

PMT Non-Linearity Studies at ISU

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Outline

- Asymmetry and Non-Linearity
- Black-Box Setup and Integrating DAQ Systems
- LED, TRIGGER and GATE timing Settings
- Qweak ADC details
- Steps In Non-Linearity Measurement
- Some Recent Measurements
- Summary Table
- Issues/Questions
- Summary and Future Plans

Asymmetry And Non-Linearity

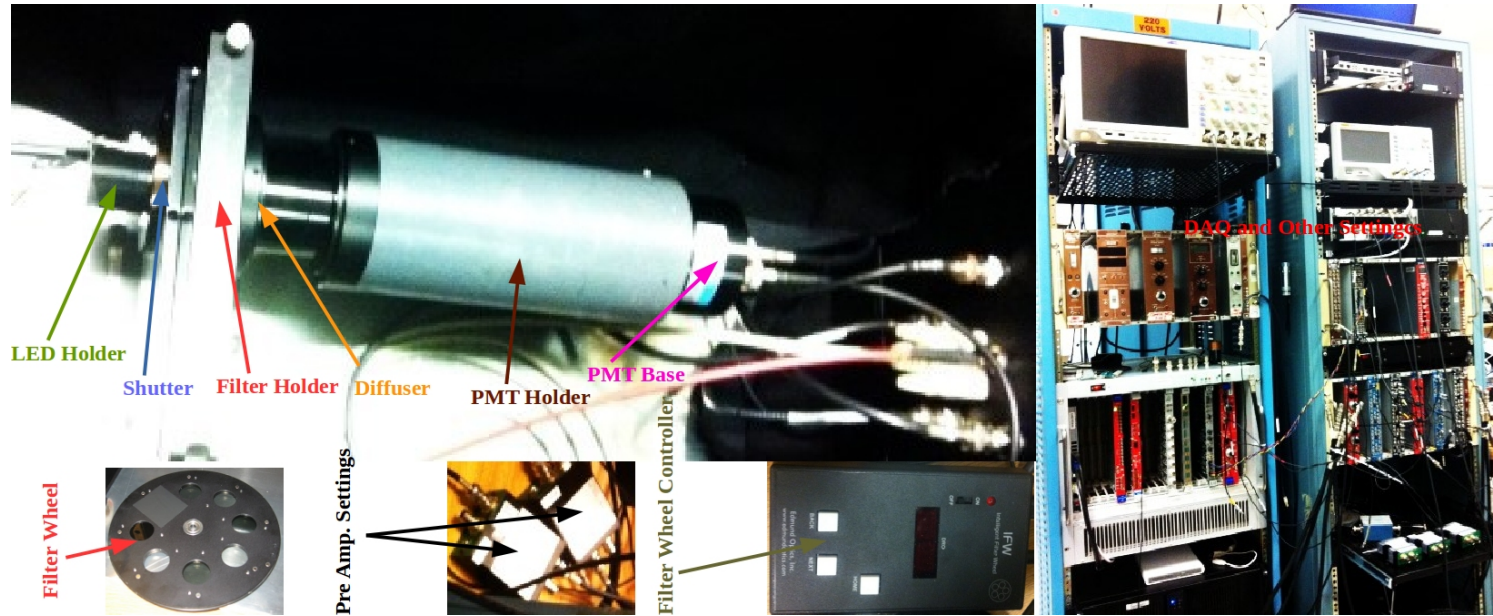
$$A_{LED} = \frac{N^+ - N^-}{N^+ + N^-}$$

$$\text{or, } A_{LED} = A_{true}(1 + \beta N_{avg})$$

$$\text{where, } N_{avg} = \frac{N^+ + N^-}{2}$$

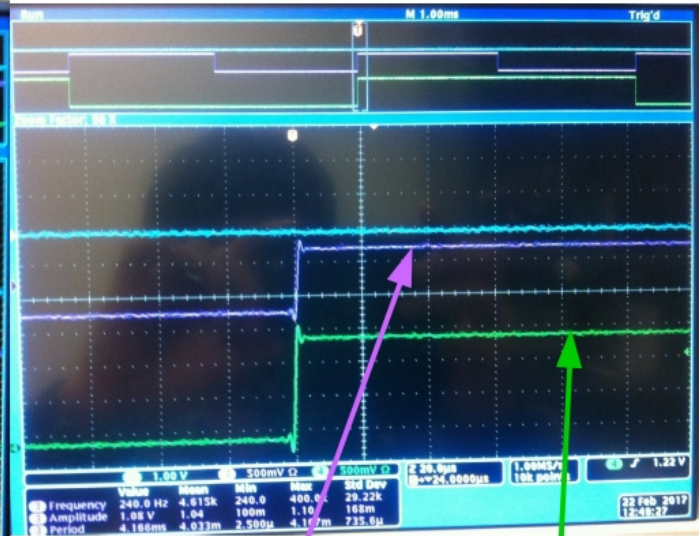
- R7723Q (Mod. base) PMT was used.
- $N^\pm = N_S^\pm(1 + \beta N_S^\pm)$ is the PMT response for the signal N_S^\pm . Where, $\pm \implies$ right(left) helicity states in the real experiment (ON(OFF) states of flashing LED in our prototype).
- A_{true} and $A_{true}\beta$ (i.e. slope) are obtained from the A_{LED} vs. N_{avg} plot.
- β is multiplied by the N_{avg} value corresponding to the filter with the highest transmittance (7th filter in our case) to get PMT Non-Linearity.

Black Box Setup and Integrating DAQ Systems



- LED Holder → steady + flashing
- Electronic Shutter → Can open and close with a switch
- Filter Holder → Computer controlled → Edmunds Optic's → Absorptive ND filters (400-700 nm) → 8 transmission settings (randomly ordered): 100, 78, 63, 50, 40, 25, 10, 0 %
- UV Diffuser → Edmunds Optic's → ground fused silica
- PMT Holder → 2" PMT → with Mod. base
- PreAmp. → MAIN11, MAIN14, LUMI14

LED, Trigger and Gate Timing Settings

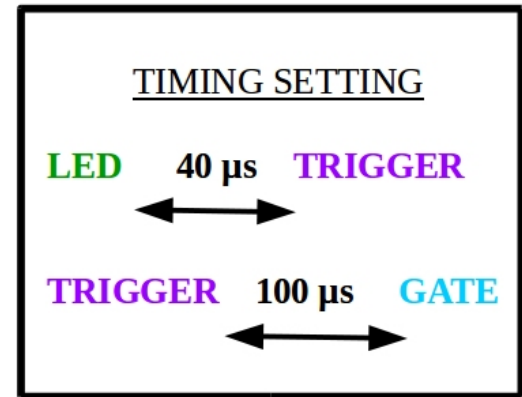


DAQ Signal LED Signal

GATE

LED

TRIGGER



Qweak ADC details

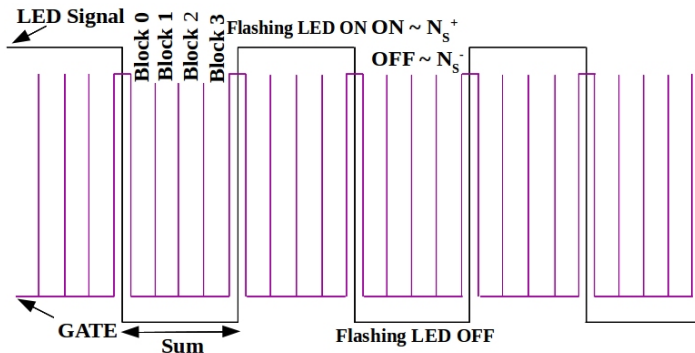


Figure: DAQ response sampled in four blocks.



