

# FEB2 'Slice' Testboard Update

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LAr Week Phase-II Upgrade Electronics Meeting, 23 June 2021



# Overview/Timeline

## Analog Testboard (2019)

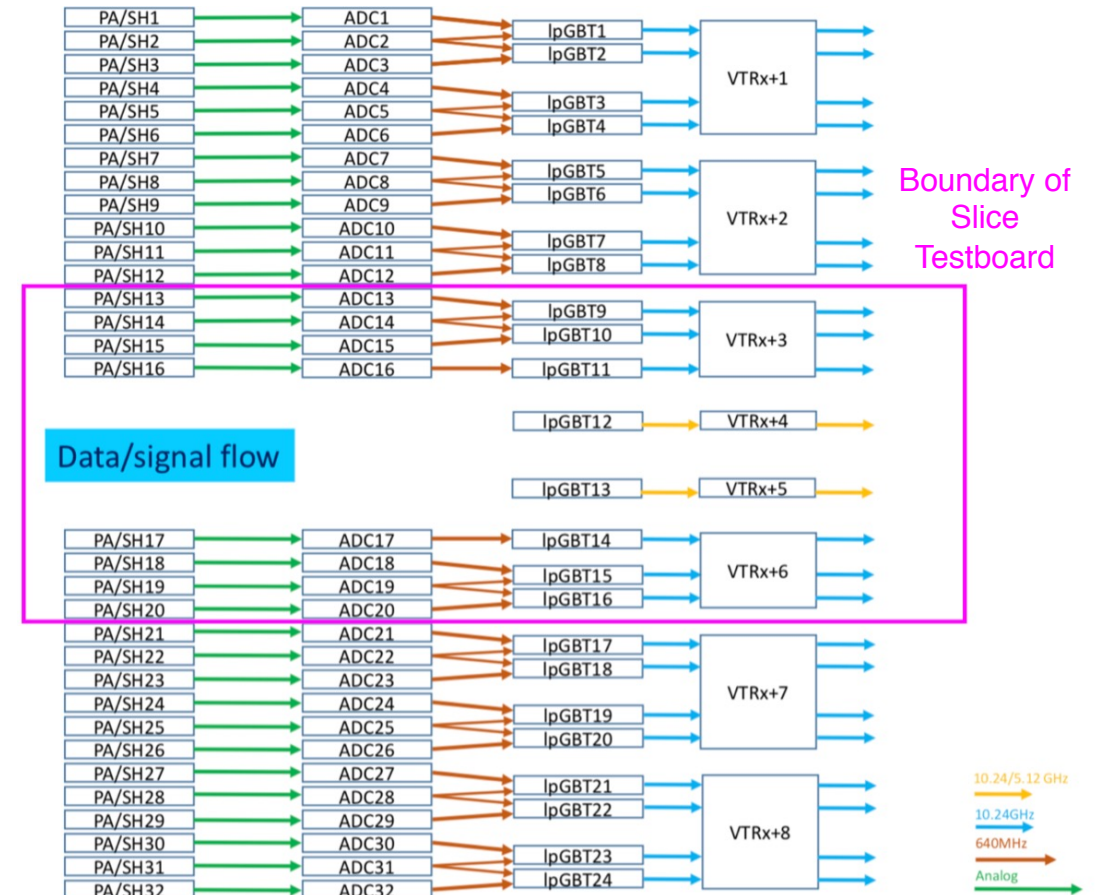
- 2 (LAUROC1 PA/S + COLUTAv2 ADC) +lpGBT
- Verified full readout chain: PA/s → ADC → optical data links

## Slice Testboard (2020-2021)

- 8 (LAUROC2 PA/S + COLUTAv3 ADC +lpGBT) chips, 32 LAr channels available
- **Goal:** demonstrate multichannel performance, bi-directional control links, characterize physics pulse gain and risetime
- board v1.1 testing currently underway on 2 fully assembled PCBs (#633 and #634)

## Full FEB2 Prototype (2022-2023)

- All 128 channels available



# Slice Testboard Layout + Features



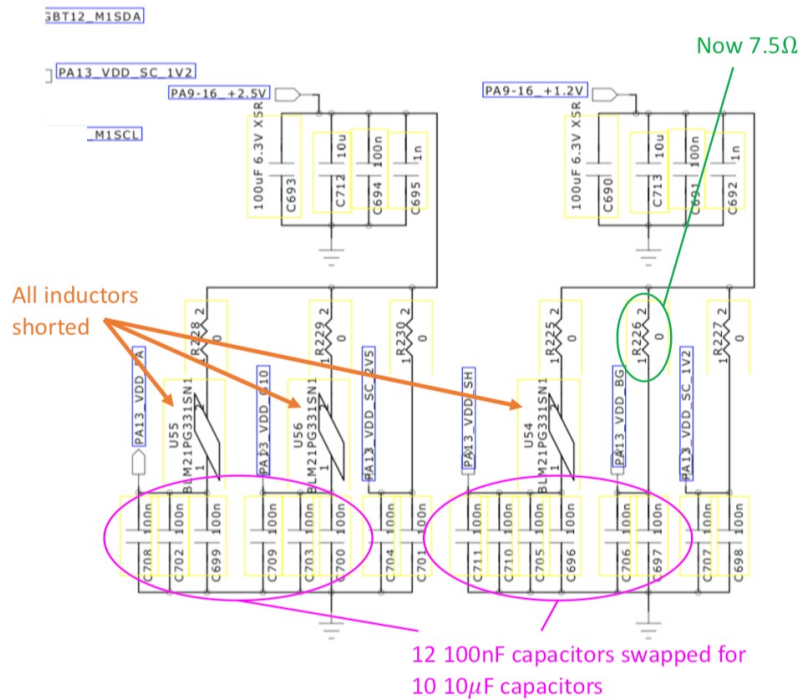
COLUTA

LAUROC

- Full sized PCB, including layout and density as planned for final FEB2
  - **32** of 128 channels implemented
- Implemented redundant bidirectional control links
- capable of fully programming both v1.1 boards at Nevis, and confirming configuration with readbacks
  - can configure and read back all LAUROC, COLUTA, and IpGBT chips
- Pulses injected through 1500pF load injector boards (not shown), with LAUROC impedance set at 250hm (or 330pF boards with 50 Ohm LAUROC configuration)
- Full board control + readout implemented through GUI software package integrated with FELIX
  - Board voltage and temperature monitoring available in GUI software

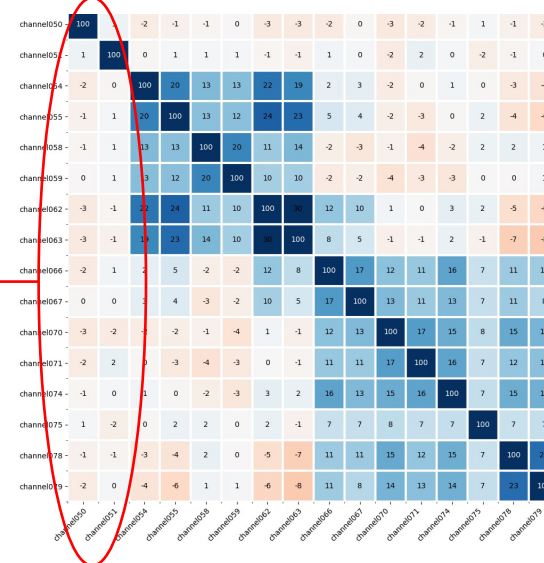
# Mitigation of Noise Issues

- Preliminary Slice Testboard results from [March LAr Week](#) showed high correlated noise across all channels, and 20kHz ripple in noise PSD spectrum
- Based on meeting with PA/S team: we modified the RLC circuit which has been recommended to implement, to filter the power feeds to the PA/S ASICs
- Following modification to PA/S reference supply voltage filtering, correlated noise is drastically reduced and 20 kHz structure removed. Details in [Upgrade Week](#) slides



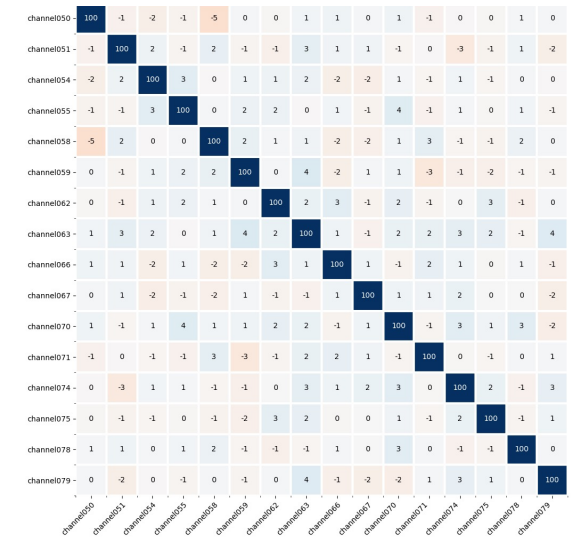
Modifications applied to COLUTA13 input network

Pairwise Noise Correlation, HG



All COLUTAS Modified

Pairwise Noise Correlation, HG





# LAUROC Configuration Parameters

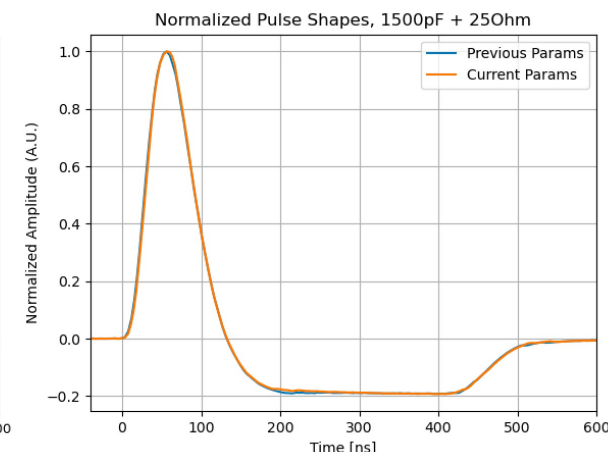
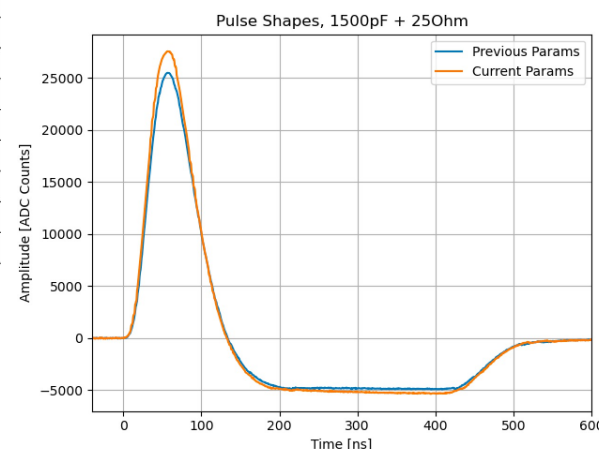
## Previous parameters

| 25Ω 10 mA config<br>DC connection between out_preamplifier and G20_amplifier input<br>SC Parameters to get a peaking time of 49 ns<br>SC parameters to set the gain SUM equal to 1 |     |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| sw_DC_g20                                                                                                                                                                          | 1   |
| sw_ibo_g20                                                                                                                                                                         | 1   |
| dac_g20<5:0> (dec code)                                                                                                                                                            | 32  |
| sw_ibi_25                                                                                                                                                                          | 1   |
| sw_ibo                                                                                                                                                                             | 1   |
| sw_R025_10mA                                                                                                                                                                       | 1   |
| sw_R025_5mA                                                                                                                                                                        | 0   |
| cr_hg_s1<2:0> (dec code)                                                                                                                                                           | 0   |
| rc_hg_s1<3:0> (dec code)                                                                                                                                                           | 9   |
| rc_hg_s2<3:0> (dec code)                                                                                                                                                           | 9   |
| rc_lg_s2<3:0> (dec code)                                                                                                                                                           | 10  |
| cr_lg_s1<2:0> (dec code)                                                                                                                                                           | 3   |
| rc_lg_s1<3:0> (dec code)                                                                                                                                                           | 13  |
| c2<8:0> (dec code)                                                                                                                                                                 | 225 |
| dacb_VDC_hg<5:0> (dec code)                                                                                                                                                        | 15  |
| dacb_VDC_lg<5:0> (dec code)                                                                                                                                                        | 5   |
| dacb_VDC_sum<5:0> (dec code)                                                                                                                                                       | 24  |
| cmd_gain_sum<2:0> (dec code)                                                                                                                                                       | 0   |

