



cherenkov
telescope
array



LST Calibration

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University of Rijeka, 17/02/21



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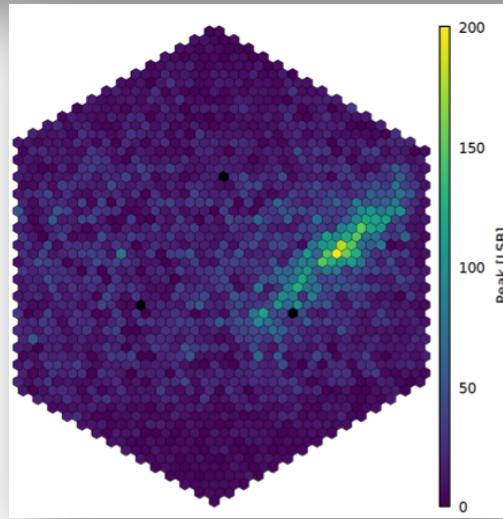
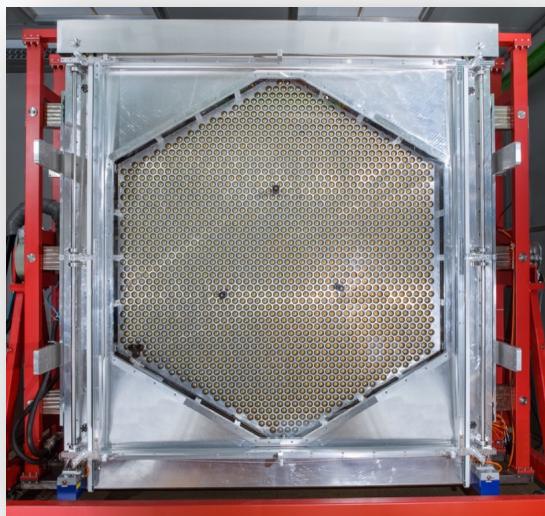
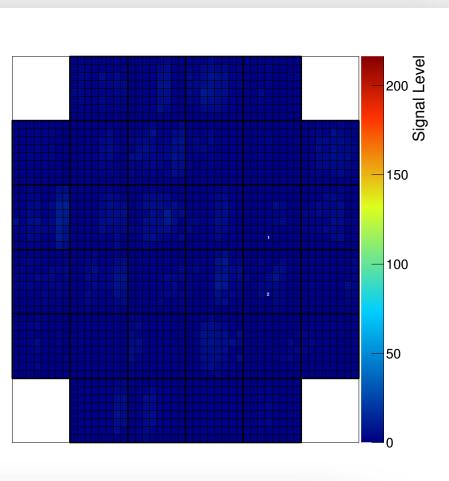
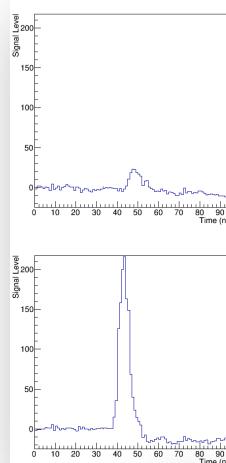




Data download

- Please get data from <http://data.lstcam.pic.es/Calib/20191124/v07/>
 - [calibration.Run1625.0000.hdf5](#)
 - [drs4_pedestal.Run1623.0000.fits](#)
 - [time_calibration.Run1625.0000.hdf5](#)
- And substitute those from the folder data/calibration

Signal detection and processing

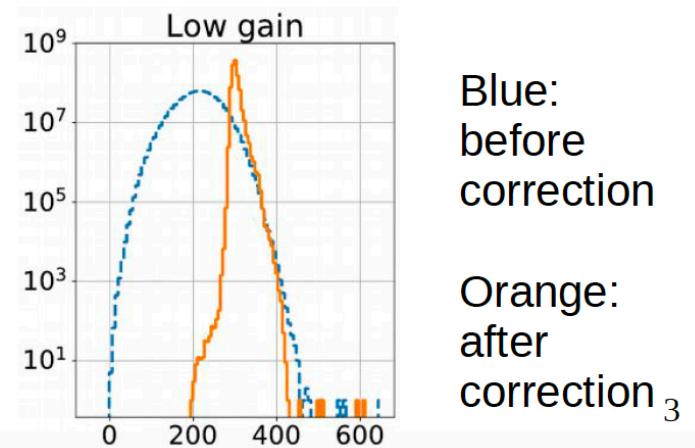
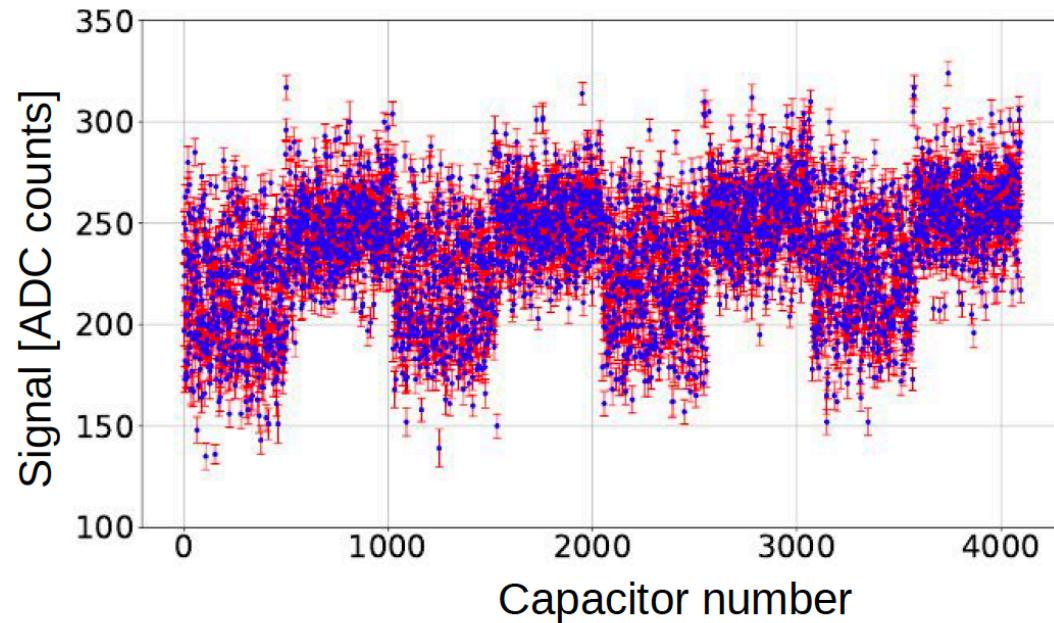


Low level calibration

- DRS4-based readout that needs to be corrected to properly extract charge and arrival time of pulses
- List of DRS4 corrections:
 - Capacitor-wise baseline correction
 - Time-lapse correction of the baseline
 - Tsutomu pattern
 - Spikes A&B
 - Spikes period32
 - Pulse arrival time correction
 - Pulse shape correction

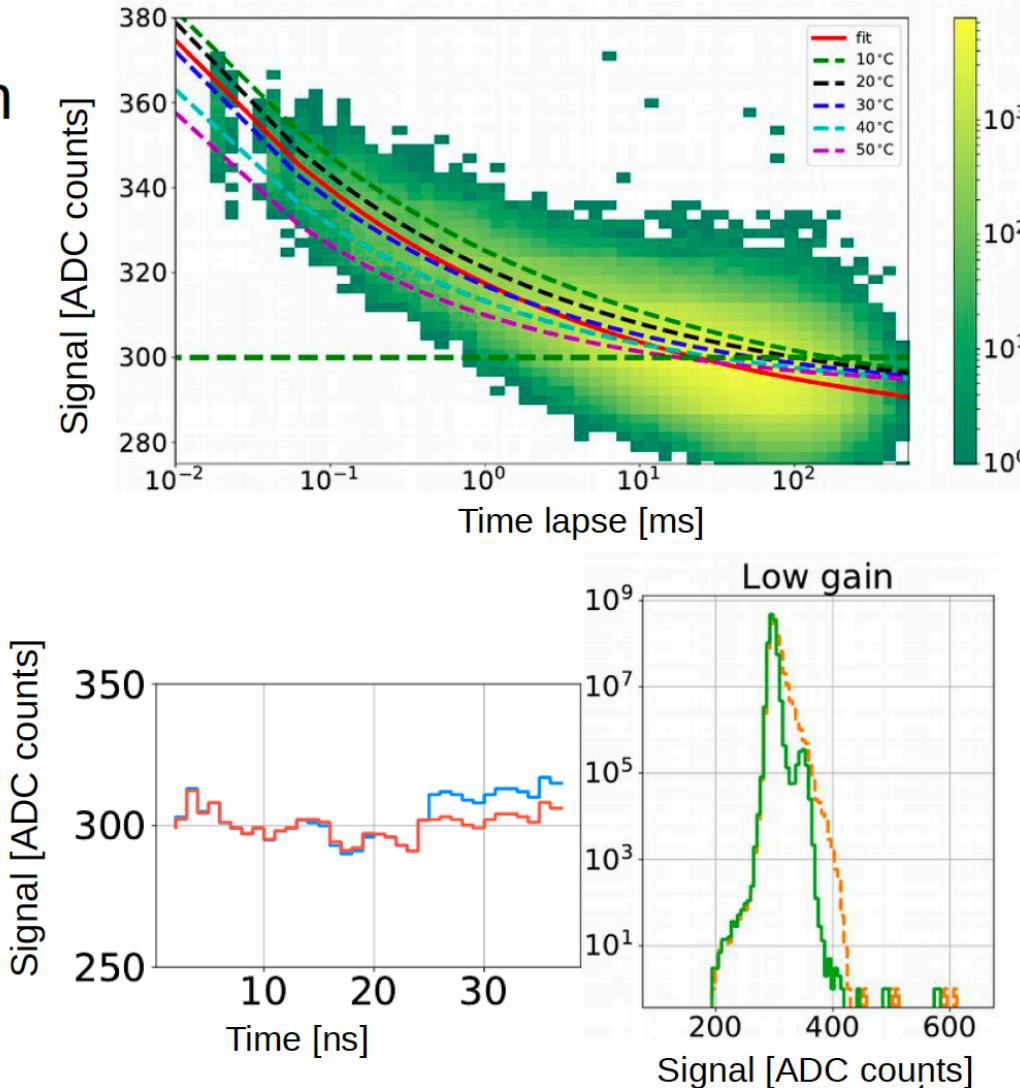
Capacitor with baseline correction

- Each capacitor has its own baseline value
- $4096 \times 2 \times 1855$ numbers obtained from pedestal file
- The most important correction
- Implemented in cta-Istchain and online in DAQ (using the same format of files with pedestal values)



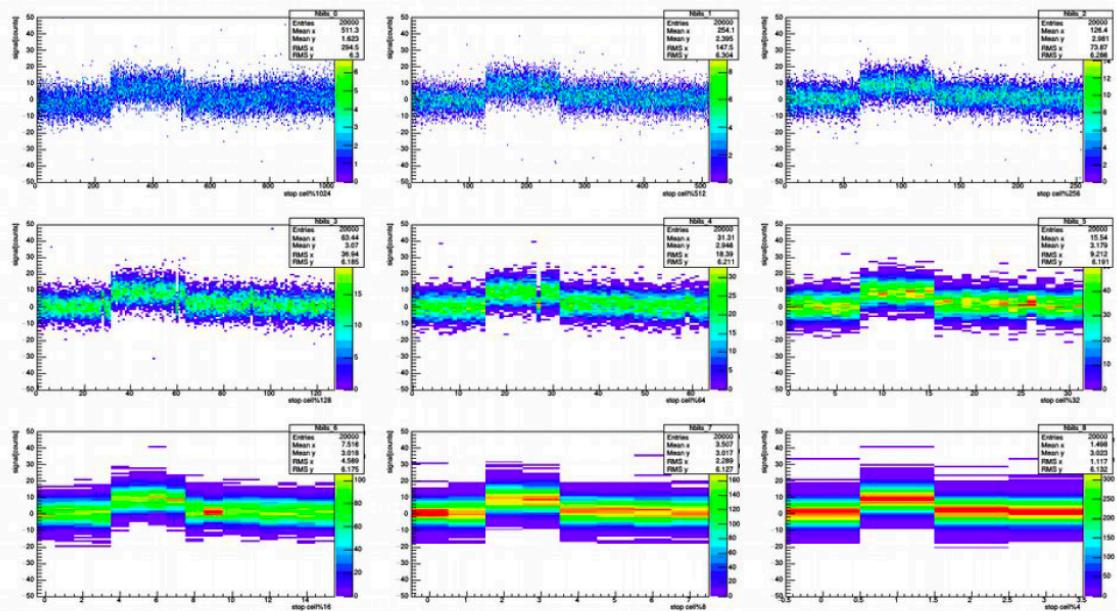
Time lapse correction

- Baseline jumps depending on the time to previous reading of the capacitor
- Implemented in cta-Istchain (including extra readings of capacitors)
- Partial implementation in DAQ
- To be investigated the effect of the unknown times in the first events



