FEB2 ‘Slice’ Testboard Update

Andrew Smith

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

ATLAS EXPERIMENT

NEVIS LABORATORIES
COLUMBIA UNIVERSITY

Overview/Timeline

Analog Testboard (2019)

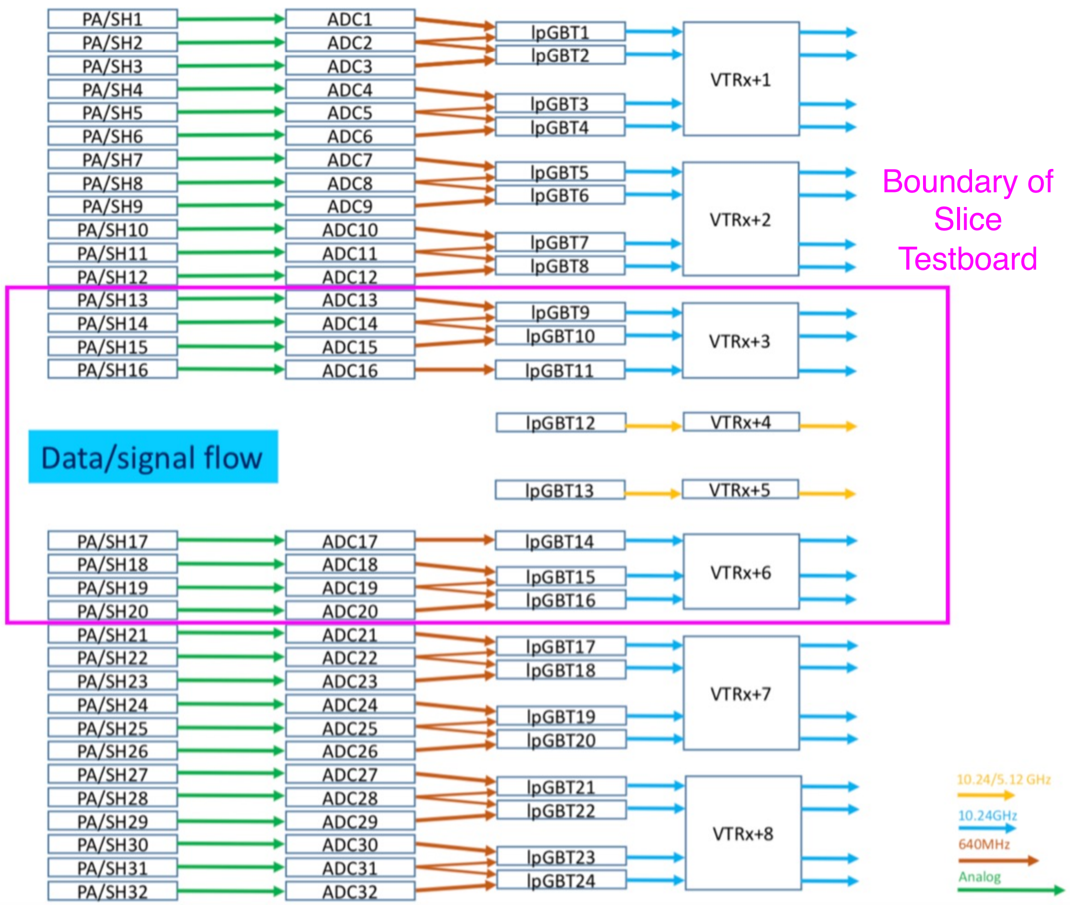
- 2 (LAUROC1 PA/S + COLUTAv2 ADC) +lpGBT
- Verified full readout chain: PA/s → ADC → optical data links

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



Boundary of Slice Testboard

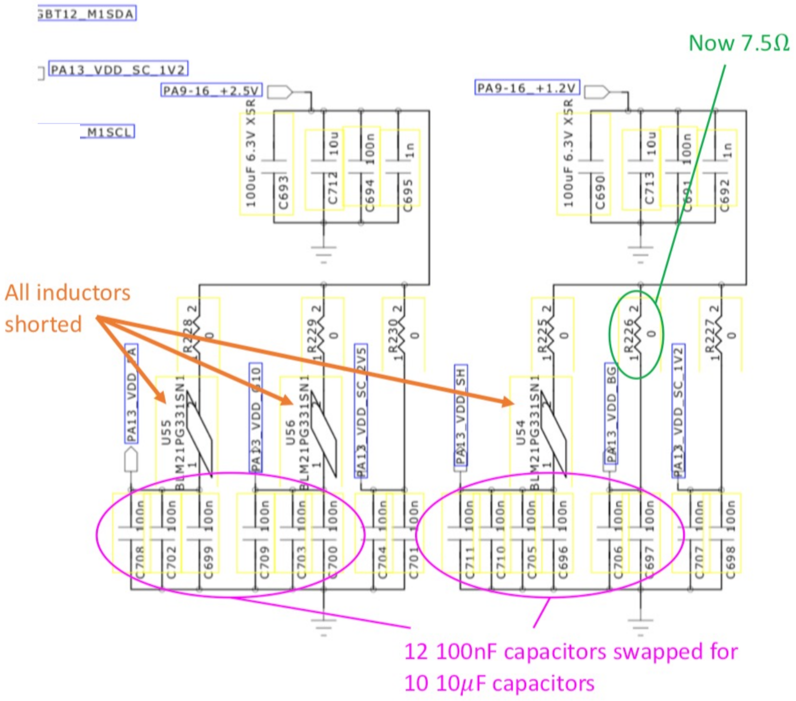
Slice Testboard Layout + Features

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 lpGBT chips
- Pulses injected through 1500pF load injector boards (not shown), with LAUROC impedance set at 25Ohm (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

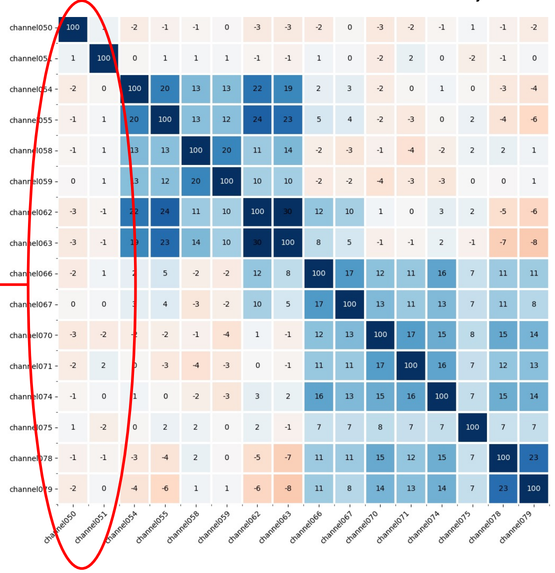
Mitigation of Noise Issues

- 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



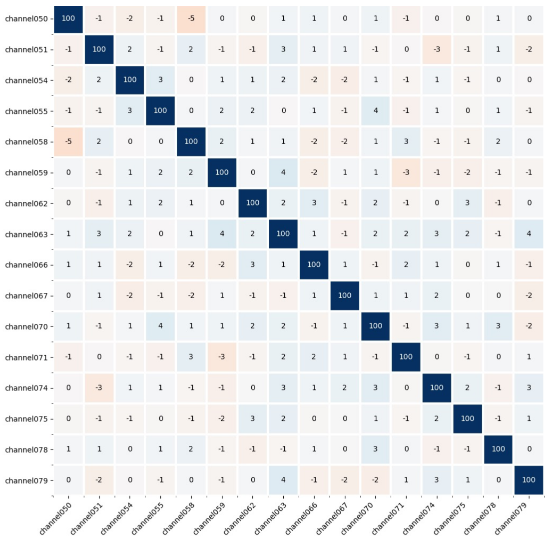
Modifications applied to COLUTA13 input network

Pairwise Noise Correlation, HG



All COLUTAS Modified

Pairwise Noise Correlation, HG



LAUROC Configuration Parameters

Previous parameters

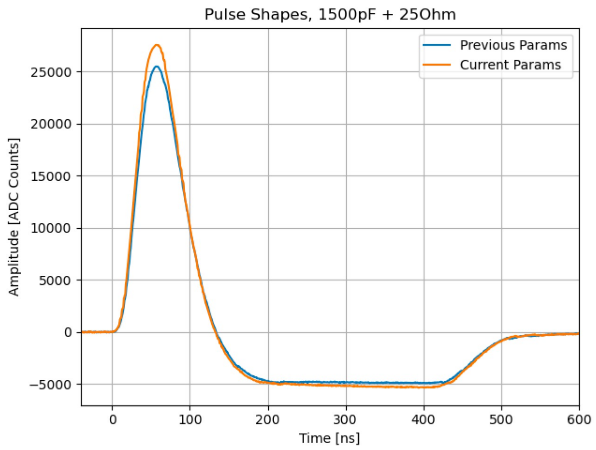
25Ω 10 mA config DC connection between out_preamp and G20_amplifier input SC Parameters to get a peaking time of 49 ns SC parameters to set the gain SUM equal to 1	
sw_DC_g20	1
sw_ibo_g20	1
dac_g20<5:0> (dec code)	32
sw_ibi_25	1
sw_ibo	1
sw_R025_10mA	1
sw_R025_5mA	0
cr_hg_s1<2 :0> (dec code)	0
rc_hg_s1<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

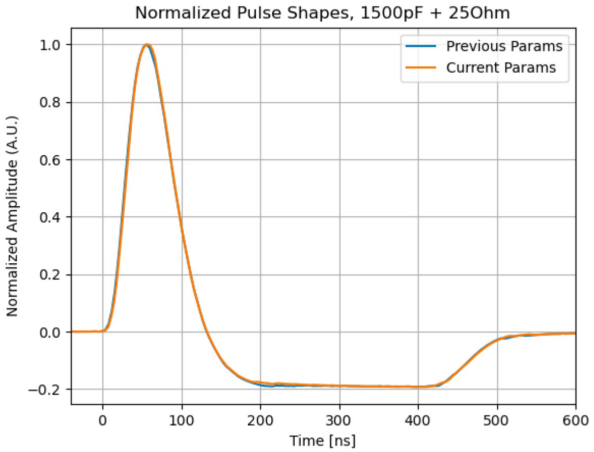
Current parameters

	25Ω 10 mA config DC connection between out_preamp and G20_amplifier input SC Parameters to get a peaking time of 49 ns 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