## Current parameters

| 25Ω 10 mA config<br>DC connection between out_preamplifier and G20_amplifier input<br>SC Parameters to get a peaking time of 49 ns<br>SC parameters to set the gain SUM equal to 1 |     |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| sw_DC_g20                                                                                                                                                                          | 1   |
| sw_ibo_g20                                                                                                                                                                         | 0   |
| dac_g20<5:0> (dec code)                                                                                                                                                            | 63  |
| sw_ibi_25                                                                                                                                                                          | 1   |
| sw_ibo                                                                                                                                                                             | 0   |
| sw_R025_10mA                                                                                                                                                                       | 1   |
| sw_R025_5mA                                                                                                                                                                        | 0   |
| cr_hg_s1<2:0> (dec code)                                                                                                                                                           | 0   |
| rc_hg_s1<3:0> (dec code)                                                                                                                                                           | 9   |
| rc_hg_s2<3:0> (dec code)                                                                                                                                                           | 8   |
| rc_lg_s2<3:0> (dec code)                                                                                                                                                           | 9   |
| cr_lg_s1<2:0> (dec code)                                                                                                                                                           | 3   |
| rc_lg_s1<3:0> (dec code)                                                                                                                                                           | 9   |
| c2<8:0> (dec code)                                                                                                                                                                 | 230 |
| dacb_VDC_hg<5:0> (dec code)                                                                                                                                                        | 28  |
| dacb_VDC_lg<5:0> (dec code)                                                                                                                                                        | 28  |
| dacb_VDC_sum<5:0> (dec code)                                                                                                                                                       | 20  |
| cmd_gain_sum<2:0> (dec code)                                                                                                                                                       | 0   |

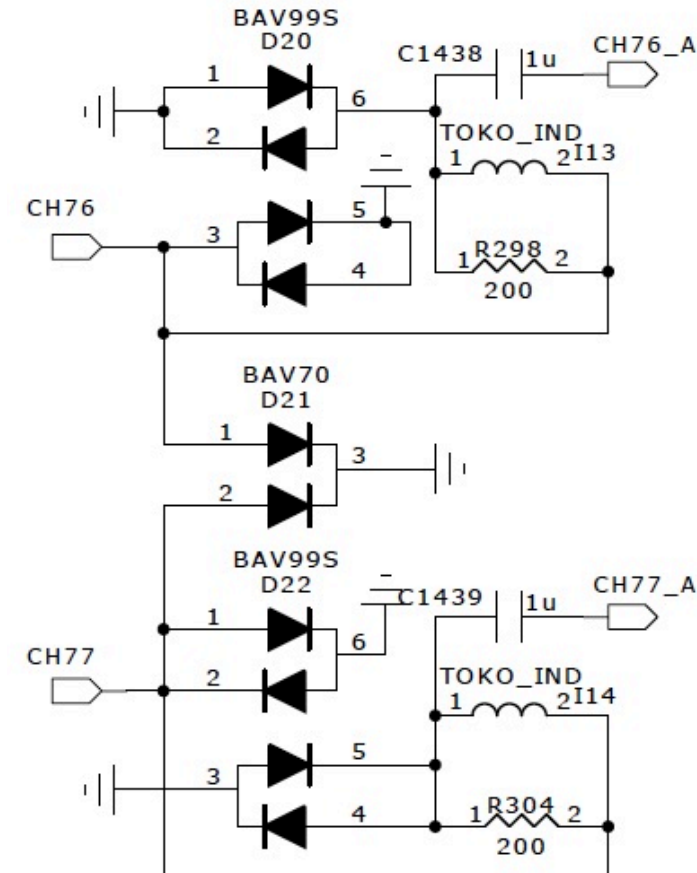
- LAUROC configured using new, recently provided parameters summarized on p. 27 of LAUROC datasheet (listed in "Current parameters" table)
  - Exception:** tune output DAC levels to obtain baseline around 7000 ADC counts (out of 32k counts total)
  - All results in these slides use this config
- Previously:
  - used "Default" parameters shown in LAUROC datasheet table pages 21-26
  - used config parameters shown in 'Previous parameters' table



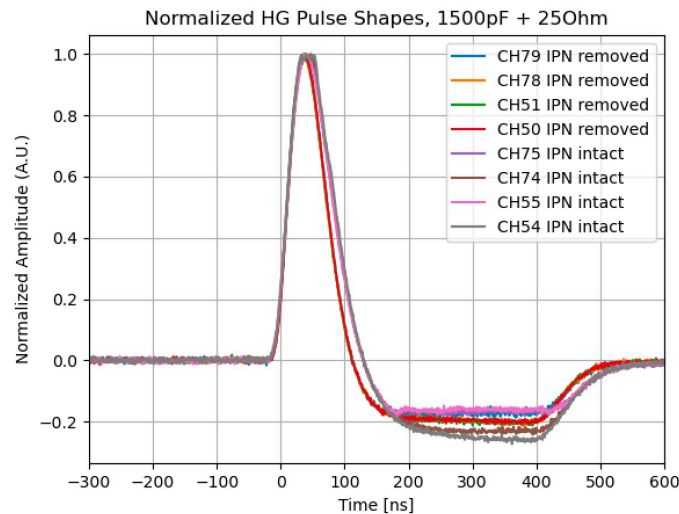
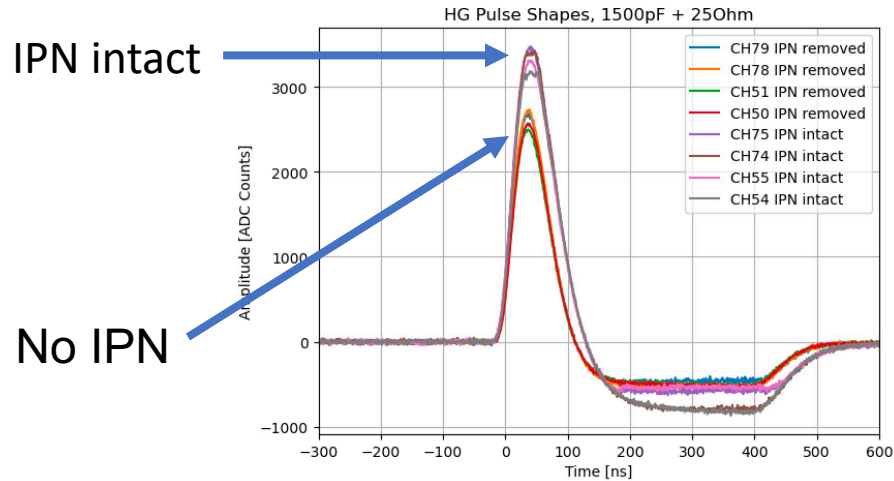
Previous Params HG Gain: **50995 ± 70 ADC Counts/mA**  
 Current Params HG Gain: **54980 ± 110 ADC Counts/mA**

# Slice Testboard Input Protection Network (IPN)

- FEB2 needs to implement input protection network (IPN) to protect PA/S input against possible HV discharges in detector
- As discussed and agreed previously, starting point was to implement on Slice Testboard a copy of the protection network as implemented on the PA hybrid on the current FEB
- The IPN as implemented in the Slice Testboard schematics is shown on the right for a pair of channels
  - In particular, note that the IPN includes a 1  $\mu\text{F}$  AC-coupling cap at the PA/S input



# Impact of IPN on Pulse Shapes (HG)



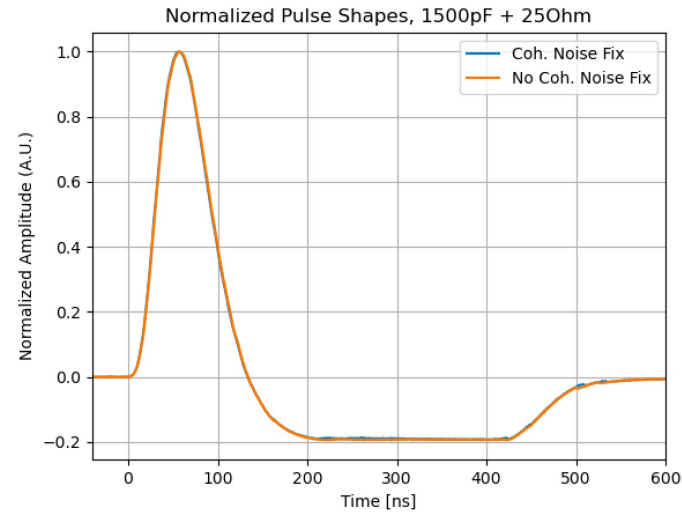
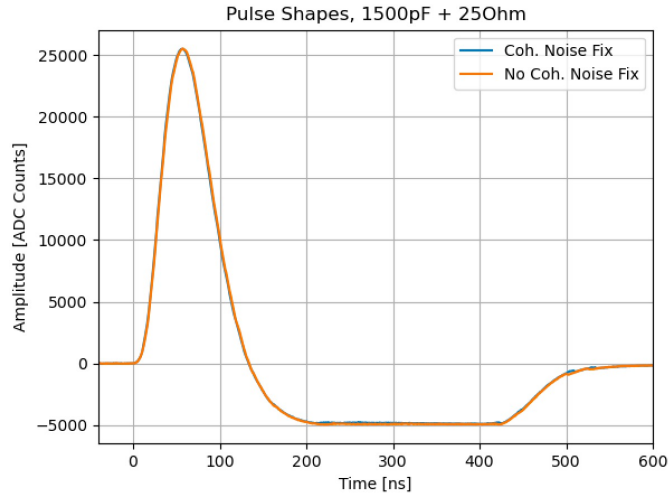
- Pulse defined by AWG, injected through 1500pF detector load
- Input signal size for all pulses shown here = 0.050mA
- IPN has a clear impact on pulse shape
  - Small increase in pulse risetime and width with IPN
  - Large increase in gain with IPN
- Focus in this talk will be on **results with IPN bypassed**, as we believe it is the most direct comparison with LAUROCC standalone test results

| HG Channel | IPN Bypass | Rise Time [ns] | Gain [ADC/mA] | Gain [mVdiff/mA] |
|------------|------------|----------------|---------------|------------------|
| 79         | Y          | 44.1±.6        | 53726±12      | 3279.2±.7        |
| 78         | Y          | 46.6±.6        | 54681±5       | 3337.5±.3        |
| 51         | Y          | 46.6±.6        | 49963±12      | 3049.5±.7        |
| 50         | Y          | 44.9±.6        | 51413±14      | 3138±.9          |
| 75         | N          | 50.7±.6        | 69549±15      | 4244.9±.9        |
| 74         | N          | 55.7±.6        | 68462±11      | 4178.6±.7        |
| 55         | N          | 50.7±.6        | 66253±6       | 4043.8±.4        |
| 54         | N          | 48.2±.6        | 63700±11      | 3887.9±.7        |

