

FEB2 ‘Slice’ Testboard Update

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October 6th, 2021



Overview

Analog Testboard (2019)

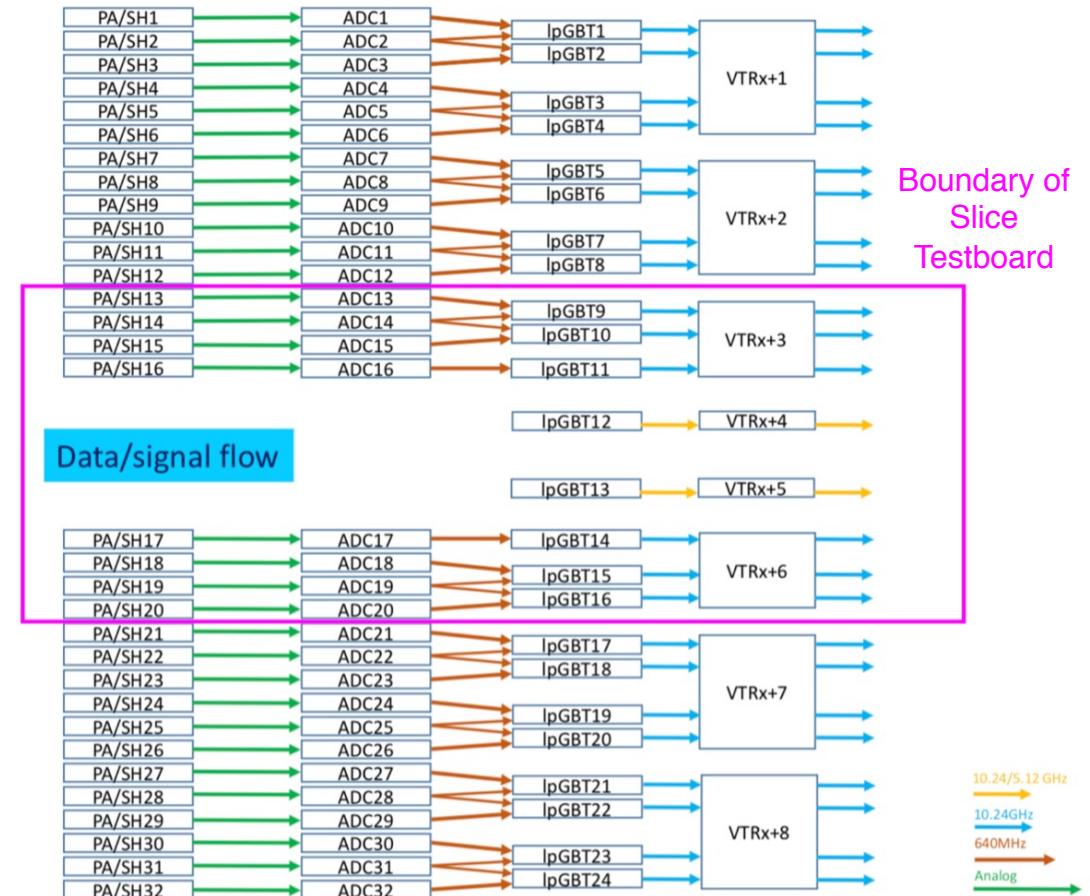
- 2 (LAUROC1 PA/S + COLUTAv2 ADC) +IpGBT
- Verified full readout chain: PA/s → ADC → optical data links

Slice Testboard (2020-2021)

- 8 (LAUROC2 PA/S + COLUTAv3 ADC +IpGBT) chips, 32 LAr channels available
- **Goal:** demonstrate multichannel performance, bi-directional control links

Full FEB2 Prototype (2022-2023)

- All 128 channels available



Timeline



Feb 15 – Began testing of 2 new fully assembled (v1.1) Slice Testboards

July 8 – Received additional LAUROC chips to allow assembly of 3 additional boards

Aug. 6 – expected to receive 3 new boards. However, had to stop assembly since PCB Assembler accidentally mixed IpGBT chips together so could no longer tell which were “all good” to be used for IpGBT12/13

Sept. 8 – received new IpGBT chips (thanks Hucheng!) in exchange for the old ones, and restarted the assembly

Sept. 30 – Oct. 4 – received 3 new v1.1 Slice Testboards (bringing total to 5)

This week – send 1 v1.1 board to BNL, to replace the partially assembled v1.0 board we delivered to them at end December 2020

End October(?) – aim to be ready to distribute v1.1 Slice Testboards to other collaborators (need to discuss where)