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

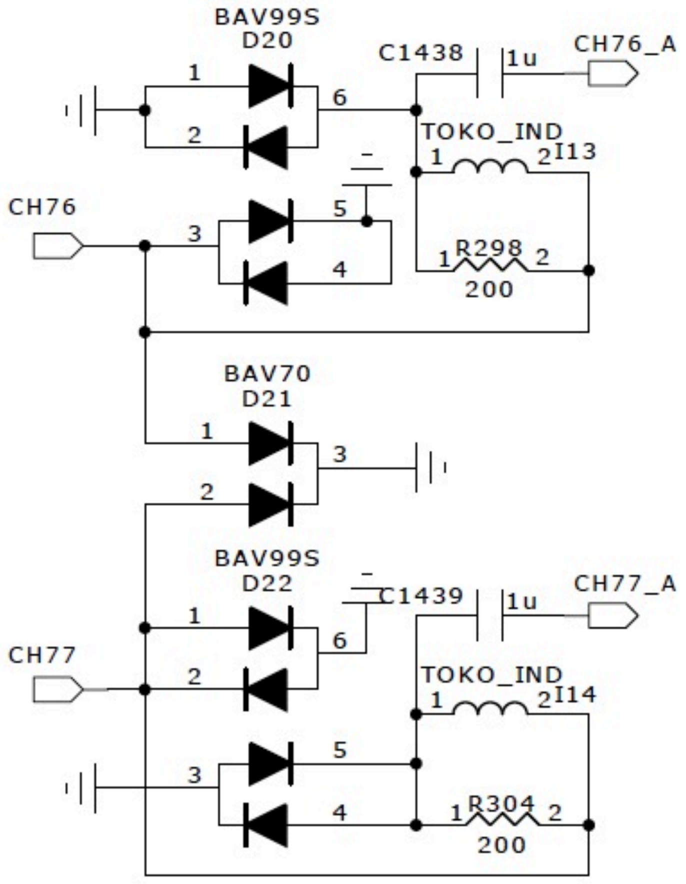
- LAUROC configured using new, recently provided parameters summarized on p. 27 of LAUROC datasheet (listed in "Current parameters" table)
  - **Exception:** tune output DAC levels to obtain baseline around 7000 ADC counts (out of 32k counts total)
  - All results in these slides use this config
- Previously: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



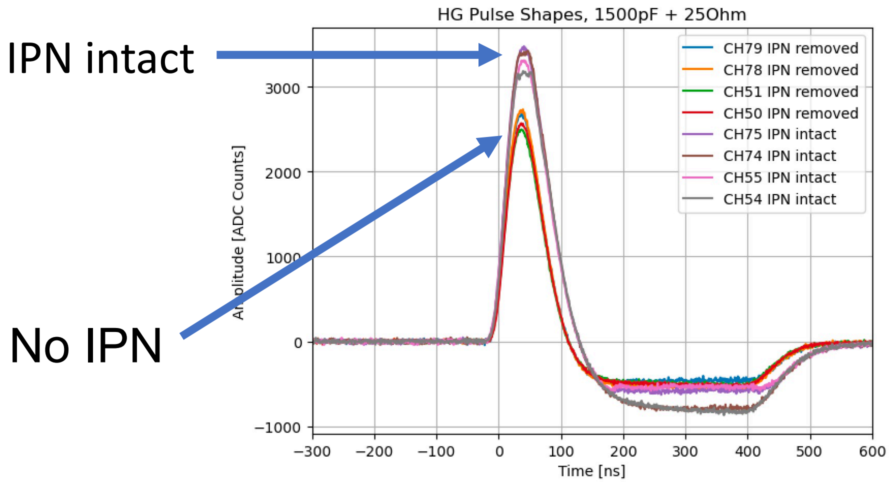


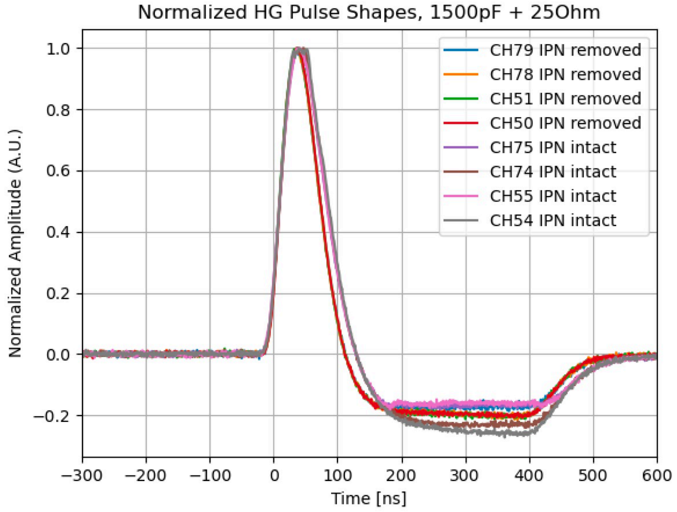
Slice Testboard Input Protection Network (IPN)

- 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 muF AC-coupling cap at the PA/S input
- **We had assumed bypassing the IPN would most closely mimic the standalone LAUROC testing environment (and therefore most results in this talk show this situation), but we just learned (today!) that AC-coupling is in fact used on the LAUROC standalone testboard, so we will need to repeat the measurements.**



Impact of IPN on Pulse Shapes, 25Ohm (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

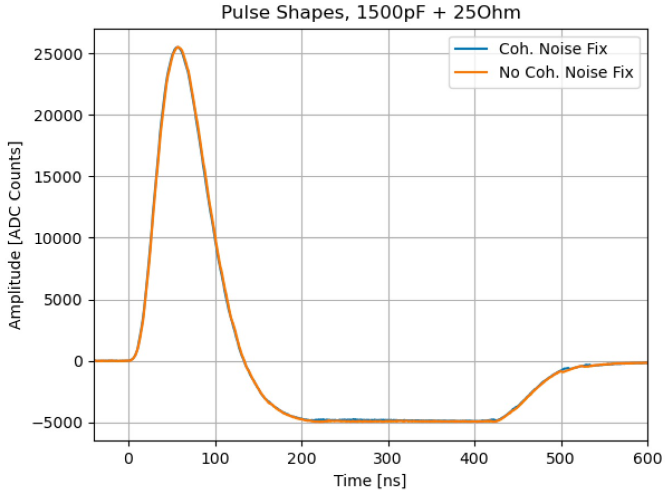
- Focus in this talk will be on **results with IPN bypassed**, as we believed it is the most direct comparison with LAUROC standalone test results

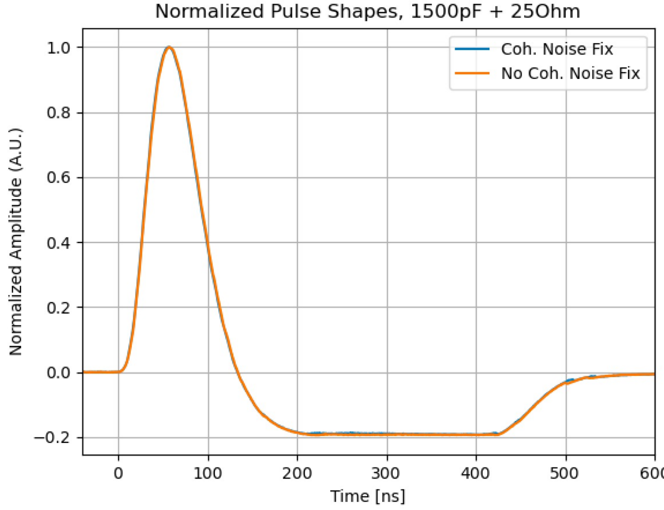
HG Channel	IPN Bypass	Rise Time [ns]	Gain [ADC/mA]	Gain [mVdiff/mA]
79	Y	44.1±.6	53726±12	3279.2±.7
78	Y	46.6±.6	54681±5	3337.5±.3
51	Y	46.6±.6	49963±12	3049.5±.7
50	Y	44.9±.6	51413±14	3138±.9
75	N	50.7±.6	69549±15	4244.9±.9
74	N	55.7±.6	68462±11	4178.6±.7
55	N	50.7±.6	66253±6	4043.8±.4
54	N	48.2±.6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

Note: Gain conversion assumes 2Vdiff / 32768 codes

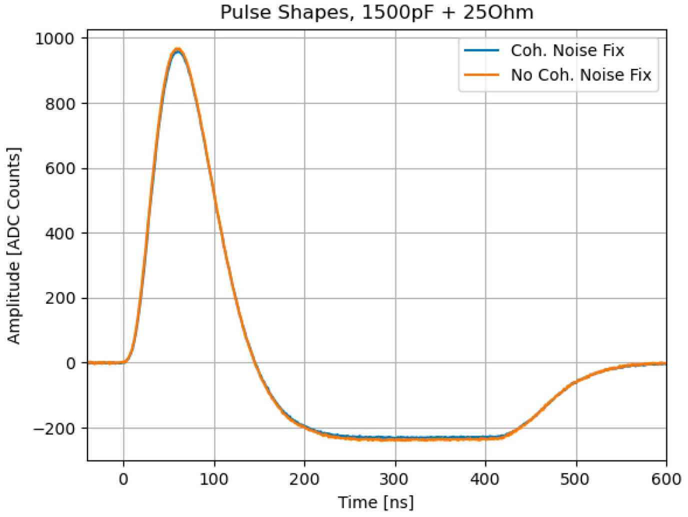
Impact of Coherent Noise Fix on Pulse shapes, 25 Ohm (IPN bypassed)

