Camera Calibration of the CTA-LST prototype

Yukiho Kobayashi, Akira Okumura, Franca Cassol, Hideaki Katagiri, Julian Sitarek, Paweł Gliwny, Seiya Nozaki and Yuto Nogami for the CTA-LST project

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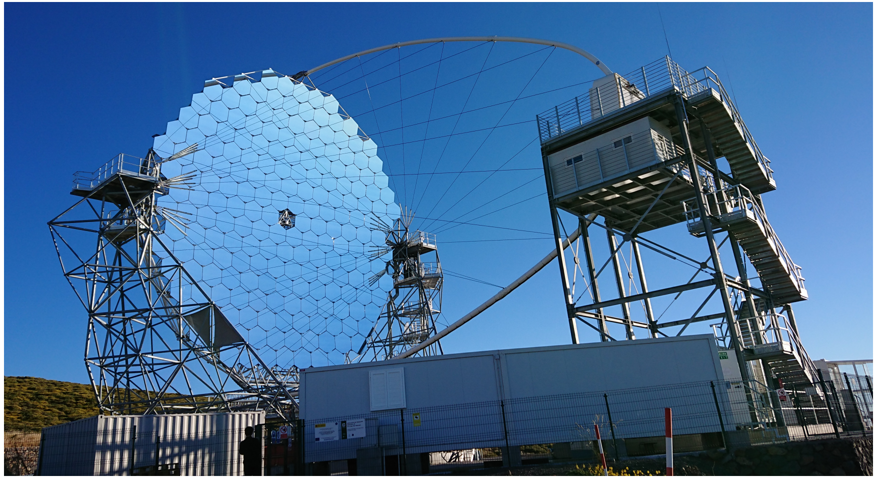
Outline

- The Large-Sized Telescope prototype (LST-1) is now in its commissioning phase.
- The camera calibration chain for LSTs has been developed.
- The calibration chain is applied to LST-1 data and the performance of each calibration step has been examined.



A picture of LST-1. Inauguration was in 2018.

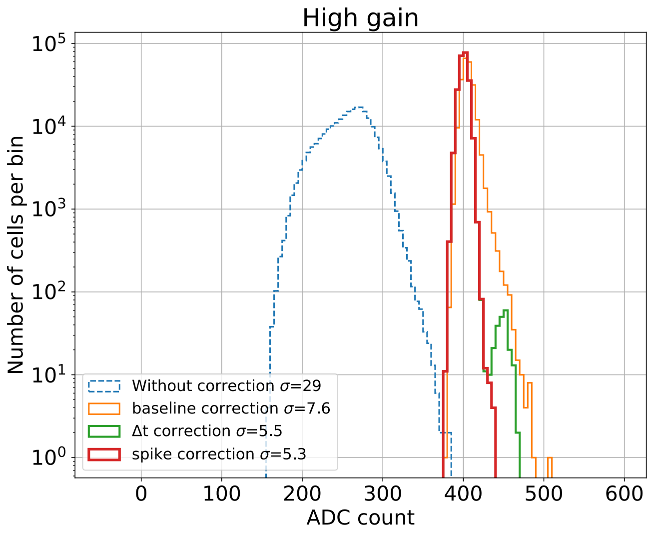
Pedestal correction / Absolute charge calibration

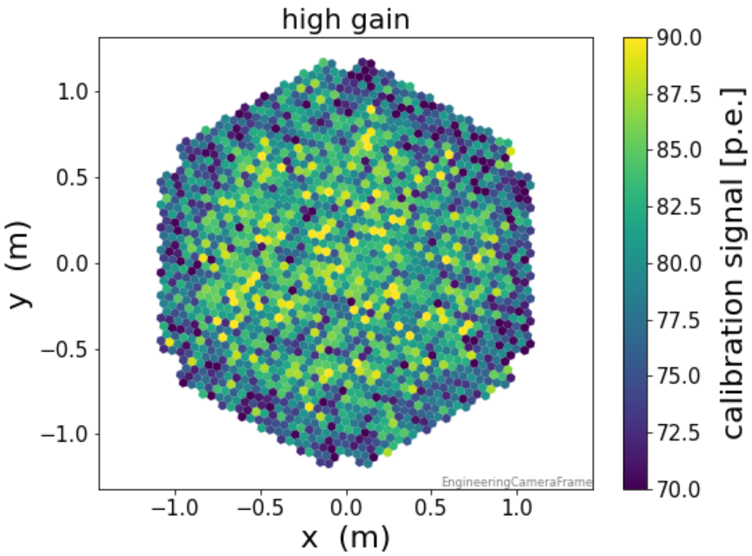
Pedestal distribution after each step of the corrections.

