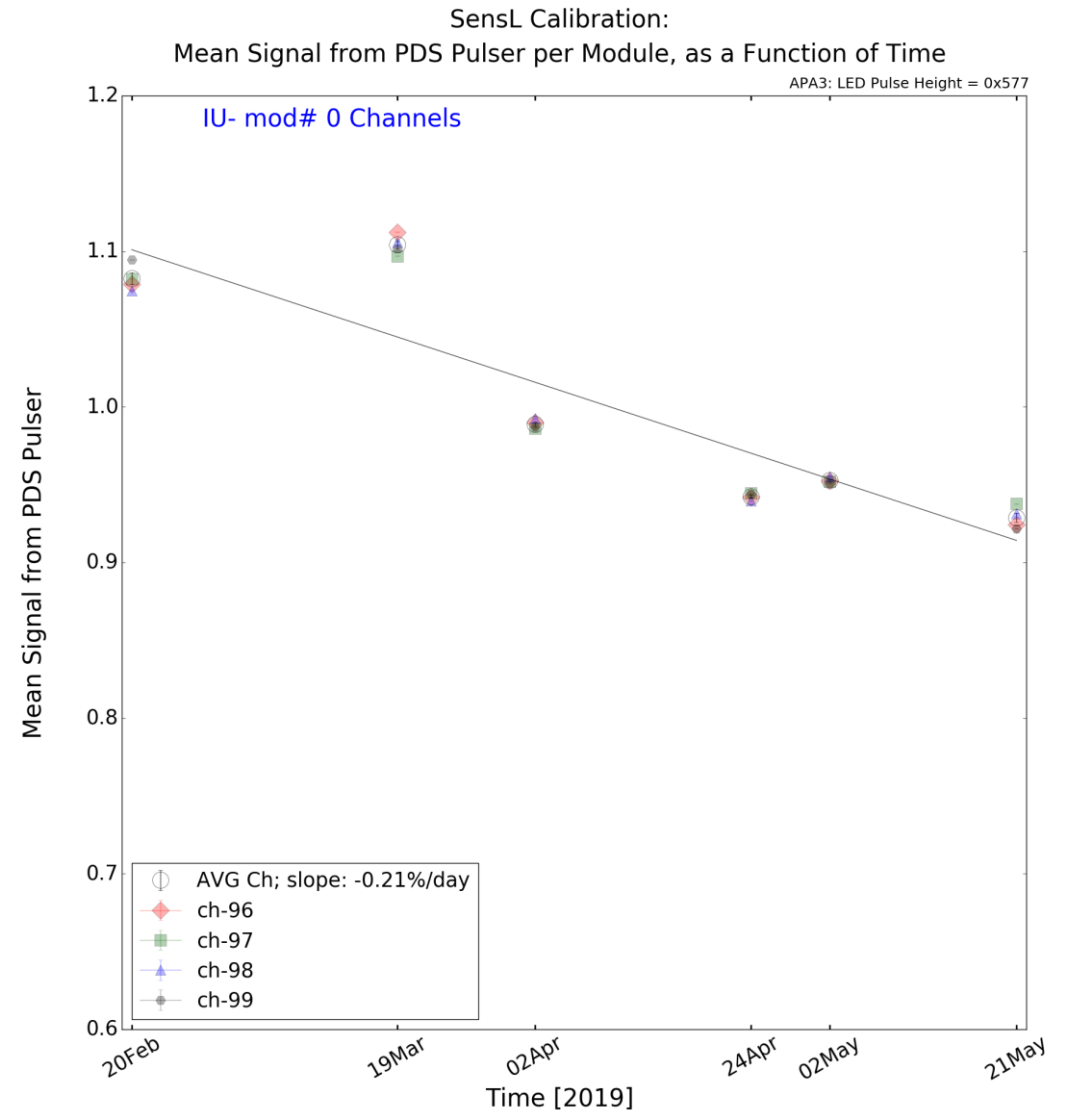
- $\langle \langle ADC/\gamma \rangle_{Ch} \rangle_{LED} = 2084.2 \pm 27.7$
- $\langle \langle PE/\gamma \rangle_{Ch} \rangle_{LED} = 1.29 \pm .01$