Slice Testboard Layout + Features



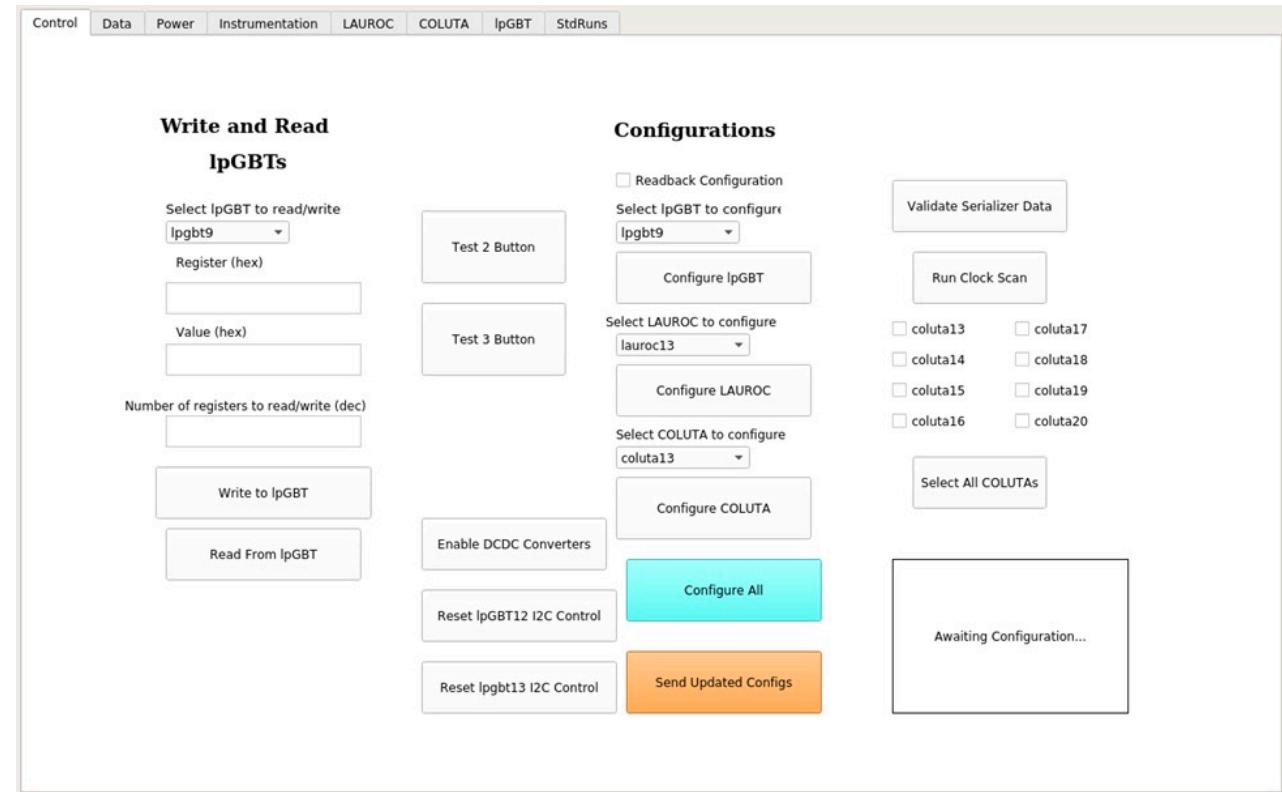
COLUTA

LAUROC

- Full sized PCB, including layout and density as planned for final FEB2
 - **32** of 128 channels implemented
- Implemented and validated redundant bidirectional control links
- capable of fully programming 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 25Ohm (or 330pF boards with 50 Ohm LAUROC configuration)

GUI Developments

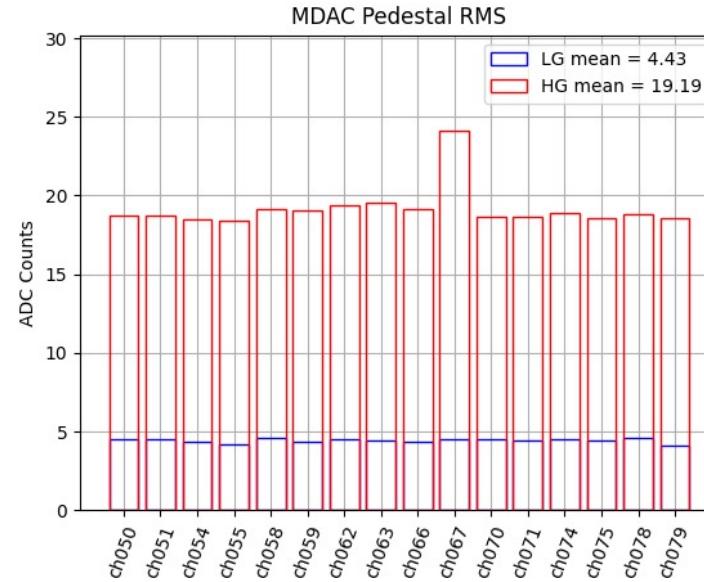
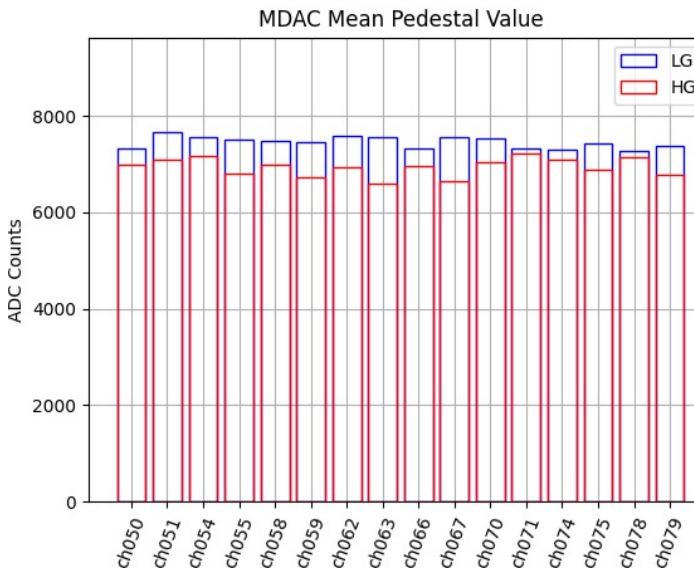
- Full board control + readout implemented through GUI software package integrated with FELIX
 - Board voltage and temperature monitoring available in GUI software
 - Synchronized clocks between FELIX and AWG for precise physics pulse energy + timing measurements
- Full ADC calibration (MDAC +SAR) available through GUI
 - Calibration done in parallel – offers speed-up relative to previous calibration method
(7hrs → 25 mins)
 - Calibration constants stored in database
 - further optimization and speed-up being investigated



	MDAC Calibration	SAR Calibration
All channels	~4.5 minutes	N/A
Even/odd channels	~8 minutes	~18 minutes
Multi-COLUTA single ch.	~12 minutes	~32 minutes

Noise Measurements (25 Ohm Setting)

- **Pedestal Analysis:** Automated board-level summary and per-channel noise analysis
- Results shown are from **fully calibrated board**
- Adjustable pedestal levels set on each channel
 - **LG Noise:** 4.0 ADC counts; **HG Noise:** 19.2 ADC counts;
 - **(Hi/Lo Gain ratio:** 25.6)
 - Somewhat higher HG noise observed on ch67 HG (under investigation)



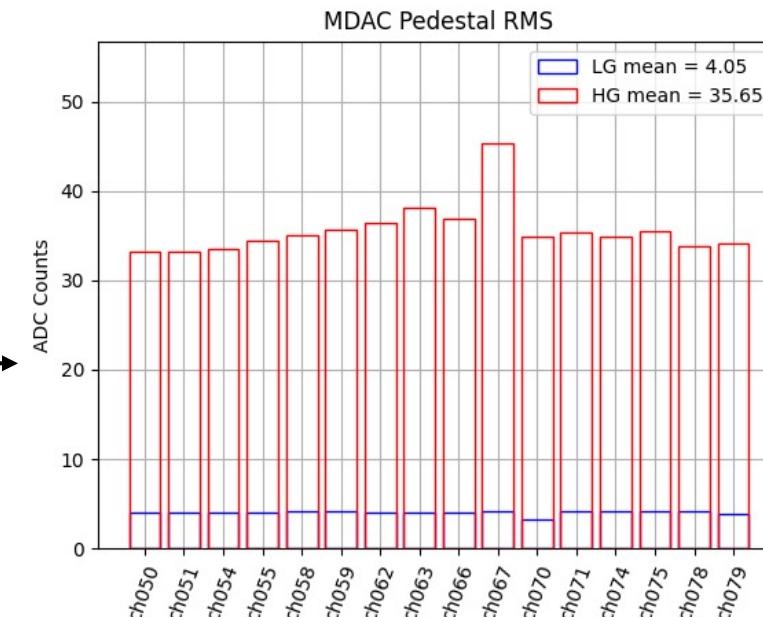
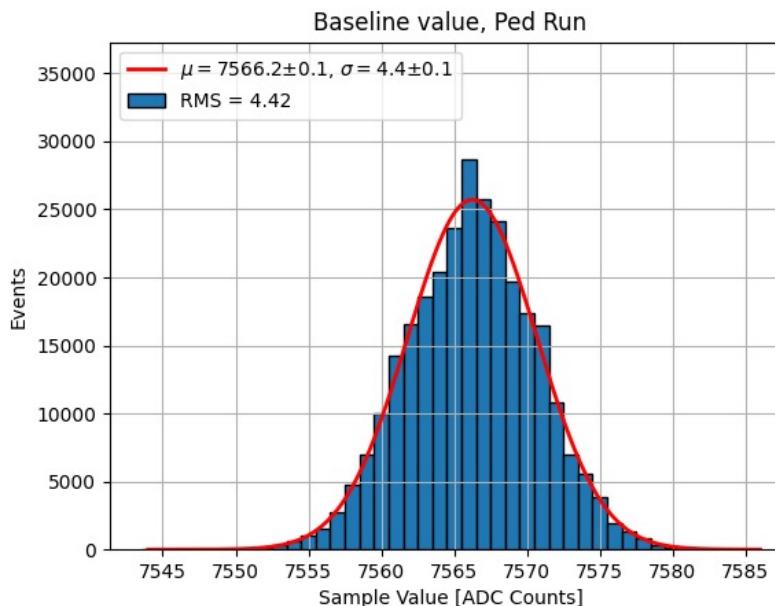
Correlated Noise