Tsutomu pattern

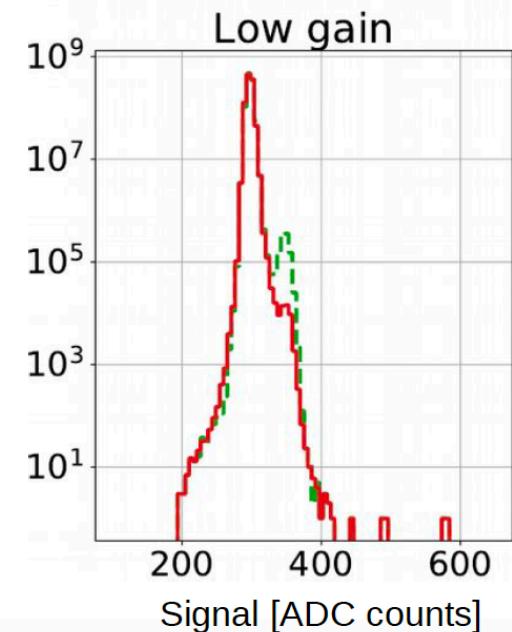
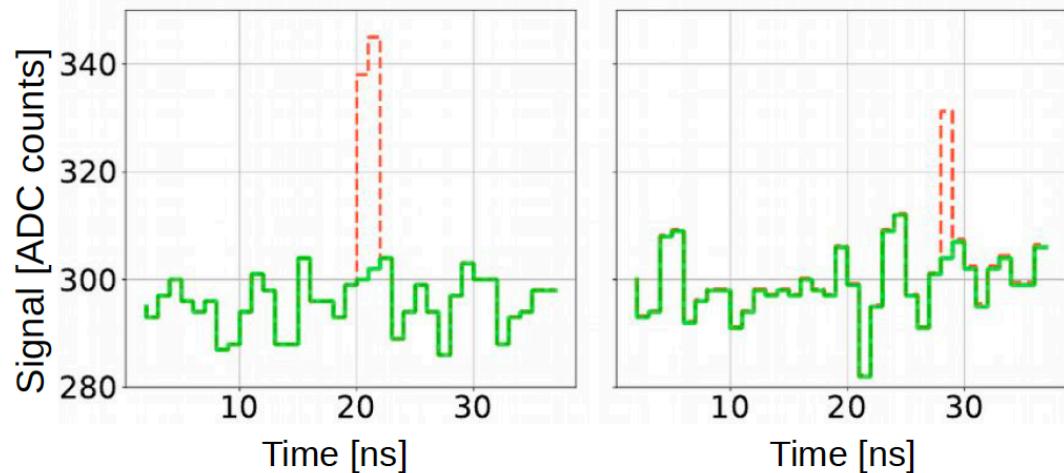
- Cross talk of individual bits of stop cell value on the first few capacitors
- Not implemented in cta-Istchain or in DAQ, but the effect is small and affects only the first ~10 samples



Plot with old lab data from Japan

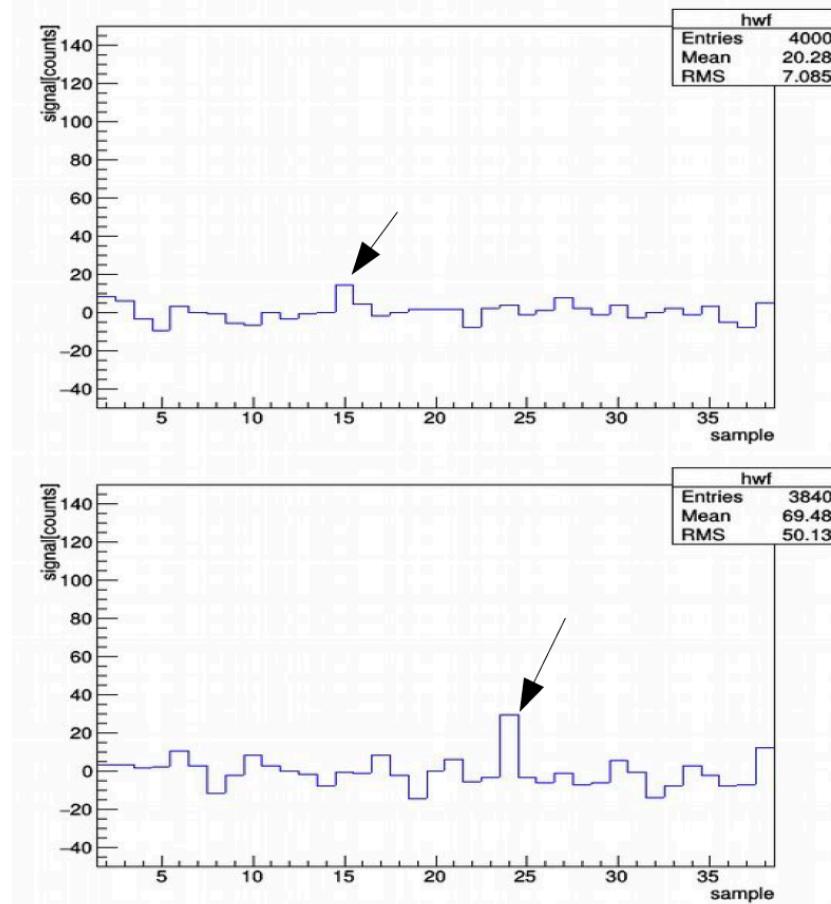
Spikes A & B

- Sharp spikes of mediocre amplitude occurring in **predictable** places in ROI
- Interpolation implemented in cta-lstchain, not yet in DAQ



Spikes with 32-slice period

- Small spikes occurring sometimes when position % 32 == 31
- Small amplitude and would require interpolation of 3% of the waveform
- No correction implemented in cta-lstchain nor in DAQ

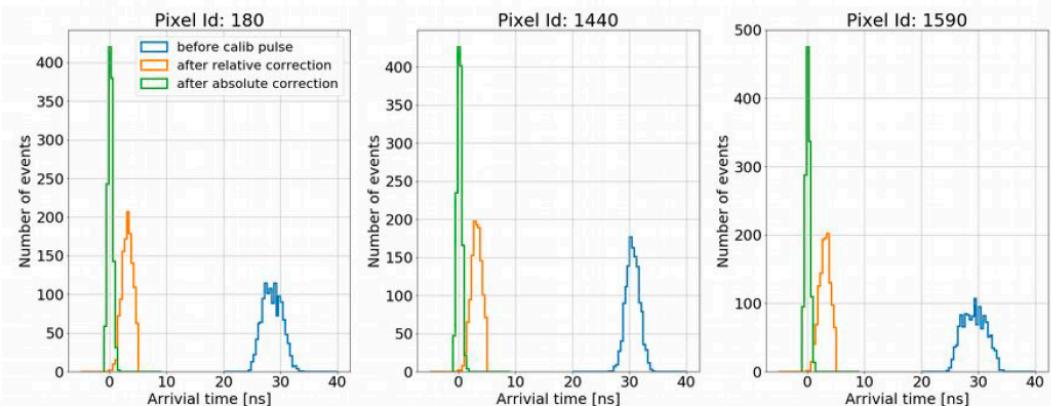
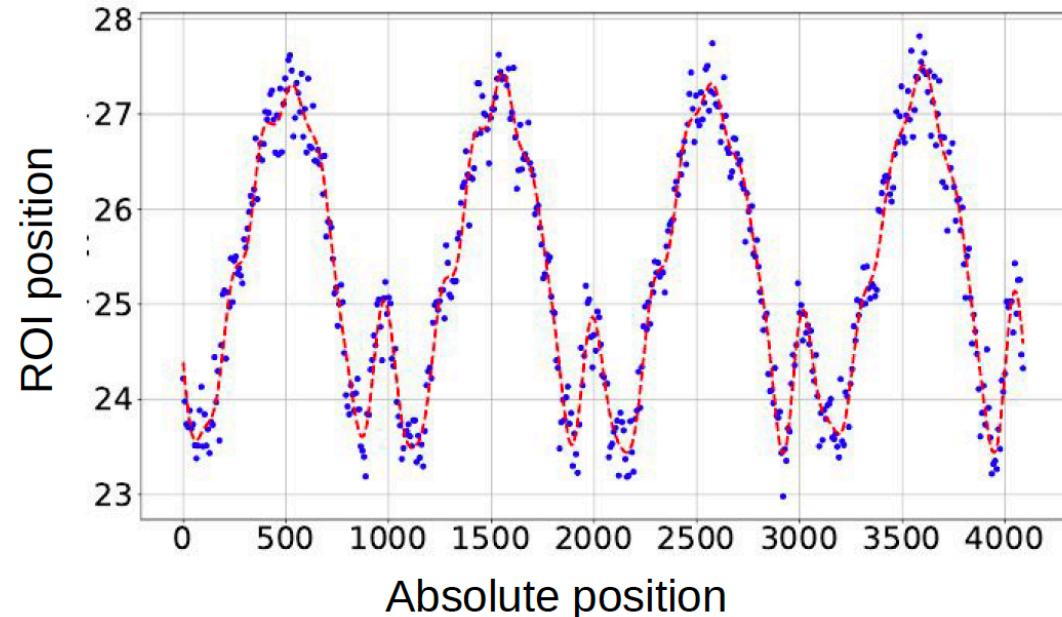


Plot with old lab data from Japan

Arrival time correction

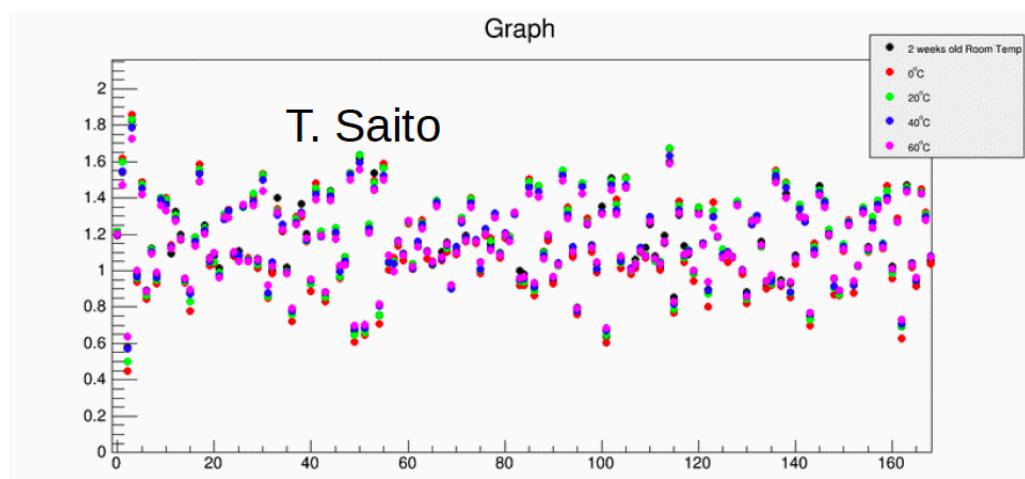
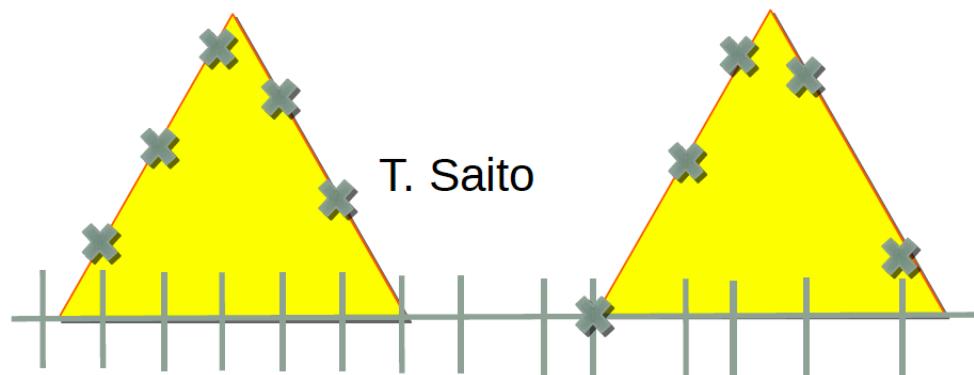


- Arrival time of pulses depends on the absolute position in DRS4 ring
- The correction curve is different for each (pair of) channel – parametrized with analytical Fourier expansion
- Code is ready in private repository, but not yet committed to cta-lstchain
- Not in DAQ (and it would be somewhat not natural to implement it there)



Pulse shape correction

- Non-uniform sampling of DRS4 can also distort somewhat the observed pulses.
- This can be calibrated with either a sine pulse, or huge (millions of events !) calibration pulse
- No correction (yet?) in cta-Istchain – need to be coordinated with signal extraction
- Correction in DAQ would be very complicated (and would increase the data size considerably)



Effect of corrections

Example: Run 1610 (DRS4 baseline correction online)

Single pixel histogram
(high gain) on closed
camera run.