Figure: Function Generator settings.

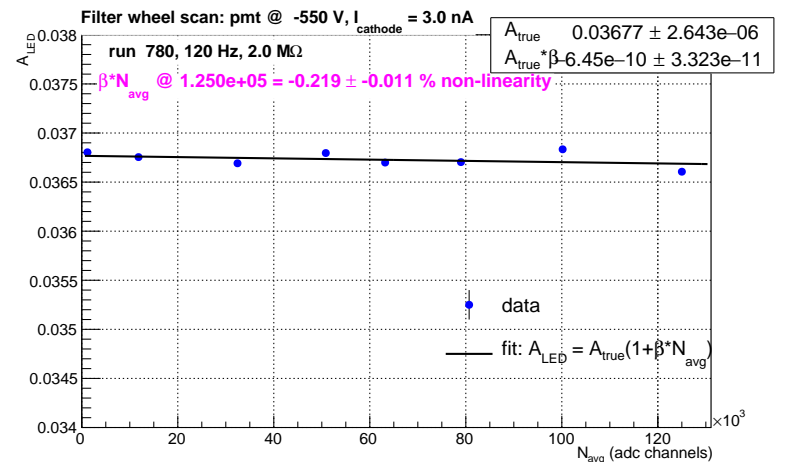
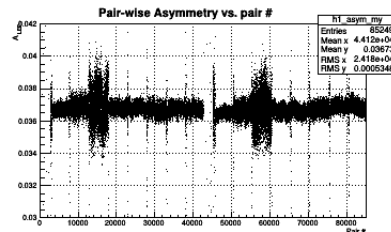
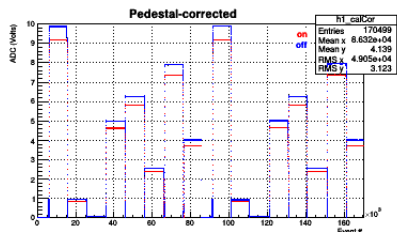
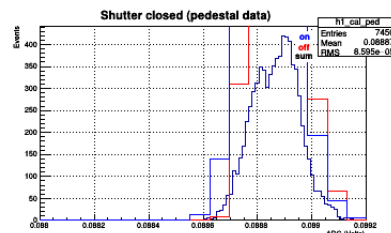
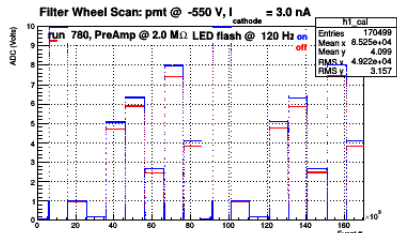
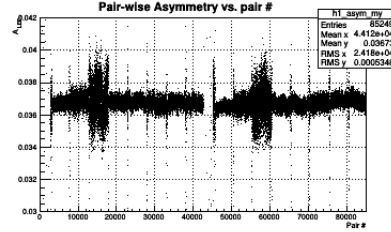
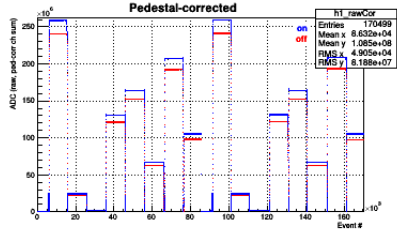
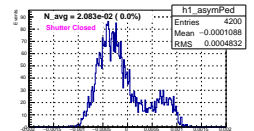
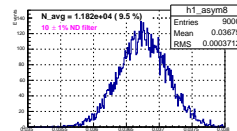
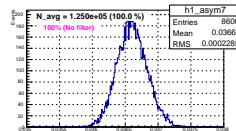
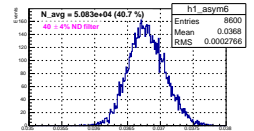
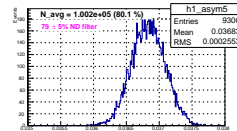
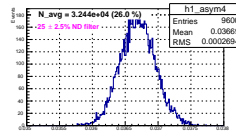
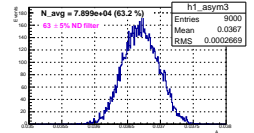
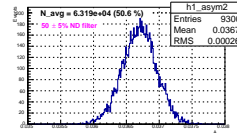
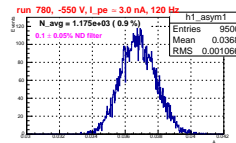
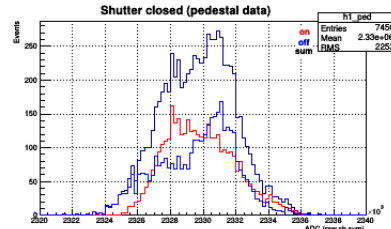
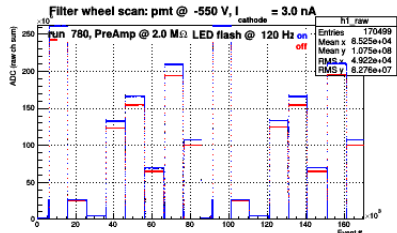
- Samples the voltage in every $2 \mu\text{s}$.
- Has a $\pm 10 \text{ V}$ range with 18 bit resolution (corresponding to $76.29 \mu\text{V}/\text{channel}$).
- Has 8 inputs with 12Ω input impedance.
- Working with CODA 2.6 and a fast Linux ROC (with Paul King's help).
- We use a Struck SIS3610 for triggering.
- Each GATE is split into 4 blocks with the length (in time) of each block specified by user.
- For 120 Hz flipping rate, we set 500 samples/block. So 2000 total samples, every $2 \mu\text{s}$, gives $8000 \mu\text{s}$ long gate.

Steps In Non-Linearity Measurement

- LED (in LED holder), filter wheel (in filter holder) and PMT (in PMT holder) are properly fixed inside the black box.
- DAC12 is calibrated using unity gain PMT.
- Unity gain PMT is replaced by high gain PMT.
- In Function Generator, frequency and amplitude of DAQ and flashing LED is adjusted as shown in previous slide.
- DAQ (240 Hz) and LED flash (120 Hz) signals are synchronized.
- Proper timing setting between LED, TRIGGER and GATE (40 μs and 100 μs respectively) is maintained. (GATE duration is 8000 μs and the GATE does not start until 20 μs after the ADC receives the GATE signal.)
- Connect power supply and PMT output to the preAmp. The out put of the preAmp is connected to the DAQ (CH2).
- Data is collected and analyzed.