Run run1787 Pairwise Noise Correlation [%], hi gain													
channel050	100	4	3	3	3	3	5	4	2	2	1	1	1
channel051	4	100	2	3	3	3	4	4	2	2	2	1	1
channel053	3	2	100	5	4	4	6	6	2	2	1	2	1
channel055	3	3	5	100	4	4	7	7	2	3	2	2	1
channel056	3	3	4	4	100	6	6	6	3	3	2	2	1
channel058	3	3	4	4	6	100	14	4	5	3	4	3	2
channel062	5	4	6	7	6	6	100	14	5	5	3	4	3
channel063	4	4	6	7	6	6	14	100	5	10	4	3	3
channel066	2	2	2	2	3	3	4	5	100	4	4	3	3
channel067	2	2	2	3	3	3	5	5	10	100	4	3	3
channel070	1	2	1	2	2	2	3	3	4	4	100	4	2
channel074	1	1	2	2	2	2	4	4	4	4	100	2	2
channel078	1	1	1	1	1	1	3	3	3	2	2	100	3
channel079	1	1	1	1	1	1	2	2	3	3	2	3	100

Run run1787 Pairwise Noise Correlation [%], lo gain														
channel050	100	2	1	1	1	0	1	0	0	0	0	1	0	0
channel051	2	100	1	1	1	1	1	1	0	0	0	0	0	0
channel054	1	1	100	2	0	1	1	1	0	0	0	0	0	0
channel055	1	1	2	100	0	1	1	1	1	1	1	2	0	0
channel058	1	1	0	0	100	3	2	1	-1	0	0	-1	-1	0
channel059	0	1	1	1	3	100	1	2	-1	1	0	0	0	0
channel062	1	1	1	1	2	1	100	3	0	1	0	0	1	0
channel063	0	1	1	1	1	2	3	100	0	1	1	1	0	0
channel066	0	0	0	1	-1	-1	0	0	100	3	2	2	1	1
channel067	0	0	0	1	0	1	1	3	100	2	2	1	1	1
channel070	0	1	0	1	0	0	0	1	2	2	100	3	1	1
channel071	1	0	0	2	-1	0	0	1	2	2	3	100	2	1
channel074	0	0	0	0	-1	0	1	0	1	1	1	2	0	1
channel075	1	0	0	0	0	0	0	1	1	1	1	3	100	1
channel078	0	0	0	1	0	0	0	0	1	1	1	2	0	3
channel079	0	0	0	1	0	0	0	0	2	1	1	3	100	1

Noise Measurements (50 Ohm Setting)

- **LG Noise:** 4.0 ADC counts; **HG Noise:** 35.65 ADC counts;
- **(Hi/Lo Gain ratio:** 37.4)
- Somewhat higher HG noise observed on ch67 HG (under investigation)
- Correlated noise towards center of the board is
Understood: due to incomplete grounding of injector boards

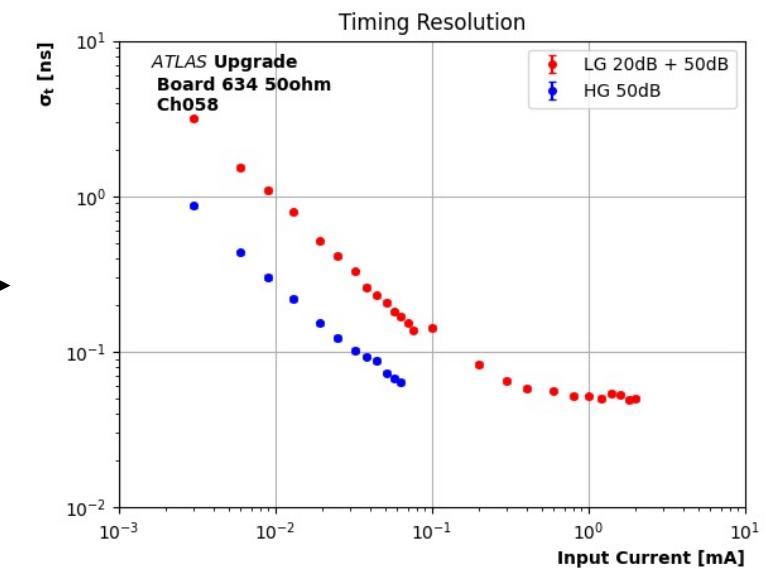
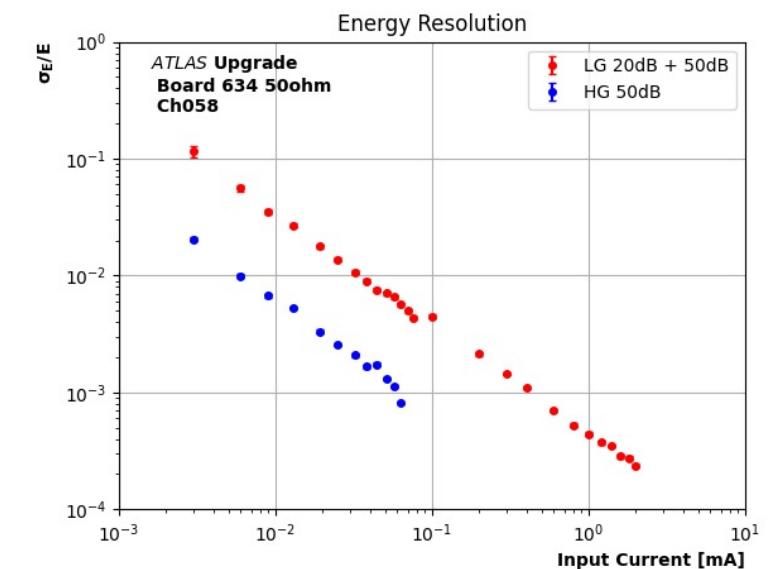
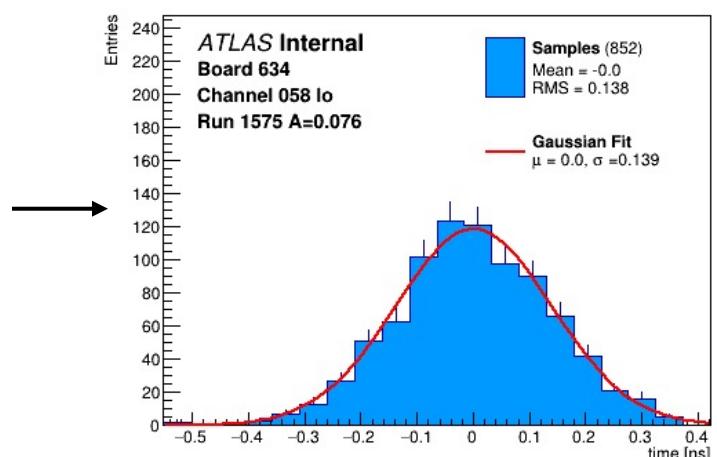
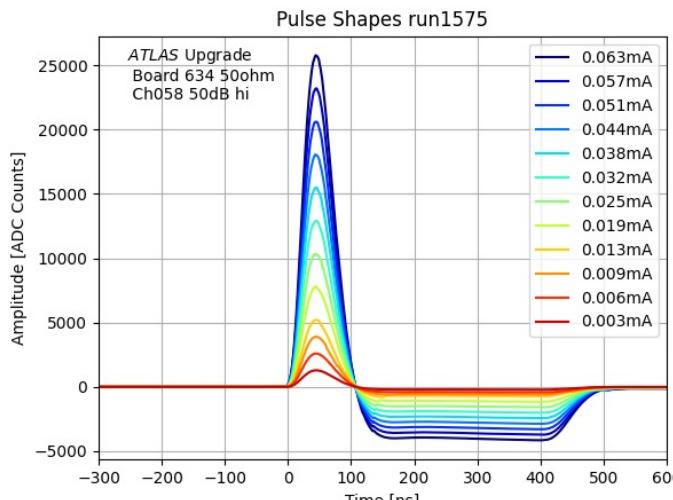