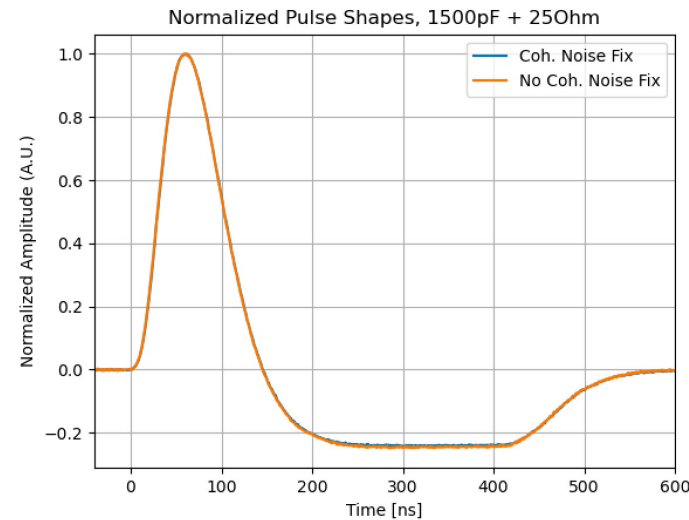
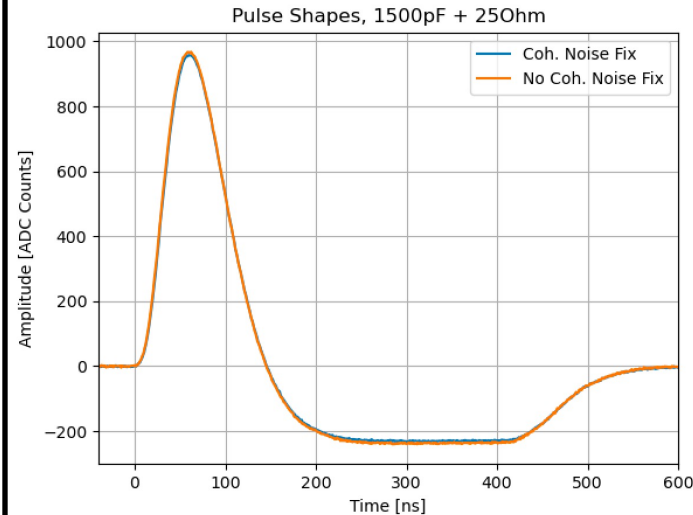
Note: Gain conversion assumes 2Vdiff / 32768 codes

# Impact of Coherent Noise Fix on Pulse shapes, 25 Ohm (IPN bypassed)

**HG**



**LG**

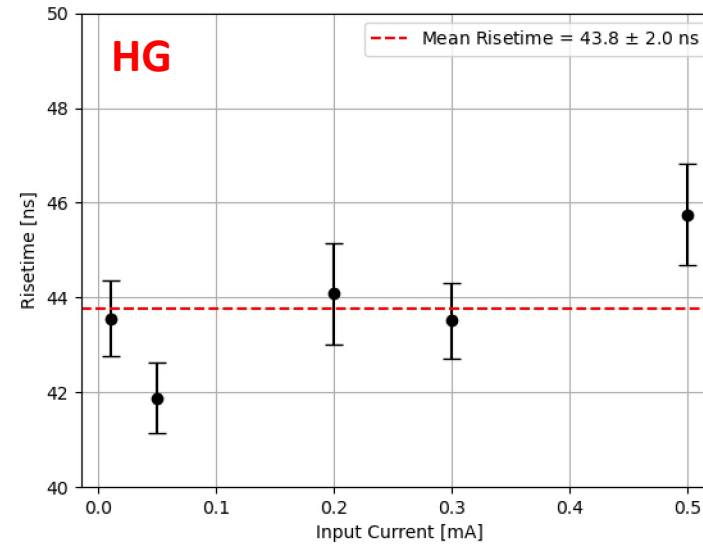
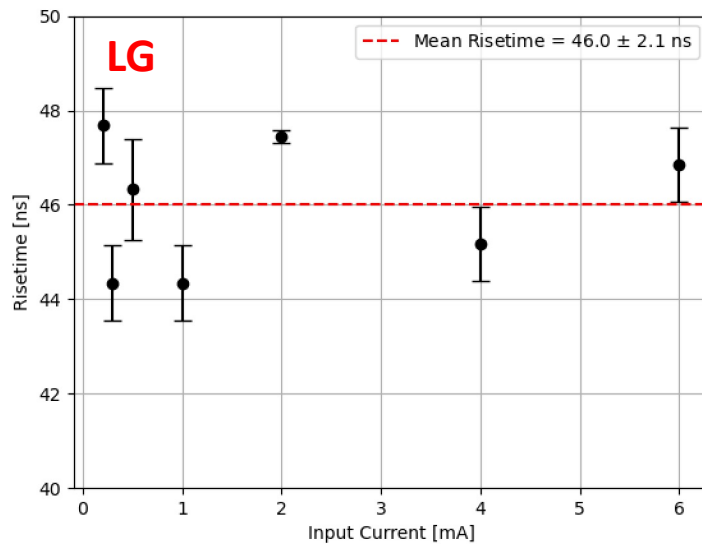


- Comparison shown at .5mA input signal amplitude
- Negligible effect of noise fix on pulse shape, pulse gain
- Reproducible result across multiple COLUTA chips



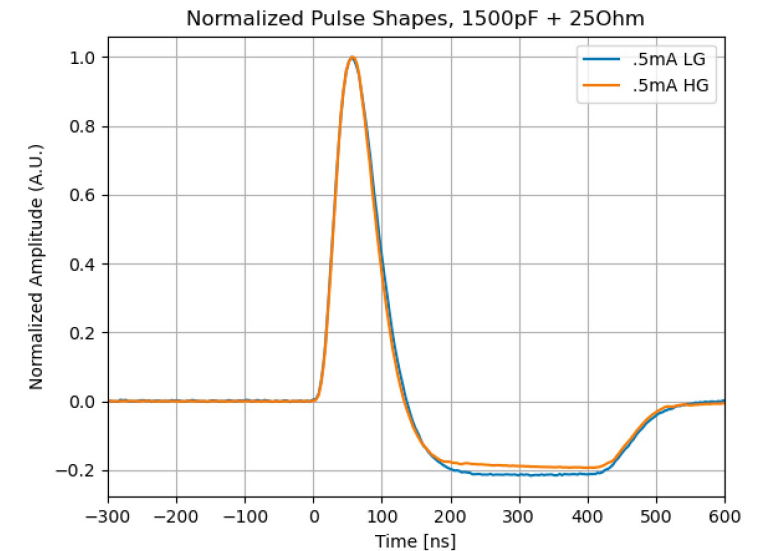
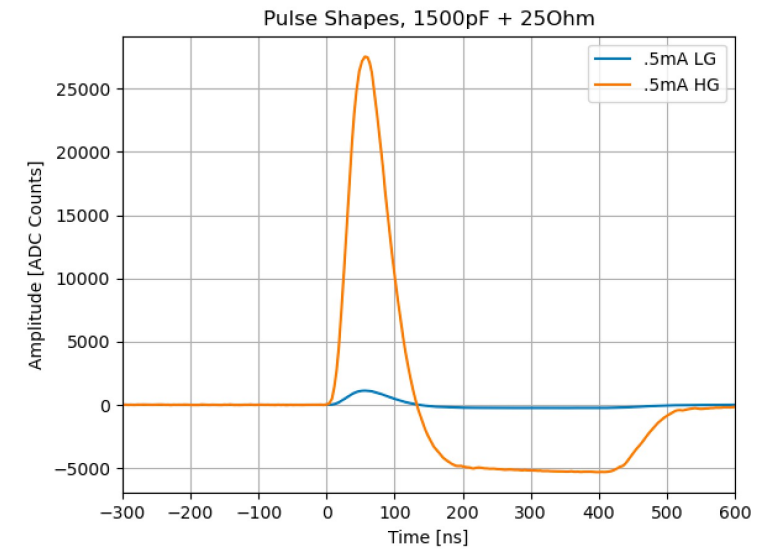
# Pulse Risetime, 25Ohm IPN bypassed

- LAUROC configured using most recent suggestions from PA/S team
- HG 5-100% risetime approx. 2ns faster than LG
- Peaking time consistent with times reported by PA/S collaborators



HG risetime:  $43.8 \pm 2.0$  ns

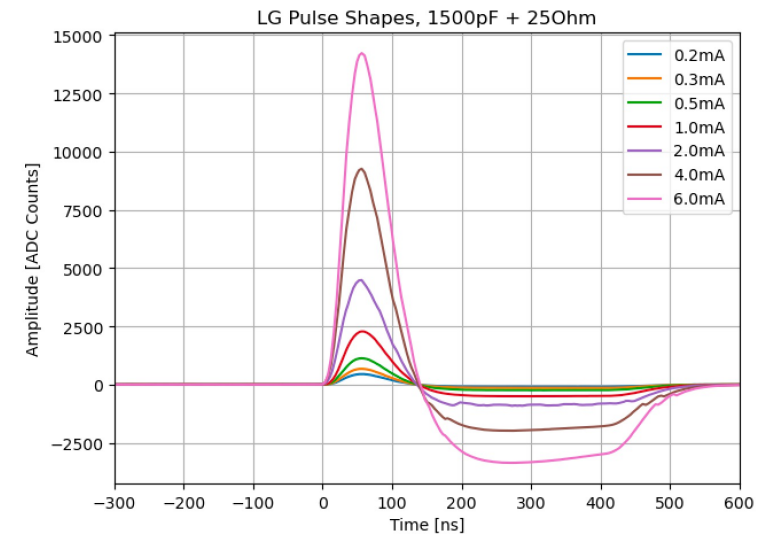
LG risetime:  $46.0 \pm 2.1$  ns



# Pulse Gains, 250hm IPN bypassed

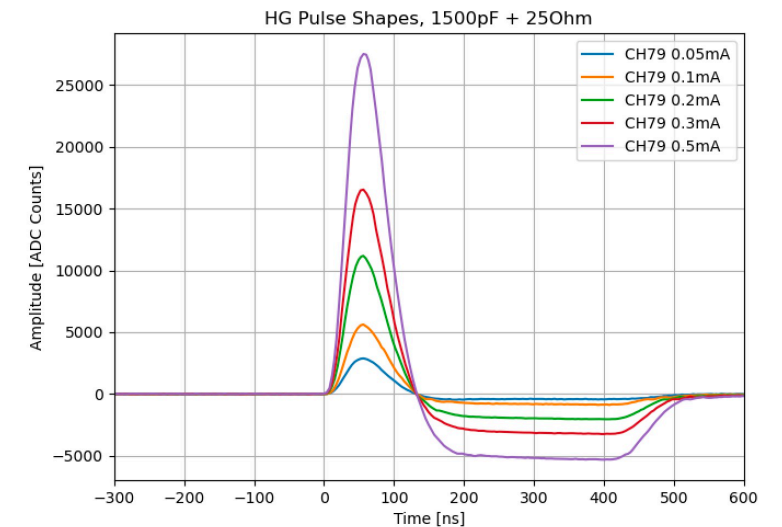
LG mean ENI : **1837 ± 9 nA**

| Input Amp [mA] | Gain [ADC/mA] | dGain [ADC/mA] | Gain [mVdiff/mA] | dGain [mVdiff/mA] | ENI [nA] | dENI [nA] |
|----------------|---------------|----------------|------------------|-------------------|----------|-----------|
| 0.2            | 2263          | 3              | 138.1            | 0.2               | 1855.9   | 2.5       |
| 0.3            | 2255          | 1              | 137.6            | 0.1               | 1862.5   | 0.8       |
| 0.5            | 2260          | 6              | 137.9            | 0.4               | 1858.4   | 4.9       |
| 1              | 2287          | 2              | 139.6            | 0.1               | 1836.5   | 1.6       |
| 2              | 2250          | 2              | 137.3            | 0.1               | 1866.7   | 1.7       |
| 4              | 2318          | 3              | 141.5            | 0.2               | 1811.9   | 2.3       |
| 6              | 2373          | 8              | 144.8            | 0.5               | 1769.9   | 6         |