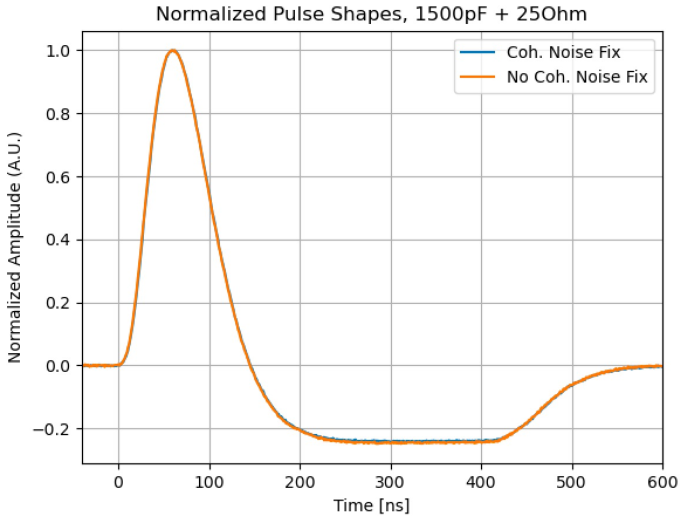
HG





LG

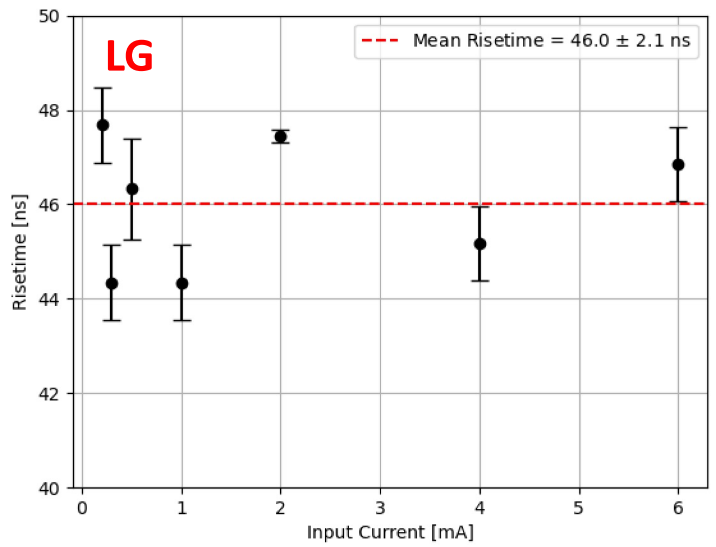


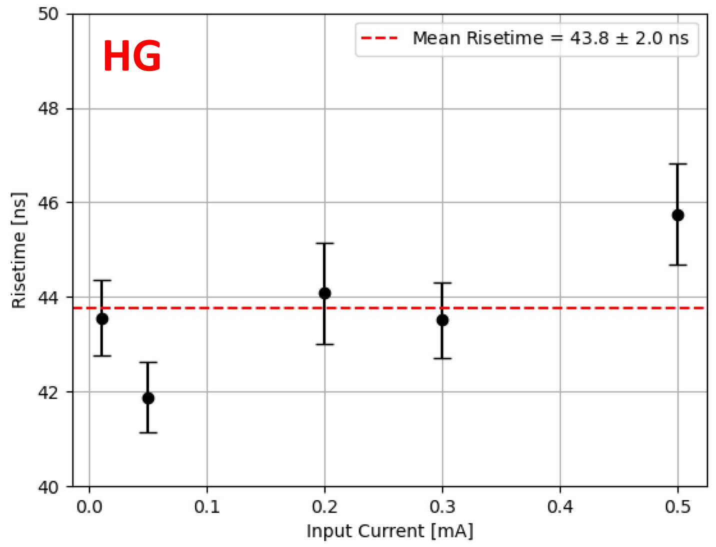


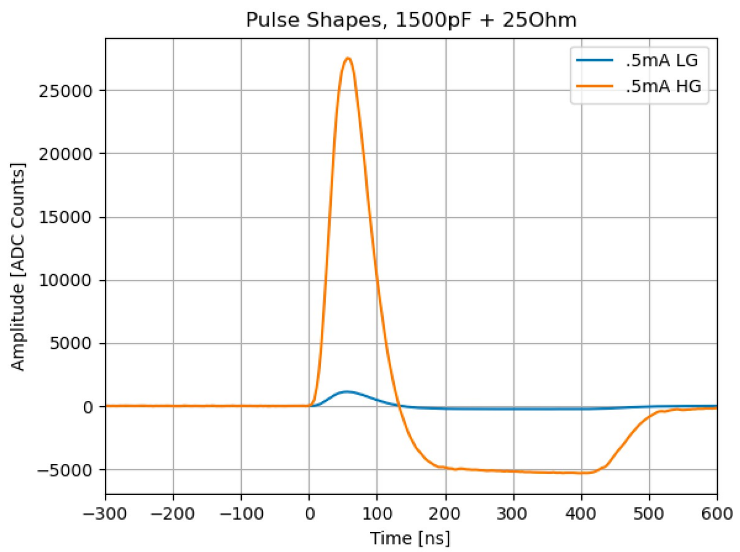
- Comparison shown at .5mA input signal amplitude
- Negligible effect of noise fix on pulse shape, pulse gain
- Reproducible result across multiple COLUTA chips

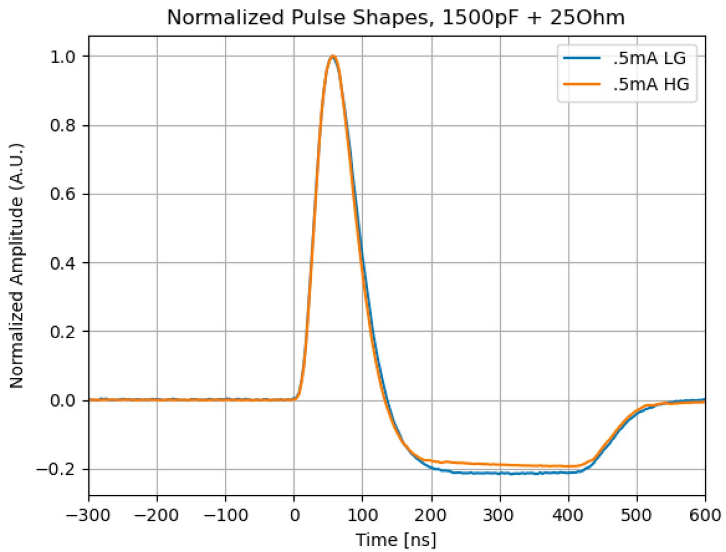
Pulse Risetime, 25Ohm IPN bypassed

- 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







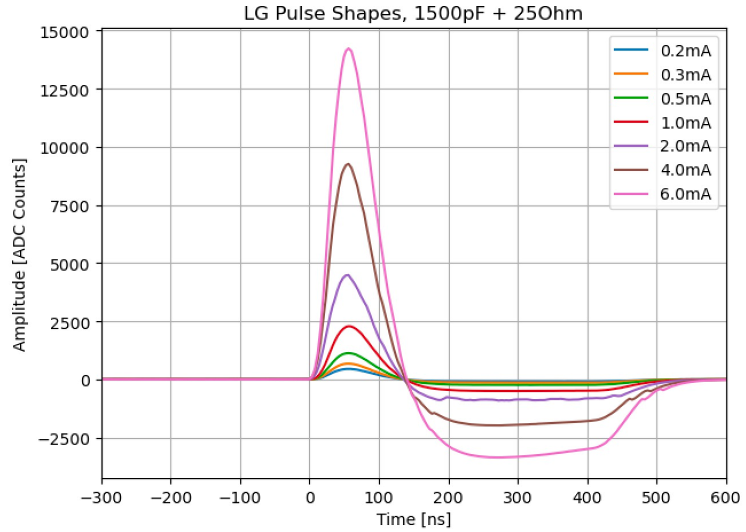


HG risetime: **43.8 ± 2.0 ns**
LG risetime: **46.0 ± 2.1 ns**

Pulse Gains, 25Ohm IPN bypassed

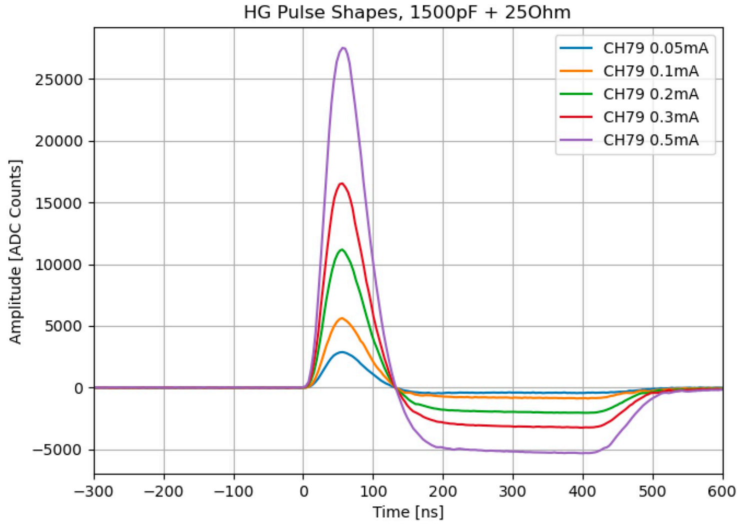
LG mean ENI : 1837 ± 9 nA

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 Gains, IPN Intact

LG mean ENI : 1653 ± 21 nA

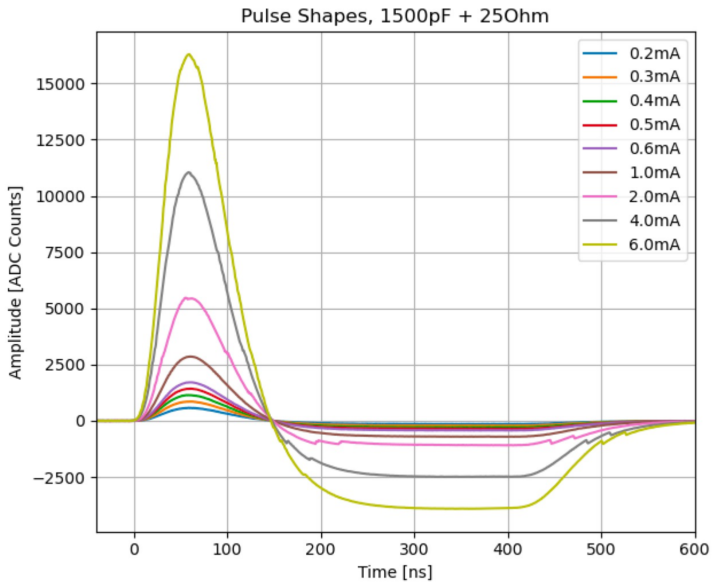
Input Amp [mA]	Gain [ADC/mA]	dGain [ADC/mA]	Gain [mVdiff/mA]	dGain [mVdiff/mA]	ENI [nA]	dENI [nA]
0.2	2898	8	176.9	0.5	1587.3	4.38
0.3	2852	5	174.1	0.3	1612.9	2.83
0.4	2860	5	174.6	0.3	1608.4	2.81
0.5	2866	2	174.9	0.1	1605	1.12
0.6	2850	5	174	0.3	1614	2.83
1	2857	4	174.4	0.2	1610.1	2.25
2	2734	33	166.9	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