Correlated Noise																		
Run run1788 Pairwise Noise Correlation [%], lo gain																		
0	2	1	1	2	1	1	1	-1	0	0	0	1	-1	0	-1	0	-1	-1
100	1	2	1	1	1	1	1	0	0	-1	0	0	0	0	0	0	0	0
1	100	3	0	1	1	1	2	1	0	1	-1	1	1	1	1	1	1	1
2	3	100	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0
1	6	1	100	3	2	2	2	0	1	-1	1	0	0	0	0	0	0	0
1	1	1	3	100	3	2	1	-1	1	-2	1	0	1	1	1	1	1	1
1	1	0	2	3	100	4	0	0	0	0	-1	1	1	1	1	1	1	0
1	2	1	2	2	2	4	100	1	0	0	-1	0	1	0	0	0	0	0
0	1	0	0	1	0	1	100	4	2	1	2	3	2	1	1	1	1	1
0	0	0	0	1	-1	0	0	4	100	1	3	1	2	2	2	1	2	2
-1	1	0	-1	1	0	0	2	1	100	2	2	2	2	2	2	2	2	2
0	-1	0	1	-2	-1	-1	1	3	2	100	1	1	1	1	1	1	1	1
0	1	1	0	1	1	0	2	1	2	1	100	3	2	2	2	2	2	2
0	1	0	0	0	1	1	3	2	2	1	3	100	2	1	1	1	1	1
0	1	0	0	1	1	0	2	2	2	1	2	2	100	4	1	1	1	1
0	1	0	0	1	0	0	1	1	2	1	2	1	4	100	1	1	1	1
name001	name002	name003	name004	name005	name006	name007	name008	name009	name010	name011	name012	name013	name014	name015	name016	name017	name018	name019