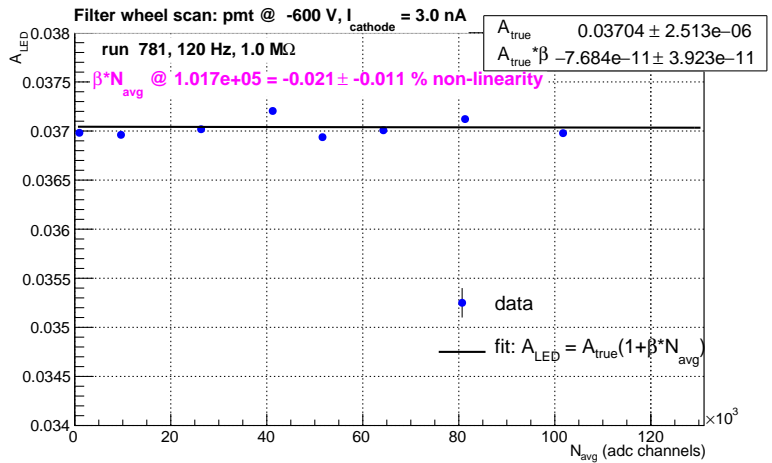
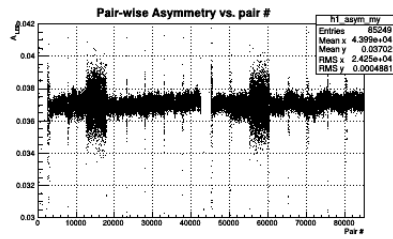
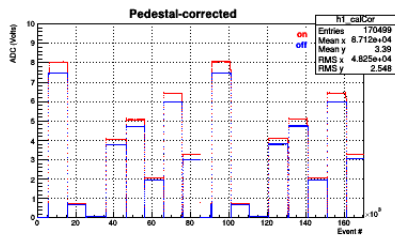
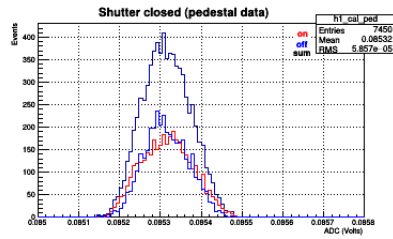
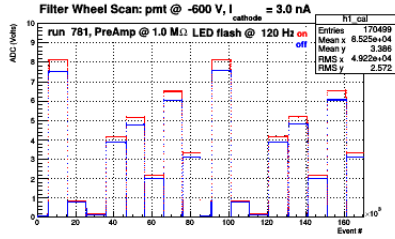
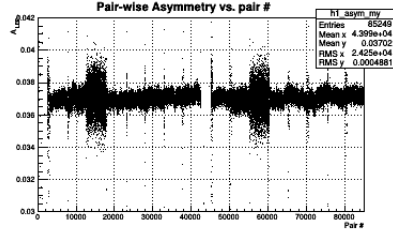
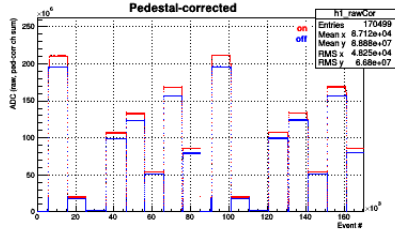
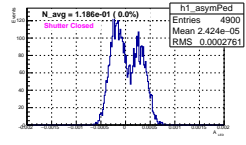
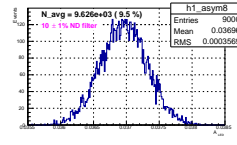
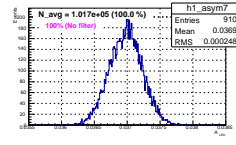
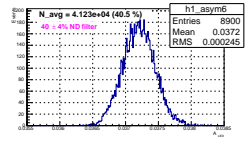
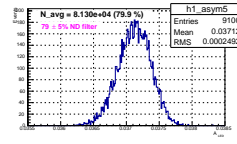
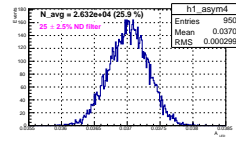
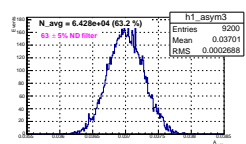
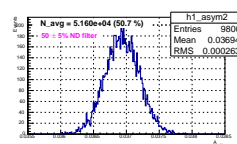
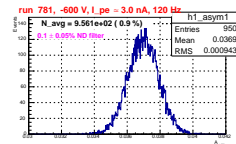
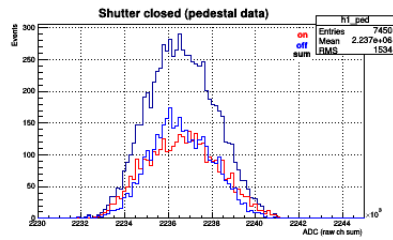
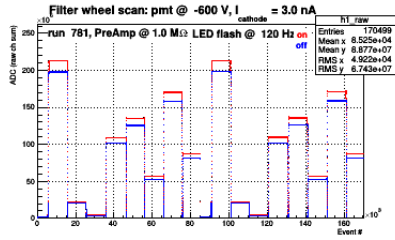
3 nA LL Measurement with DynaOhm LED driver

- 2 MΩ preAmp. and -550 V High Voltage.