The corrections are confirmed to be working well.

Photoelectron (p.e.) distribution on the camera obtained with flat-field events.

Higher quantum efficiency of the inner pixels can be seen.

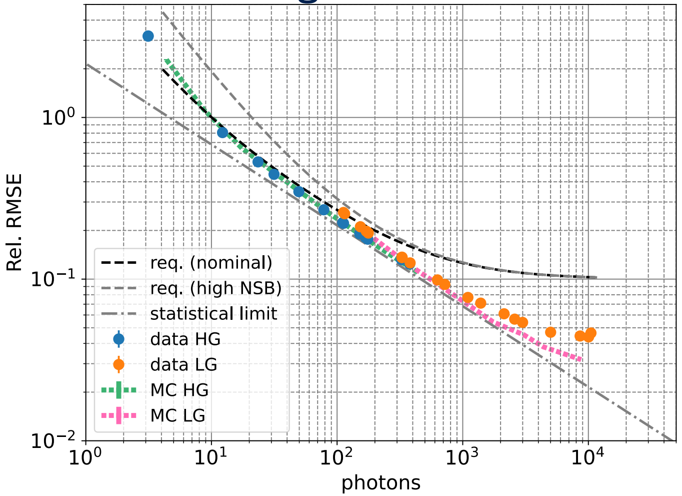




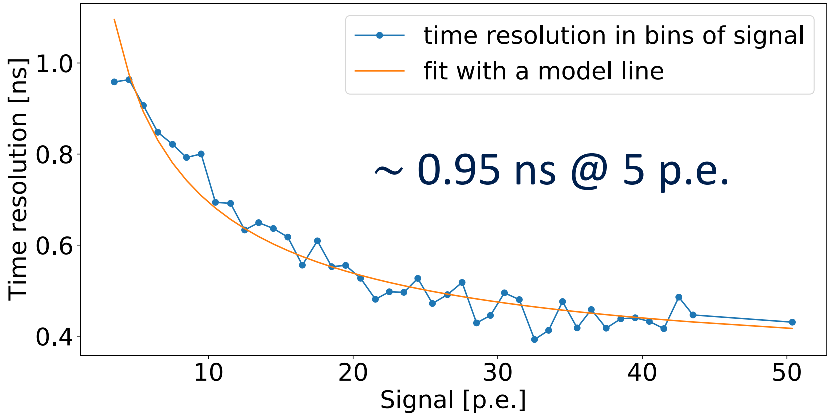
Performance of signal reconstruction

Performance of signal reconstruction is obtained for flat-filed events.

Charge resolution



Time resolution



The requirements are basically fulfilled.

The calibration chain is ready for analysis of LST-1 observational data.

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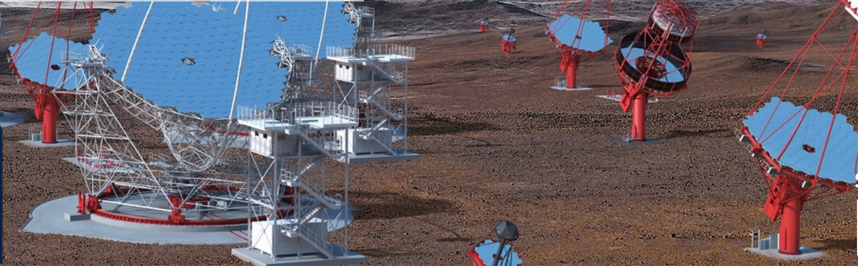
cherenkov telescope array



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ABSTRACT

The Large-Sized Telescope (LST) prototype proposed for the Cherenkov Telescope Array is currently in its commissioning phase. A calibration pipeline of the camera readout has been developed as part of the LST analysis chain. The pipeline performs the pedestal corrections, the extraction and calibration of charge and time of pulses for subsequent higher-level analysis. We report on the current status of the calibration pipeline, including the performance of each step through to signal reconstruction.