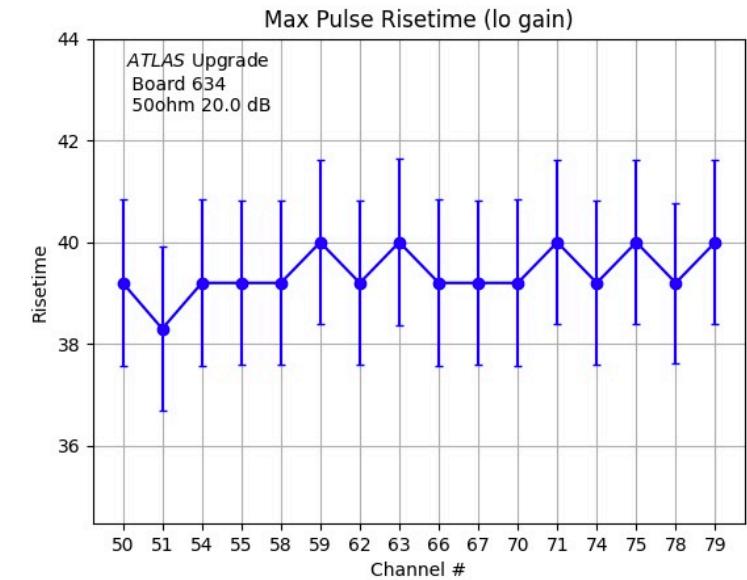
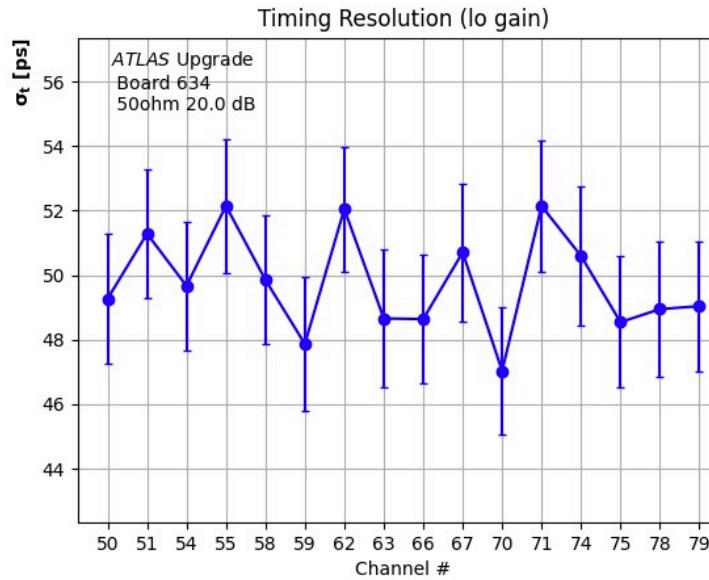
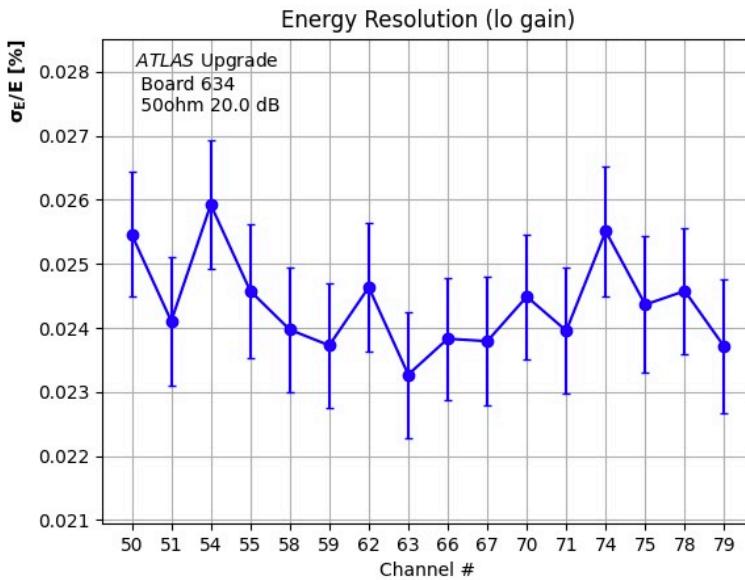
Run run1788 Pairwise Noise Correlation [%], hi gain																
3	2	3	3	4	5	5	0	0	0	0	0	0	0	0	0	0
100	2	3	4	5	6	7	0	-1	-1	-1	0	-1	0	0	0	0
2	100	6	4	5	8	8	0	-1	-1	-1	0	-1	0	0	0	0
3	6	100	5	6	9	10	-2	-2	-2	-2	0	-1	0	-1	0	-1
4	4	5	100	8	10	11	-1	-2	-1	-2	-1	-2	0	0	0	0
5	5	6	8	100	12	14	-2	-3	-2	-3	-1	-2	0	0	0	0
6	8	9	10	12	100	22	-3	-4	-3	-4	-2	-3	-1	-1	-1	-1
7	8	10	11	14	22	100	-5	-5	-4	-5	-2	-3	-1	-1	-1	-1
0	0	-2	-1	-2	-3	-5	100	18	10	12	8	9	6	8	0	0
-1	-1	-2	-2	-3	-4	-5	18	100	10	12	7	9	6	7	0	0
-1	-1	-2	-1	-2	-3	-4	10	10	100	11	6	7	5	6	0	0
-1	-1	-2	-2	-3	-4	-5	12	12	11	100	7	8	6	7	0	0
0	0	0	-1	-1	-2	-2	8	7	6	7	100	6	4	5	0	0
-1	-1	-1	-2	-2	-3	-3	9	9	7	8	6	100	5	6	0	0
0	0	0	0	0	0	-1	-1	6	6	5	6	4	5	100	5	0
0	0	-1	0	0	-1	-1	8	7	6	7	5	6	5	5	100	0
channel01	channel02	channel03	channel04	channel05	channel06	channel07	channel08	channel09	channel10	channel11	channel12	channel13	channel14	channel15	channel16	channel17

Single-Channel Performance (50 Ohm)

- ADCs derives 40 MHz CLK from FELIX, which is synchronized to AWG signal source
 - Pulse HG+LG channel at amplitudes spanning dynamic range
 - Combine different attenuations at input to access full range
 - Apply OFCs to repeated measurements, perform gaussian fit on results to obtain Energy, timing resolution
 - Energy resolution $\sim 0.02\%$ for large pulses
 - Timing resolution ~ 50 ps (dominated by system CLK jitter, not by Slice Testboard)



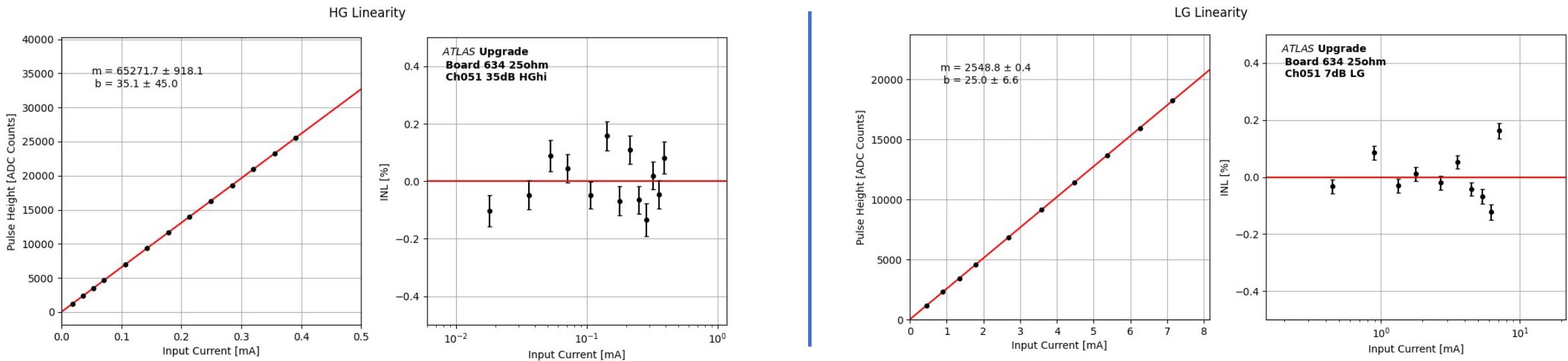
Multi-channel Performance (50 Ohm Setting)



- Automated **Full-board characterization** software package in development
- Energy resolution, timing resolution, and pulse risetime for large pulse heights consistent across channels on PCB #634

Linearity (25 Ohm Setting)