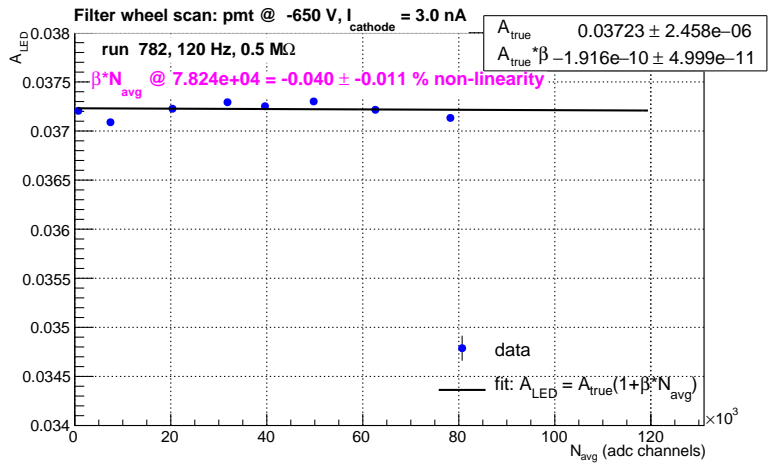
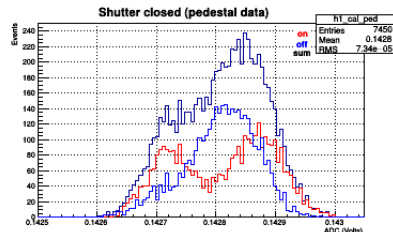
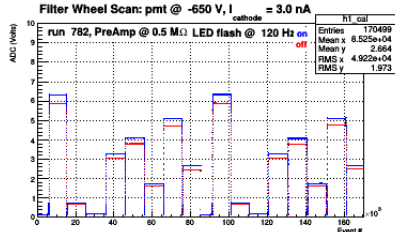
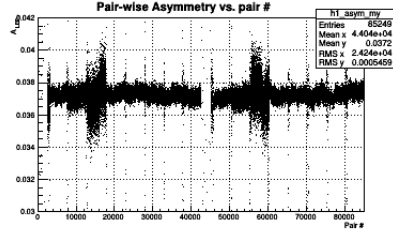
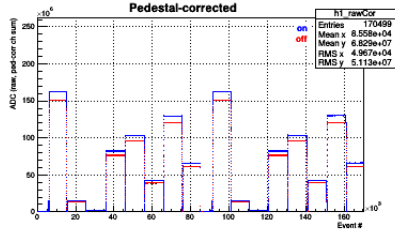
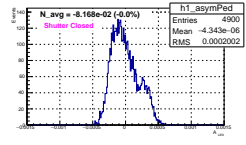
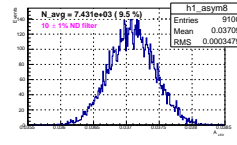
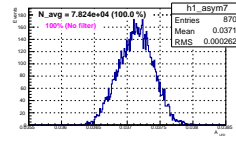
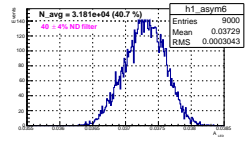
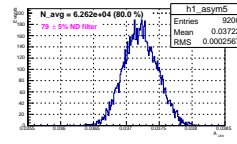
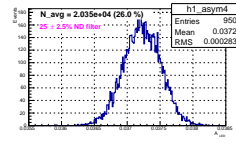
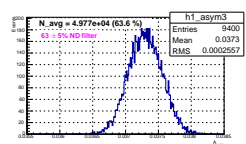
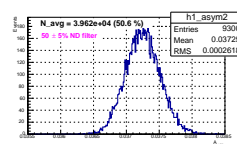
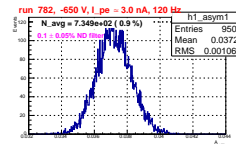
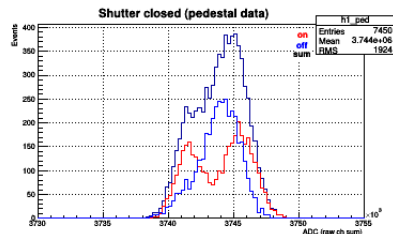
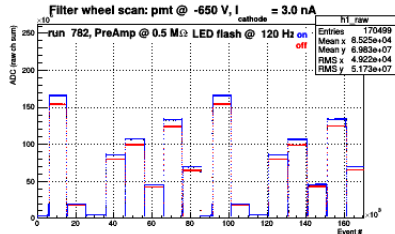
3 nA LL Measurement with DyanOhm LED driver

- 1 MΩ preAmp. and -600 V High Voltage.



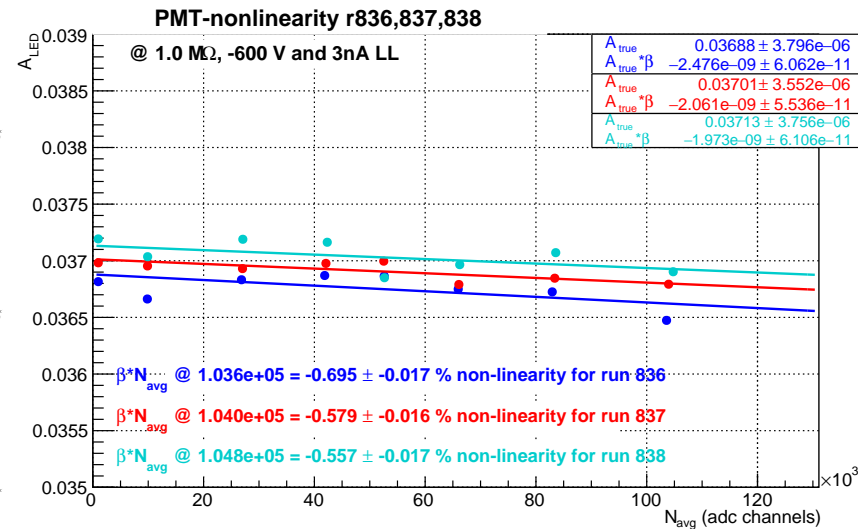
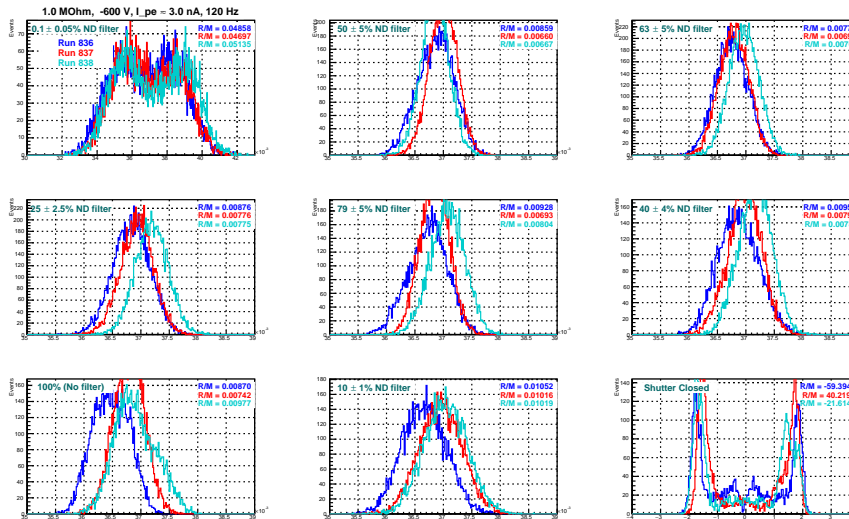
3 nA LL Measurement with DynaOhm LED driver

- 0.5 M Ω preAmp. and -650 V High Voltage.



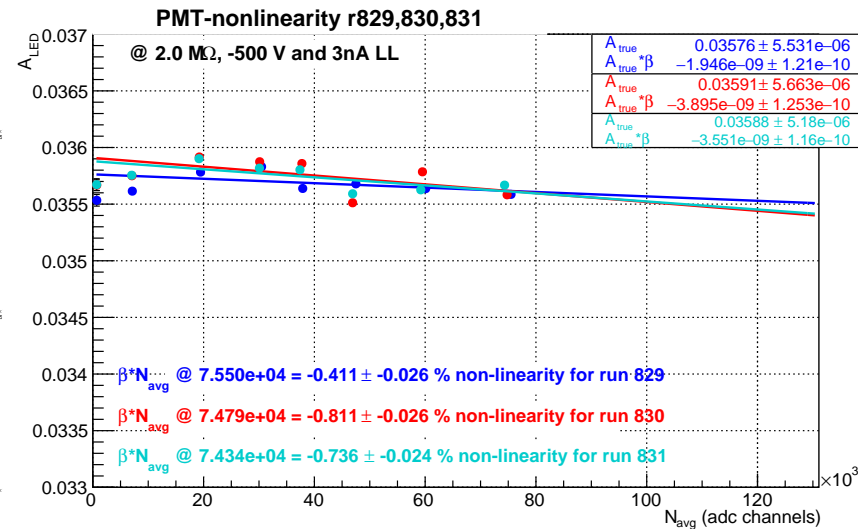
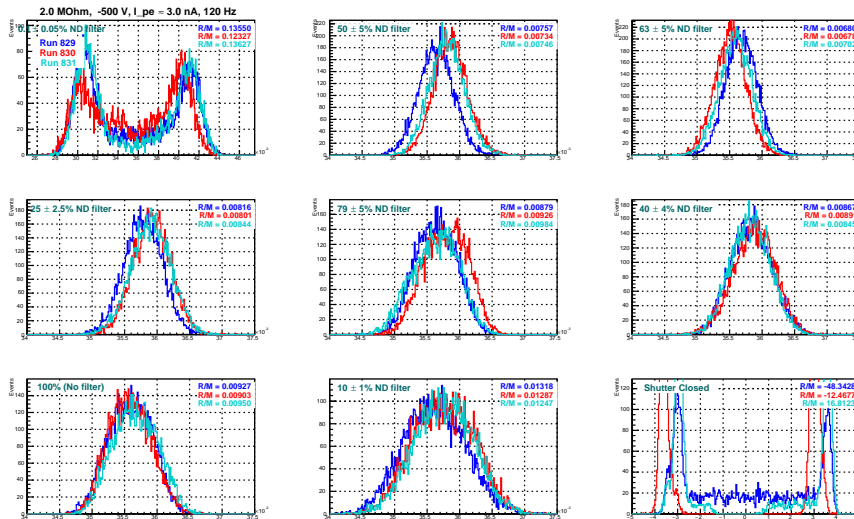
3 nA LL Measurement with simple LED driver (i.e. 470 Ω resistor)