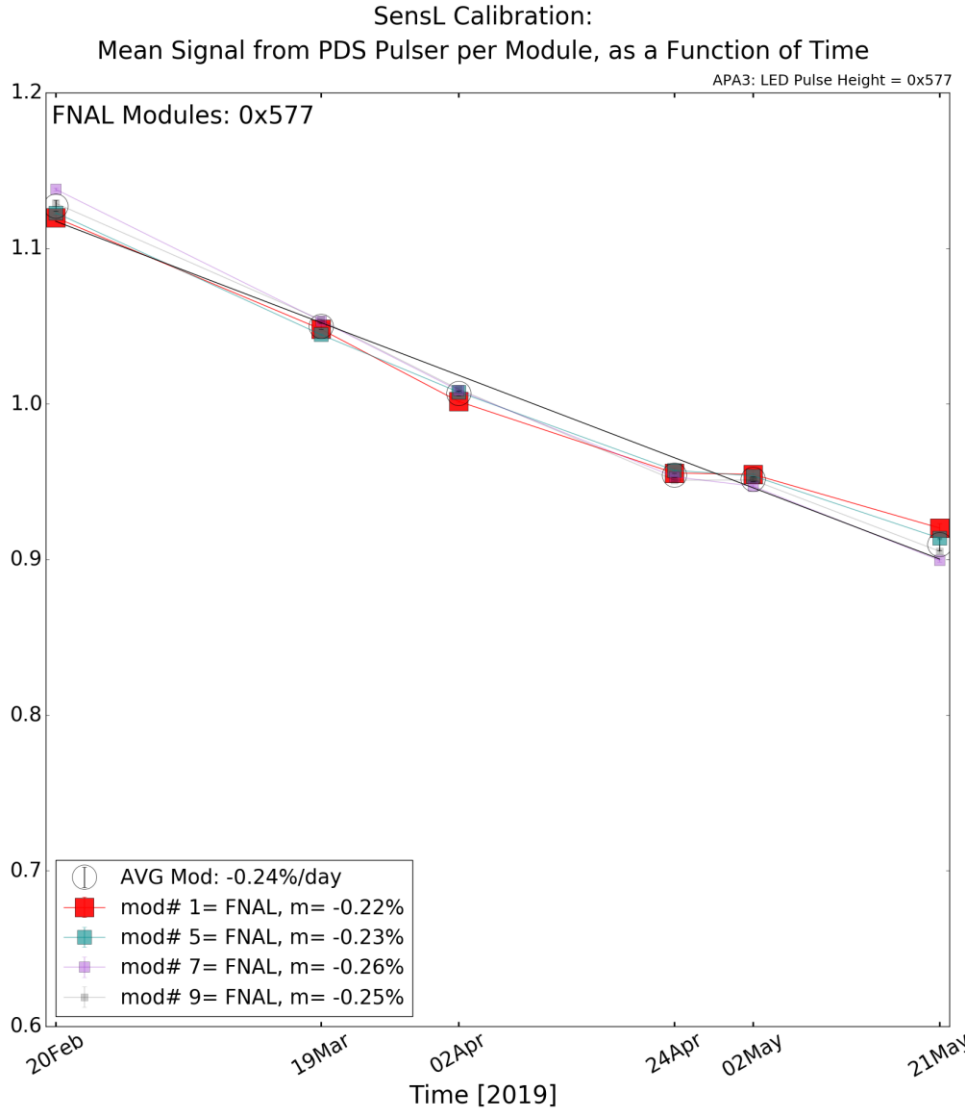