- Hi/Lo gain ratio: 25.6

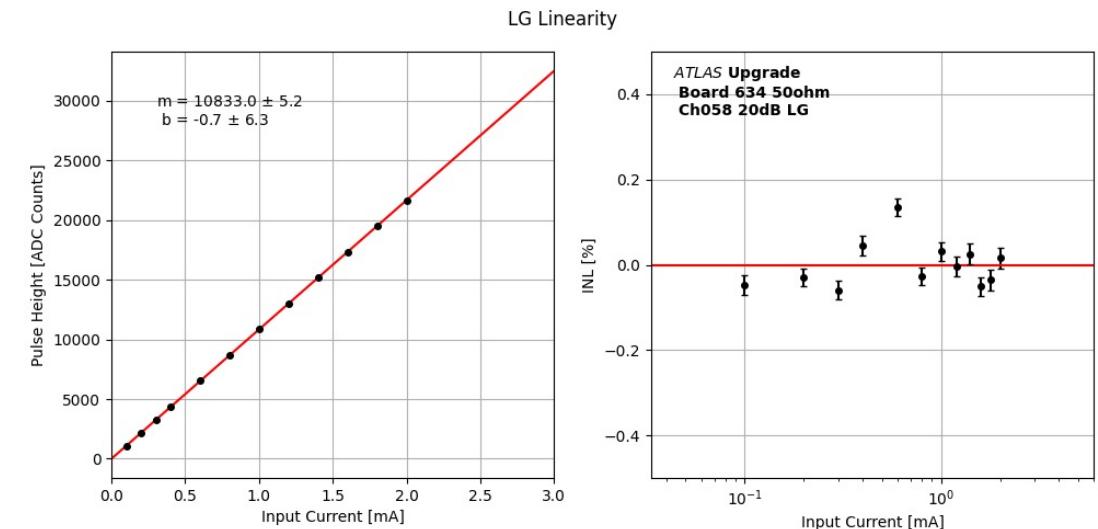
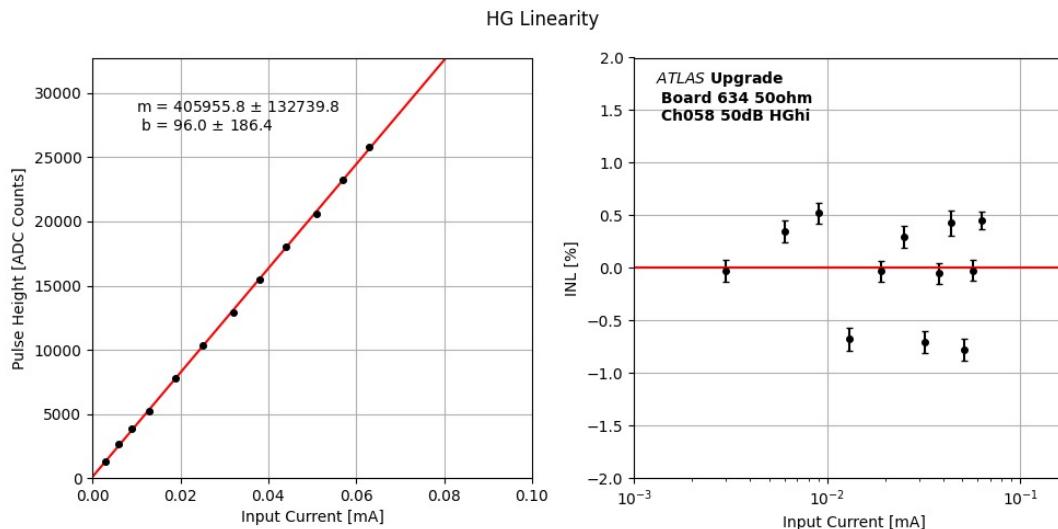


Setting	Gain	Ch	Gain [ADC/mA]	Noise [ADC]	Gain [mV/mA]	ENI [nA]	risetime [ns]
25 Ohm	HG	51	65300	18.7	3985.6	286.4	48.3
25 Ohm	LG	51	2549	4.5	155.6	1765.4	49.2

- LG INL < .2%, HG INL < .2 %
- Compare with results from [LAUROC PDR](#) :
HG ENI 265nA, 46ns risetime, HG/LG ratio ~24

Linearity (50 Ohm Setting)

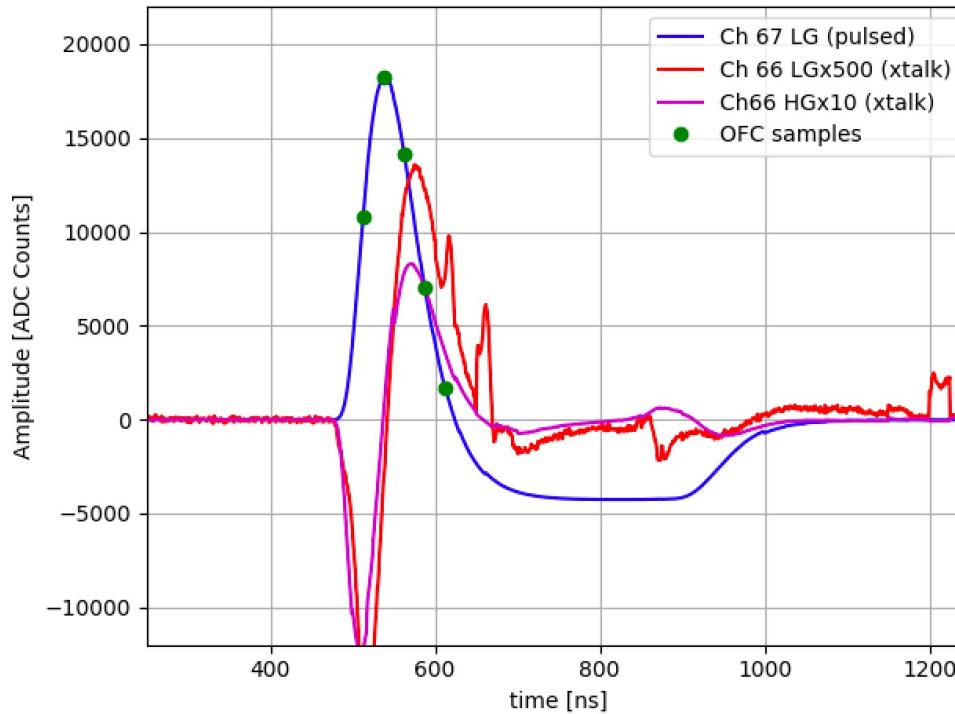
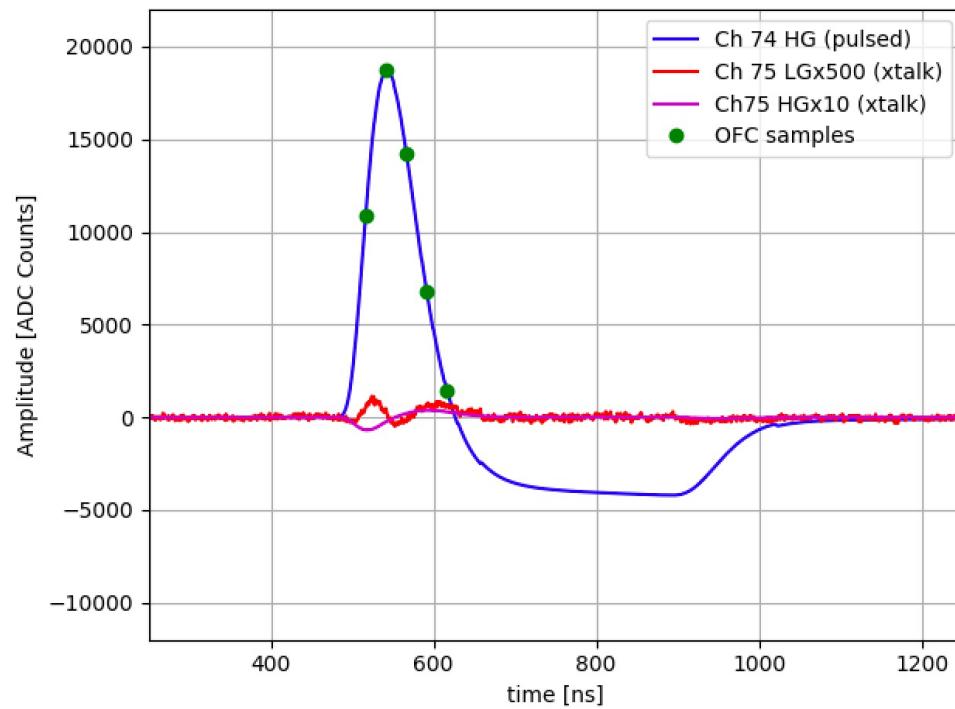
- Hi/Lo gain ratio: 37.4