HG mean ENI : **351 ± 1 nA**

| Input Amp [mA] | Gain [ADC/mA] | dGain [ADC/mA] | Gain [mVdiff/mA] | dGain [mVdiff/mA] | ENI [nA] | dENI [nA] |
|----------------|---------------|----------------|------------------|-------------------|----------|-----------|
| 0.05           | 57733         | 31             | 3523.7           | 1.9               | 341.2    | 0.18      |
| 0.1            | 56483         | 50             | 3447.4           | 3.1               | 348.8    | 0.31      |
| 0.2            | 56117         | 55             | 3425.1           | 3.4               | 351.1    | 0.34      |
| 0.3            | 55214         | 61             | 3370             | 3.7               | 356.8    | 0.39      |
| 0.5            | 55131         | 17             | 3364.9           | 1                 | 357.3    | 0.11      |

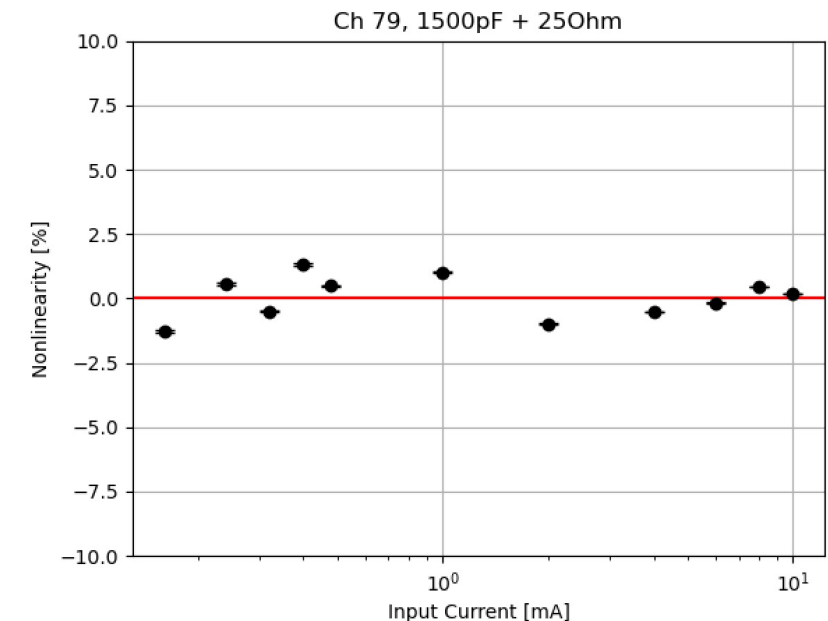
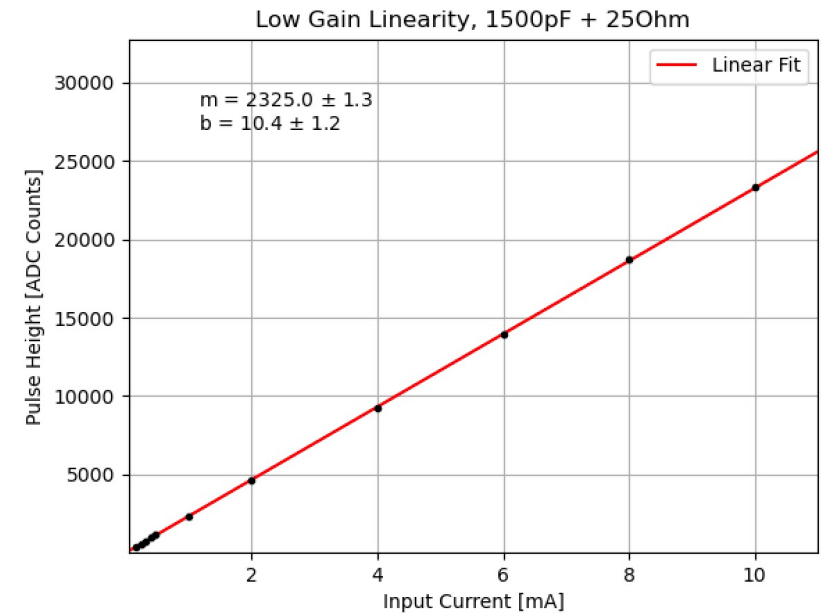
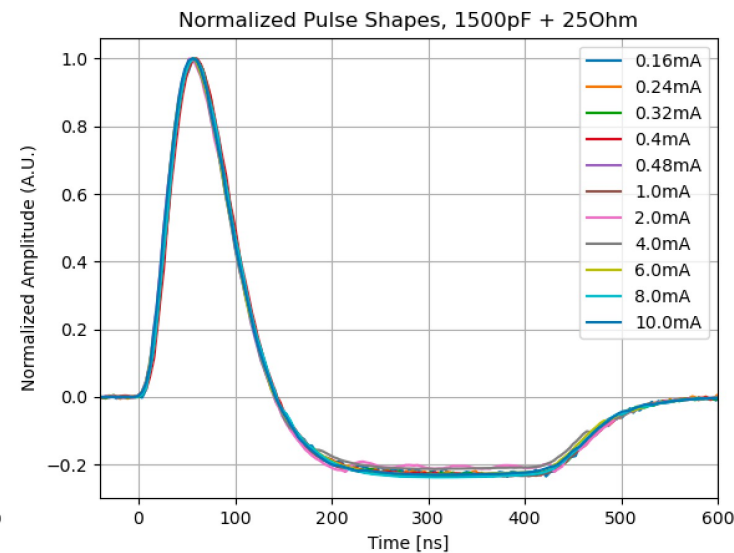
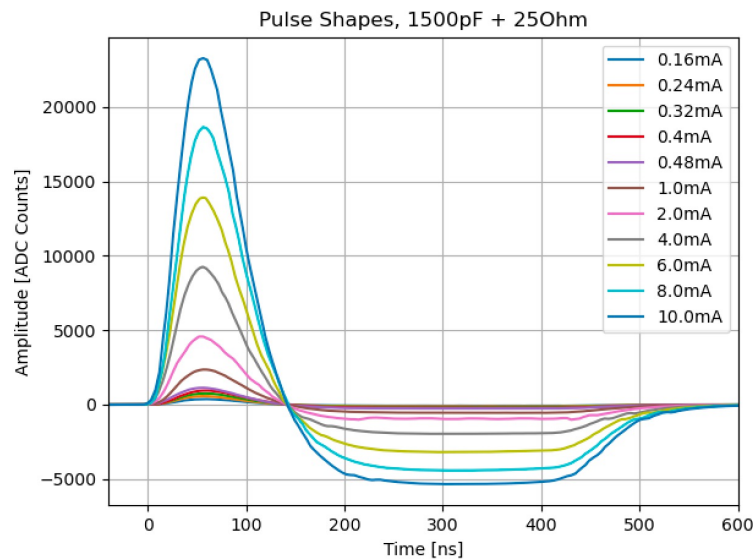


Note: Gain conversion assumes 2Vdiff / 32768 codes

- ENI expected HG value 264 nA
- Hi/Lo gain ratio: 24.6

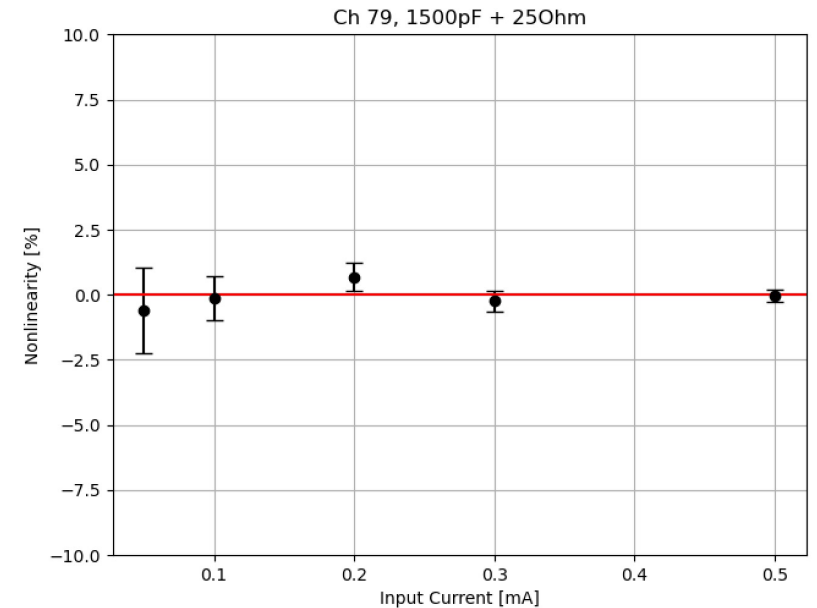
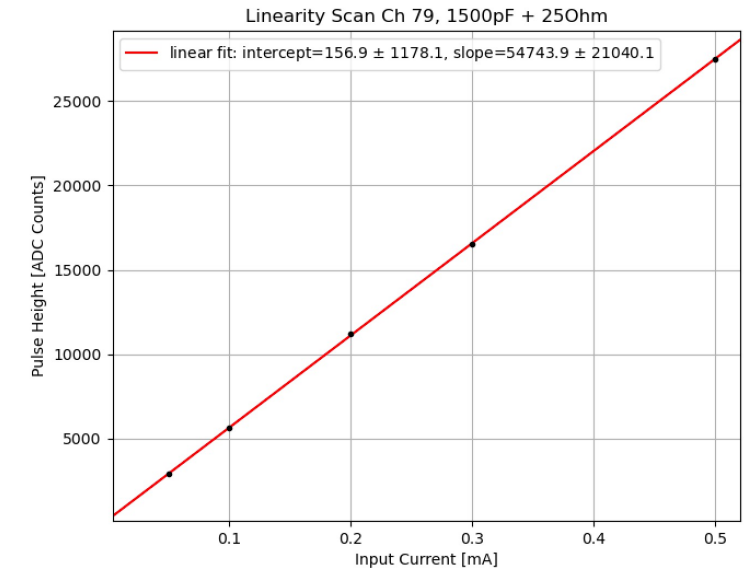
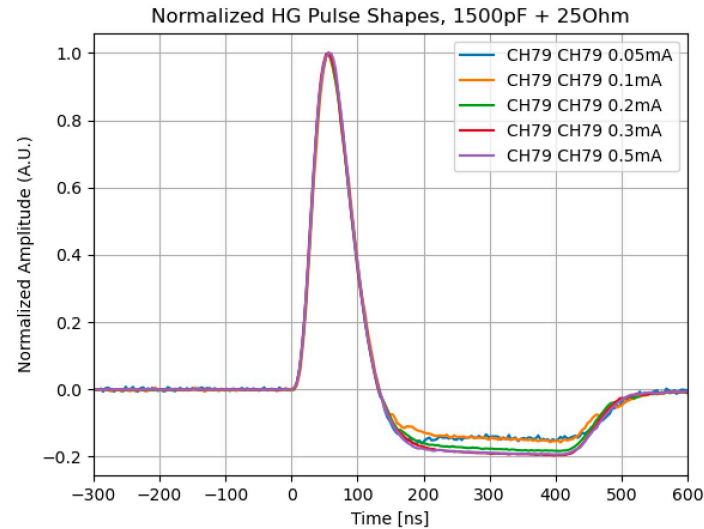
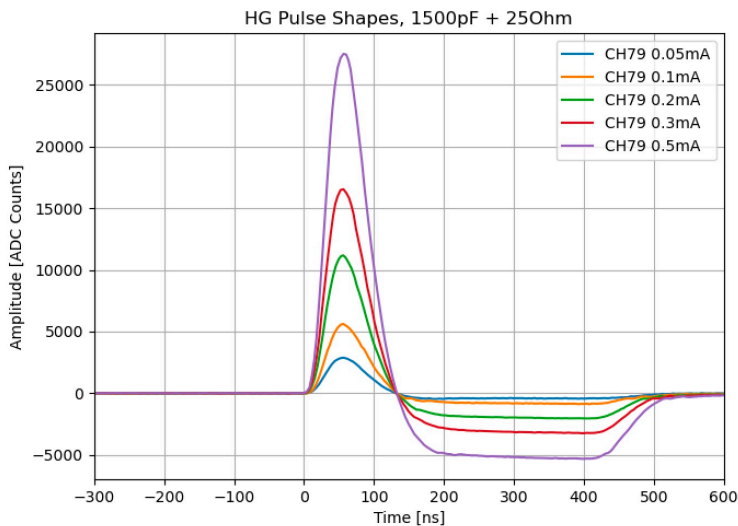
# Pulse Linearity, 250hm IPN bypassed (LG)