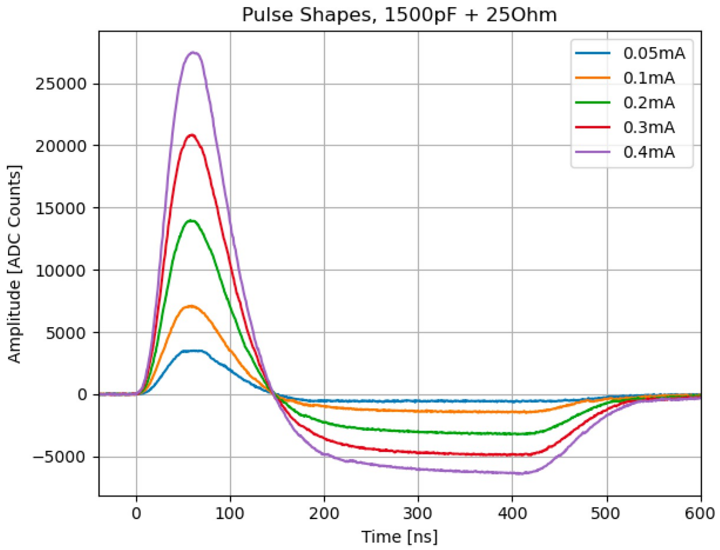
HG mean ENI : 279 ± 1 nA

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

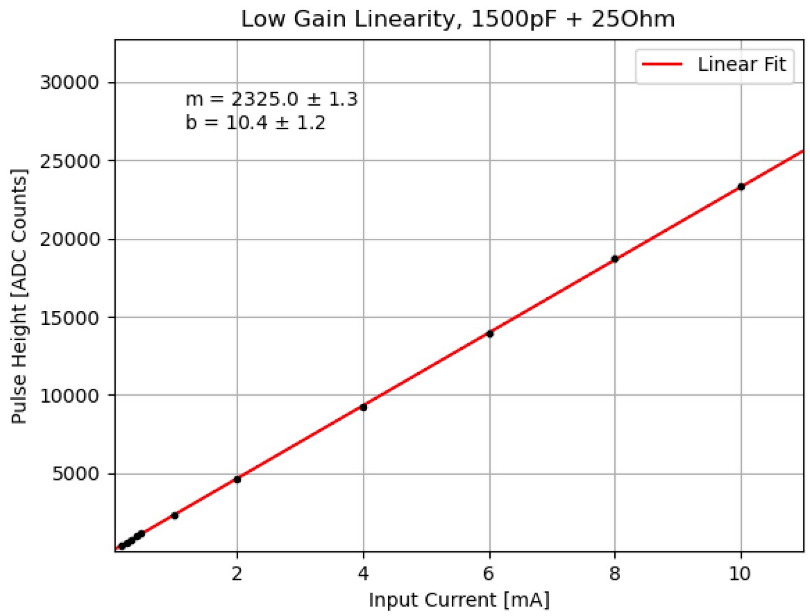
- Gain + ENI values in better agreement with those reported by PA/S collaborators than results without IPN
- Hi/lo gain ratio: 24.8

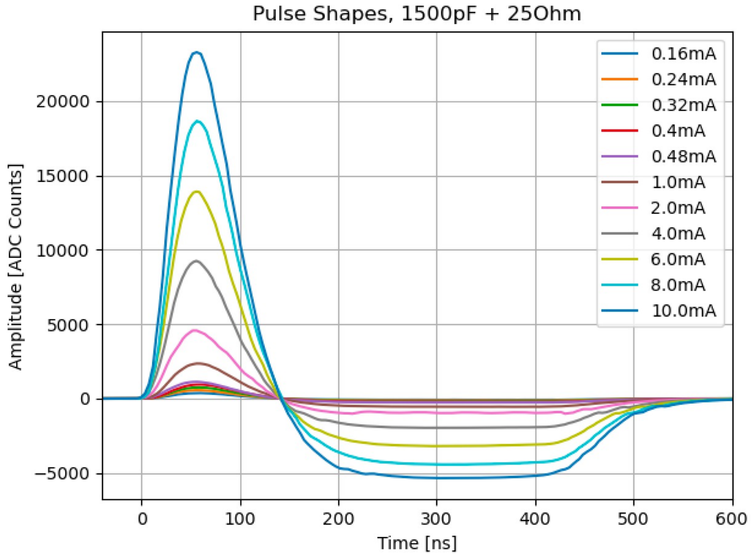


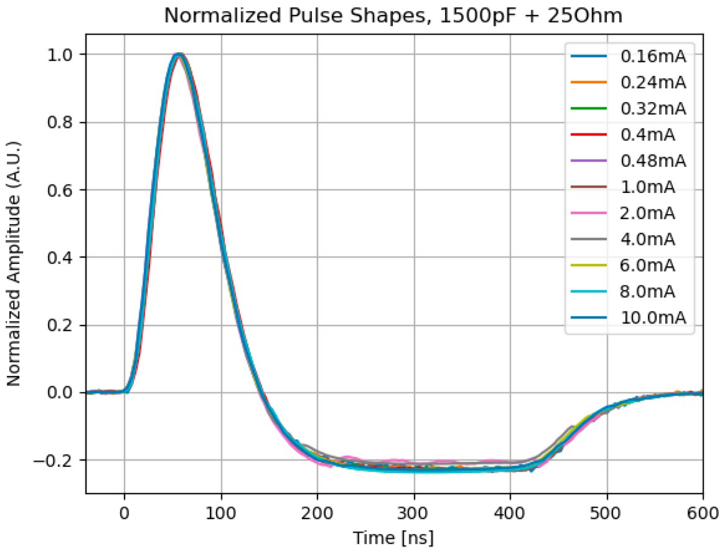


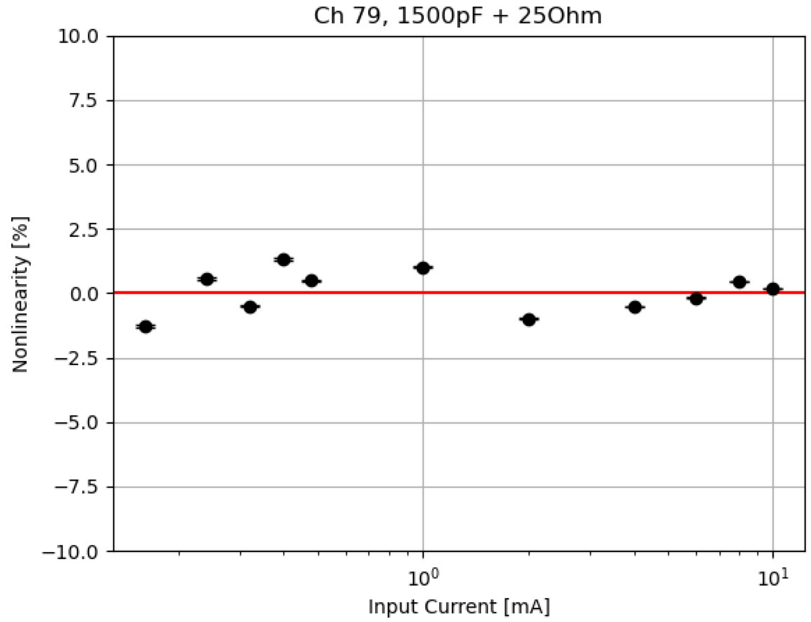
Pulse Linearity, 25Ohm IPN bypassed (LG)

- 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

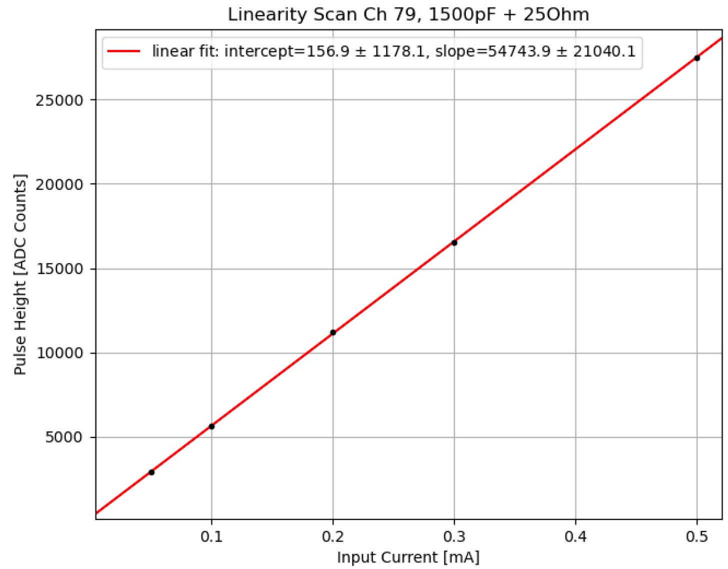




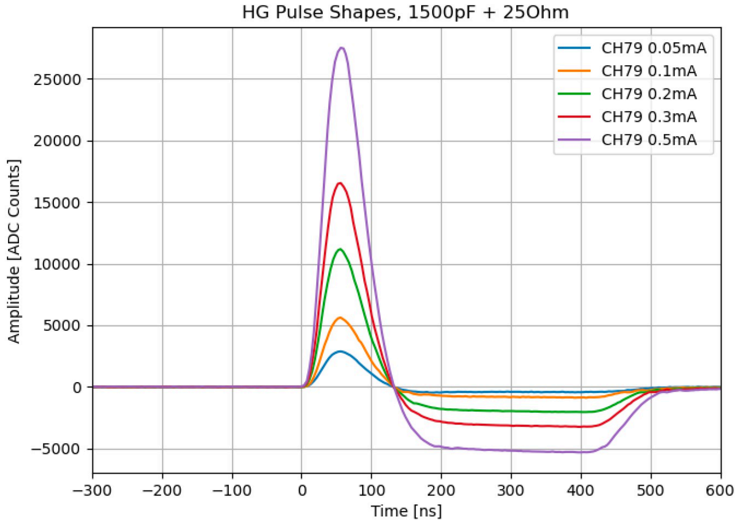


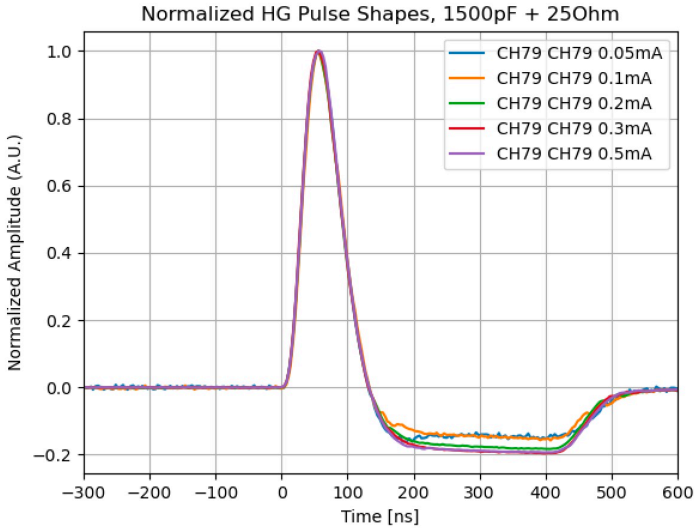


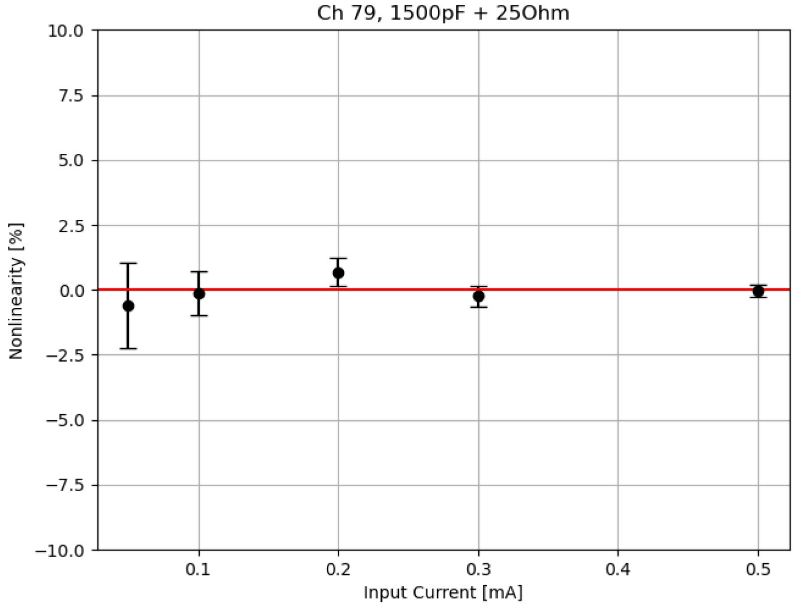
Pulse Linearity, 25Ohm IPN bypassed (HG)