Setting	Gain	Ch	Gain [ADC/mA]	Noise [ADC]	Gain [mV/mA]	ENI [nA]	risetime [ns]
50 Ohm	HG	58	406000	35.1	24780.3	86.5	39.4
50 Ohm	LG	58	10833	4.3	661.2	396.9	39.7

- LG INL < .2%, HG INL < 1.0 % (currently investigating)
- Compare with results from [LAUROC PDR](#) :
HG ENI 78nA, 38ns risetime, HG/LG ratio ~35

Crosstalk Studies (25 Ohm)



Pulsed Channel	OFC Pulse Height [ADC]	PP LG xtalk [%]	OFC LG xtalk [%]	PP HG xtalk [%]	OFC HG xtalk [%]
ch 74 HG 25 Ohm	18728	0.41	0.14	0.58	0.07
ch 67 LG 25 Ohm	18247	0.33	0.01	0.44	0.02

- Send near-saturating pulse to single channel, measure HG+LG response on neighbor
- Use HG/LG ratio from linear fits to convert between gain scales for xtalk calculation
- Applying OFCs suppresses measured crosstalk by ~order of magnitude (xtalk is mostly capacitive)

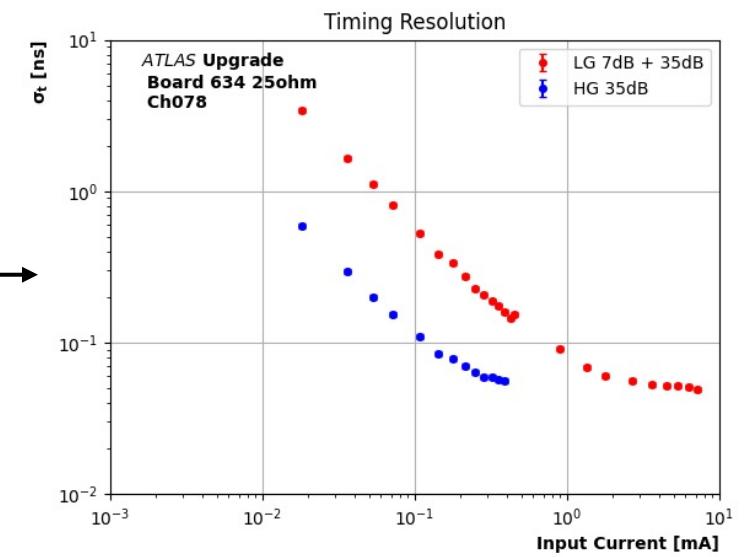
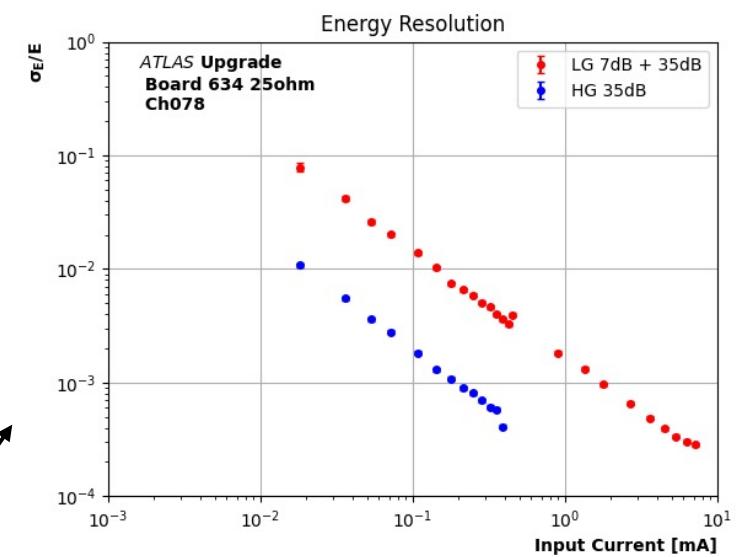
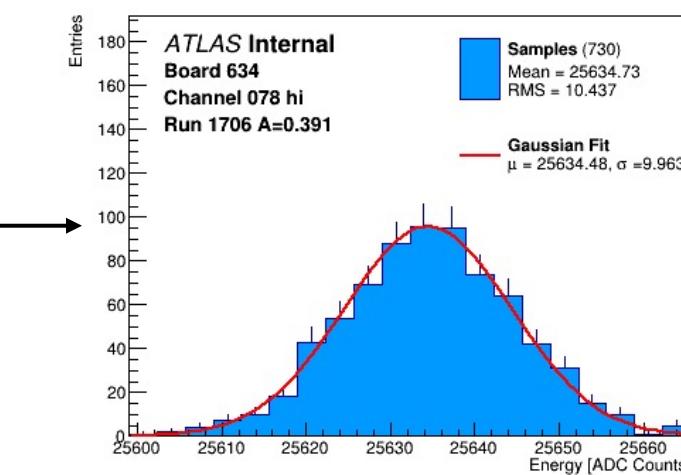
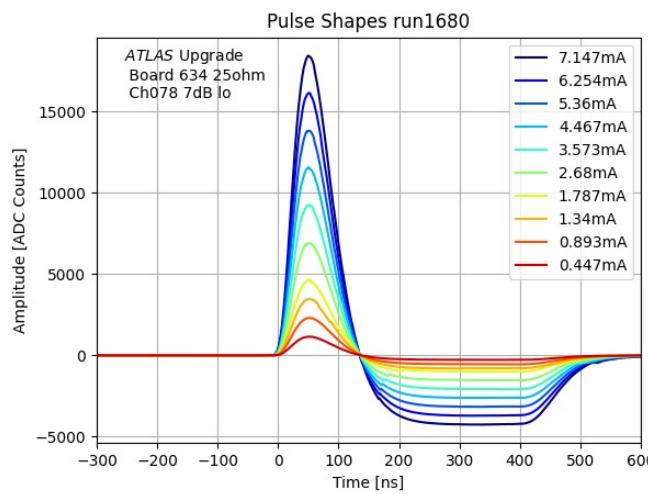
Conclusions