- PMT Asymmetry and Non-Linearity plots.
 → 1 M Ω preAmp. and -600 V High Voltage.



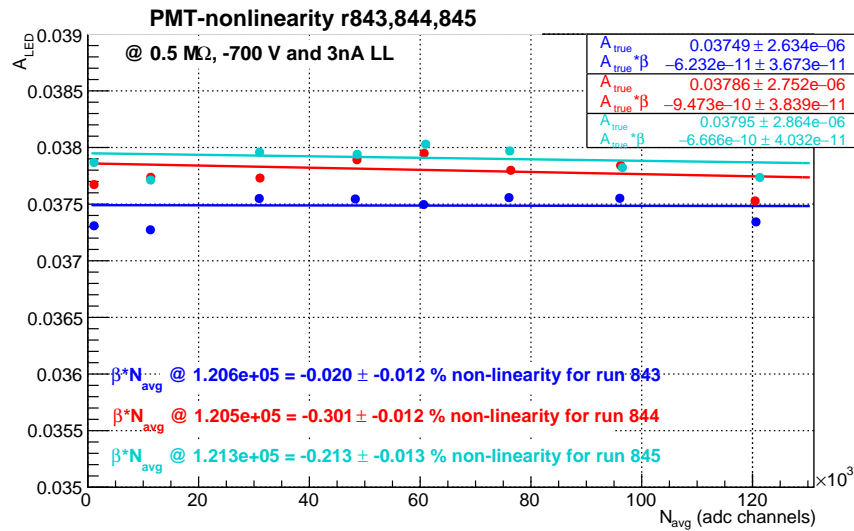
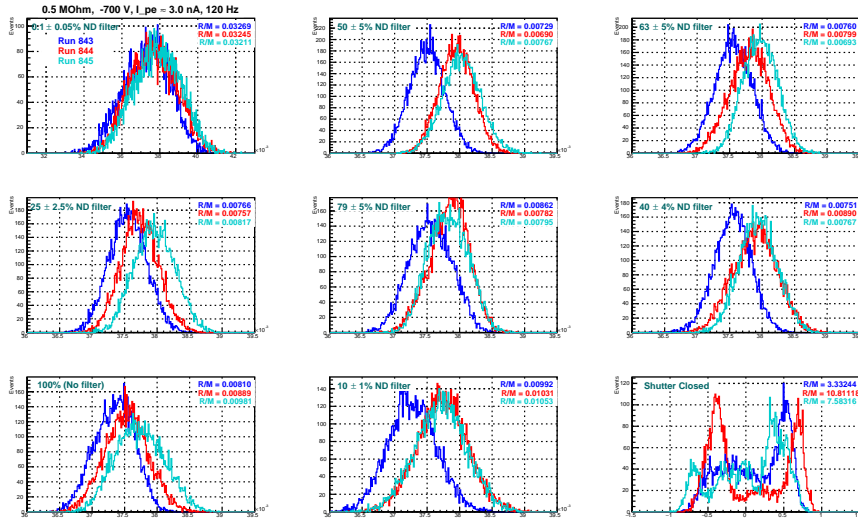
3 nA LL Measurement with simple LED driver (i.e. 470 Ω resistor)

- PMT Asymmetry and Non-Linearity plots.
 → 2 M Ω preAmp. and -500 V High Voltage.



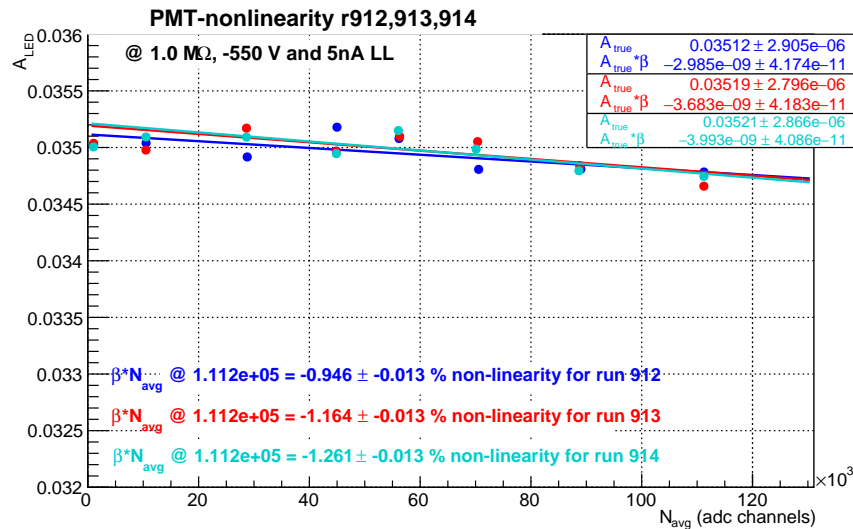
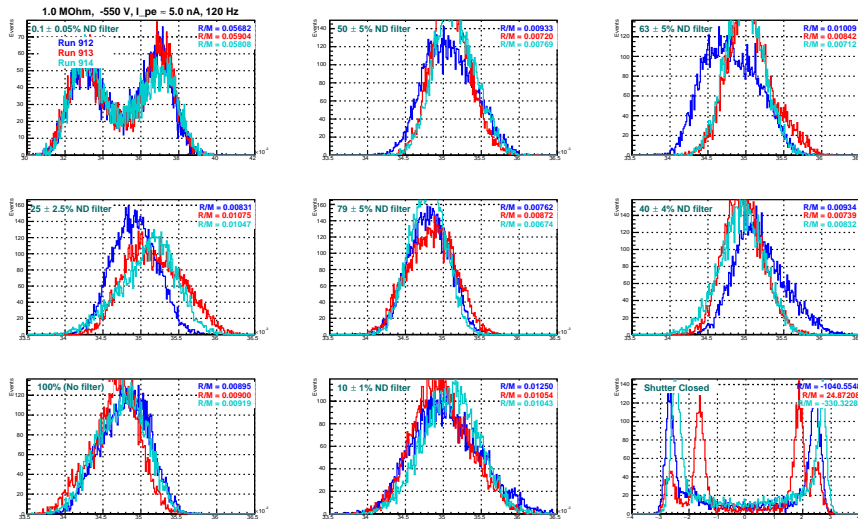
3 nA LL Measurement with simple LED driver (i.e. 470 Ω resistor)

- PMT Asymmetry and Non-Linearity plots.
 → 0.5 M Ω preAmp. and -700 V High Voltage.