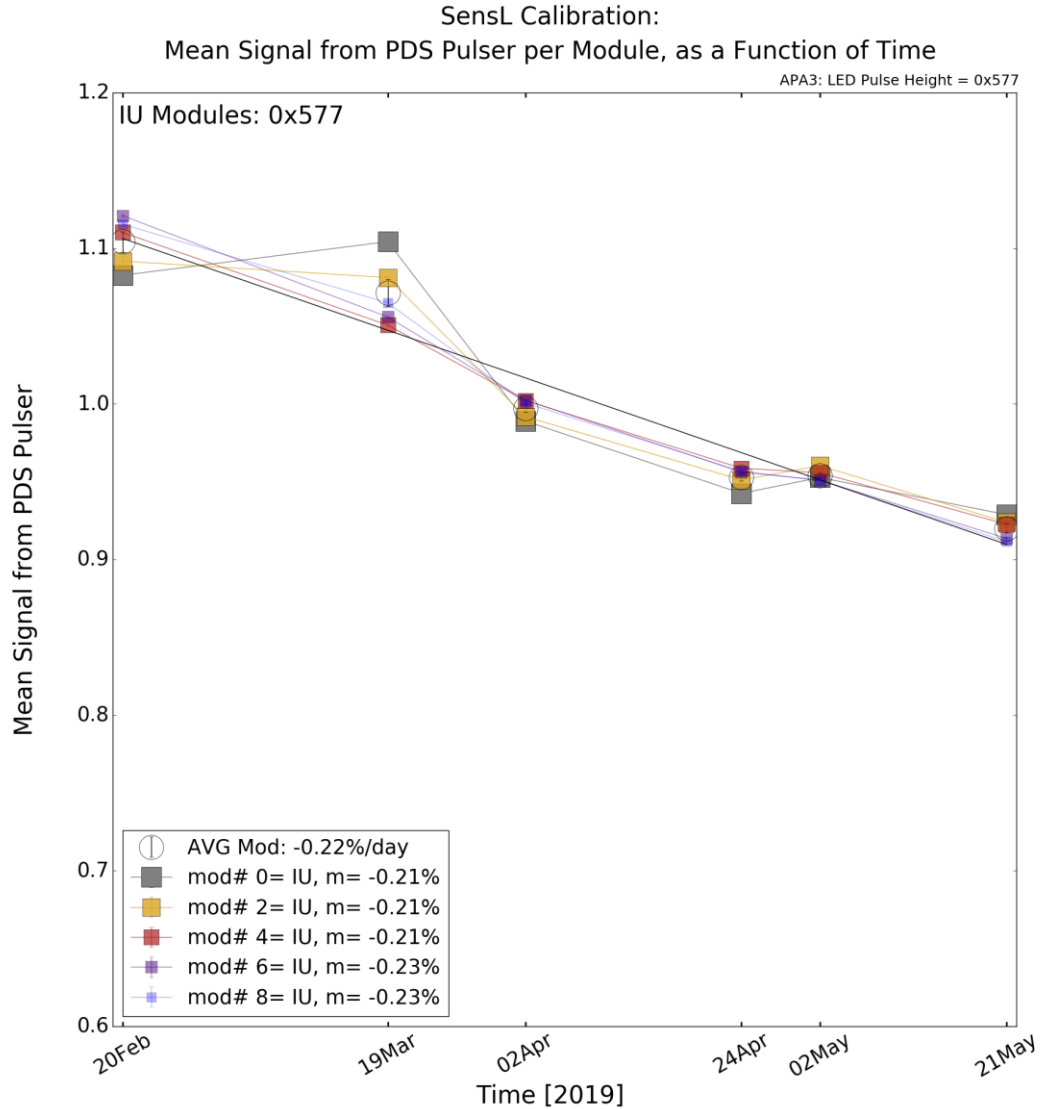
SensL Calibration Stability w/ LEDs