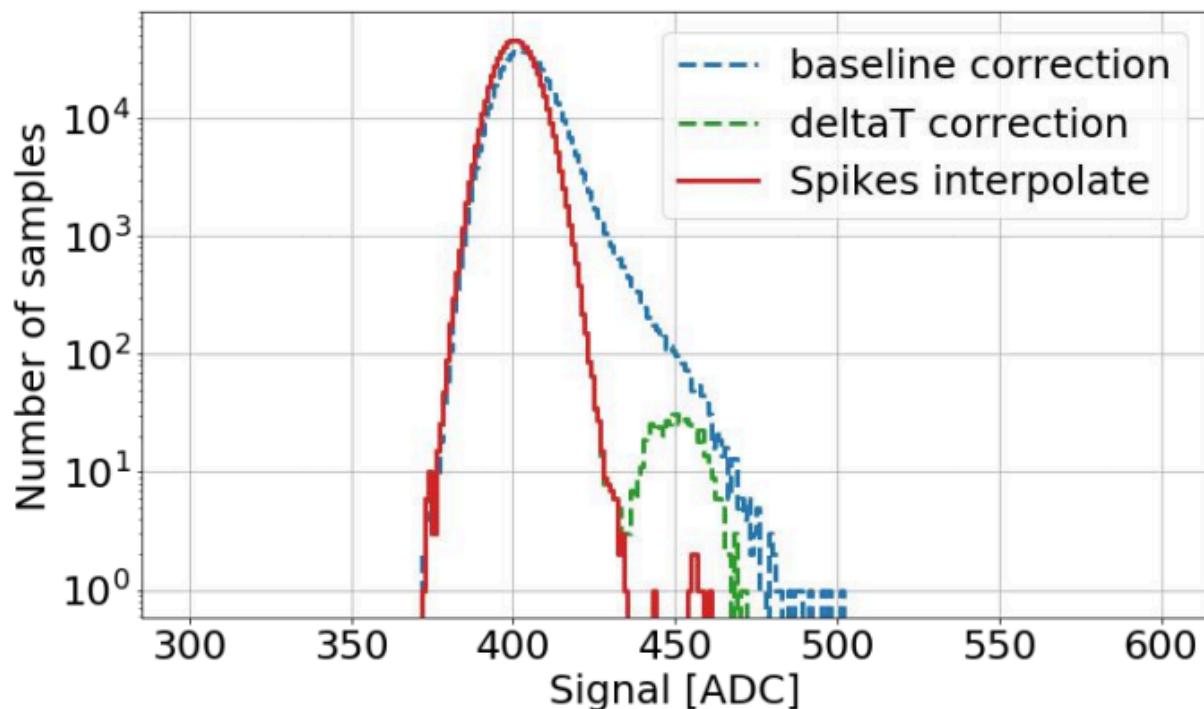
RMS after:

- baseline corr: 8.2

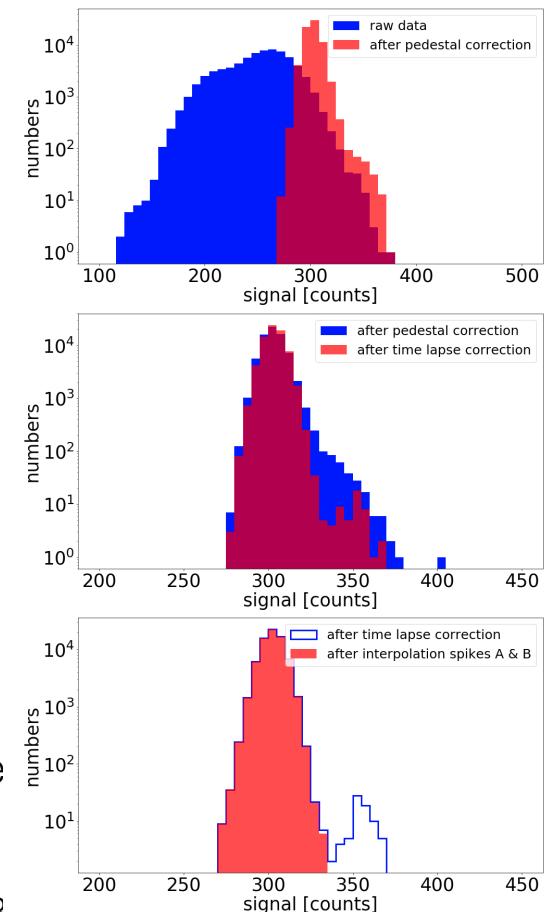
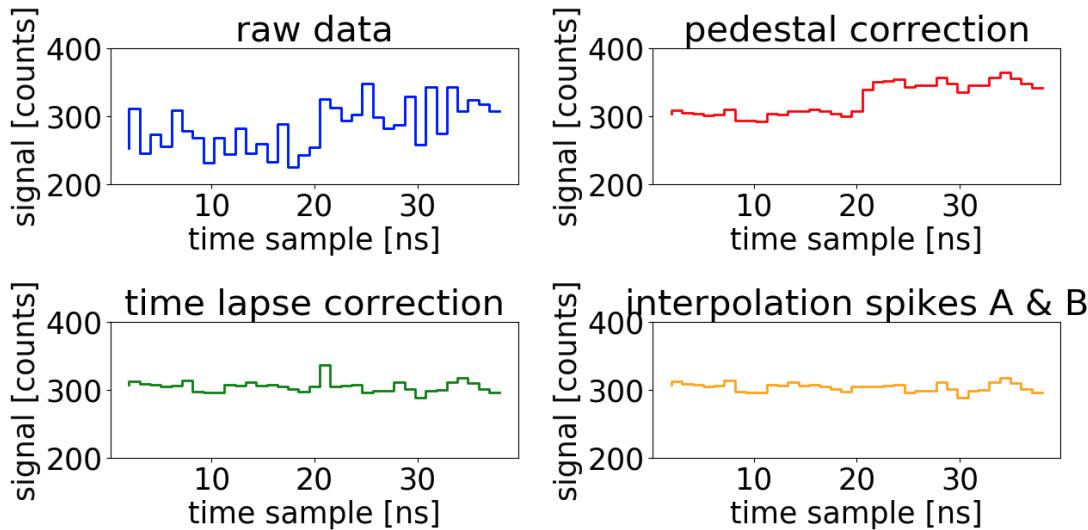
ADC

- deltaT corr: 6.4 ADC
- spikes interpolate: 6.3

ADC



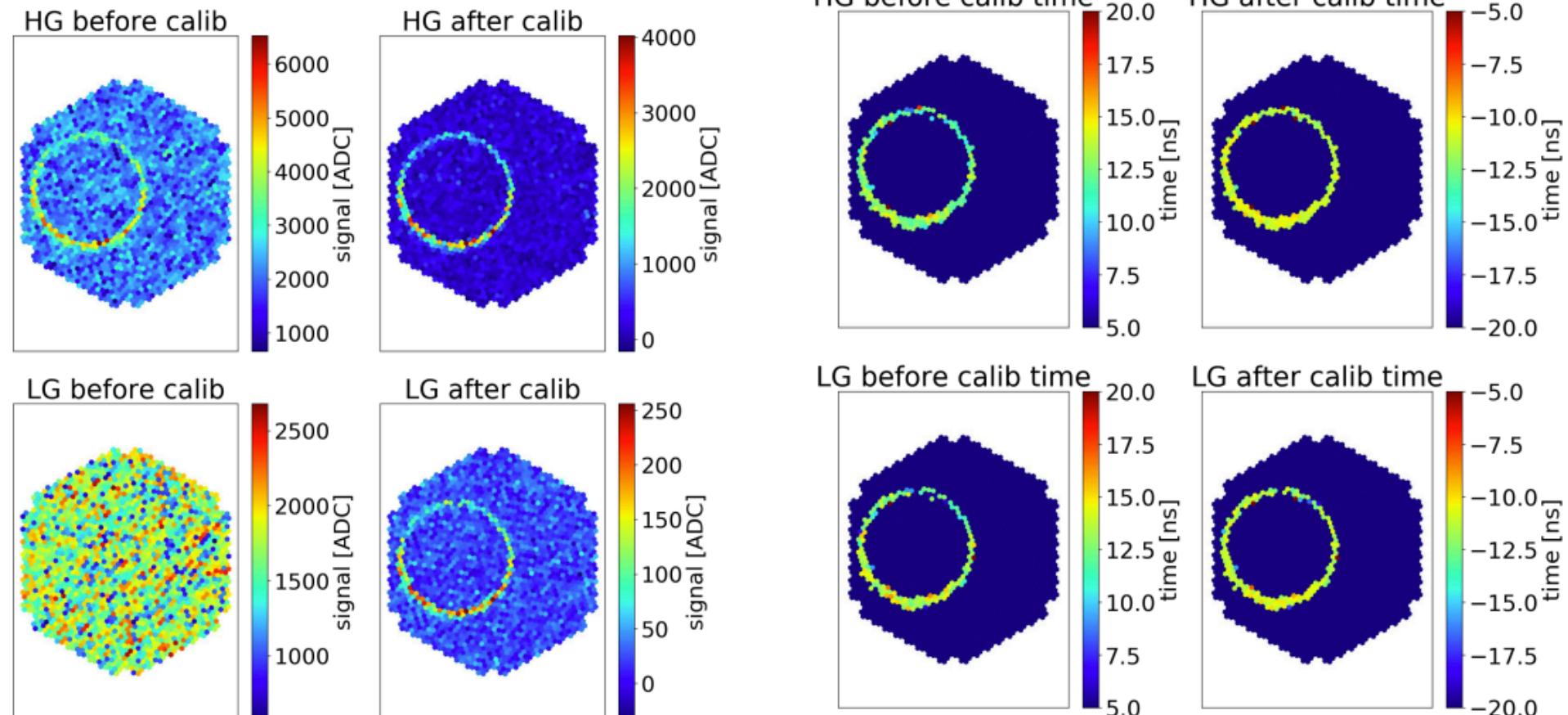
Effect of corrections



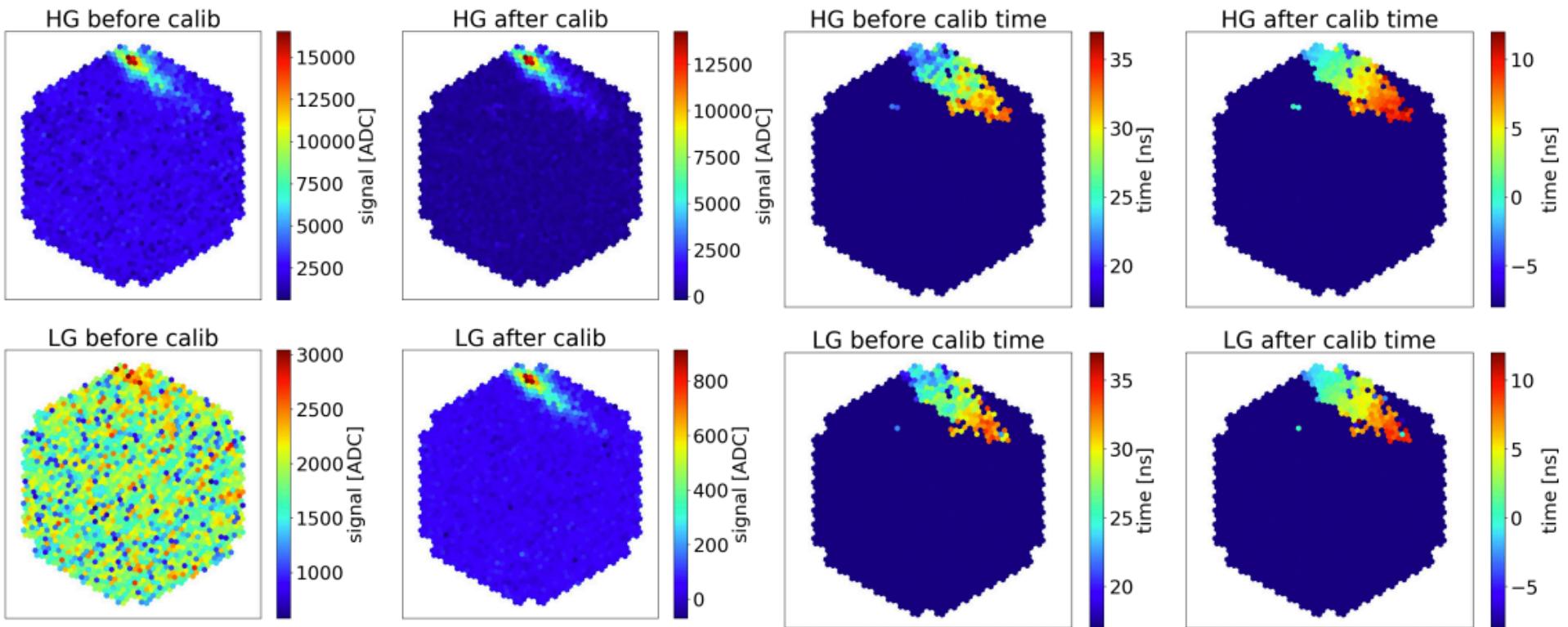
- We use a DRS4-based readout that needs to be corrected
- Readout Corrections currently applied at software level:
 - Subtract pedestal (baseline) of each of the 4096 capacitors of a given pixel.
 - Dependence of the baseline on the time elapsed since the last reading of the given DRS4 cell.
 - Interpolate spikes A & B.
- They will be directly implemented in the Event Builder (EvB3,
 - Everything implemented and under validation