- Consistent pulse shape observed in LG for up to 10.0mA input signal
- Pulse height linear to within 1.5% up to 10.0mA input signal, nonlinearity likely due to uncalibrated MDAC + SAR constants

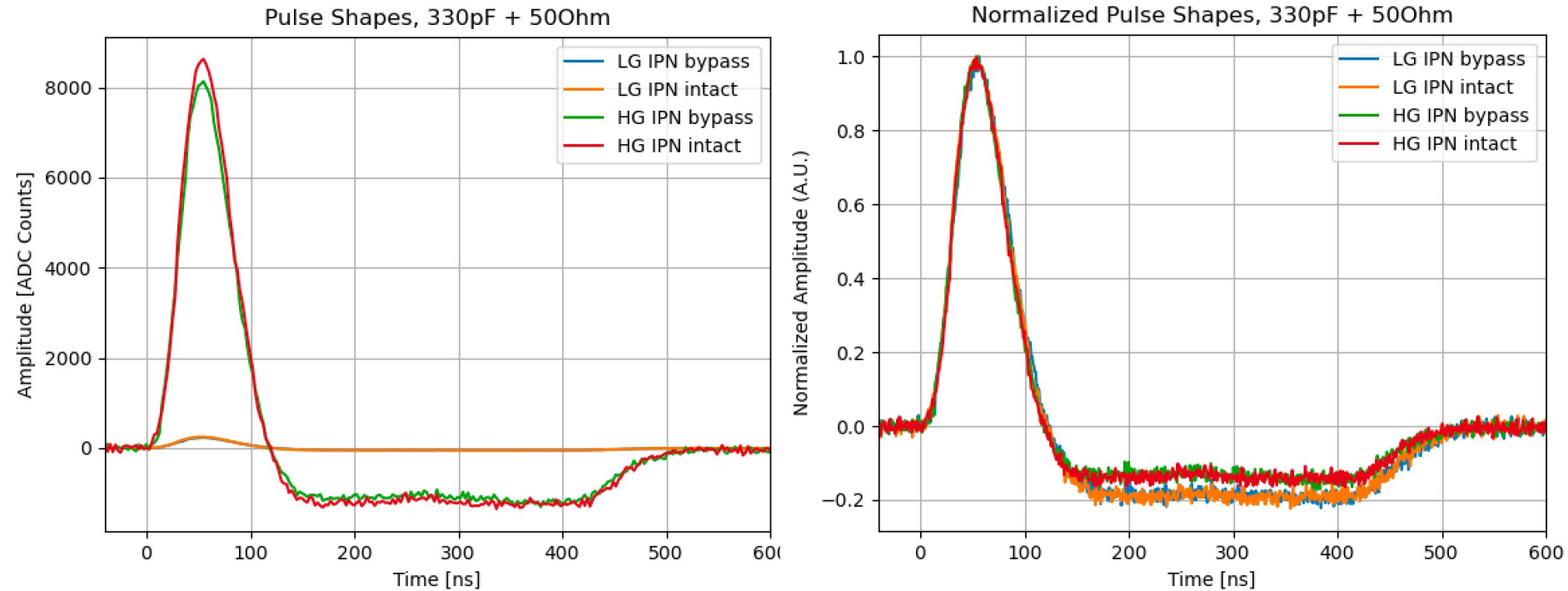


# Pulse Linearity, 250hm IPN bypassed (HG)

- HG linearity within 1.0% up to 0.5mA input signal
- Saturation observed above 0.5mA input signal with IPN bypassed, and above 0.4mA input signal with IPN intact



# 50Ohm LAUROC setting Gain + Risetime Measurements



| Ch    | IPN Bypass | Input Amp [mA] | Gain [ADC/mA] | dGain [ADC/mA] | Gain [mVdiff/mA] | dGain [mVdiff/mA] | ENI [nA] | dENI [nA] | Risetime [ns] | dRisetime [ns] |
|-------|------------|----------------|---------------|----------------|------------------|-------------------|----------|-----------|---------------|----------------|
| 79 LG | Y          | 0.02           | 11670         | 80             | 712.3            | 4.9               | 359.9    | 2.47      | 37            | 1              |
| 79 HG | Y          | 0.02           | 406400        | 2400           | 24804.7          | 146.5             | 88.6     | 0.52      | 36            | 1              |
| 75 LG | N          | 0.02           | 12400         | 100            | 756.8            | 6.1               | 338.7    | 23.41     | 33            | 1              |
| 75 HG | N          | 0.02           | 431300        | 3500           | 26324.5          | 213.6             | 83.5     | 0.68      | 35            | 1              |

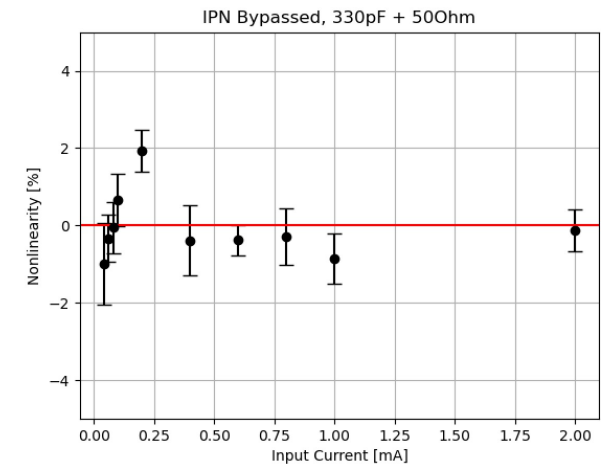
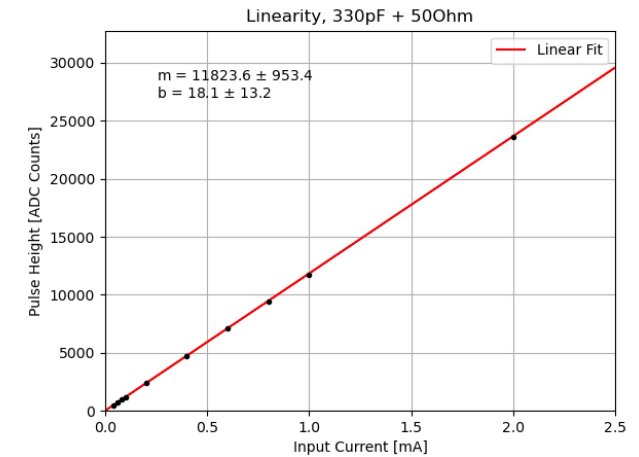
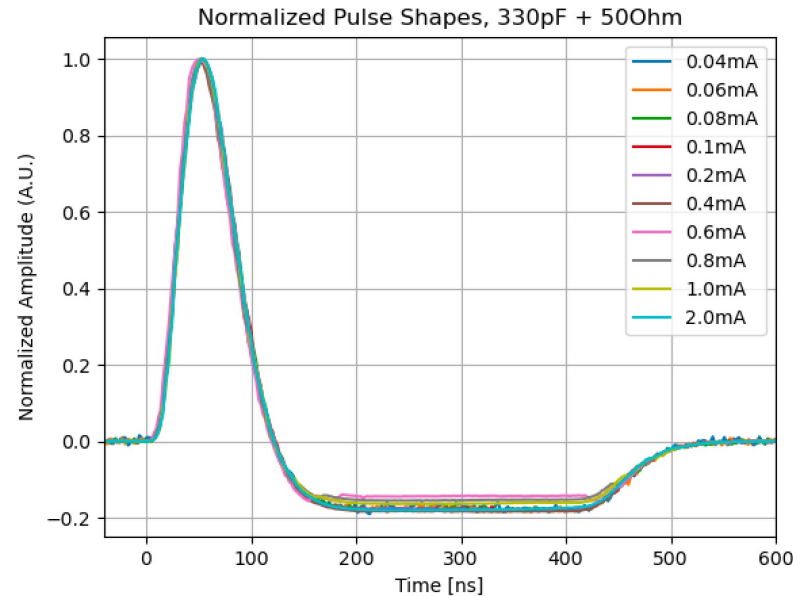
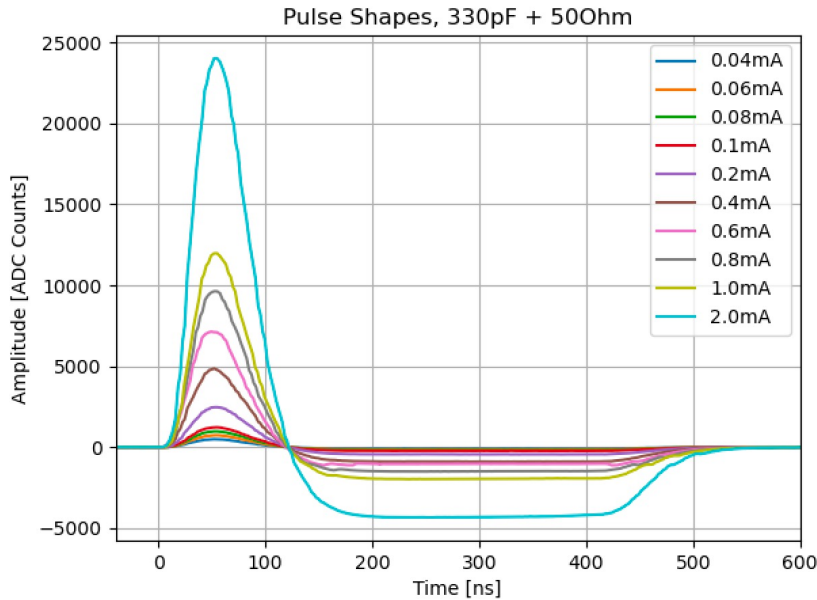
- Small increase in pulse risetime and width with IPN
- Large increase in gain with IPN