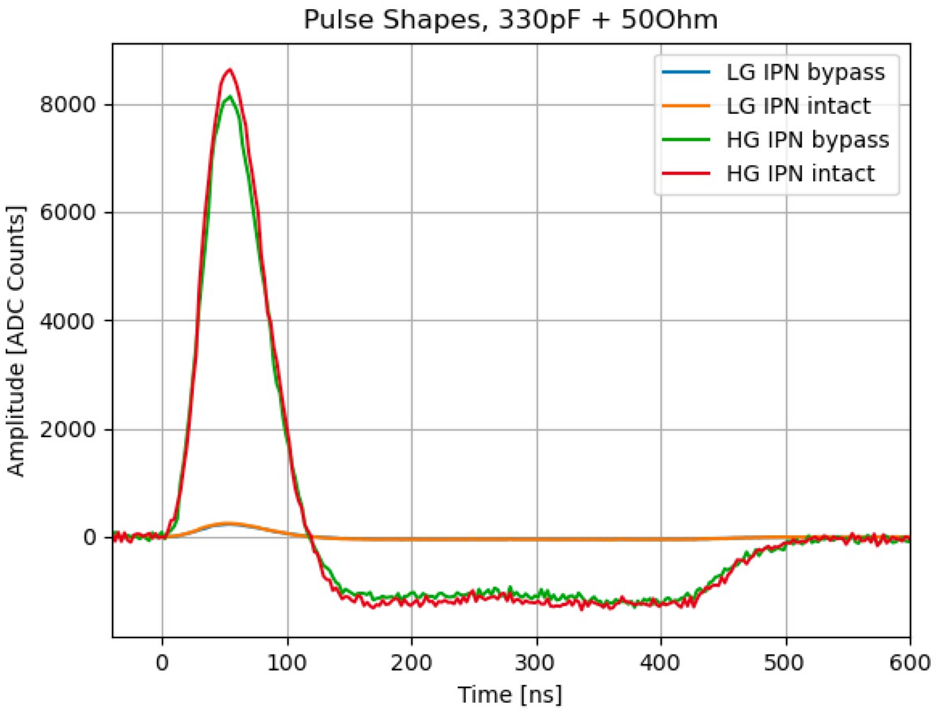
- HG linearity within 1.0% up to 0.5mA input signal
- Saturation observed above 0.5mA input signal with IPN bypassed, and above 0.4mA input signal with IPN intact

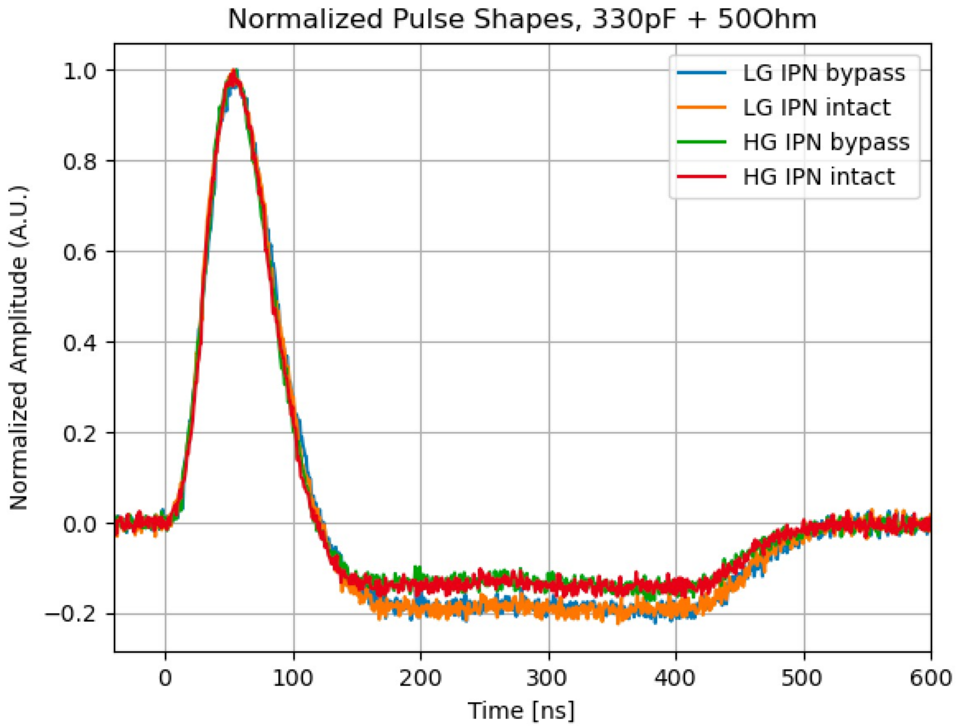






50Ohm LAUROC setting Gain + Risetime Measurements

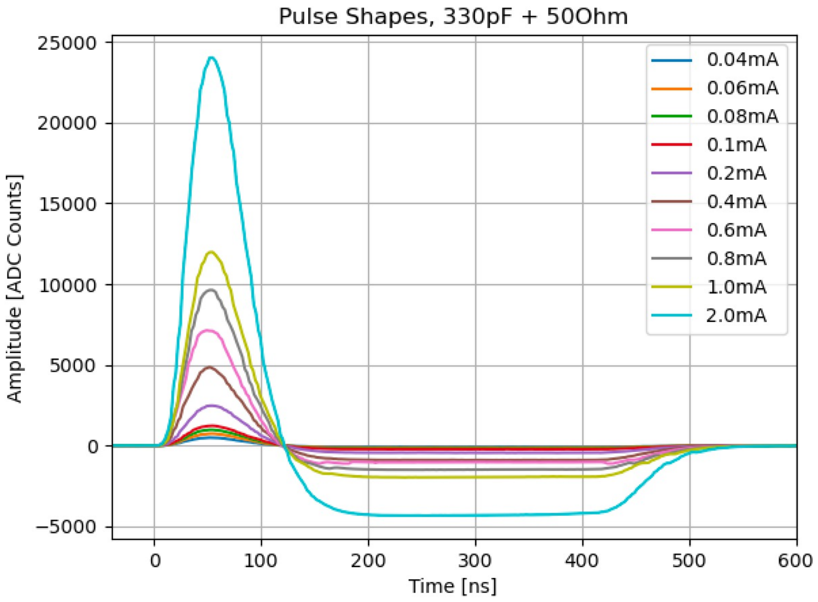


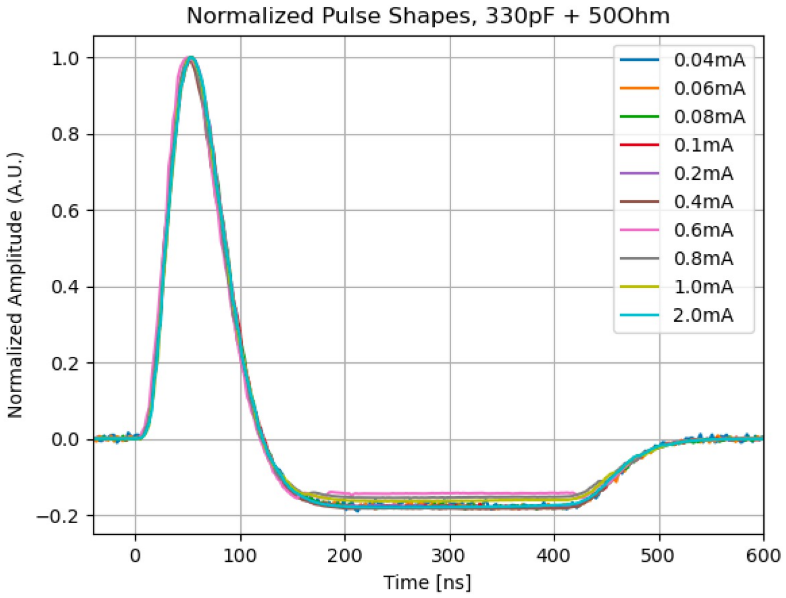


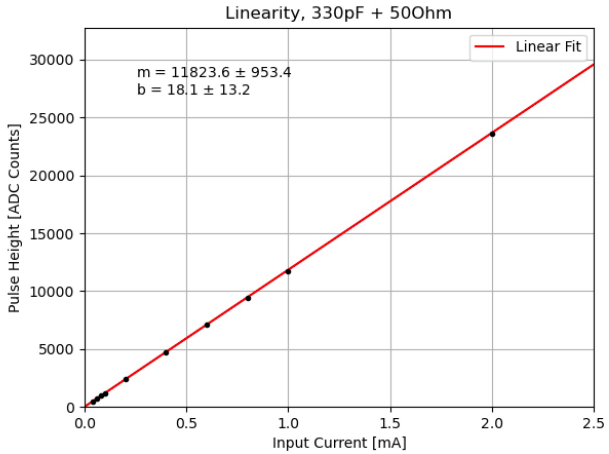
Ch	IPN Bypass	Input Amp [mA]	Gain [ADC/mA]	dGain [ADC/mA]	Gain [mVdiff/mA]	dGain [mVdiff/mA]	ENI [nA]	dENI [nA]	Risetime [ns]	dRisetime [ns]
79 LG	Y	0.02	11670	80	712.3	4.9	359.9	2.47	37	1
79 HG	Y	0.02	406400	2400	24804.7	146.5	88.6	0.52	36	1
75 LG	N	0.02	12400	100	756.8	6.1	338.7	23.41	33	1
75 HG	N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