RMS=7.5 ADC counts

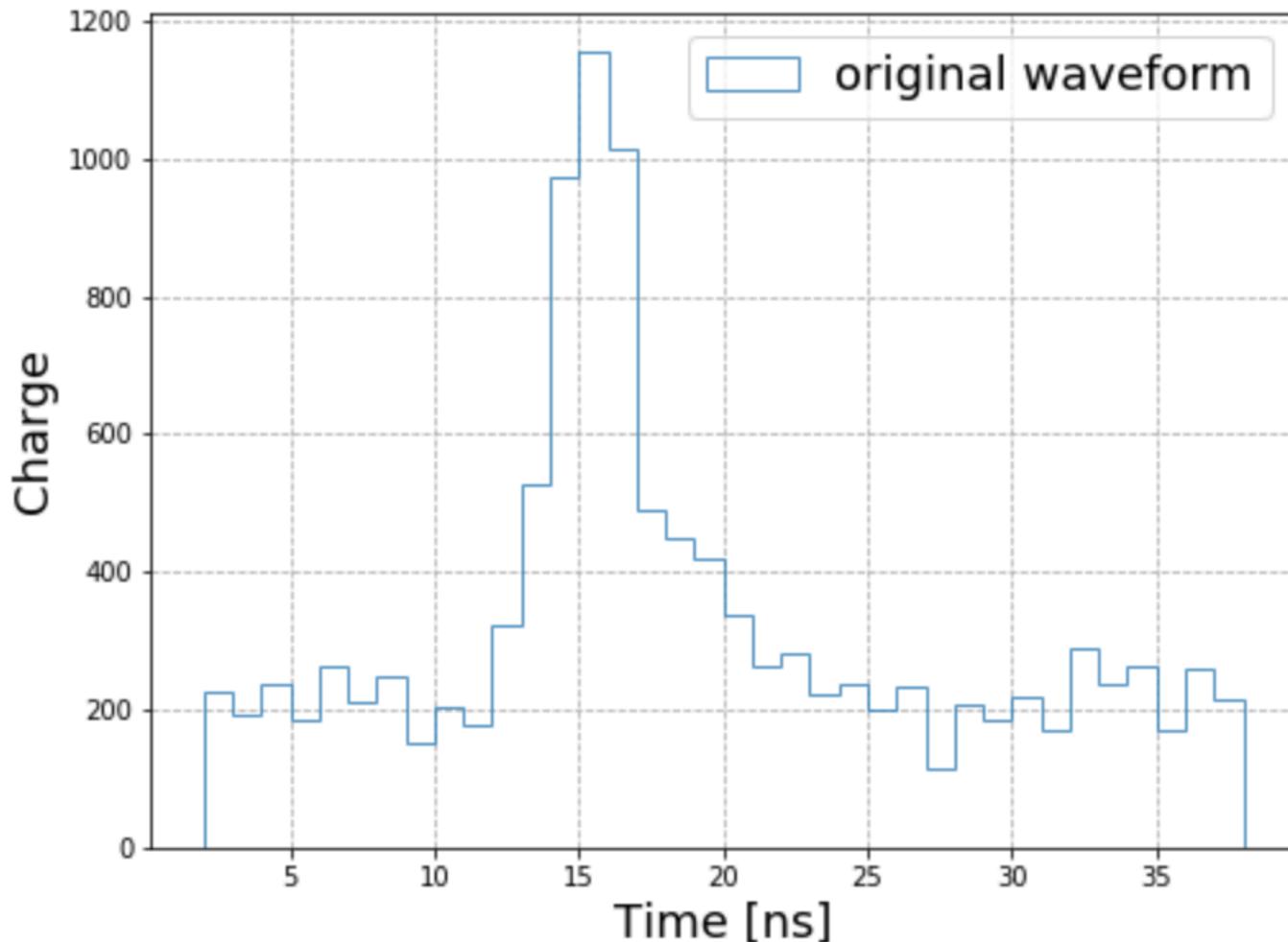
Images before and after corrections



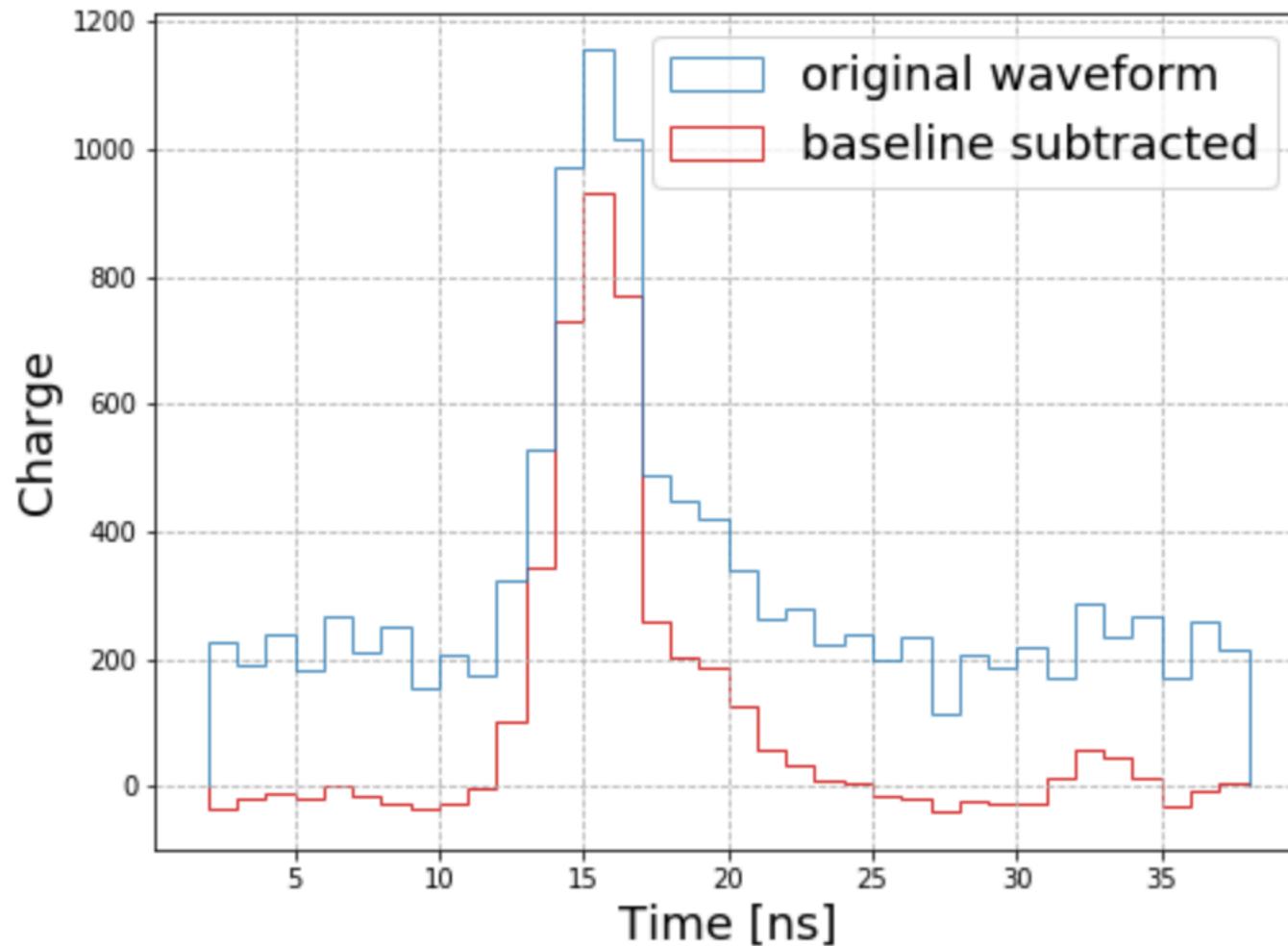
Images before and after corrections



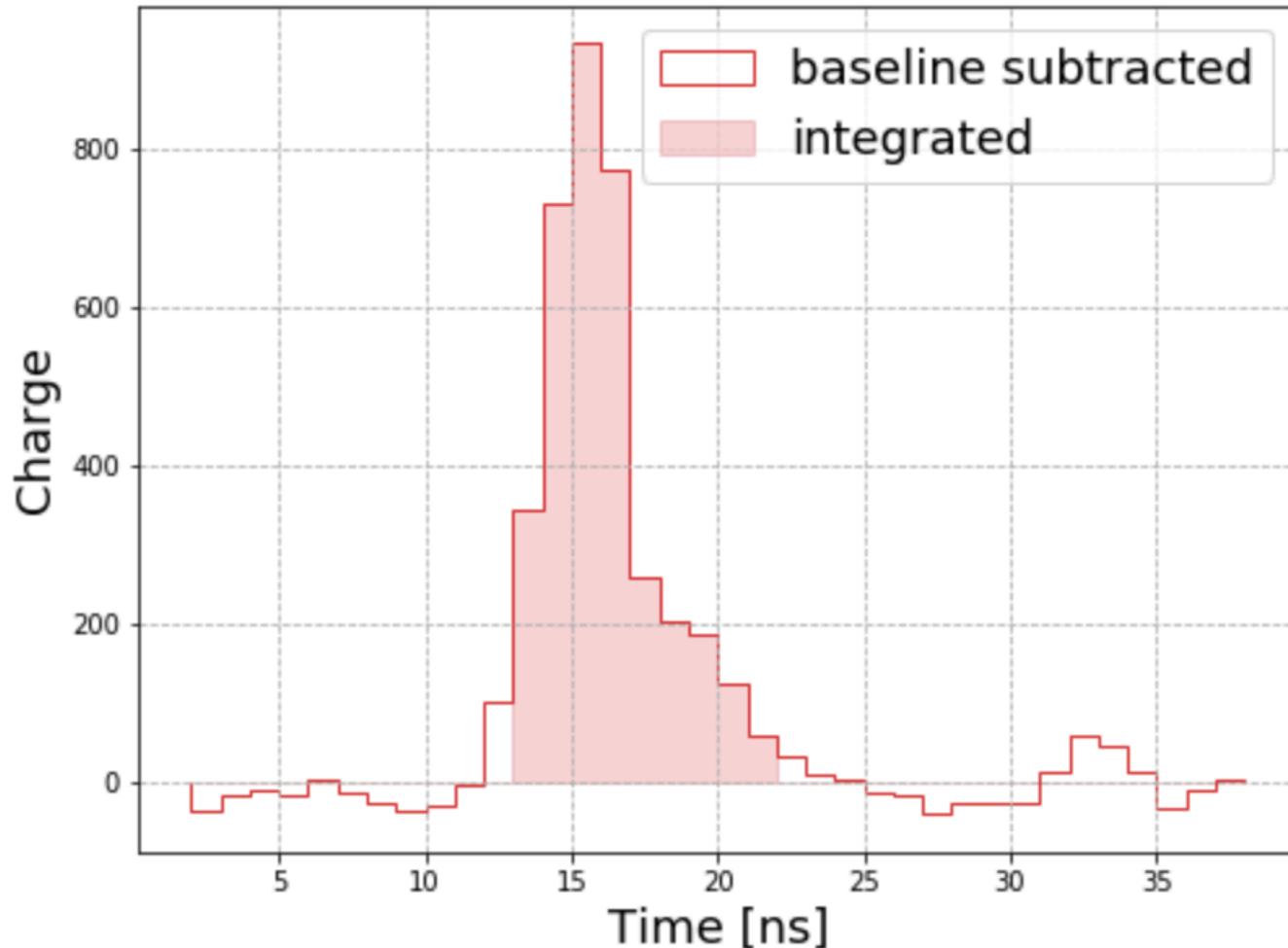
Signal extraction



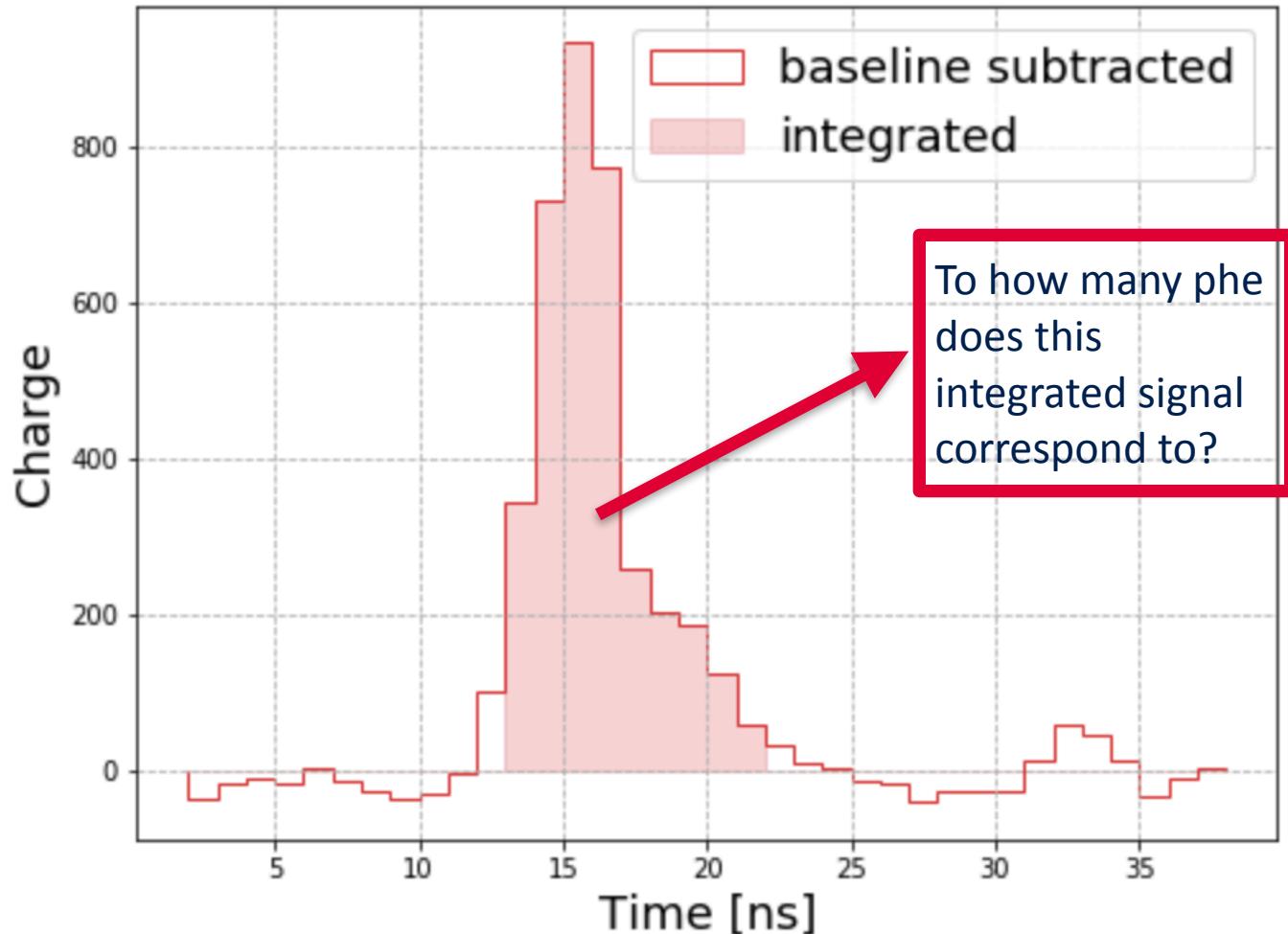
Signal extraction



Calibration

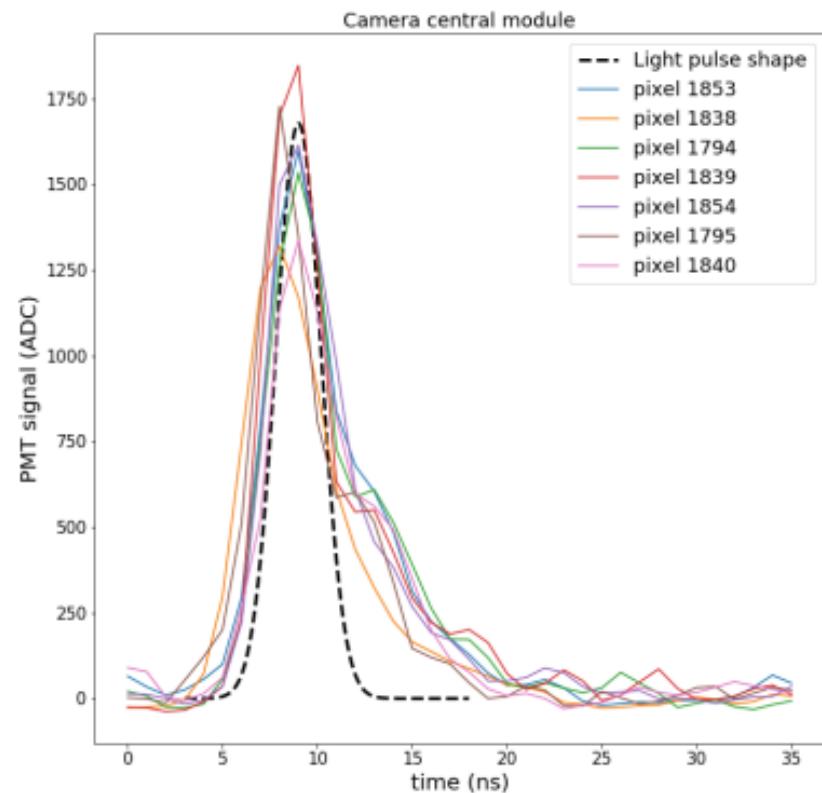
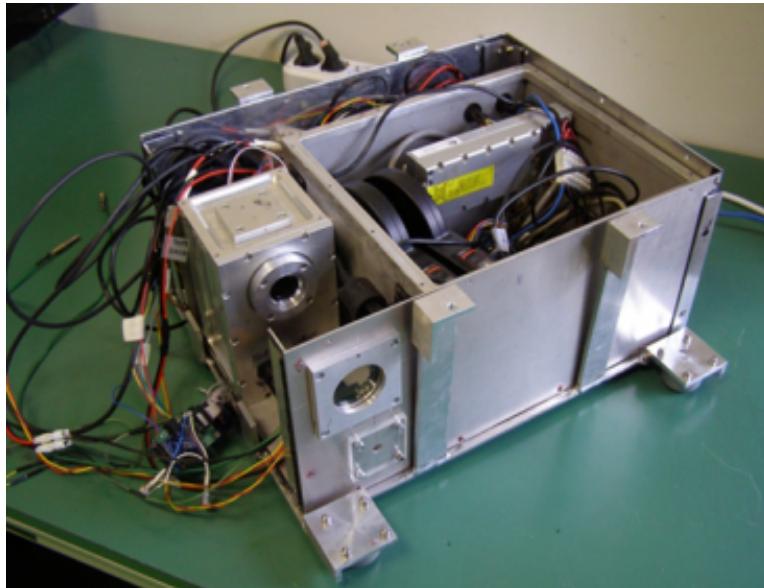


Calibration



High level calibration

- Transformation of integrated ADC counts into photoelectrons
 - We need a light flasher (calibration box) and perform a calculation of conversion factors



Absolute camera calibration

R1 calibration is based on the following formula

$$\text{waveform(p.e.)} = \frac{\text{waveform(ADC)} - \text{pedestal(ADC)}}{\text{gain}} \times \text{FF}$$

Estimation of the gain in LST:

- Photon statistics method
- Others?

Photon statistics method

Permits to estimate the gain: ADC to p.e. conversion coefficient

In ideal detector:

	Response	gain
	$\langle R \rangle = g \langle N_{pe} \rangle$	\rightarrow $g = \frac{\sigma_R^2}{\langle R \rangle}$
	$\sigma_R = g \sqrt{N_{pe}}$	

In real detector:

$$g = \frac{1}{(1+\beta^2)} \frac{\sigma_R^2 - \sigma_{ped}^2}{\langle R \rangle - P}$$

β = Width of SPE in pe

$\sqrt{1+\beta^2}$ = Excess Noise Factor

Photon statistics method

If the flasher has a resolution: $B_f = \sigma_f / \bar{f}$ f = light flux

$$g \sim \frac{1}{ENF^2} \frac{\sigma_R^2 - \sigma_{ped}^2}{(1+B_f^2)(\langle R \rangle - P)}$$



Gain estimation with a light pulser