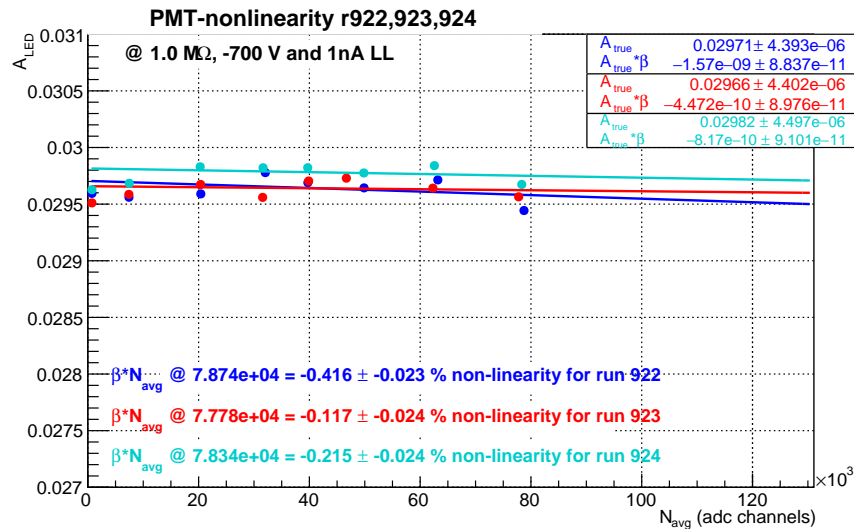
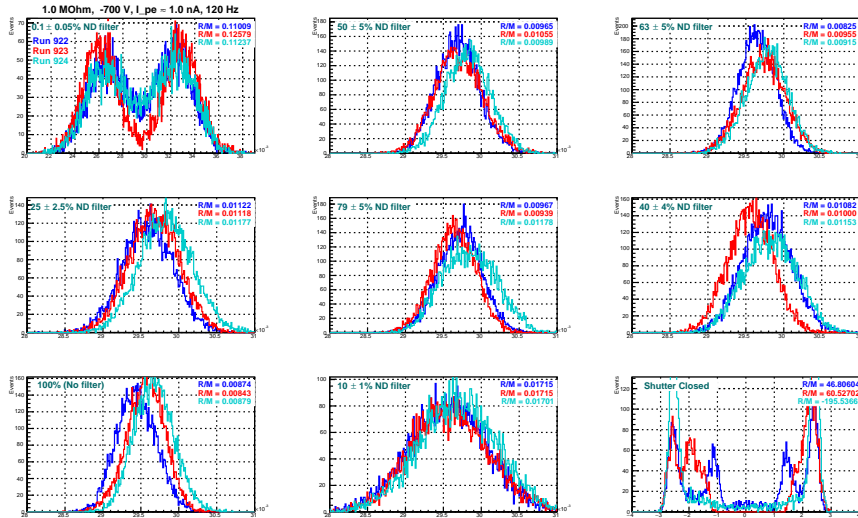
5 nA LL Measurement with simple LED driver (i.e. 470 Ω resistor)

- PMT Asymmetry and Non-Linearity plots.
 → 1 M Ω preAmp. and -550 V High Voltage.



1 nA LL Measurement with simple LED driver (i.e. 470 Ω resistor)

- PMT Asymmetry and Non-Linearity plots.
 → 1 M Ω preAmp. and -700 V High Voltage.



Summary Table

Run	PMT	PreAmp.	HV	LL	Non-Linearity
780	4	2.0 (MAIN14)	-550	3	-0.220 ± 0.011
801	4	1.0 (MAIN11)	-600	3	-0.150 ± 0.012
802	4	0.5 (LUMI14)	-650	3	0.043 ± 0.011
829	4	2.0 (MAIN14)	-500	3	-0.411 ± 0.026
830	4	2.0 (MAIN14)	-500	3	-0.811 ± 0.026
831	4	2.0 (MAIN14)	-500	3	-0.736 ± 0.024
836	4	1.0 (MAIN11)	-600	3	-0.695 ± 0.017
837	4	1.0 (MAIN11)	-600	3	-0.579 ± 0.016
838	4	1.0 (MAIN11)	-600	3	-0.557 ± 0.017
843	4	0.5 (LUMI14)	-700	3	-0.020 ± 0.012
844	4	0.5 (LUMI14)	-700	3	-0.301 ± 0.012
845	4	0.5 (LUMI14)	-700	3	-0.213 ± 0.013
912	4	1.0 (MAIN11)	-550	5	-0.946 ± 0.013
913	4	1.0 (MAIN11)	-550	5	-1.164 ± 0.013
914	4	1.0 (MAIN11)	-550	5	-1.261 ± 0.013
922	4	1.0 (MAIN11)	-700	1	-0.416 ± 0.023
923	4	1.0 (MAIN11)	-700	1	-0.117 ± 0.024
924	4	1.0 (MAIN11)	-700	1	-0.215 ± 0.024