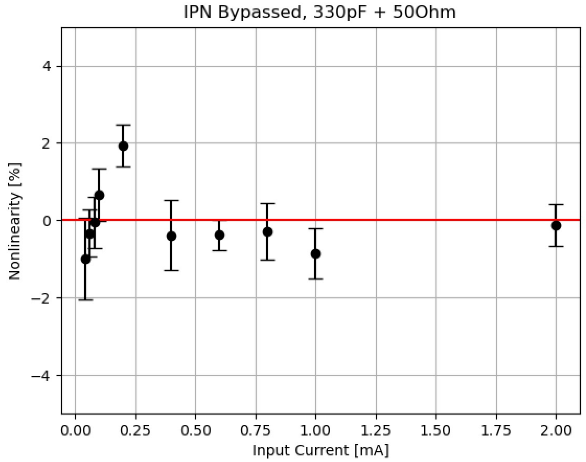
- Large increase in gain with IPN intact, consistent with 25Ohm result

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





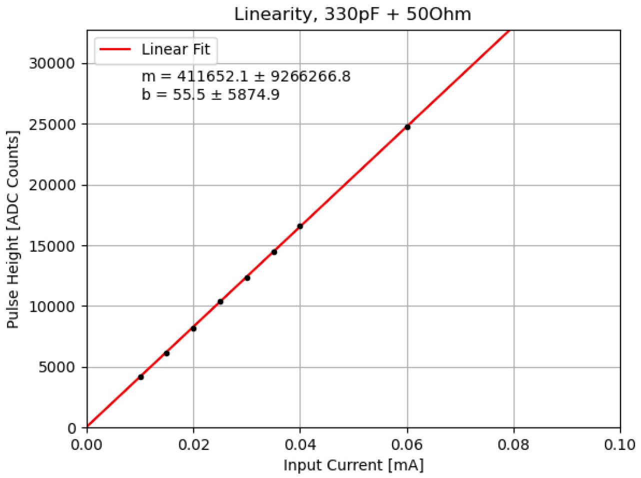


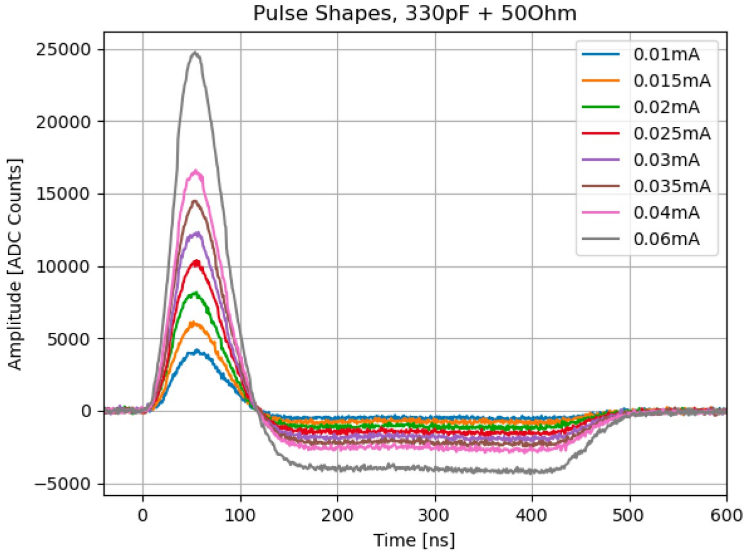


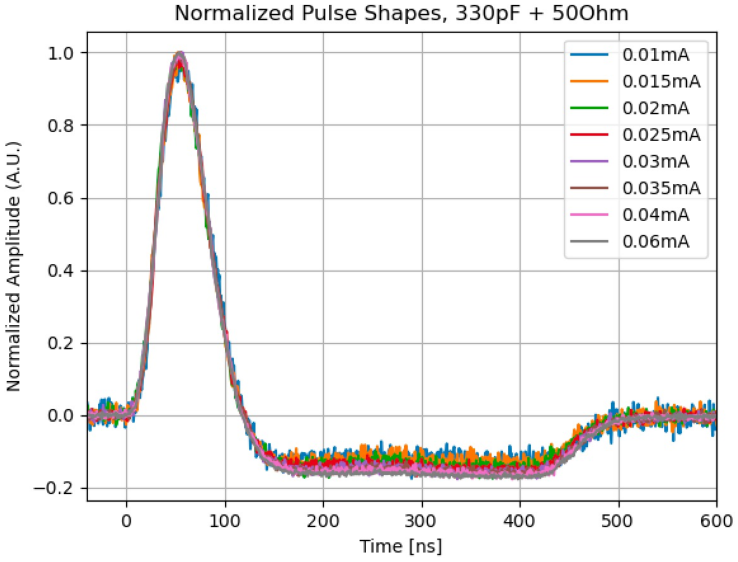
- Consistent pulse shape observed in LG for up to 2.0mA input signal, above which signal saturates
- Pulse height linear to within 2% up to saturating input signal, nonlinearity likely due to uncalibrated MDAC + SAR constants

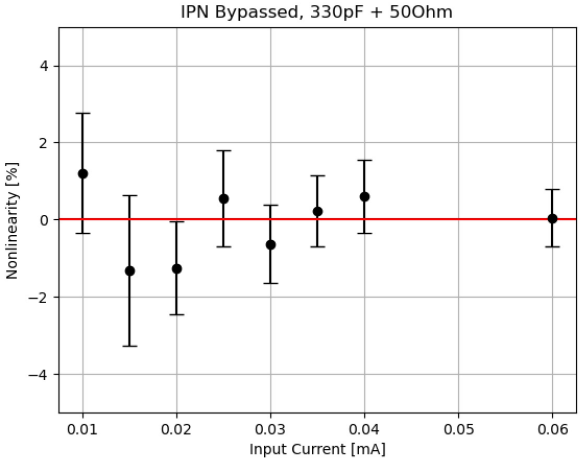
Pulse Scan, 50Ohm LAUROC Setting IPN Bypassed (HG)

- 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









Summary

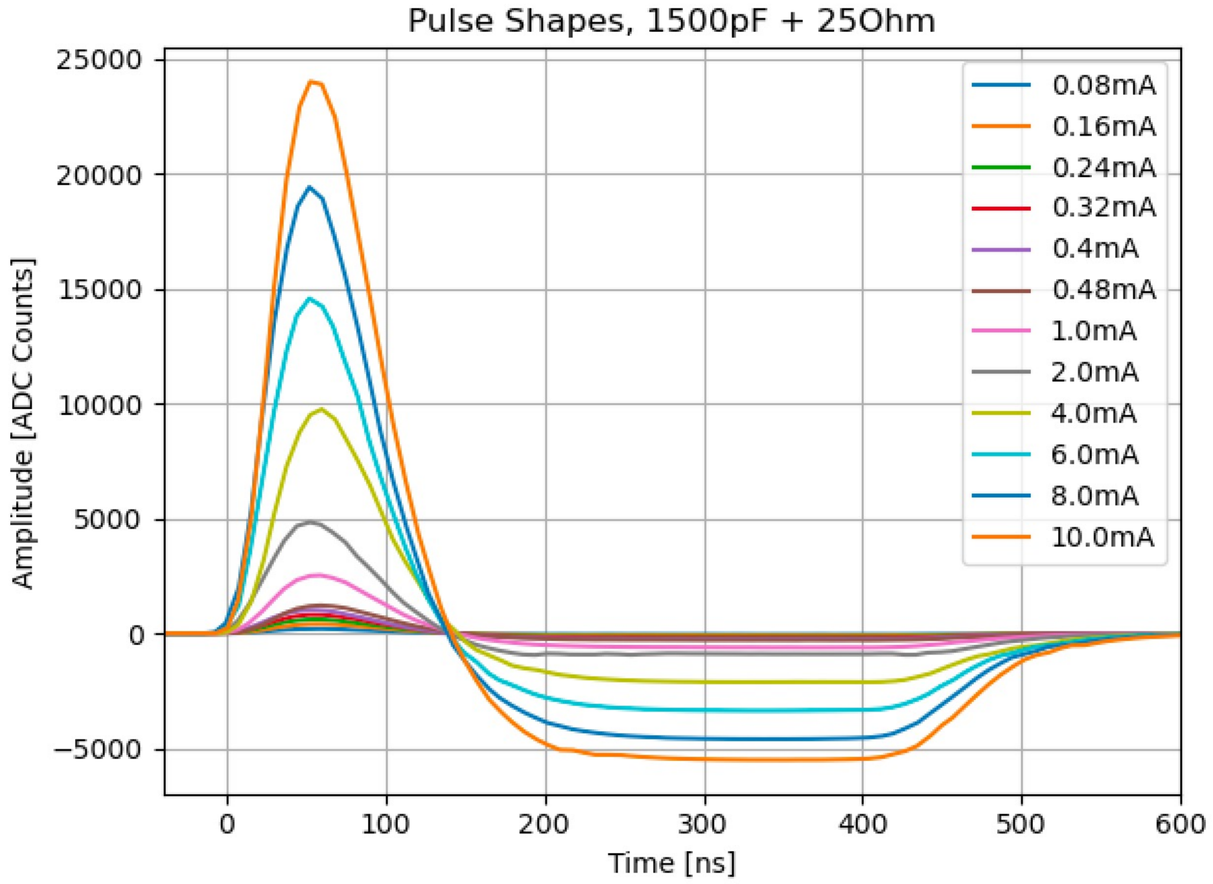
- Testing on v1.1 of Slice Testboard is well underway
  - We have demonstrated fully functional data readout on all 32 channels
  - We have demonstrated use of the redundant control feature between lpGBT12 & lpGBT13
  - With the help of PA/S collaborators, we have identified and fixed the issue causing high coherent noise across the board

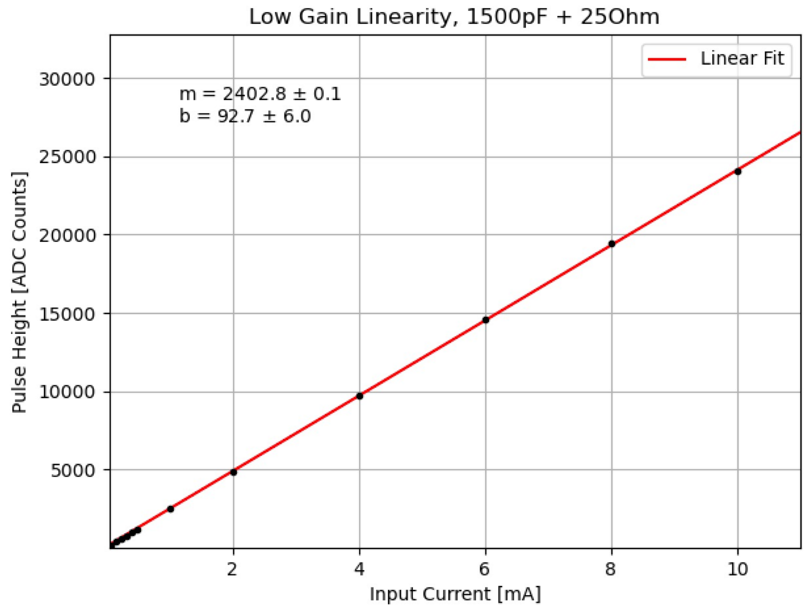
- Pulse injection analysis is proceeding
  - Gain measurements and noise made with IPN intact seem to correspond relatively closely to results reported from standalone LAUROC testing… although some discrepancies remain so far
  - With IPN bypassed (more precise results expected once ADC calibration implemented), get somewhat lower gain and higher noise
  - **Measurements will be repeated now that we know the AC-coupling is required**
  - Pulse response is linear within **2.0%** across dynamic range with IPN bypassed