Ref: MST-CAM-TN-0060
Version: 1.0
Date: December 1, 2014
Page: 1/39

Described in detail in:

Gain estimation with a light pulser

Authors:

Stephen Fegan - LLR (France)

Approved By:

Not required – informational only

Calibration

- Interleaved information included in the DLx files
 - Unfortunately tagging information of current interleaved data is mostly non reliable.
- HG vs LG agreement pretty good after the implementation of the latest low level correction curves.

File Node Dataset Settings Window Help

Tree of databases

- dl1_LST-1.1.Run01626.0000.h5
 - instrument
 - dl1
 - event
 - telescope
 - monitoring
 - pedestal
 - flatfield
 - calibration
 - image
 - parameters

Query results

calibration Storage of DL1MonitoringEventIndex

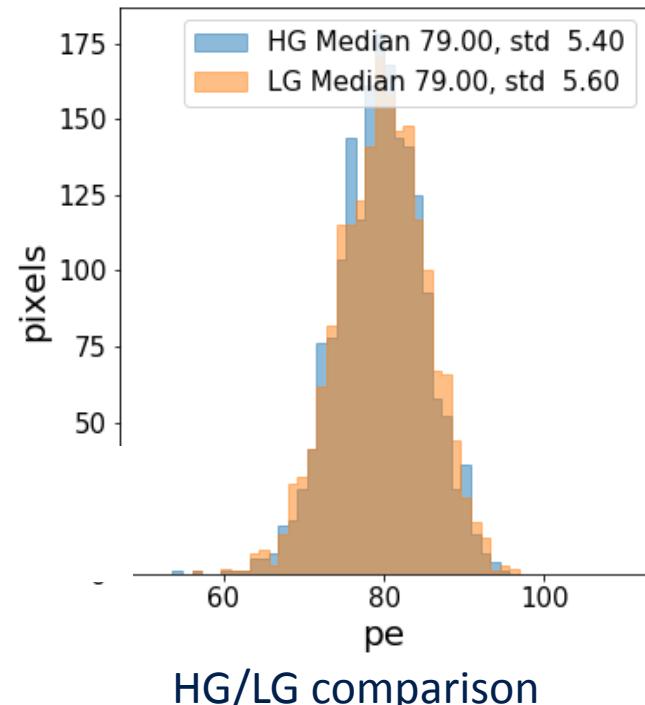
calibration_id	dc_to_pe	flatfield_id	n_pe	pede
0	[[0.0115130...	0	[[85.760906...	0
1	[[0.0132450...	1	[[38.188792...	1
2	[[0.0129185...	2	[[89.21834...	2

pedestal Storage of DL1MonitoringEven

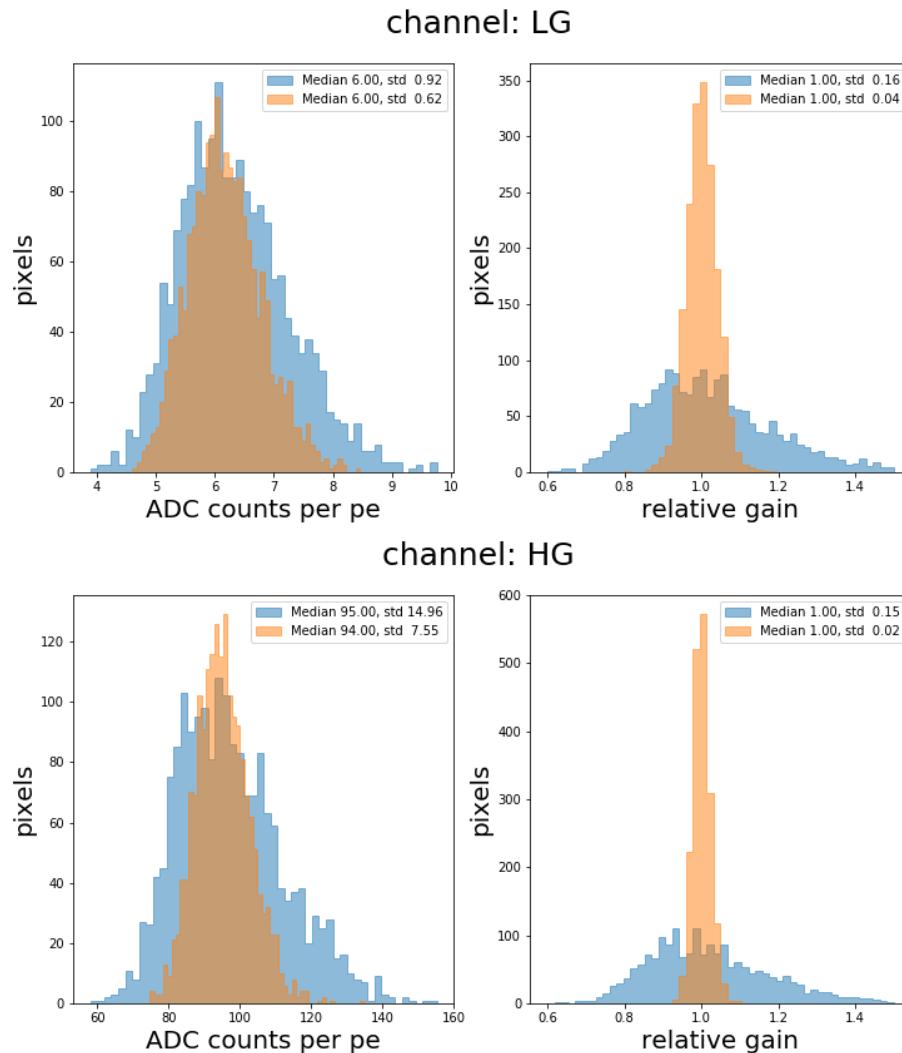
charge_std	charge_std_out	flatfield_id	n_events	pede
[[187.28809...	[[False, False, ...	0	10000	0
[[209.06305...	[[False, False, ...	0	10	1
[[122.65190...	[[False, False, ...	1	10	2

flatfield Storage of DL1MonitoringEvent

calibration_id	charge_mean	charge_median	charge_std	charge
0	[[7460.4141,...	[[7439. ,713...	[[False, False, ...	[[900.
1	[[7149.8,659...	[[6607., ,659...	[[False, False, ...	[[1199
2	[[6820.2,700...	[[6848.5,703...	[[False, False, ...	[[823.