**Consistent with 25 Ohm Results**



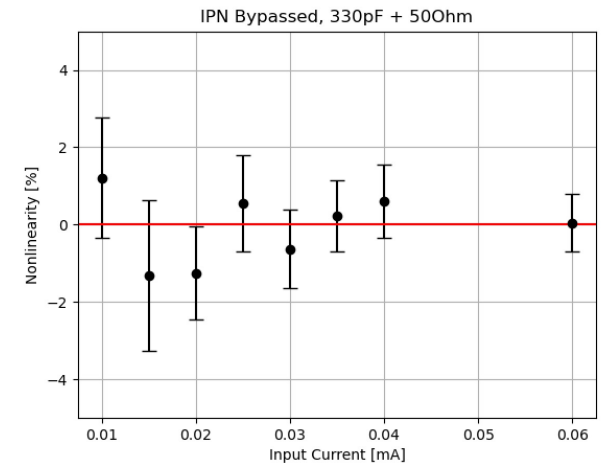
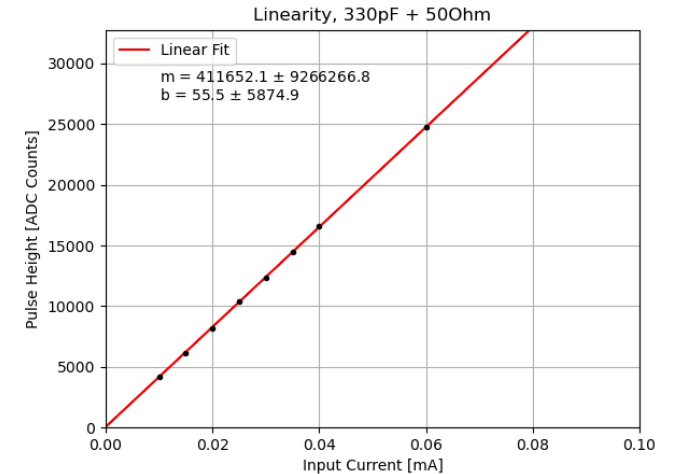
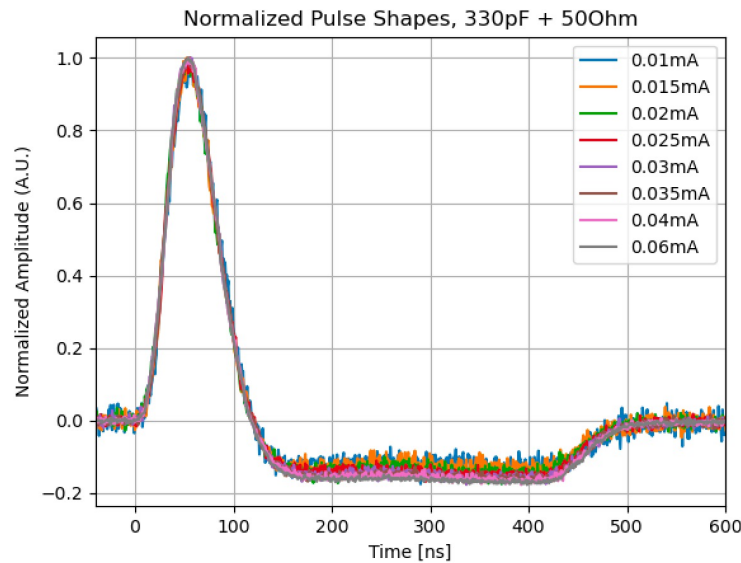
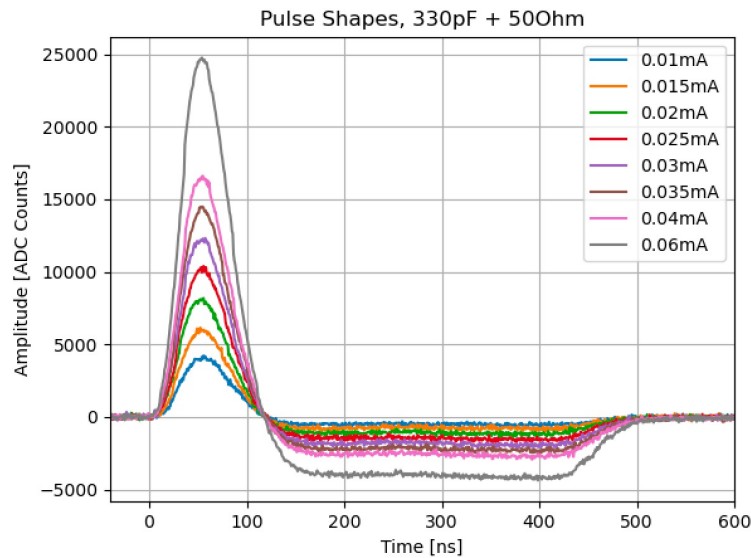
# Pulse Linearity, 50Ohm LAUROC Setting IPN Bypassed (LG)



- Consistent pulse shape observed in LG for up to 2.0mA input signal, above which signal saturates
- Pulse height linear to within 2% up to saturating input signal, nonlinearity likely due to uncalibrated MDAC + SAR constants

# Pulse Scan, 50Ohm LAUROC Setting IPN Bypassed (HG)

- Consistent pulse shape observed in HG for up to 0.06mA input signal, above which signal saturates
- Pulse height linear to within 1.5% up to saturating input signal, nonlinearity likely due to uncalibrated MDAC + SAR constants



# Pulse Gains, IPN Intact

LG mean ENI : **1653 ± 21 nA**

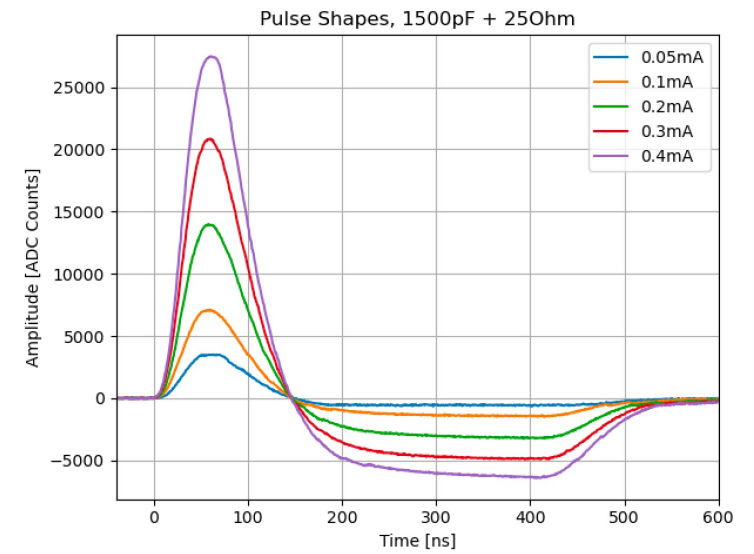
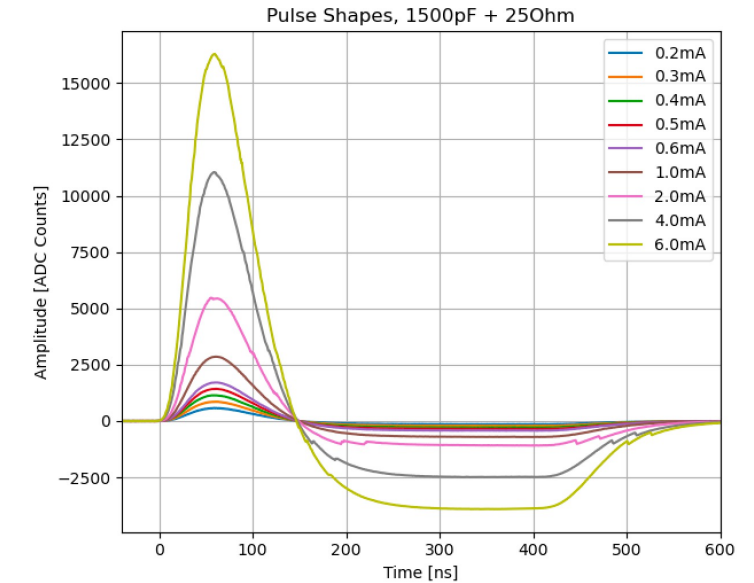
| Input Amp [mA] | Gain [ADC/mA] | dGain [ADC/mA] | Gain [mVdiff/mA] | dGain [mVdiff/mA] | ENI [nA] | dENI [nA] |
|----------------|---------------|----------------|------------------|-------------------|----------|-----------|
| 0.2            | 2898          | 8              | 176.9            | 0.5               | 1587.3   | 4.38      |
| 0.3            | 2852          | 5              | 174.1            | 0.3               | 1612.9   | 2.83      |
| 0.4            | 2860          | 5              | 174.6            | 0.3               | 1608.4   | 2.81      |
| 0.5            | 2866          | 2              | 174.9            | 0.1               | 1605     | 1.12      |
| 0.6            | 2850          | 5              | 174              | 0.3               | 1614     | 2.83      |
| 1              | 2857          | 4              | 174.4            | 0.2               | 1610.1   | 2.25      |
| 2              | 2734          | 33             | 166.9            | 2                 | 1682.5   | 20.31     |
| 4              | 2762          | 7              | 168.6            | 0.4               | 1665.5   | 4.22      |
| 6              | 2715          | 6              | 165.7            | 0.4               | 1694.3   | 3.74      |

HG mean ENI : **279 ± 1 nA**

| Input Amp [mA] | Gain [ADC/mA] | dGain [ADC/mA] | Gain [mVdiff/mA] | dGain [mVdiff/mA] | ENI [nA] | dENI [nA] |
|----------------|---------------|----------------|------------------|-------------------|----------|-----------|
| 0.05           | 70131         | 58             | 4280.5           | 3.5               | 278.1    | 0.23      |
| 0.1            | 71126         | 37             | 4341.2           | 2.3               | 274.2    | 0.14      |
| 0.2            | 69925         | 72             | 4267.9           | 4.4               | 278.9    | 0.29      |
| 0.3            | 69456         | 56             | 4239.3           | 3.4               | 280.8    | 0.23      |
| 0.4            | 68685         | 41             | 4192.2           | 2.5               | 283.9    | 0.17      |

Note: Gain conversion assumes 2Vdiff / 32768 codes

- Gain + ENI values in better agreement with those reported by PA/S collaborators than results without IPN
- Hi/lo gain ratio: 24.8