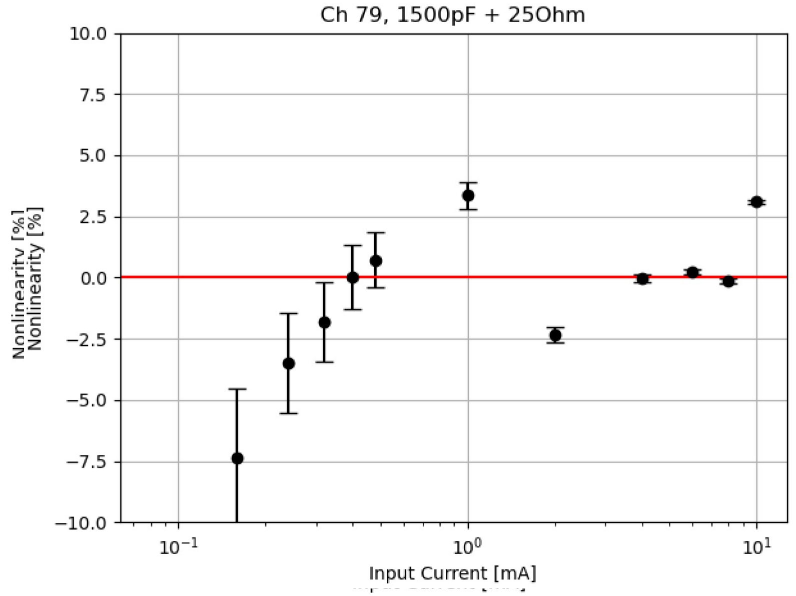
- An additional 3 boards can be produced and delivered to collaborators, once additional LAUROC chips are packaged, tested, and delivered to us

BACKUP

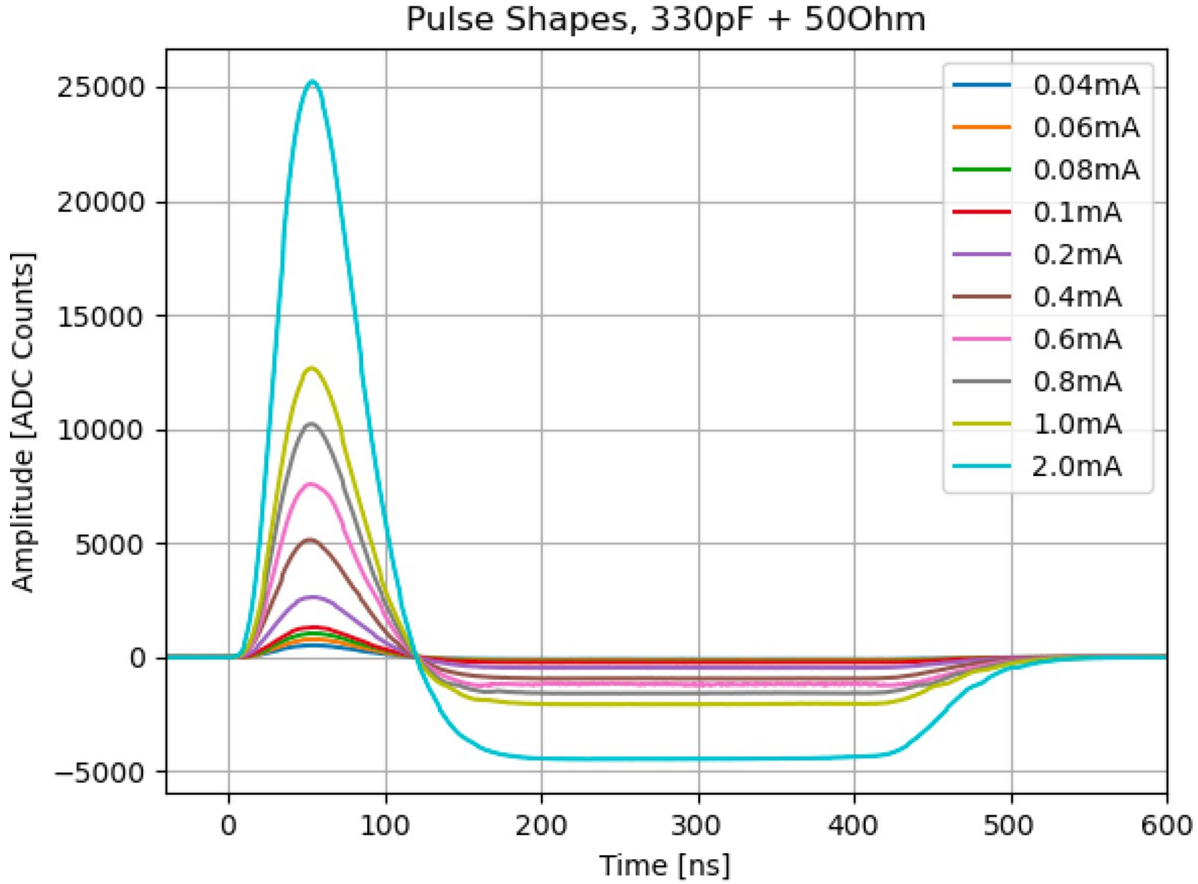
Pulse Linearity, IPN intact 25Ohm (LG)

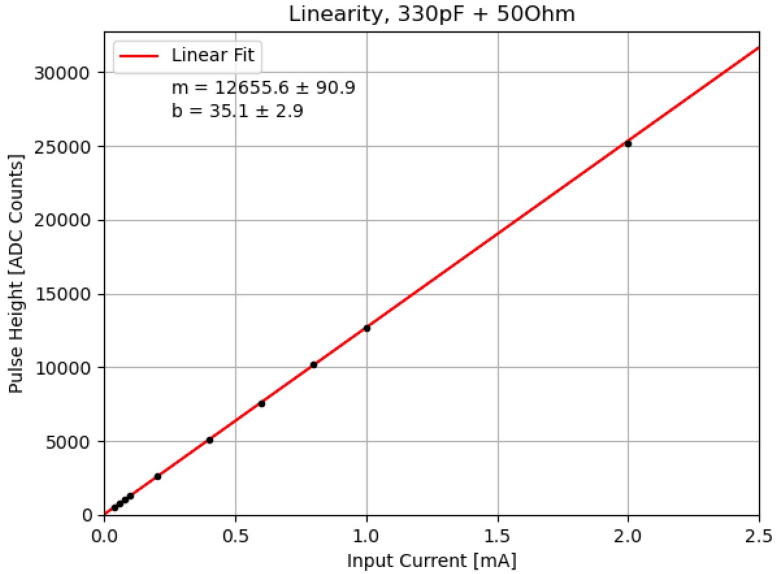


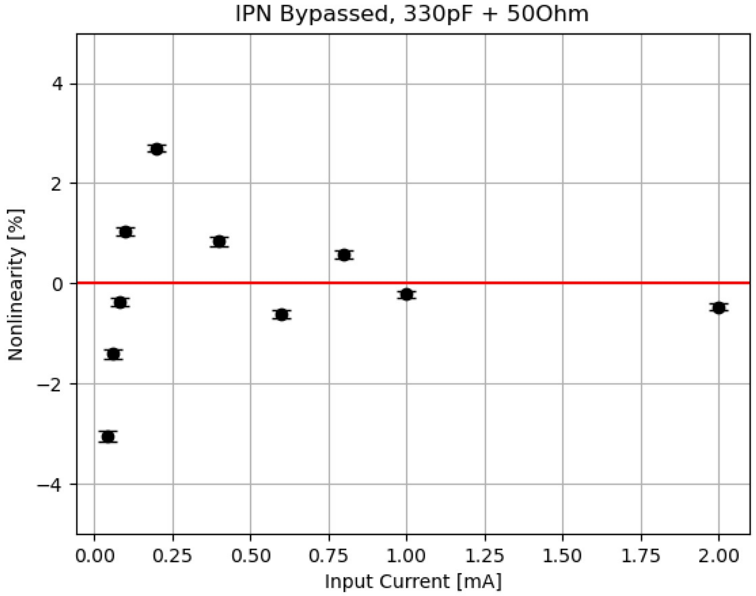




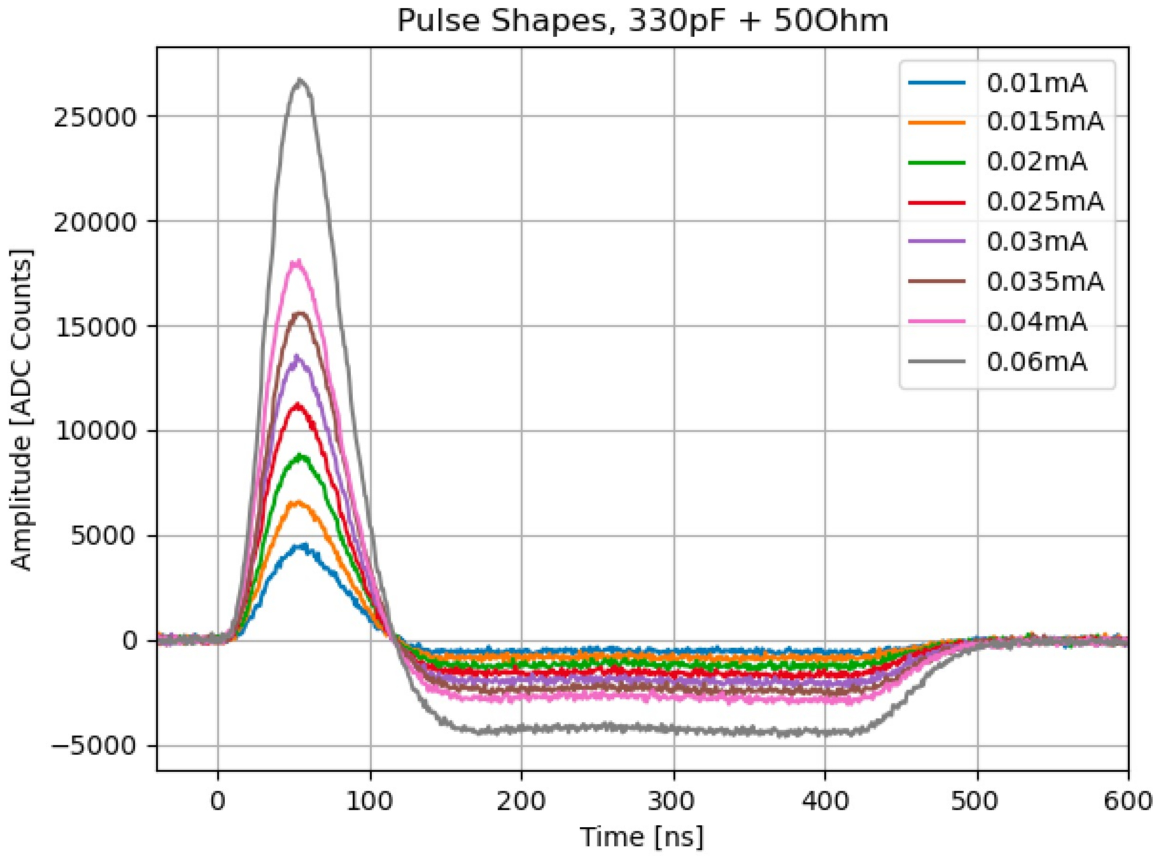
Pulse Linearity, IPN intact 50Ohm (LG)