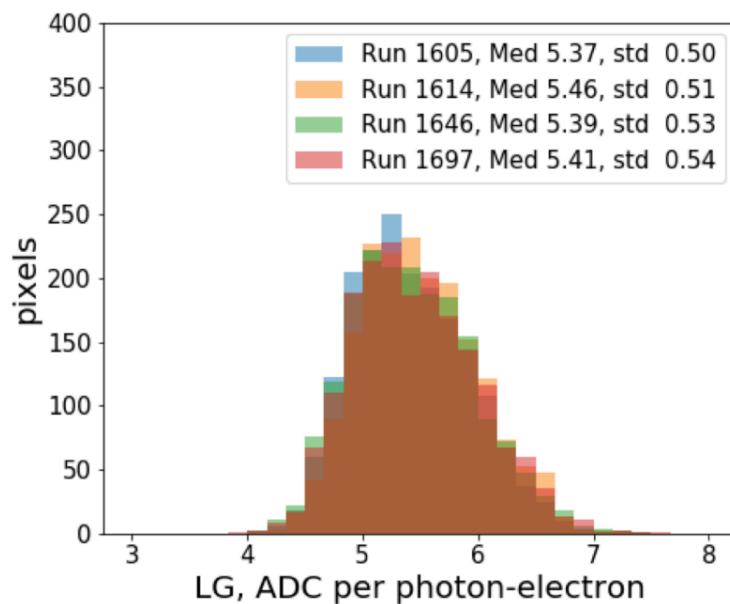
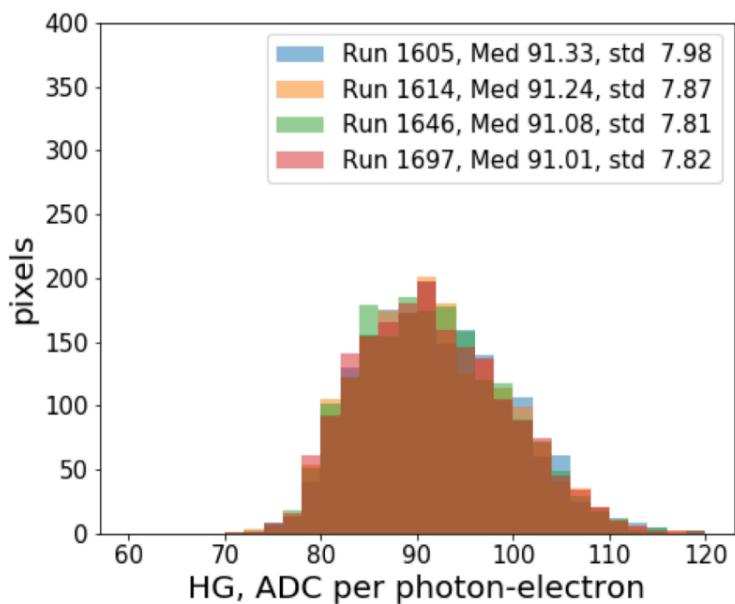
Flatfield with interleaved pedestals

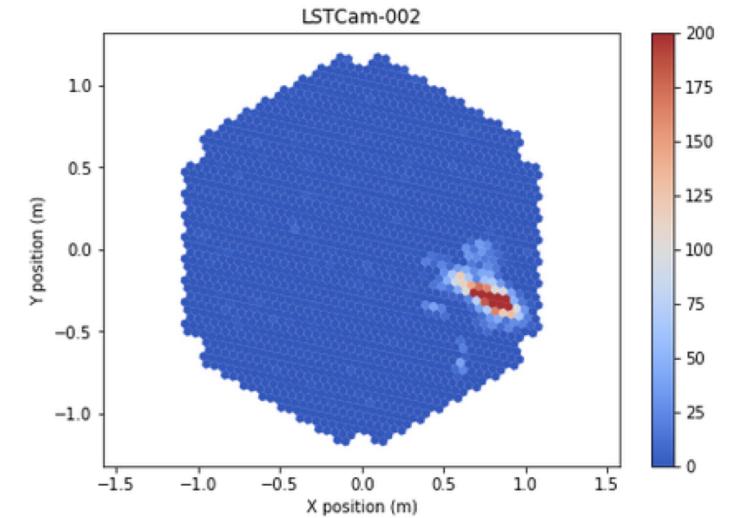
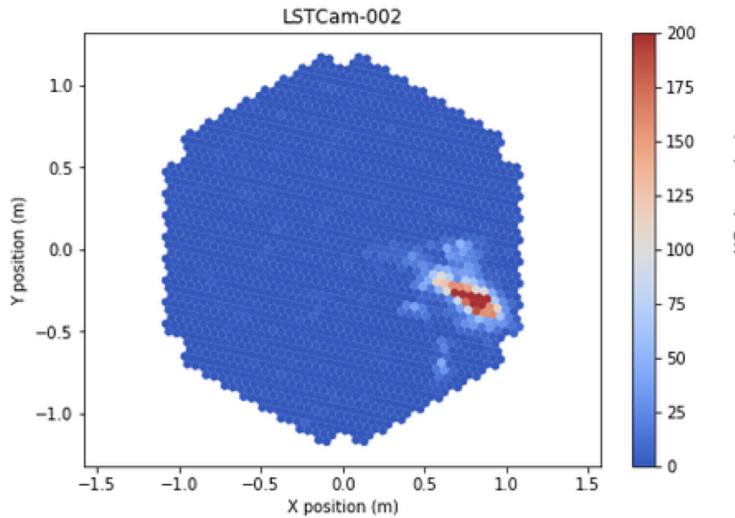
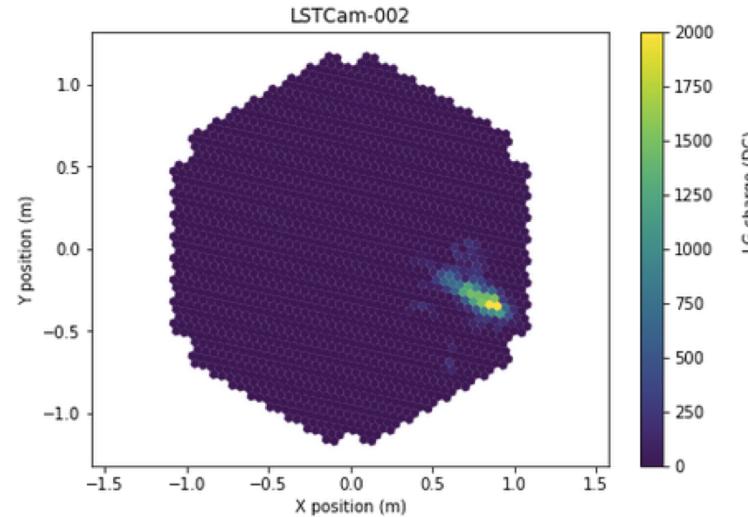
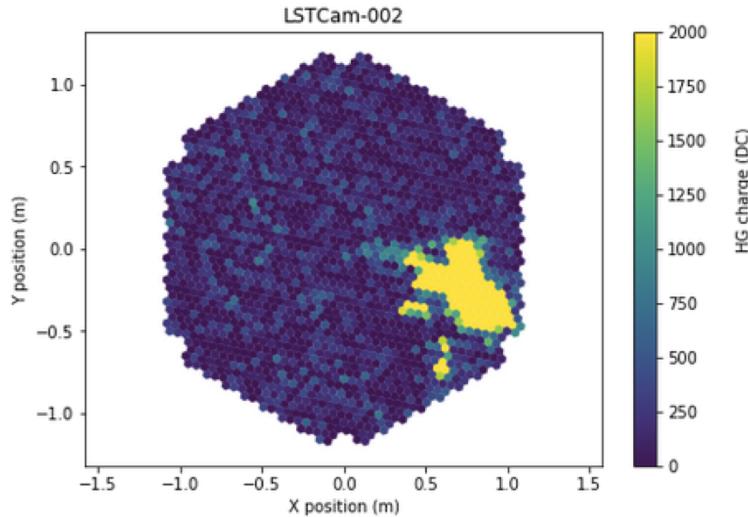


- Flatfield dataset taken with interleaved pedestals
- ADC values before and after flat fielding
- Gain standard deviation after flat-fielding is $\sim 2\%$
- See talk by Franca in this session

Gain stability

- Gain stable over different days
- HG/LG ~ 17

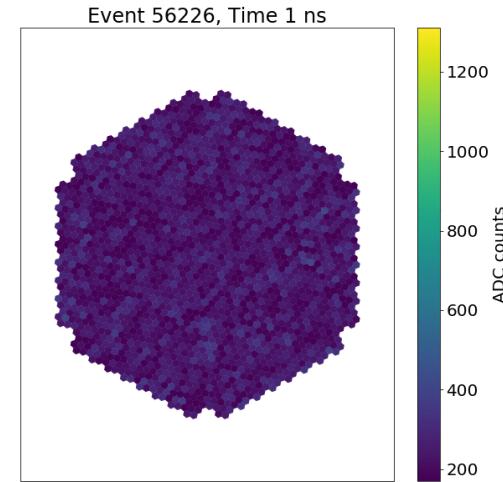




Muons: what are they used for?

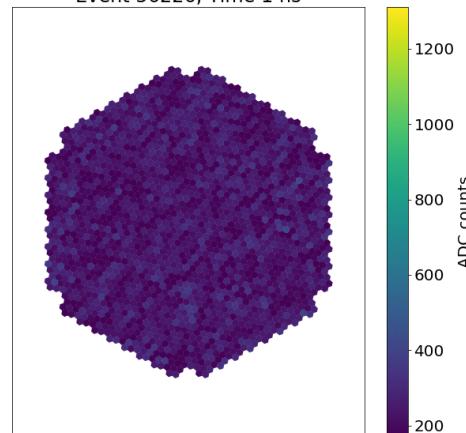


- Fast online calibration + monitoring of optical performance
- Essential to calculate the absolute optical efficiency of the system
- Charge integration using the **GlobalPeak** integrator
 - It takes an average of the arrival times of the full camera array and integrates a signal around that time.
 - The window we choose is the same as for real data (width 8ns)
 - It makes the signal extraction unbiased (contrary to LocalF that searches for the maximum of the signal).
 - The signal is **corrected** for sampling inhomogeneities and different integration windows in FlatField and cosmic events.
- Analysis now using new developments available in ctapipe v0.8 and moving towards an integrated analysis into the dl1-stage writing.