APA3 SensL Mean Signal Stability- Example

- Mean Signal per Channel
- Runs 6848, 7224, 7447, 7461, 7475, 7651, 7726, 7944
 - Stability Run
 - Pulse Peak Height = '0x577'
 - All viable LEDs on
- Normalization
 - Mean(mean signal) per channel
- \langle Channel \rangle value
 - Mean(channels)
 - Statistical error = $\text{RMS}(\text{chs})/\text{sqrt}(N)$
- Linear regression
 - Measure any channel degradation [% / day]

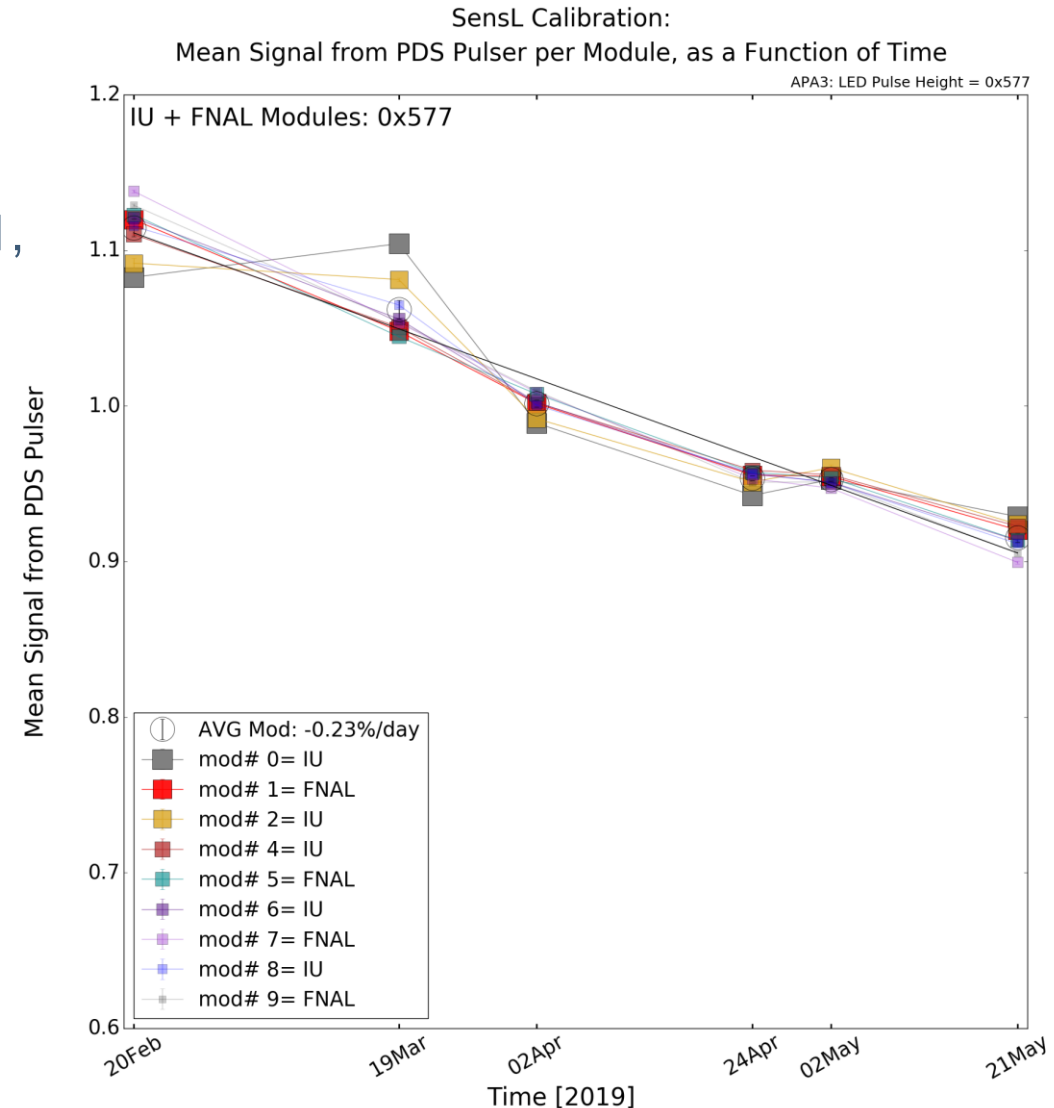


APA3 SensL Mean Signal Stability- Module Comparison