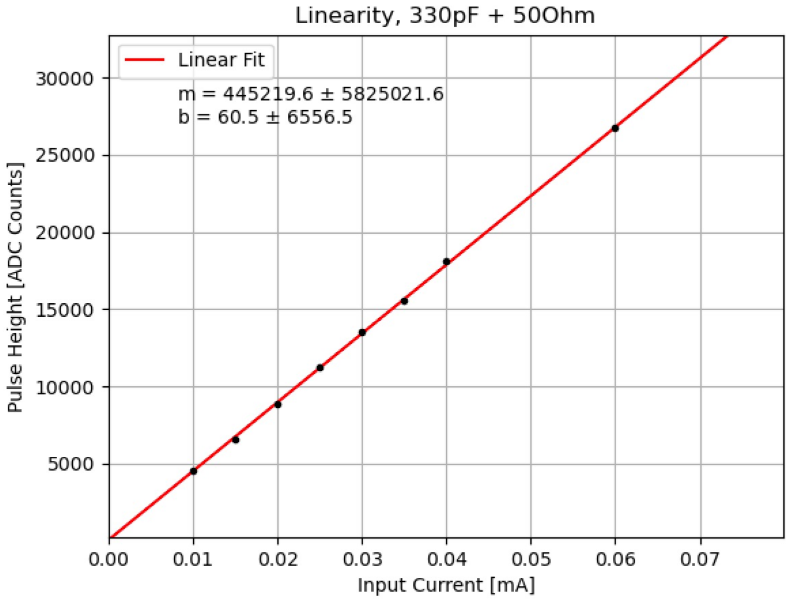


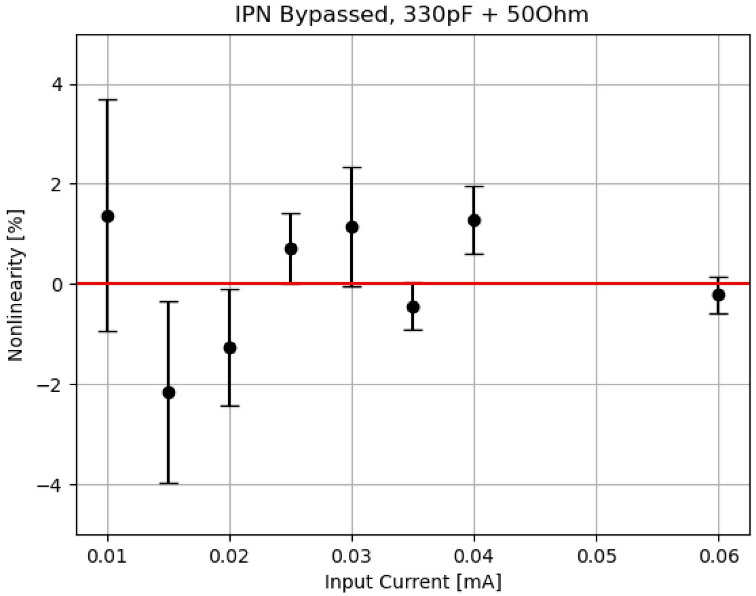




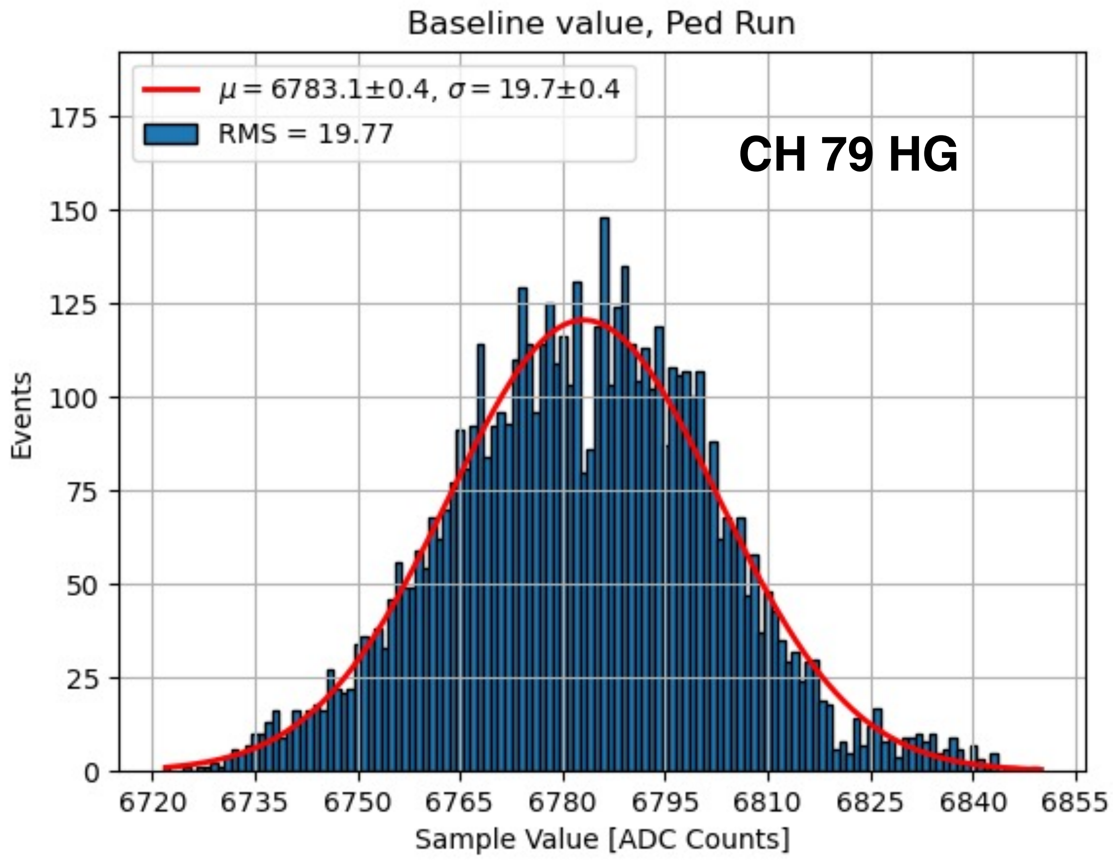
Pulse Linearity, IPN intact 50Ohm (HG)

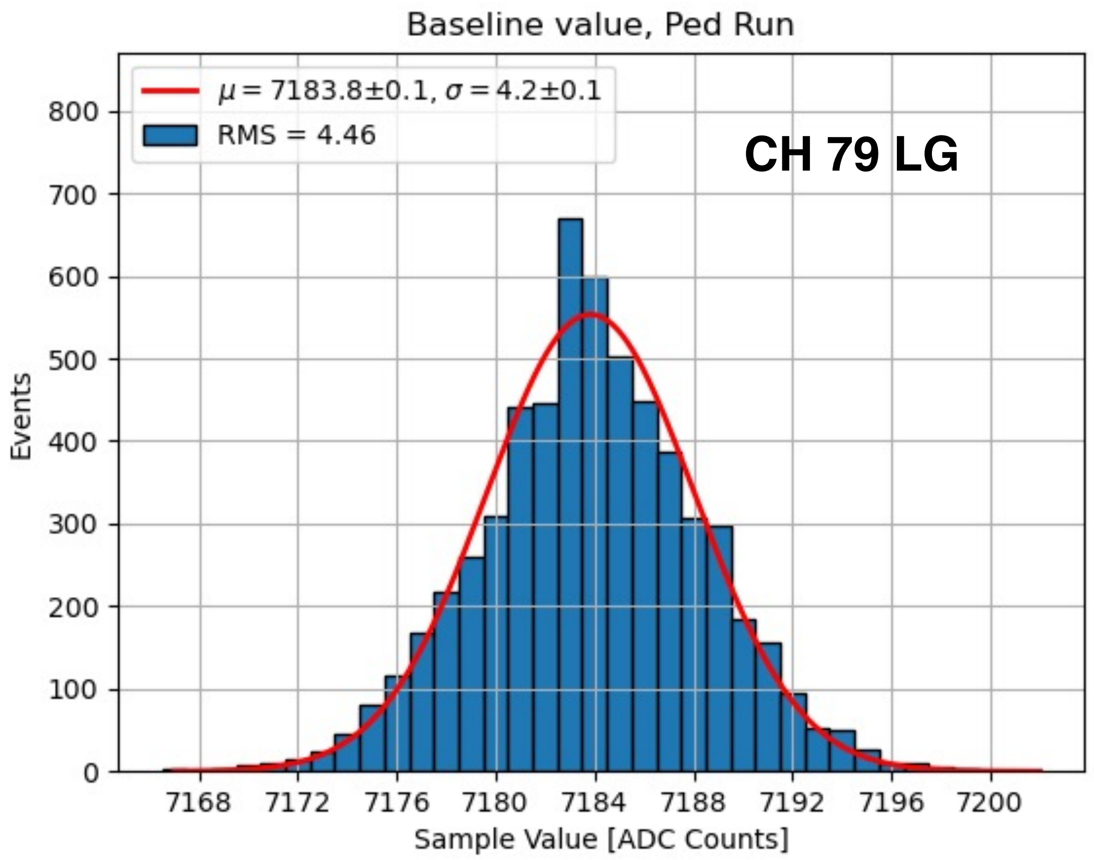






Single-channel Noise Measurements, 25Ohm LAUROC Setting





Single-channel Noise Measurements, 50Ohm LAUROC Setting