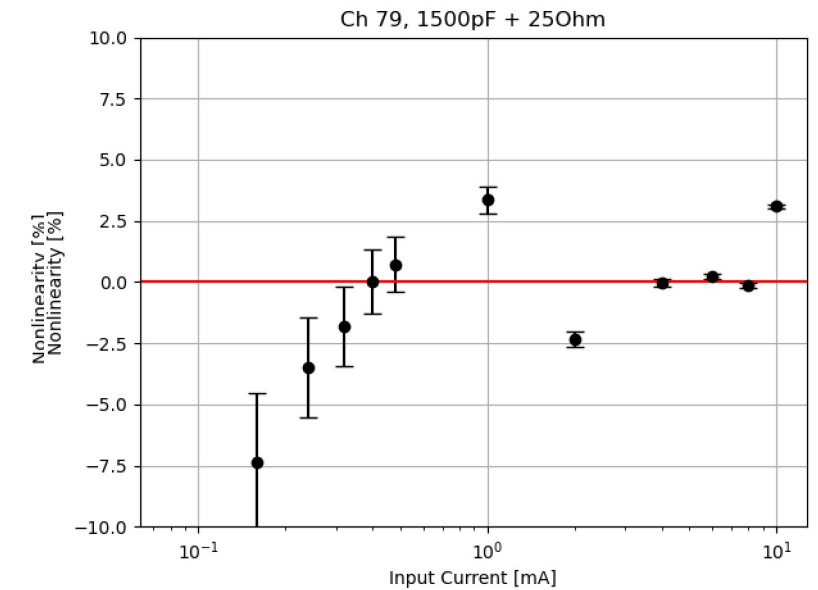
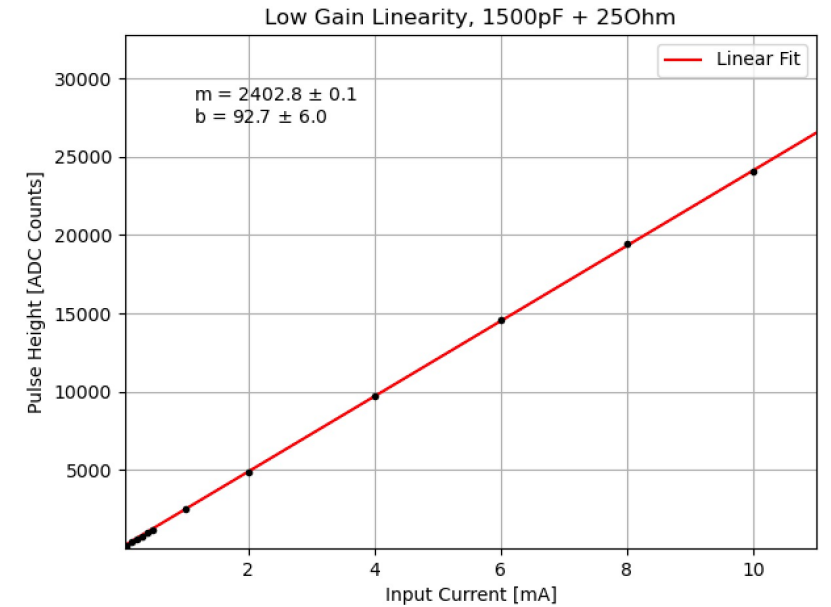
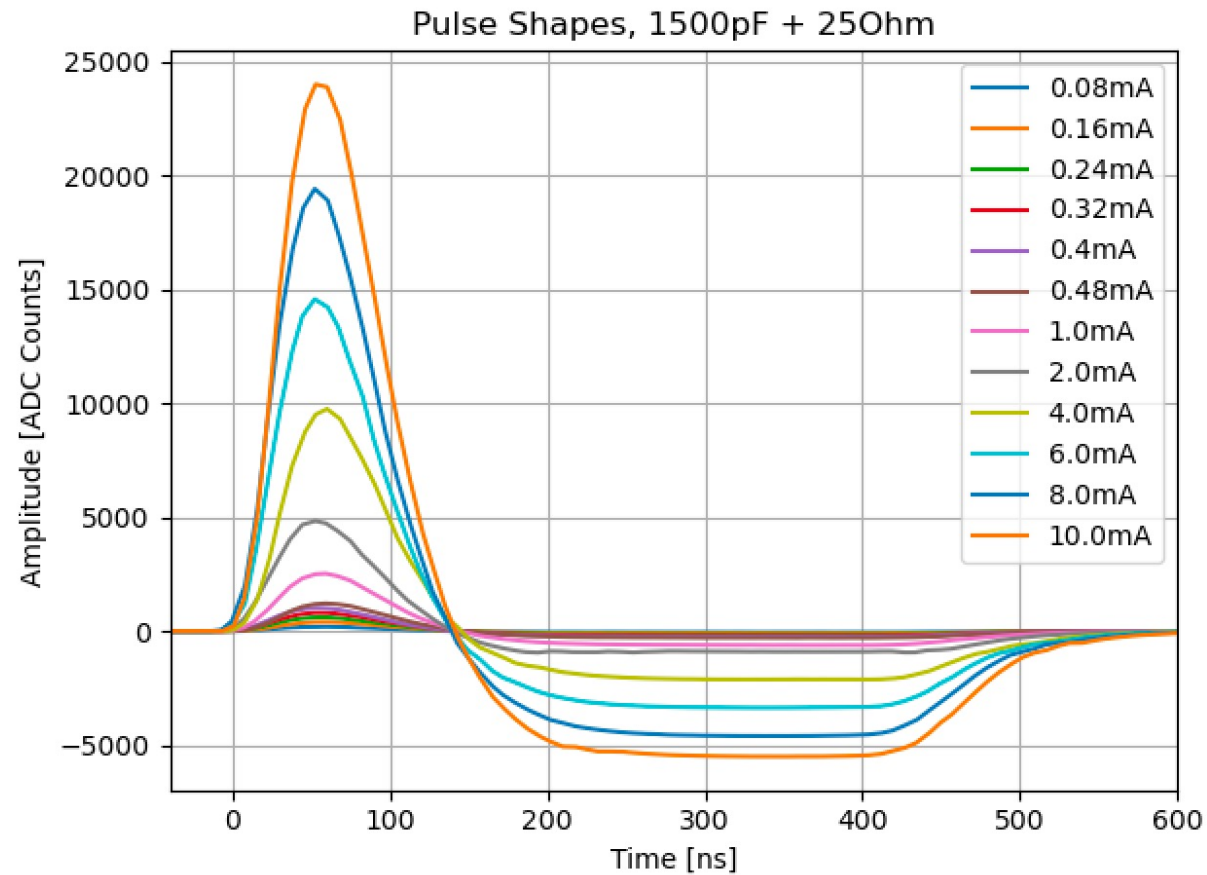
# Summary

- Testing on v1.1 of Slice Testboard is well underway
  - We have demonstrated fully functional data readout on all 32 channels
  - We have demonstrated use of the redundant control feature between IpGBT12 & IpGBT13
  - With the help of PA/S collaborators, we have identified and fixed the issue causing high coherent noise across the board
- Pulse injection analysis is proceeding
  - Gain measurements and noise made with IPN intact seem to correspond relatively closely to results reported from standalone LAUROC testing... although some discrepancies remain so far
  - With IPN bypassed (more precise results expected once ADC calibration implemented), get somewhat lower gain and higher noise
  - Pulse response is linear within **2.0%** across dynamic range with IPN bypassed
- An additional 3 boards can be produced and delivered to collaborators, once additional LAUROC chips are packaged, tested, and delivered to us

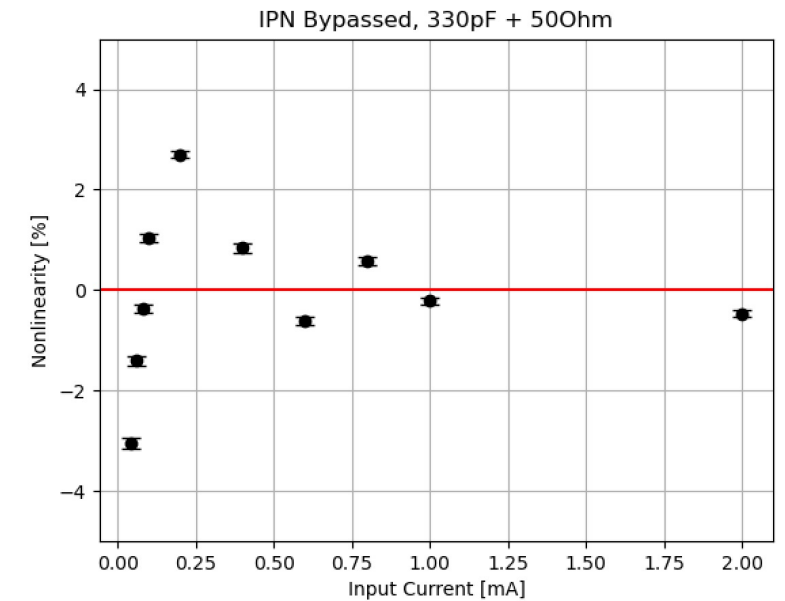
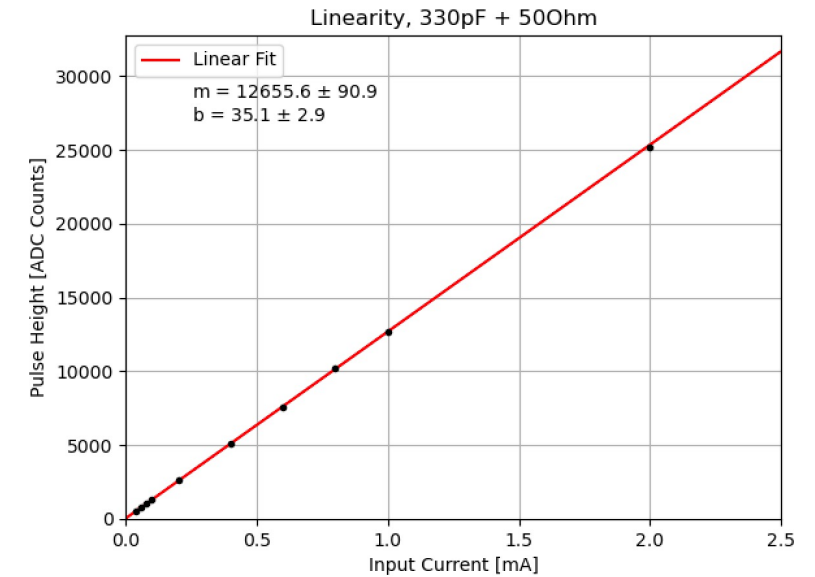
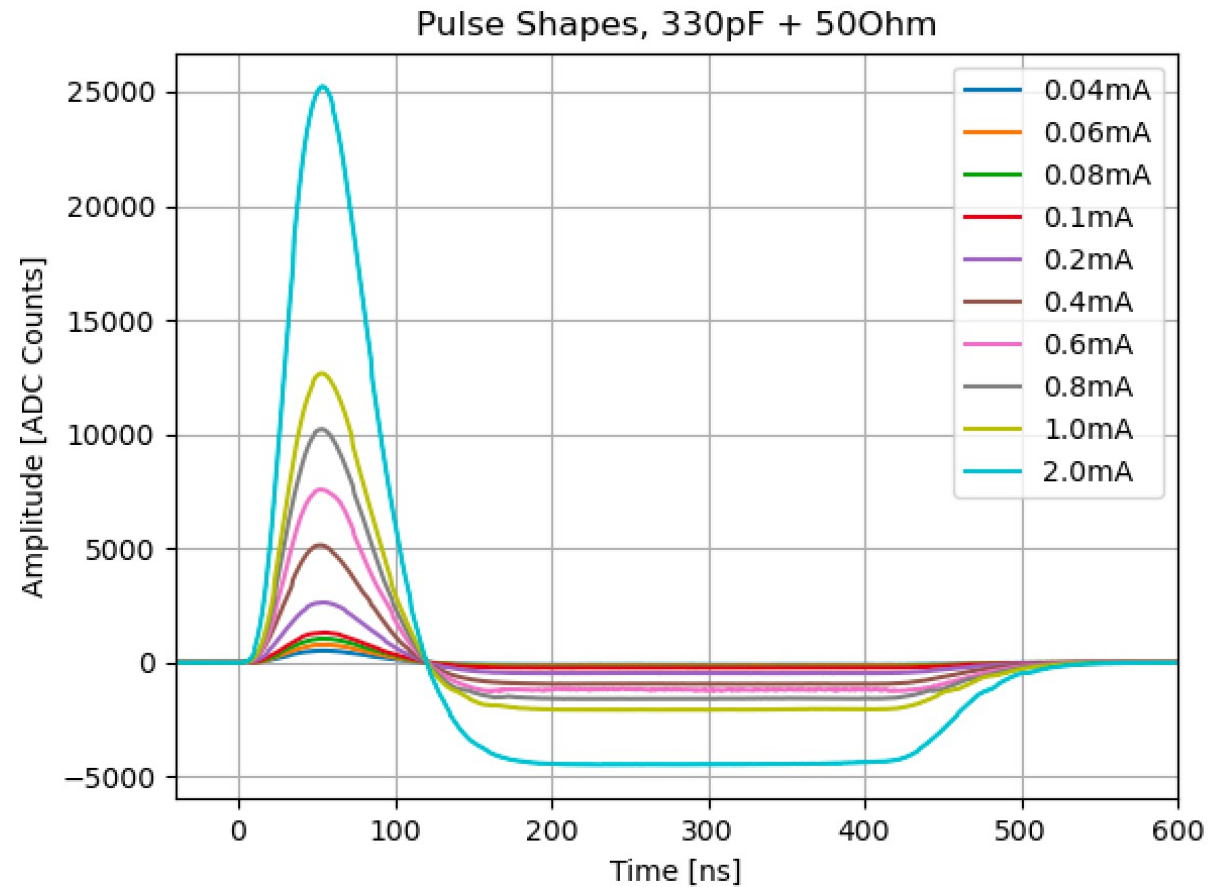
**BACKUP**