Issues/Questions

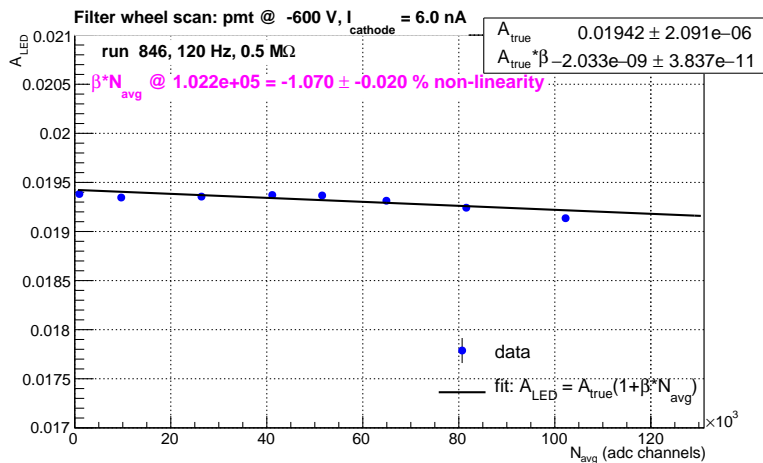
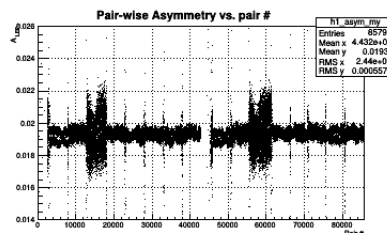
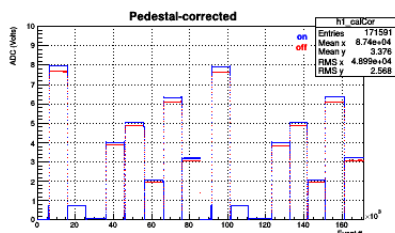
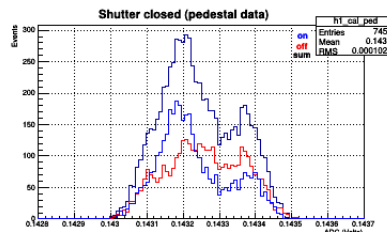
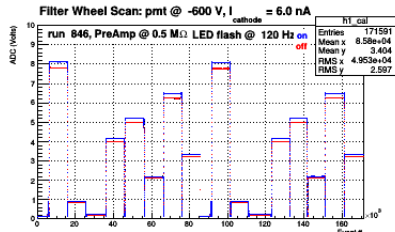
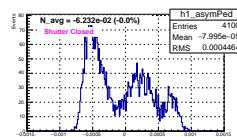
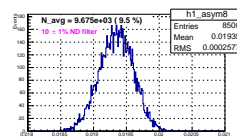
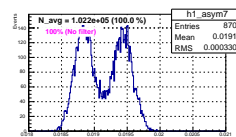
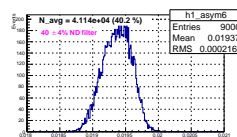
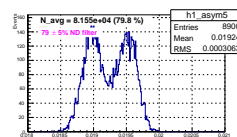
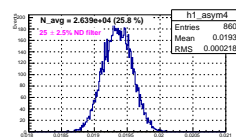
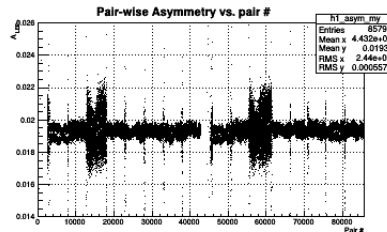
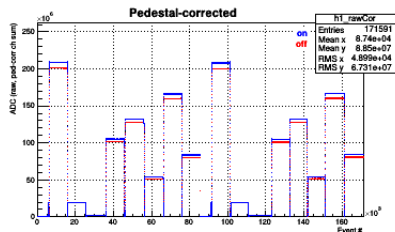
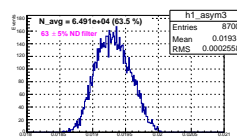
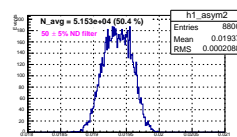
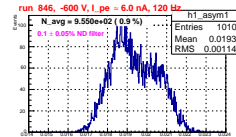
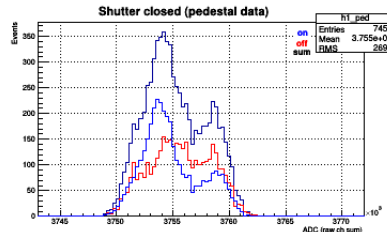
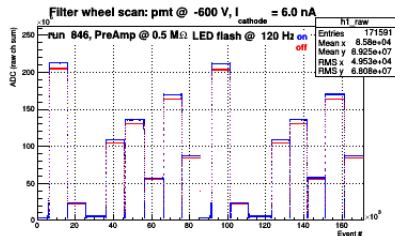
- What should LED Asymmetry be: 1%, 2%, 3%?
- Why is pedestal asymmetry bifurcated?
- How to handle 0.1% filter (very sensitive to pedestal fluctuations)?
- Repeatability Issue?
- The asymmetry plots for 6 nA LL seemed to be unusual (double Gaussian peaks for some filters).
- Strangeness for 6 nA LL?

Summary and future plans

- Very promising preliminary results for ≤ 3 nA LLs.
- Still need to take some more data and analyze before making any final conclusion.
- Non-linearity for PMT(# 4) was tested at four different LL (1nA, 3nA, 5nA and 6nA).
- Planning to calibrate DAC12 for some other (higher) LL and study non-linearity at those LLs.
- Other PMTs will also be tested in a similar way.
- Planning to explore the Qweak style non-linearity measurements which uses 3 LEDs (two of them will be flashing at different rate and one will be steady).

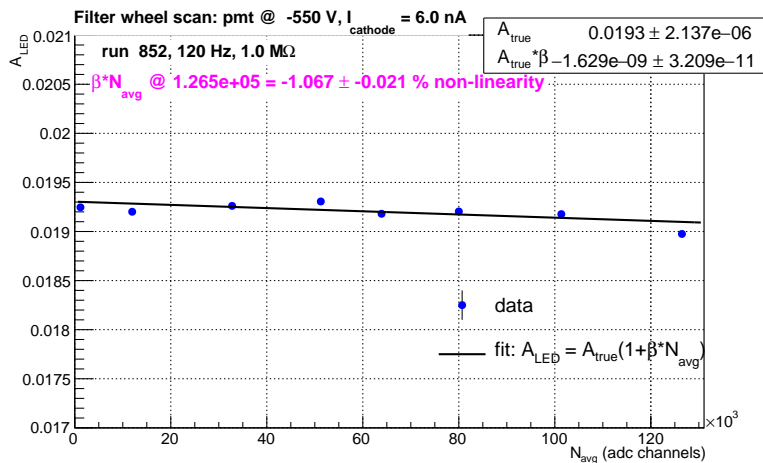
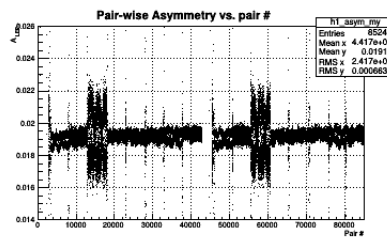
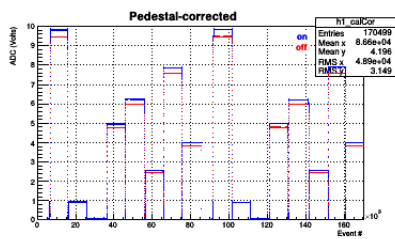
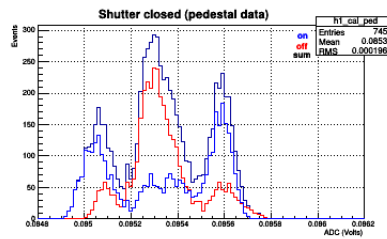
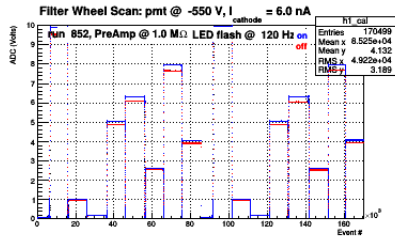
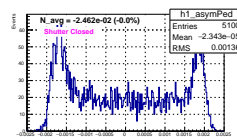
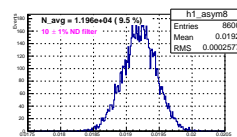
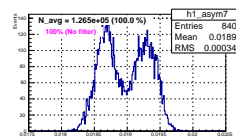
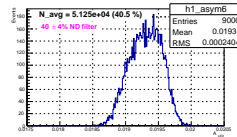
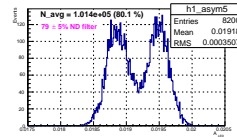
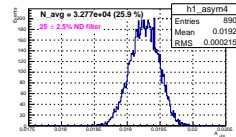
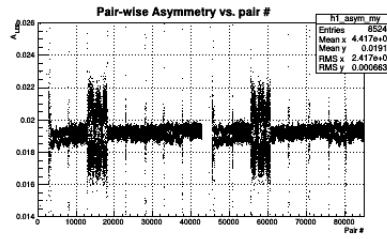
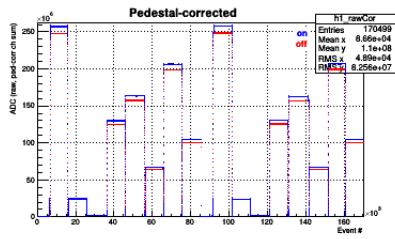
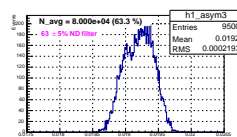
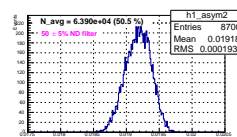
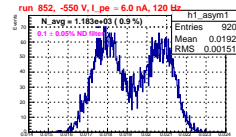
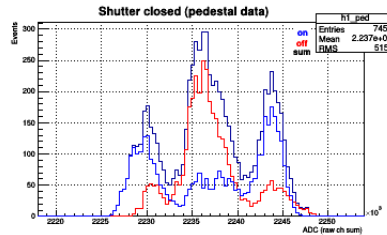
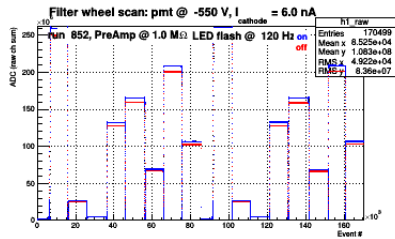
Some backup slides