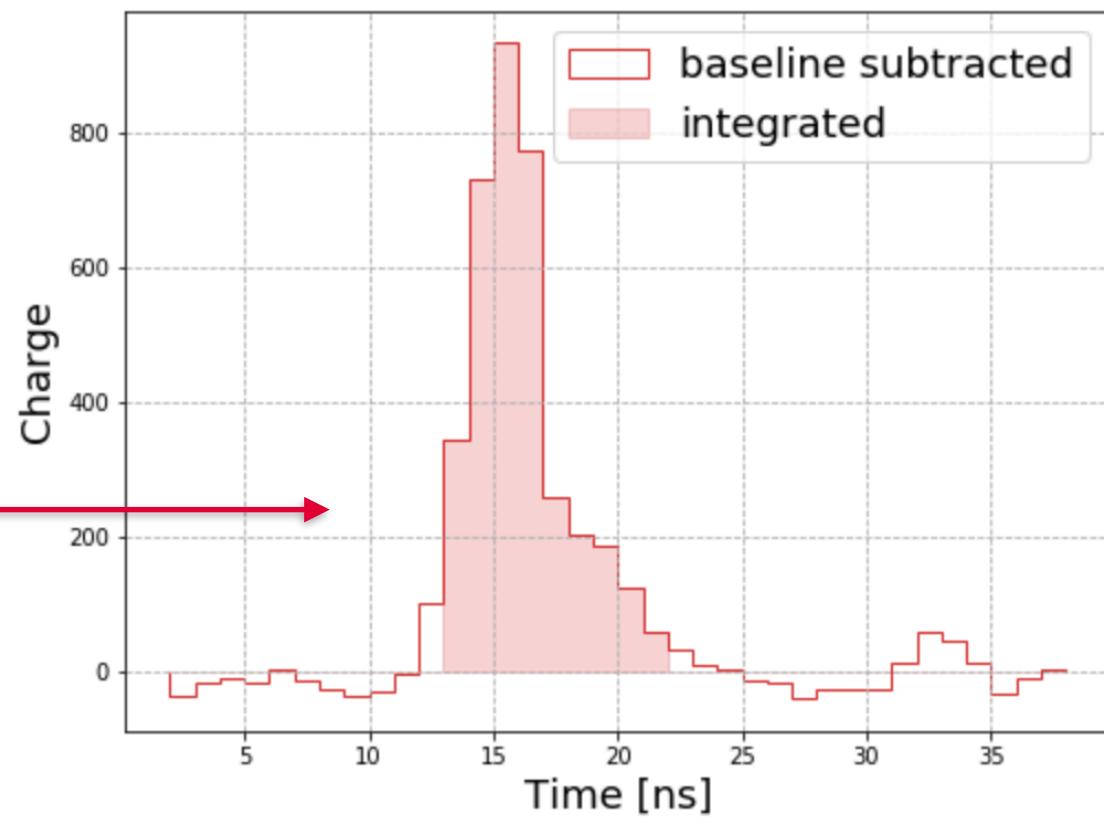
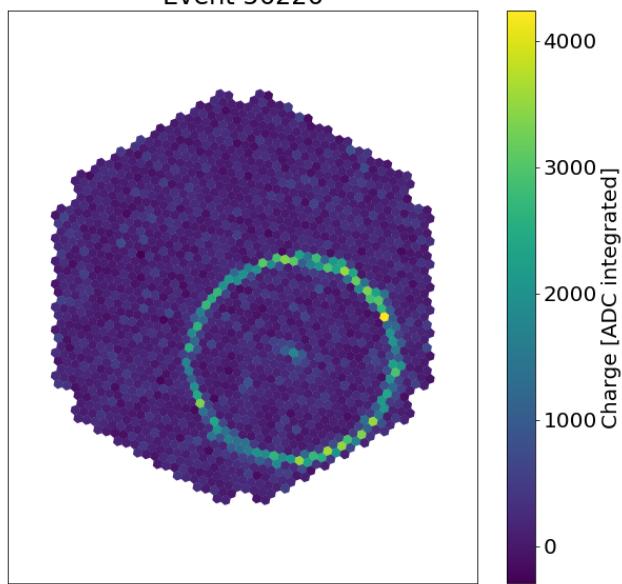