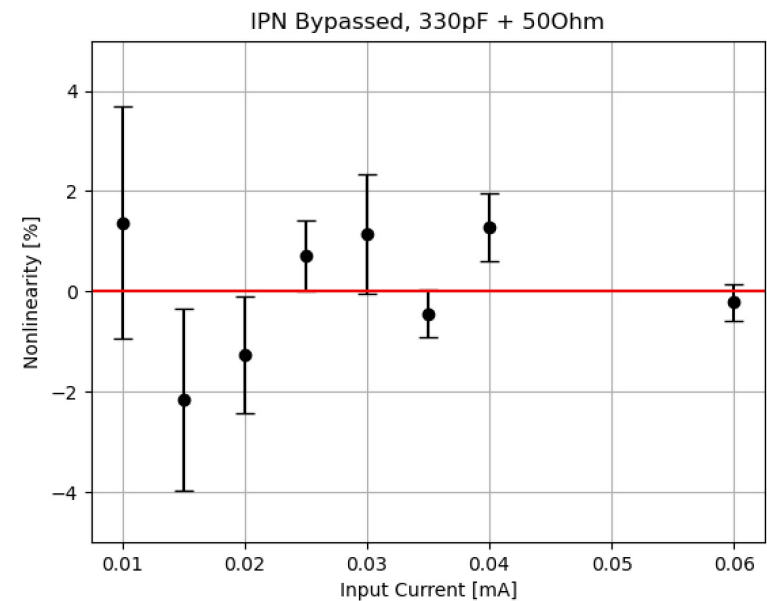
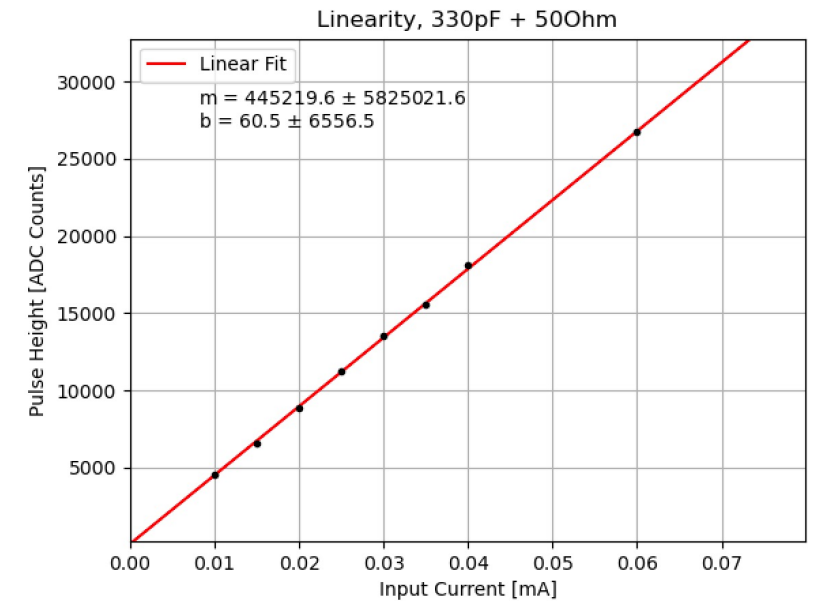
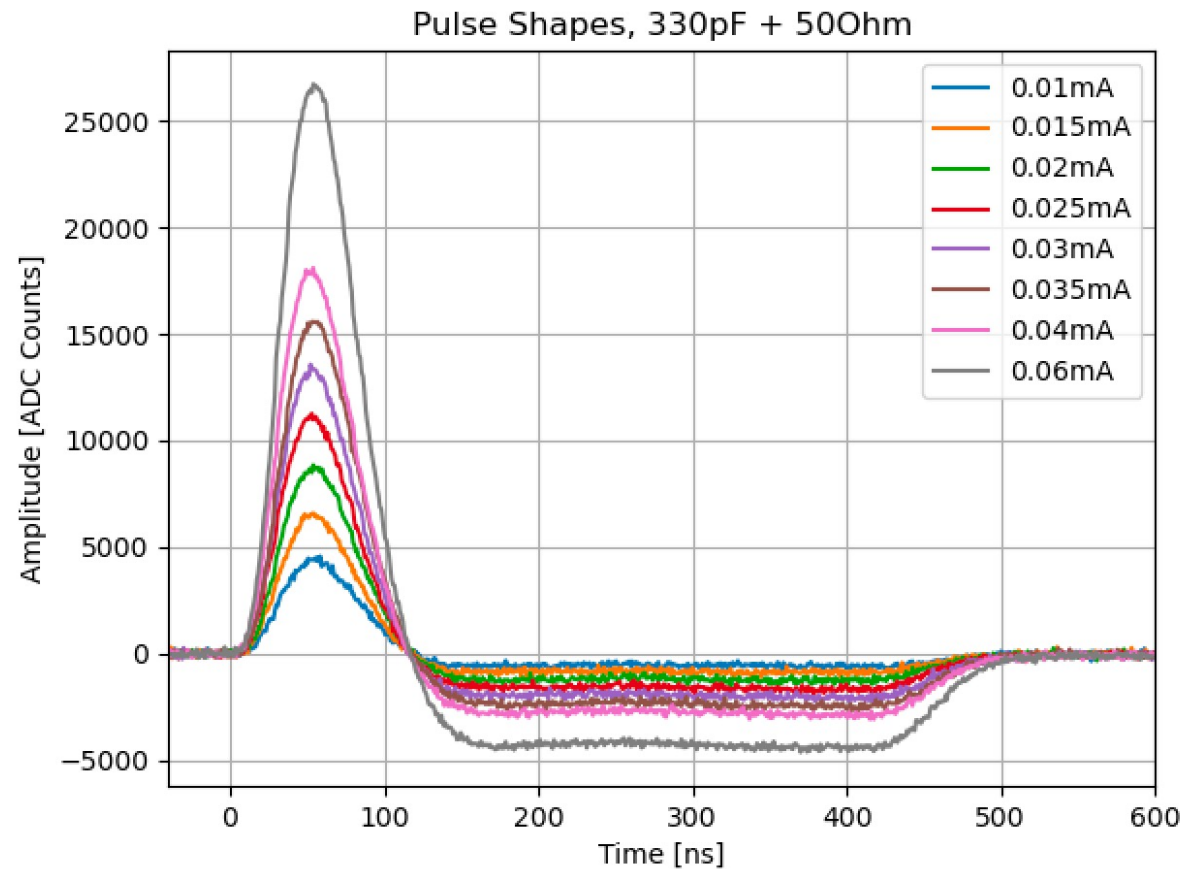
# Pulse Linearity, IPN intact 25Ohm (LG)



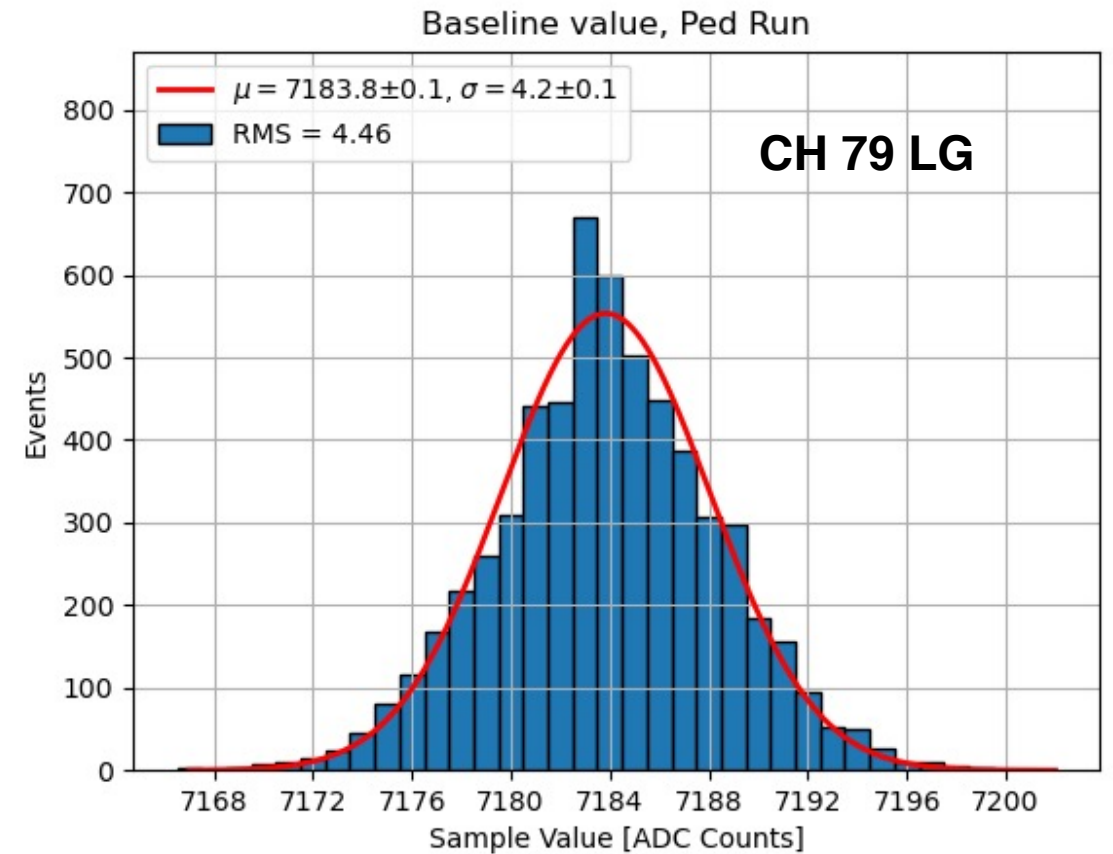
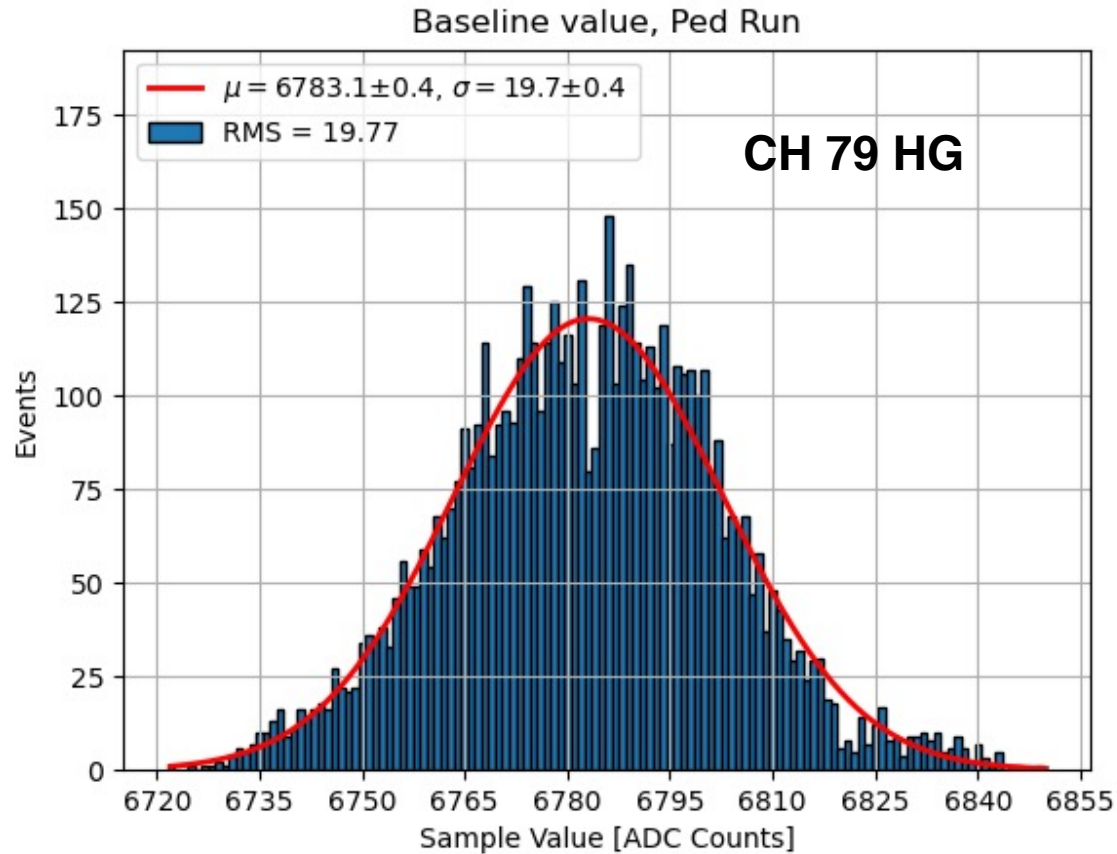
# Pulse Linearity, IPN intact 50Ohm (LG)



# Pulse Linearity, IPN intact 50Ohm (HG)



# Single-channel Noise Measurements, 25Ohm LAUROC Setting



# Single-channel Noise Measurements, 50Ohm LAUROC Setting