Introduction

The camera of the Large-Sized Telescope (LST) prototype is composed of 1855 photomultiplier tubes (PMTs) with high quantum efficiency (QE). PMT signals are sampled at 1 GHz by Domino Ring Sampler version 4 (DRS4) chips. The camera readout has high gain (HG) and low gain (LG) channels to cover the wide dynamic range. The LST calibration chain performs DRS4 pedestal corrections, absolute charge calibration and signal reconstruction.

DRS4 Pedestal correction

The DRS4 chips have intrinsic pedestal characteristics which should be corrected by analysis for minimizing pedestal noise. The major characteristics to be corrected are offset of individual capacitors, dependence of offset on on the time since the last reading of the capacitor and spikes. Our calibration chain deals with all of these systematic effects. Average pedestal noise after all the corrections is 5.6 ADC count in HG and 3.4 ADC count in LG (Fig. 1). This is compatible with ~0.2 photoelectron (p.e.) in HG and ~3 p.e. in LG.

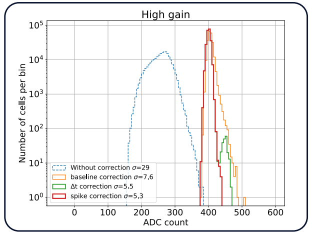

Fig. 1: Pedestal distribution in one HG channel after each step of the corrections.

Absolute charge calibration

Absolute charge calibration is performed by the F-factor method. This is based on flat-field events achieved by the uniform illumination of the camera by a laser at the center of the telescope dish. The number of p.e. detected at each pixel is estimated by analyzing the first and the second order moments of the charge distribution. The spatial distribution of the estimated numbed of p.e. reflects the PMT sorting, by which the higher QE PMTs are placed in the inner part of the camera (Fig. 2). The two gain channels give equivalent results. Additional systematic noise in charge reconstruction Is evaluated from flat-field runs with different light intensities and its effect on the F-factor method is corrected. The different pulse shape between Cherenkov and calibration signal is also taken into account in the calibration.

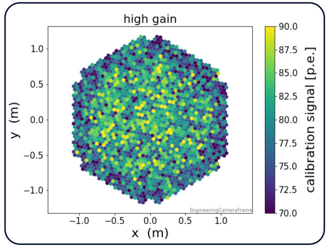

Fig. 2: p.e. distribution on the camera estimated in HG.

Performance of signal reconstruction

Performance of signal reconstruction by the current calibration chain is evaluated from flat-field runs with different light intensities. Fig. 3 shows the obtained charge resolution including bias. The data meet the requirement (req.) excluding the lowest intensity, where the bias is significant. Note that, when observing gamma rays, making use of overall time evolution of air showers will improve the resolution at the lowest intensities. The worse resolution in the data than Monte Carlo (MC) simulation above ~1000 photons can be due to systematic noise which is specific to the data, e.g., uneven sampling intervals in the DRS4 chips. The req. is apparently loose at high intensities because it considers uncertainty in the absolute charge calibration, which is not taken into account in the data. Signal arrival time is reconstructed with applying the DRS4 capacitor-wise time correction. Any global jitter is removed to see the relative time resolution between individual pixels. Time resolution is computed from Gaussian fit to the distribution of reconstructed time at each intensity. Fig. 4 shows the result obtained with an exemplary pixel. Typical resolution at 5 p.e. is ~0.95 ns. All the pixels are confirmed to fulfill the req., which is < 1.3 ns at 5 p.e.

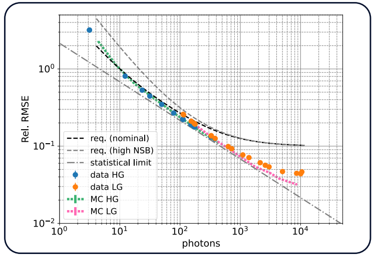

Fig. 3: Charge resolution evaluated with the current calibration chain.

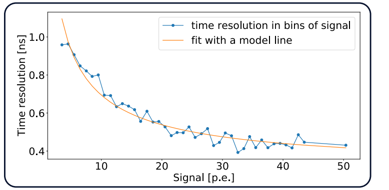

Fig. 4: Time resolution at different light intensities obtained from a typical pixel .

ACKNOWLEDGEMENTS

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