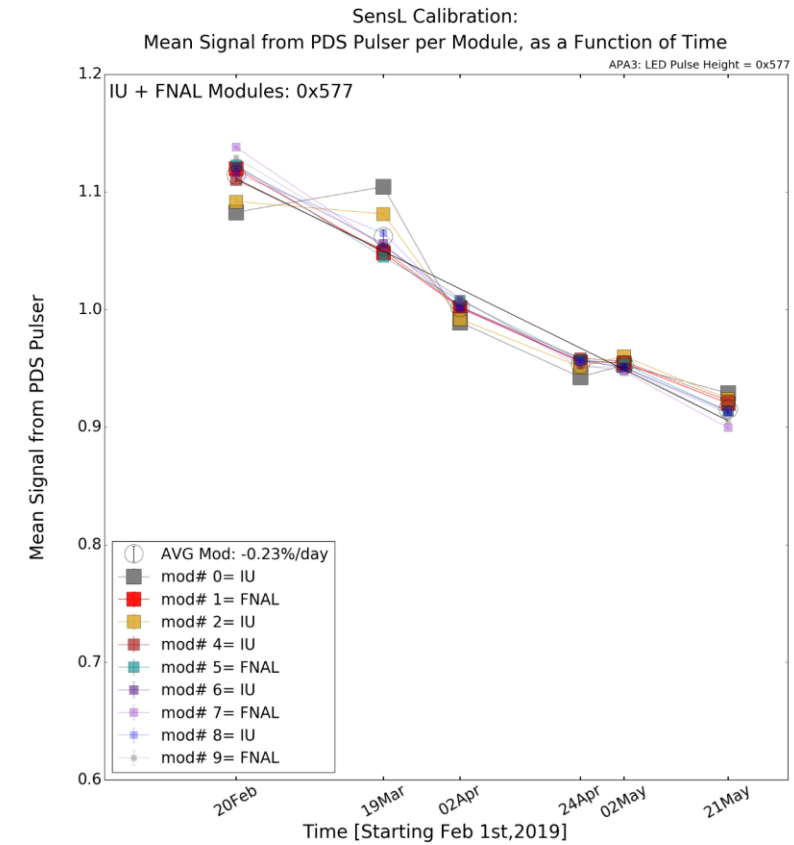
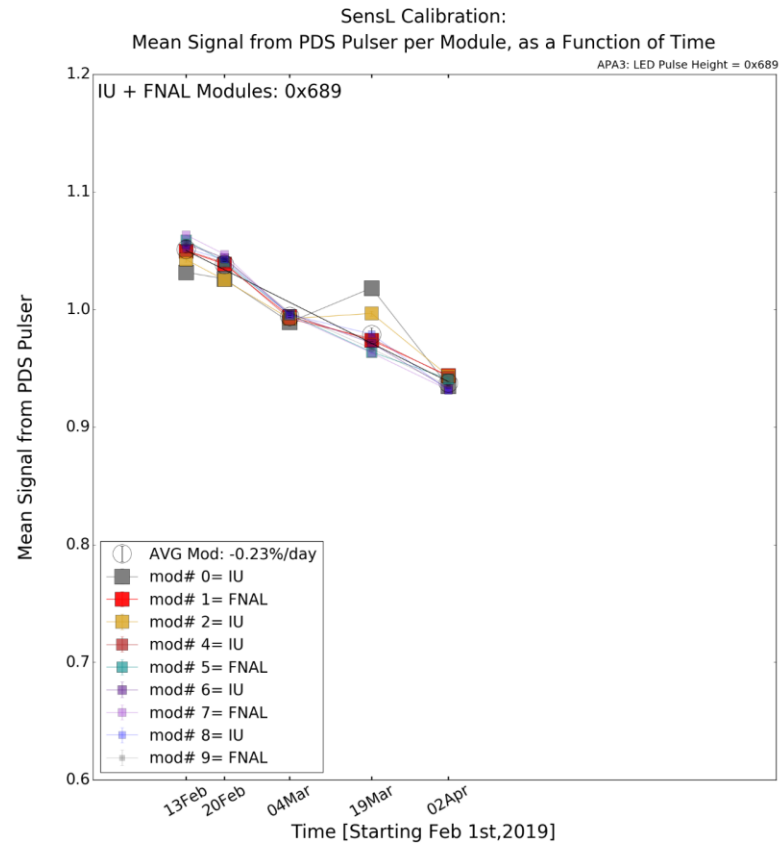
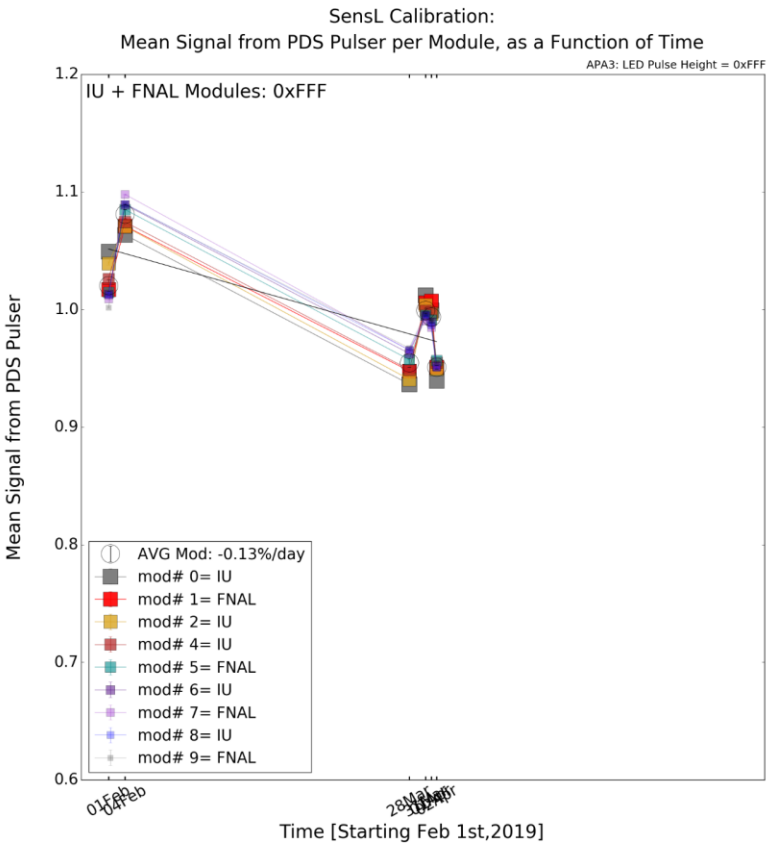


APA3 SensL Mean Signal Stability- Summary

- Mean Signal per Module
- Runs 6848, 7224, 7447, 7461, 7475, 7651, 7726, 7944
 - Stability Run
 - Pulse Peak Height = '0x577'
 - All viable LEDs on
- Normalization
 - Mean(mean signal) per channel
- $\langle \text{Module} \rangle$ value
 - Mean(modules)
 - Statistical error = $\text{RMS}(\text{mods})/\text{sqrt}(N)$
- Linear regression
 - Measure any module degradation [% / day]