Calibration

Event 56226, Time 1 ns

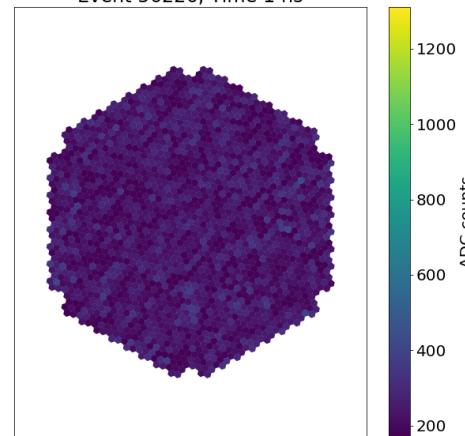


Event 56226

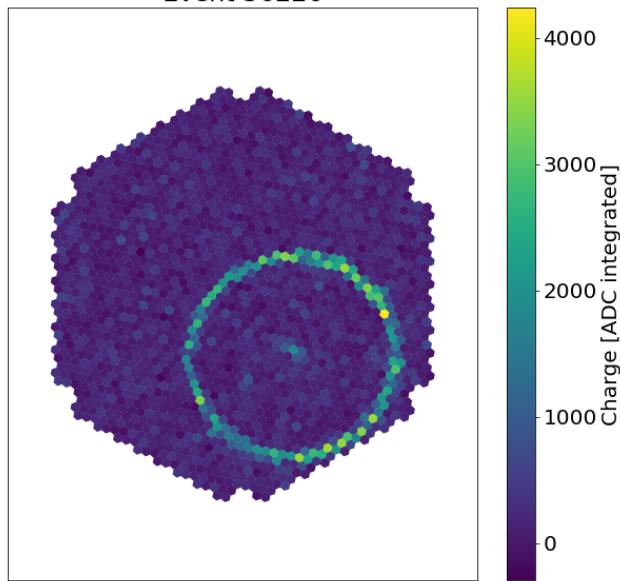


Calibration

Event 56226, Time 1 ns

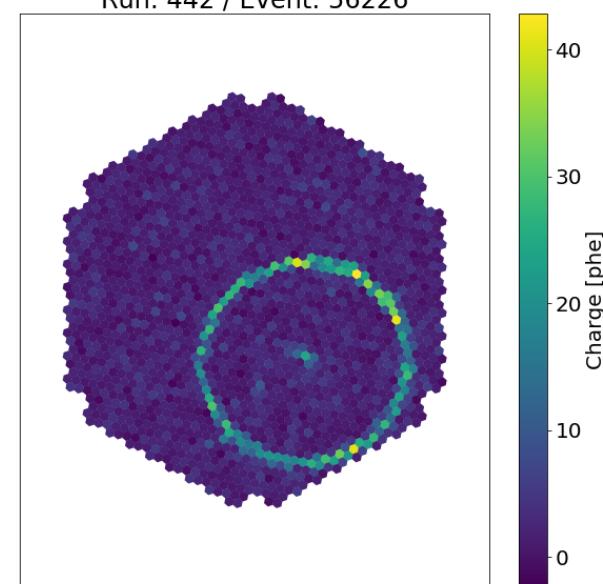


Event 56226

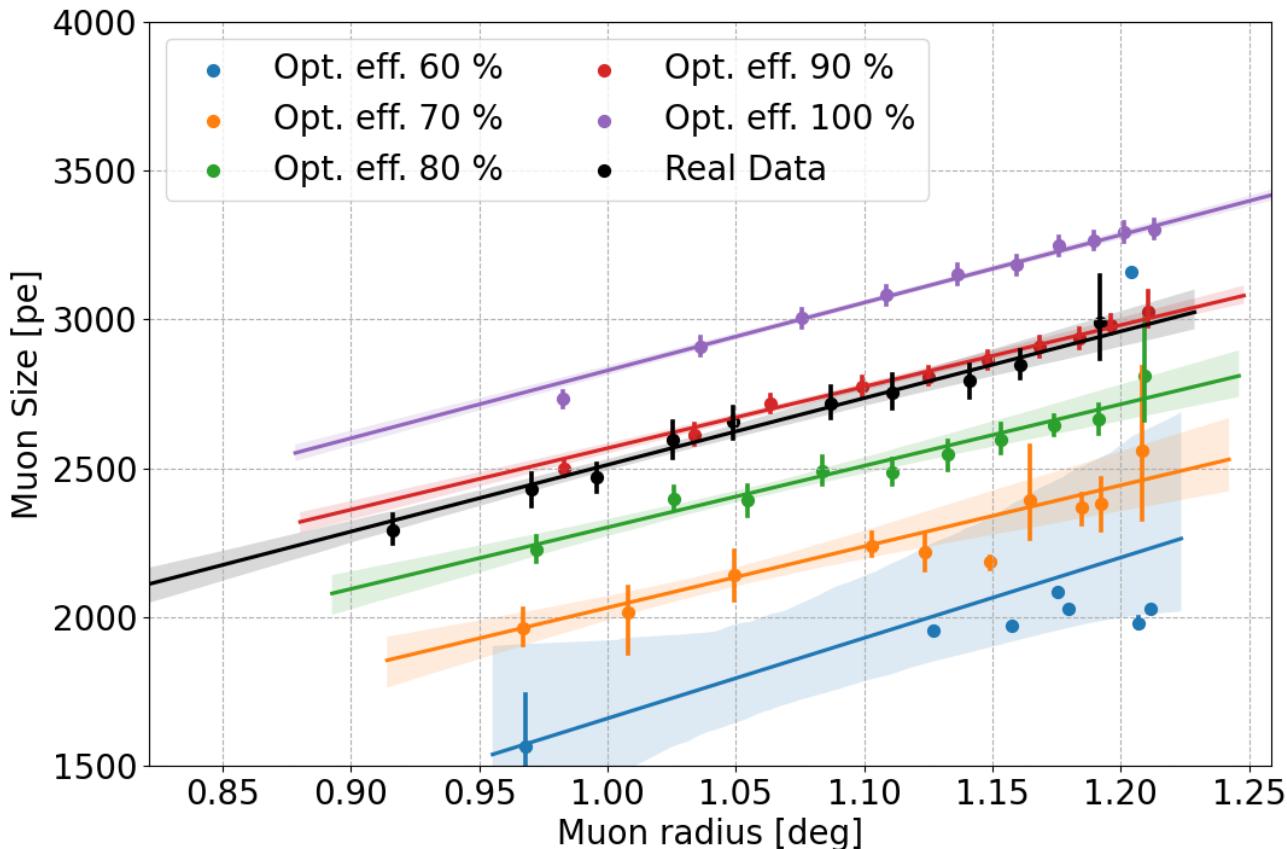


ADC to phe

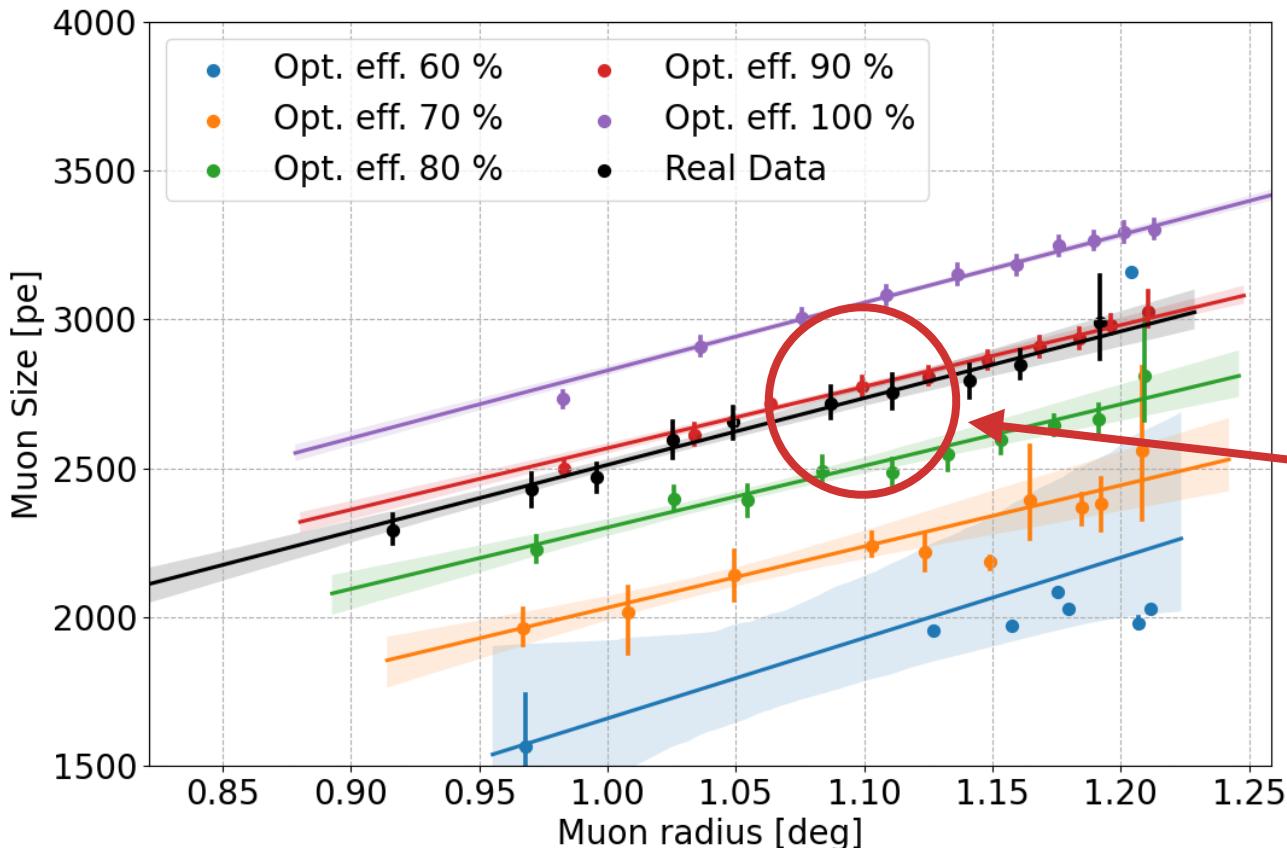
Run: 442 / Event: 56226



Optical efficiency

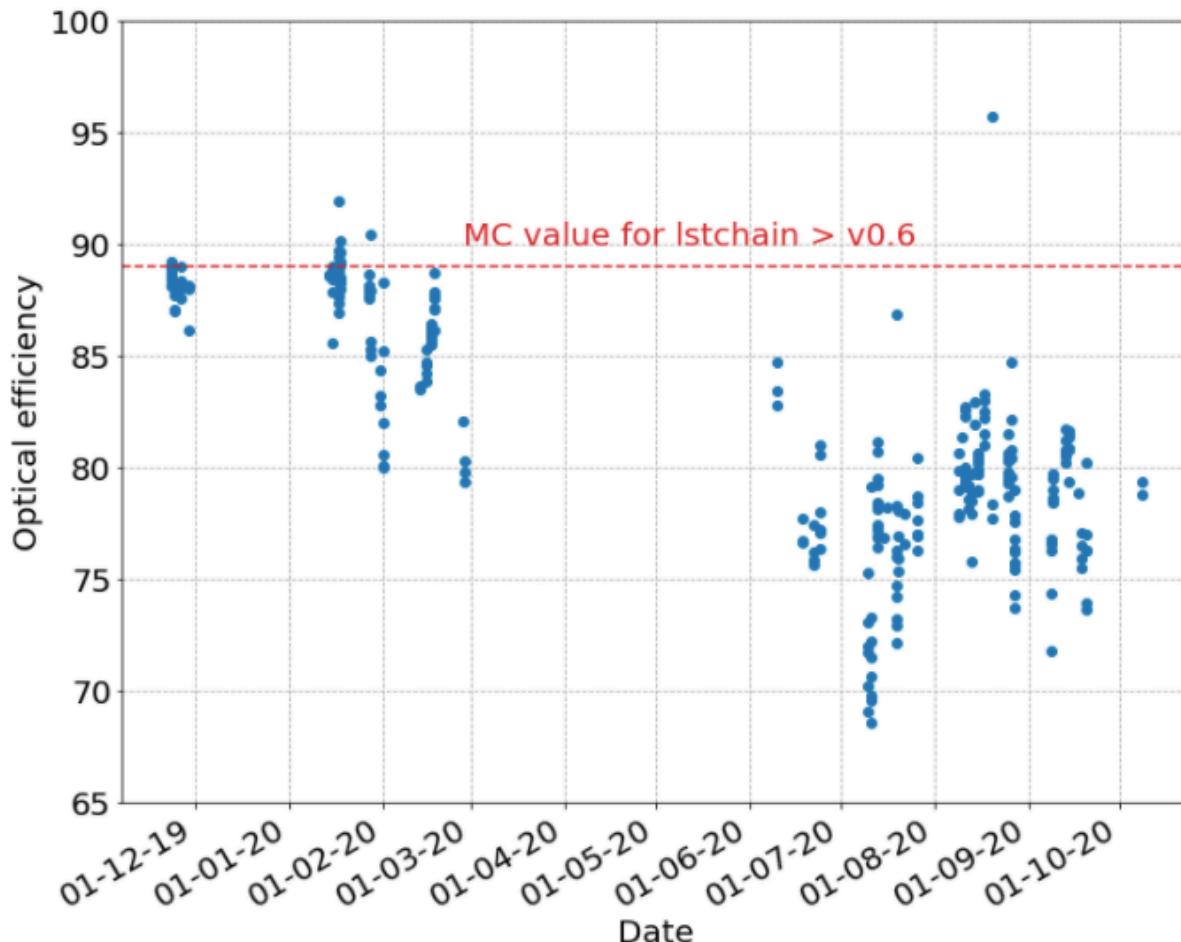


Optical efficiency



Compare size at 1.1 deg to establish the overall efficiency compared to that of MC

Long-term Optical efficiency

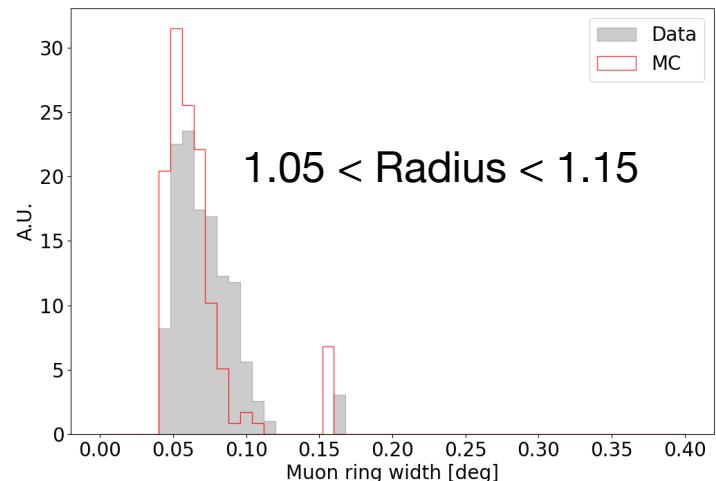
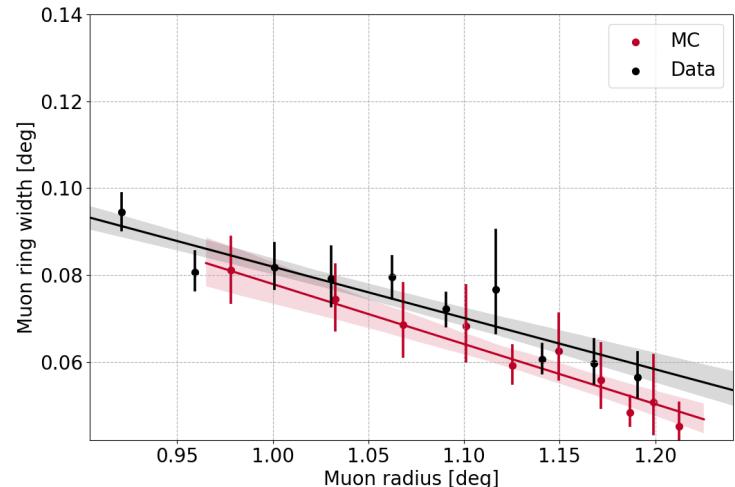


- Reference runs show ~89 % (compared to that of MC)
- After lock-down period has a lower optical efficiency.

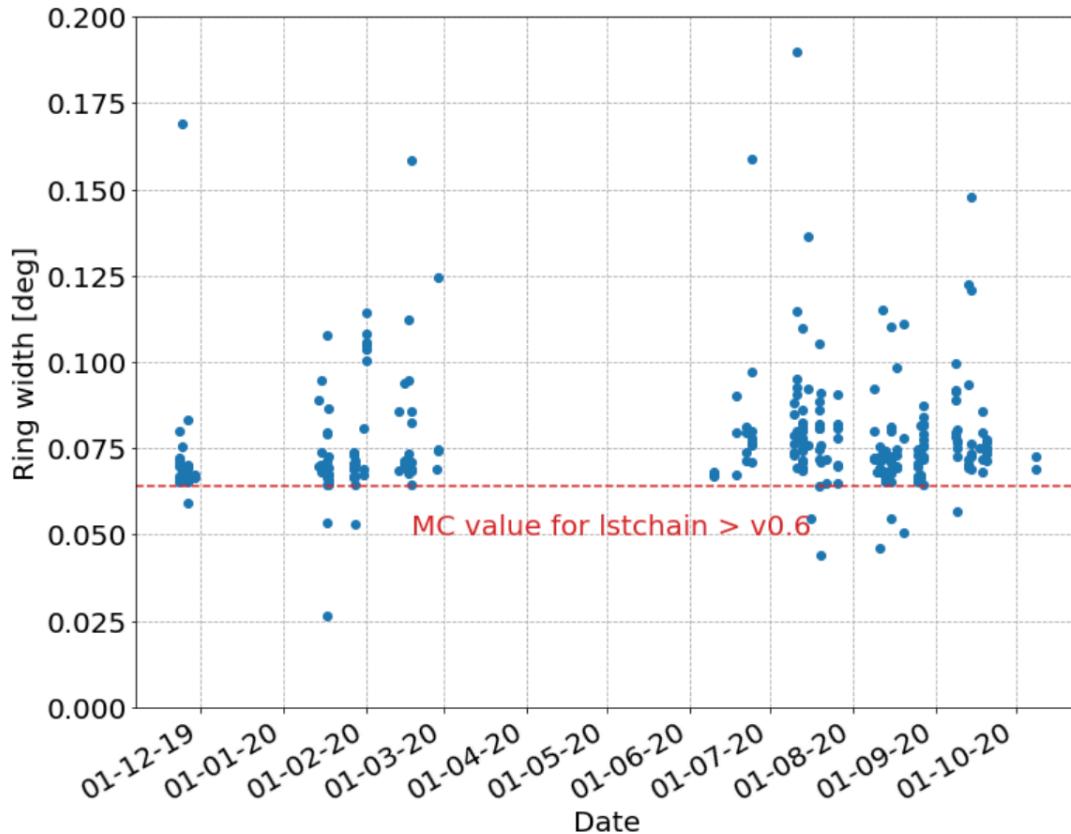
Ring Width



- Using Prod5 MC parameters for the new simulations
- Main changes w.r.t. previous analyses:
 - New simulations using Prod5 measured parameters -> simulations more similar to telescope performance
 - correction for the different integration windows used in FF and cosmic events
 - correction introduced by the uneven sampling of DRS4

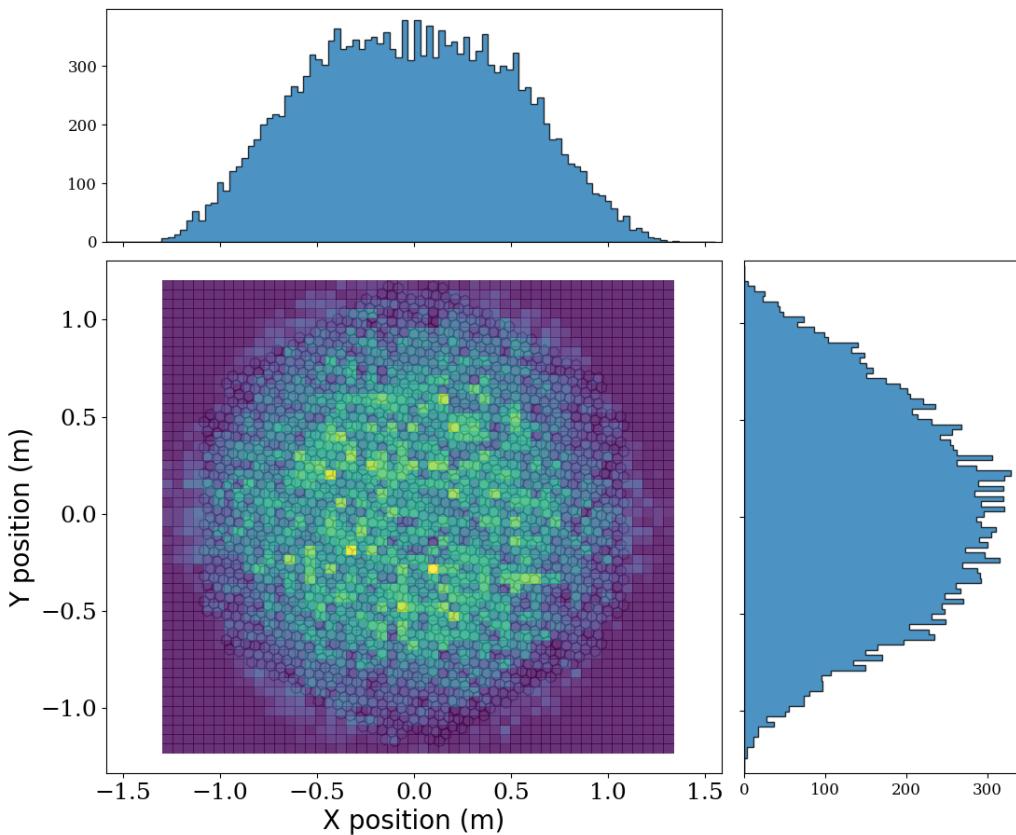


Long-term ring width



- Unfortunately not a clear trend of width vs PSF.
- Width probably dominated by pixels surviving cleaning that do not belong to the ring

2D Distribution of centers



- 2D distributions of ring centers to the images
- They are roughly uniformly distributed



Hands on

- Notebooks from the **notebooks/lst/calibration** folder:
 - [high_level_calibration.ipynb](#)
 - [low_level_calibration.ipynb](#)
 - [muon_data_mc_comparison.ipynb](#)

main ▾ intro-iact-analysis / notebooks / lst / calibration /

Go to file Add file ▾ ...

..	rlopezcoto mv notebooks	8d0c805 8 minutes ago	History
high_level_calibration.ipynb	mv notebooks	8 minutes ago	
low_level_calibration.ipynb	mv notebooks	8 minutes ago	
muon_data_mc_comparison.ipynb	mv notebooks	8 minutes ago	