Abstract

FlashCam is a camera proposed for the medium-sized telescopes of the Cherenkov Telescope Array (CTA). We compare camera trigger rates obtained from measurements with the camera prototype in the laboratory and Monte-Carlo simulations, when scanning the parameter space of the fully-digital trigger logic and the intensity of a continuous light source mimicking the night sky background (NSB) during on-site operation. The comparisons of the measured data results to the Monte-Carlo simulations are used to verify the FlashCam trigger logic and the expected trigger performance.

Keywords: Front End, Trigger, DAQ, Data Management, CTA, FlashCam

1. Introduction

FlashCam [1] implements a fully-digital trigger processing and readout based on FADCs and FPGAs. The signals of the 1758 photomultiplier tubes (PMTs) are sampled continuously at a rate of 250 MS/s, and upon a trigger decision the digitised waveforms are sent via Ethernet to the data-acquisition server. The trigger firmware logic has also been implemented in a software framework, which, when applied to the read-out traces, computes the same trigger signals as the camera electronics.

The trigger firmware logic is realised as a digital sum trigger forming continuous background light using an LED. The first stage is a channel-wise differentiating filter. These differentiated signals are then scaled down because of bandwidth limitations and clipped to a maximum value. The clipping also prevents triggering on large single-pixel signals such as PMT-afterpulses.

In the last stage, a sample-wise summation of the clipped signals over 9 neighbouring pixels is carried out each time-step, ensuring a homogeneous and seamless coverage over the camera plane. A camera readout is triggered if one of these patch sums exceeds a predefined threshold.

2. Monte-Carlo simulations vs Measurements

Monte-Carlo simulations of the camera have been produced using the sim_telarray simulation package [2] resulting in full-trace simulations of 1 s of digitisation of all camera pixels per simulation configuration. The simulations were produced for two camera configurations (7- and 8-dynode PMTs), differing in their afterpulsing probability distributions and their pulse shapes, and with two NSB intensities each (300 MHz and 1.2 GHz). These intensities represent the lower and upper end of the NSB conditions on site.

The camera prototype, equipped with an even mixture of 7- and 8-dynode PMTs 12-pixel modules, was used to take randomly triggered data, while being illuminated with an LED, reading out events with a trace length of 3900 samples (15.6 µs), until also 1 s of digitised data was accumulated. Both types of dataset were fed into the FlashCam trigger emulation framework to calculate the final camera trigger rates. The camera trigger rates computed by this framework have been compared to camera trigger rate measurements with the camera prototype and shown to match within the statistical uncertainties.

The comparison of camera trigger rates produced with measured and simulated input datasets at 300 MHz NSB is shown...
can be explained by a higher afterpulsing probability (1
}< 1)

Nevertheless, this difference is less than 5% in trigger threshold for trigger rates >500 Hz for all clipping levels. The relative trigger rate between 7- and 8-dynode simulations changes between low (8 p.e.) and high (45 p.e.) clipping levels, which can be explained by a higher afterpulsing probability (1.2 · 10⁻⁴ for pulses > 4 p.e.) of the 7-dynode PMTs compared to the 8-dynode PMTs (1.0 · 10⁻⁴ for pulses > 4 p.e.). In contrast the rise time of the 7-dynode pulses is shorter than the 8-dynode rise time (5.6 ns versus 6.1 ns), reducing the coincidence time of NSB photoelectrons.

The comparisons at 1.2 GHz NSB are presented in Figure 2. The simulations show a very good agreement with the measurements over the full range of trigger thresholds. There is a small overall shift towards higher thresholds of the simulations compared to the rates from measured input data due to the single p.e. resolution used in the simulations. The better match at low clippings (8 p.e.) compared to the 300 MHz case is due to photoelectron pile-up, as the expected number of photo electrons is higher with an NSB of 1.2 GHz (4.8 p.e./pixel/sample).

The differences in camera trigger rates from all measurements (more pronounced in the 46 p.e. clipping levels) stem from atmospheric muons interacting with the plexiglass window or individual PMTs producing large signals.

References
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