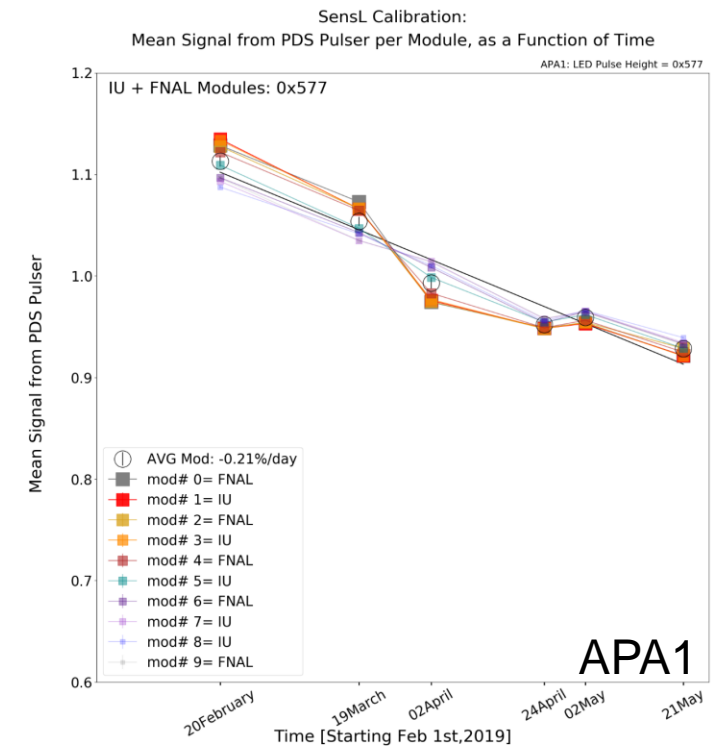
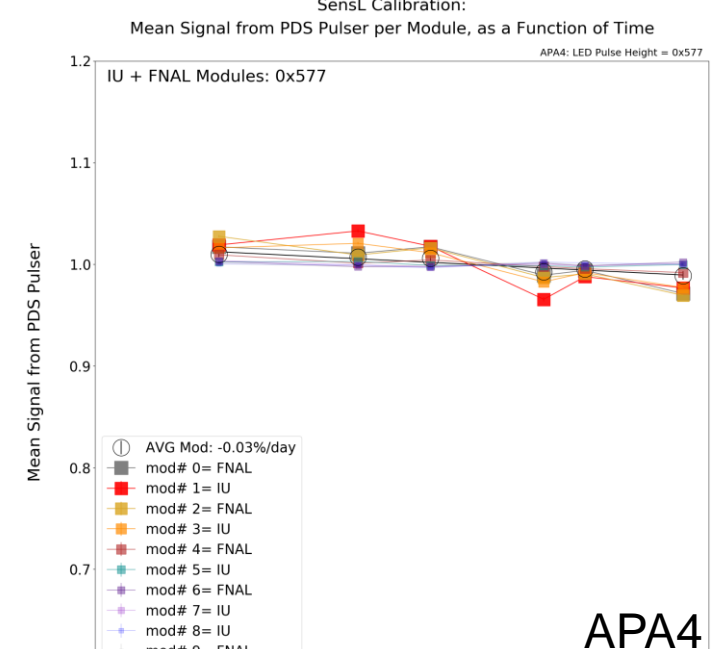
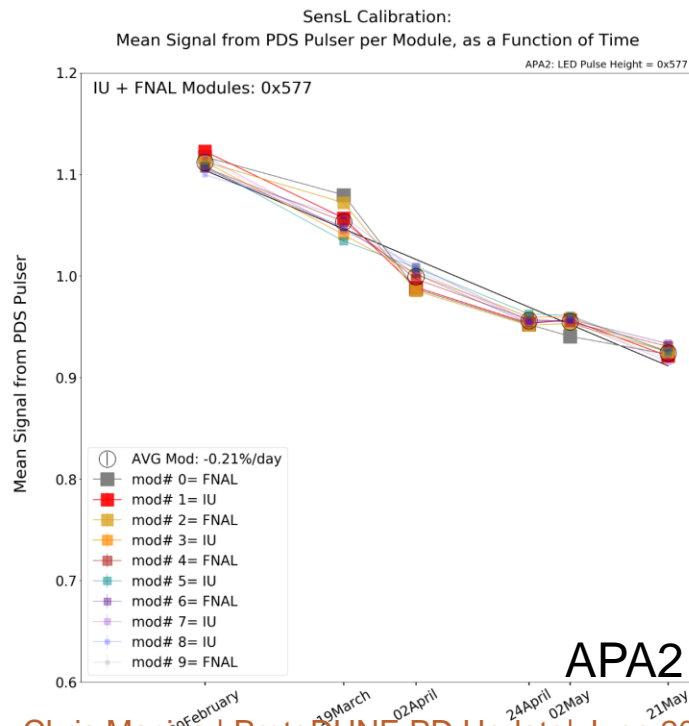
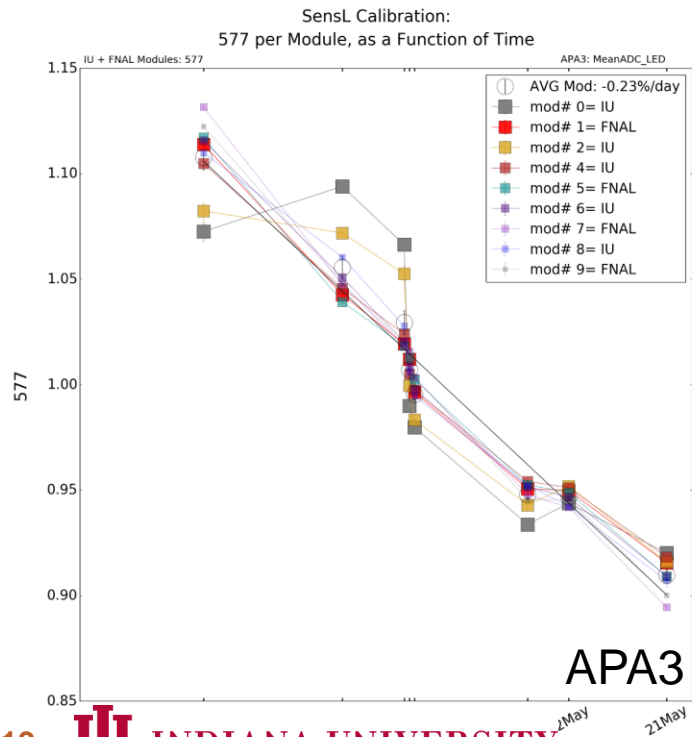