- 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
 - ✓ We have implemented parallel ADC calibration method, which offers 16x speedup from previous calibration setup
- Pulse injection analysis is proceeding
 - ✓ Pulse data has been taken and validated on all channels of board 64
 - ✓ Pulse data analysis is fully automated
 - Measurements show relatively good agreement with those from [LAUROC PDR](#)
- **An additional 3 boards have arrived at Nevis last week, testing is currently underway**
 - **This week** – send 1 v1.1 board to BNL, to replace the partially assembled v1.0 board we delivered to them at end December 2020
 - **End October(?)** – aim to be ready to distribute v1.1 Slice Testboards to other collaborators (need to discuss where)

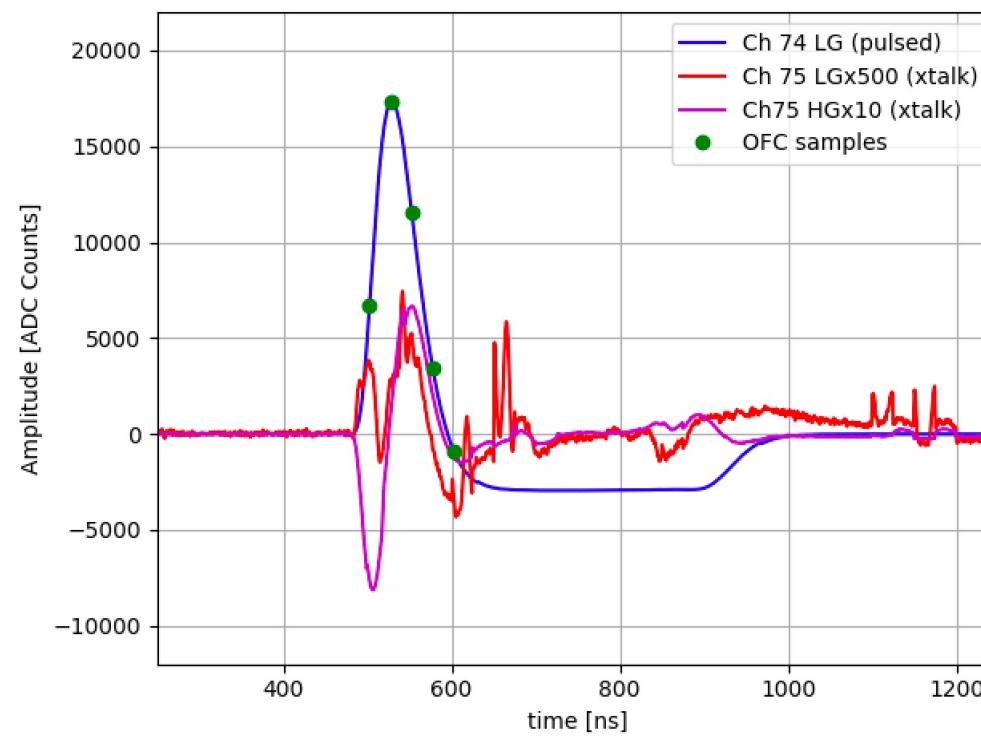
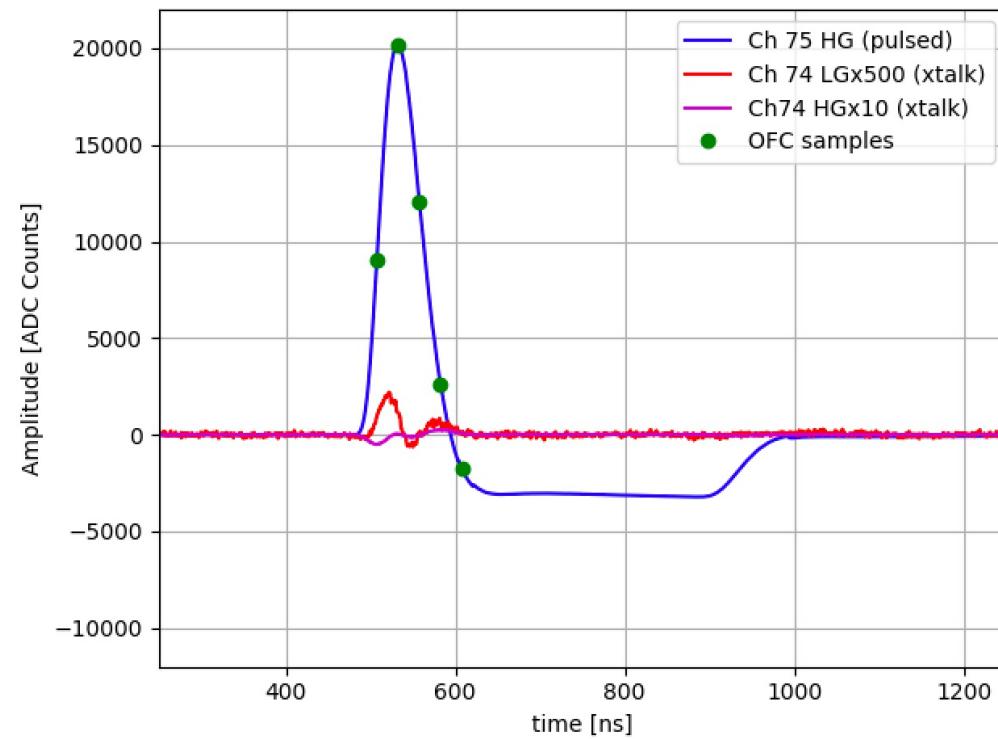
BACKUP

Single-channel Performance (25 Ohm)

- FELIX Clock Synchronized to AWG
 - Pulse HG+LG channel at amplitudes spanning dynamic range
 - Apply OFCs to repeated measurements, perform gaussian fit on results to obtain Energy, timing resolution
 - Energy resolution $\sim .02\%$ for large pulses
 - Timing resolution ~ 50 ps (dominated by clock jitter)



Crosstalk Studies (50 Ohm)



Pulsed Channel	OFC Pulse Height [ADC]	PP LG xtalk [%]	OFC LG xtalk [%]	PP HG xtalk [%]	OFC HG xtalk [%]
ch 75 HG 50 Ohm	20200	0.56	0.19	0.38	0.04
ch 74 LG 50 Ohm	17342	0.14	0.05	0.23	0.03

- Send near-saturating pulse to single channel, measure HG+LG response on neighbor
- Use HG/LG ratio from linear fits to convert between gain scales for xtalk calculation

Coherent noise histograms (Pedestal analysis)