- 6 nA LL Measurement with simple LED driver (i.e. 470 Ω resistor).
- 0.5 M Ω preAmp. and -600 V High Voltage.



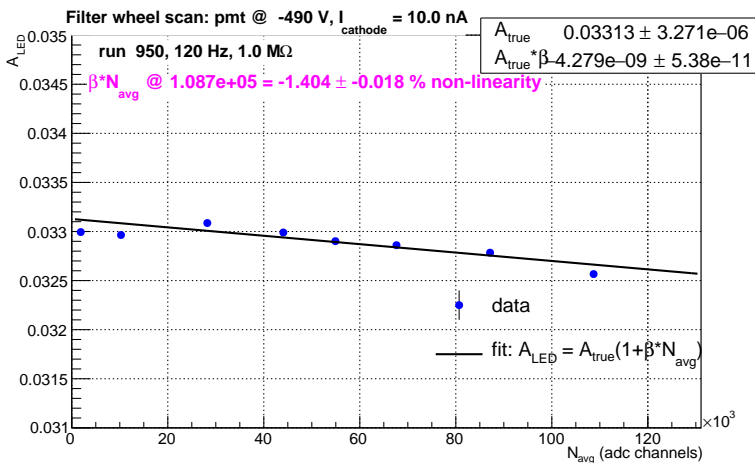
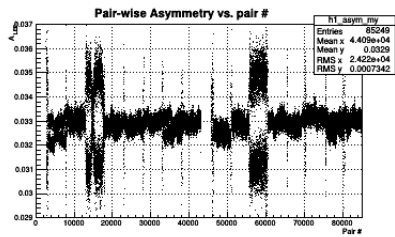
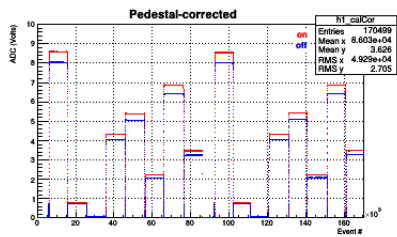
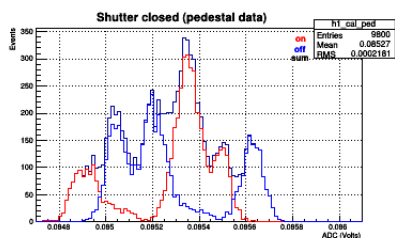
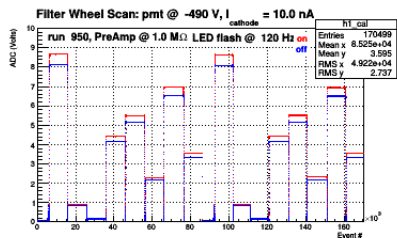
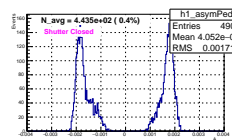
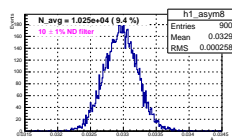
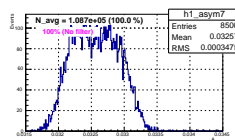
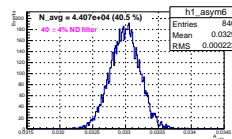
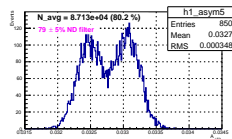
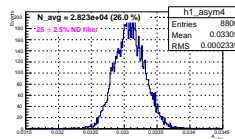
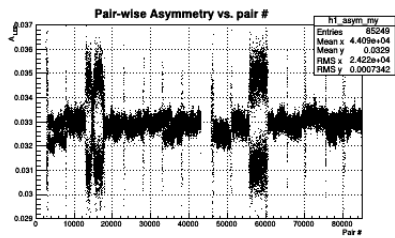
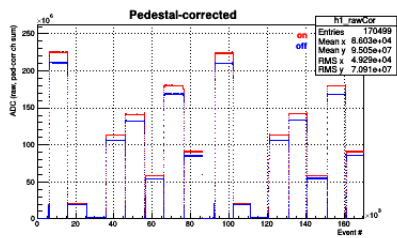
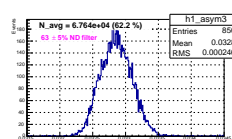
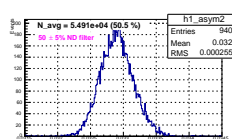
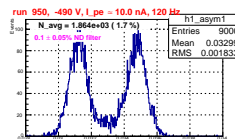
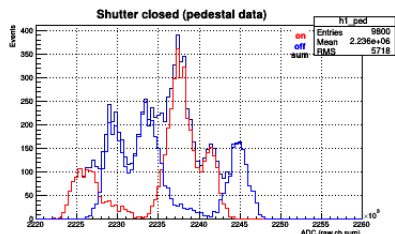
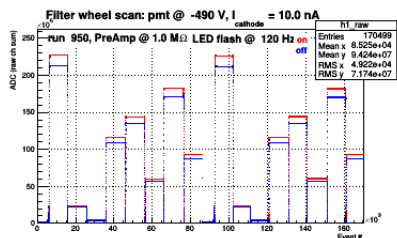
Some backup slides

- 6 nA LL Measurement with simple LED driver (i.e. 470 Ω resistor).
- 1 M Ω preAmp. and -550 V High Voltage.



Some backup slides

- 10 nA LL Measurement with simple LED driver (i.e. 470 Ω resistor).
- 1 M Ω preAmp. and -490 V High Voltage.



Some backup slides

- 10 nA LL Measurement with simple LED driver (i.e. 470 Ω resistor).
- 0.5 M Ω preAmp. and -550 V High Voltage.