APA3 SensL Mean Signal Stability- LED Peak Height Comparison



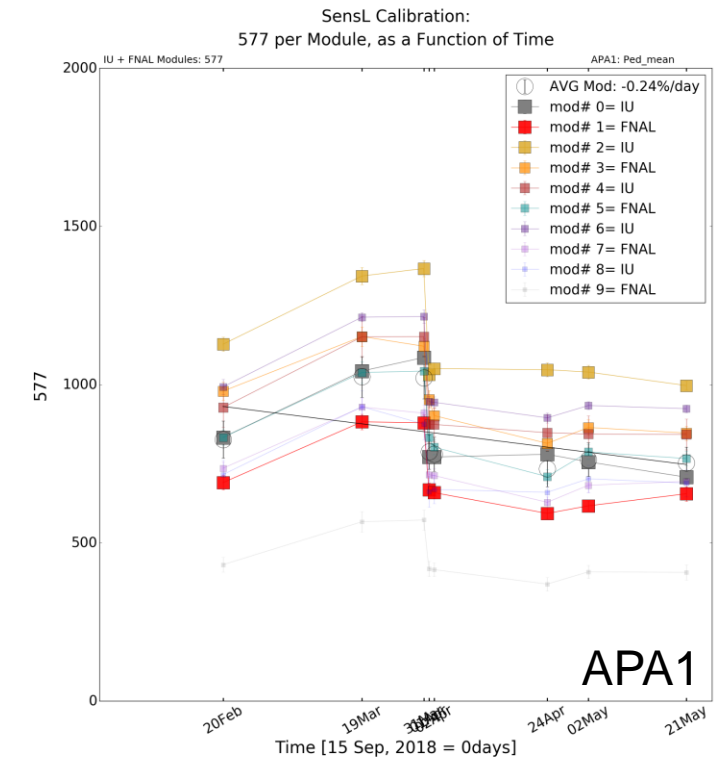
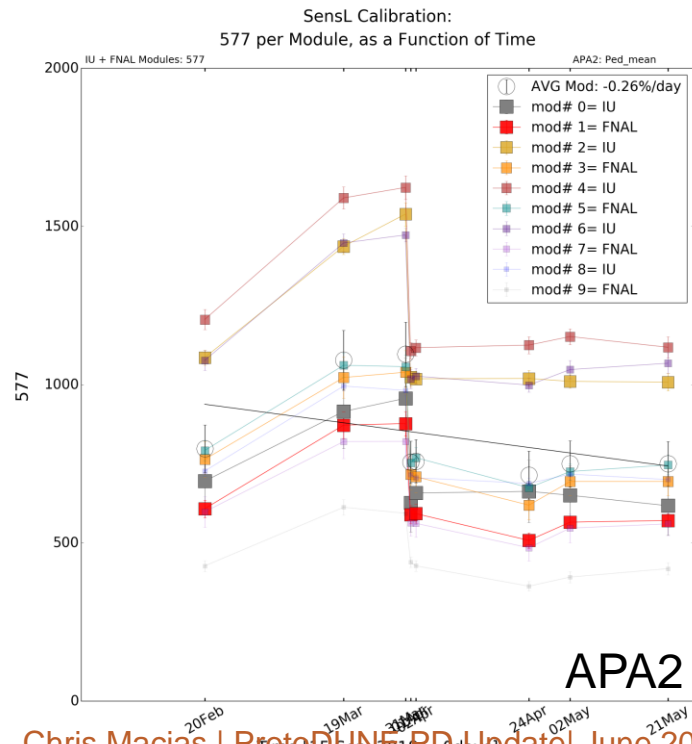
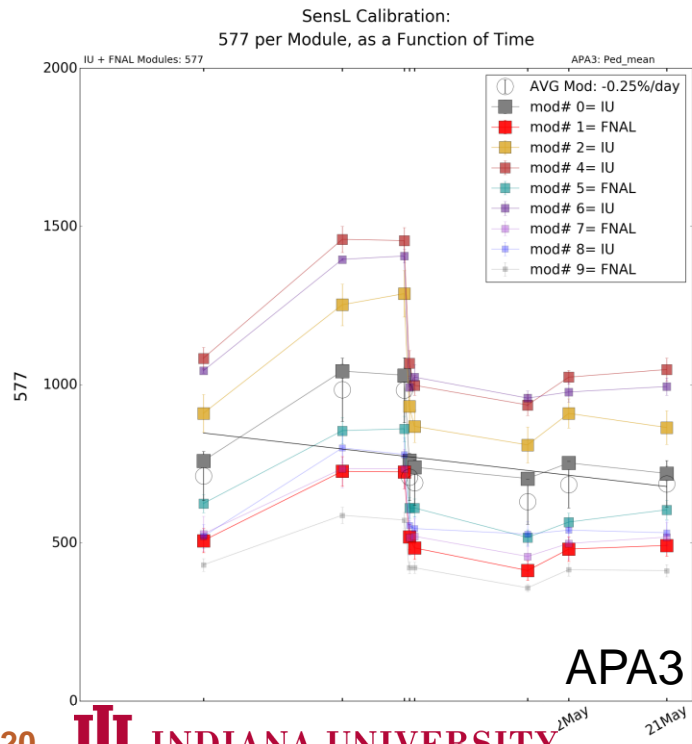
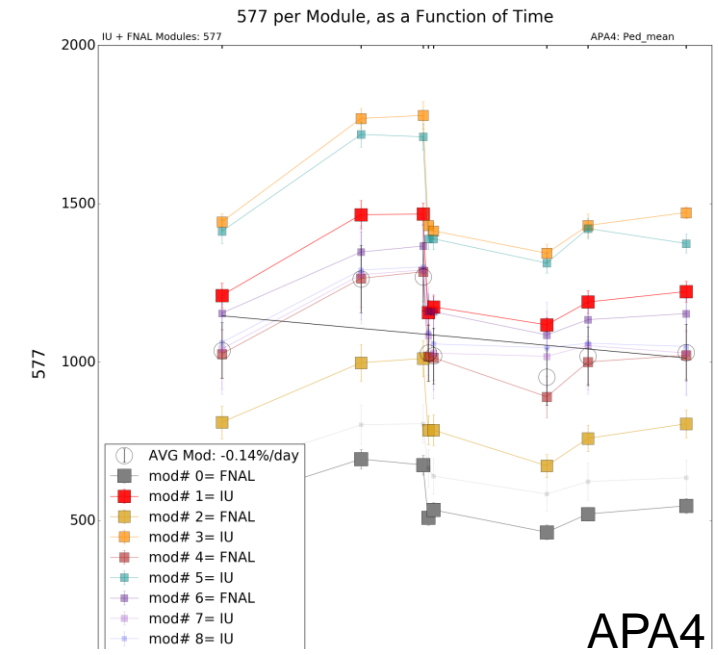
APAs 1-4 SensL Mean Signal Stability

Possible TDR Plot ->



APAs 1-4 SensL Mean Ped Signal Stability

Work in Progress



SensL Calibration Stability w/ Random Triggers

Work in Progress

APAs 1-4 SensL Mean Background Stability Random Trigger

Work in Progress

