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A fast muon tagger method for Imaging Atmospheric Cherenkov Telescopes

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Summary. — The Cherenkov Telescope Array (CTA) will be the next major observatory for Very High Energy (VHE) γ-ray astronomy. Its optical throughput calibration relies on muon Cherenkov rings. This work is aimed at developing a fast and efficient muon tagger at the camera level for the CTA telescopes. A novel technique to tag muons using the capabilities of silicon photomultiplier Compact High-Energy Camera CHEC-S, one of the design options for the camera of the Small Size Telescopes (SSTs), has been developed, studying and comparing different algorithms such as circle fitting, machine learning and simple pixel counting. Their performance in terms of efficiency and computation speed was investigated using simulations with varying levels of night sky background light. The application of the best performing method to the Large Size Telescope (LST) camera has been also studied, with the goal of improving the speed of the muon preselection.

1. – Introduction

The Cherenkov Telescope Array (CTA) will be the most important observatory for Very High Energy (VHE) γ-ray astronomy for the next decade and beyond, covering an energy range from 20 GeV up to 300 TeV. Improved performances with respect to the current Imaging Atmospheric Cherenkov Telescopes (IACTs) generation in terms of field of view, sensitivity and angular resolution are forseen. There will be 100 telescopes with different dimensions: the Large-Sized Telescopes (LSTs), the Medium-Sized Telescopes (MSTs) and the Small-Sized Telescopes (SSTs) covering the low, medium and high energy ranges of CTA respectively. One of the challenges to obtain the required performance

(*) Full consortium list available at `www.cta-observatory.org`.

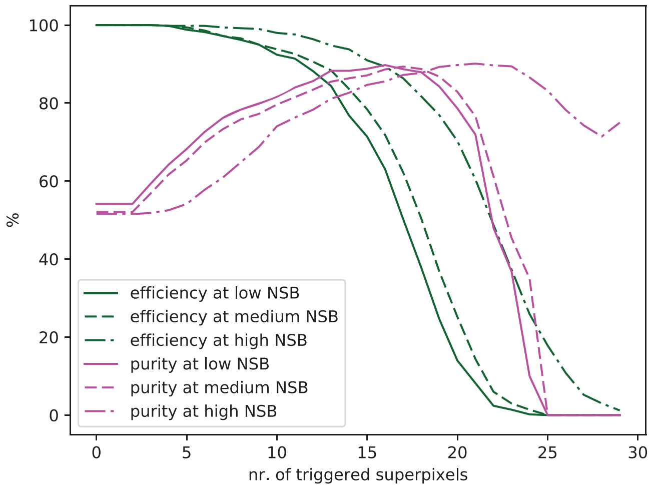

Fig. 1. – Selection efficiency and purity for CHEC with varying NSB for the majority method.

improvement is the optical throughput calibration. Muons produced in Extensive Air Showers (EASs) are an important absolute calibration source of IACTs and this is a well-established technique for telescope optical efficiency calibration [1]. In this work camera level muon preselection algorithms have been studied.

2. – A muon trigger for CHEC-S

Since the muon Cherenkov images are local to individual telescopes, but the readout is array-triggered, in case of the SSTs, a muon trigger is necessary. The CTA telescopes are required to tag 90% of muons. For the trigger of prototype camera CHEC (Compact High Energy Camera) [2] we have evaluated the Taubin circle fit [3], a neural network and the majority method that consists in identifying a trigger cluster number selection threshold. The performance in terms of speed, hence compatibility with the readout of 1 kHz, has been evaluated resulting in 188 Hz, 63 kHz and 130 kHz, respectively. The majority method is the most suitable for a trigger due to its simplicity. The simplicity and the stability with increasing Night Sky Background (NSB) have been analyzed (fig. 1).

3. – Offline muon preselection for LSTs

In the case of large diameter telescopes like LSTs a dedicated trigger is not necessary since the muon flux is high enough, given the high event rate ($\sim$10 kHz) [4]. However, most of the events are protons, hence the need for a fast offline muon preselection method. We studied a possible application of the previously described algorithms to LSTs. A modified version of the simplest method, the majority method, has been tested, having a rate compatible speed. The selection is done on the image size, *i.e.*, the sum of the photoelectron content of each pixel. The preliminary efficiency performance can be seen in fig. 2. The resulting speed performance is of 27 kHz.

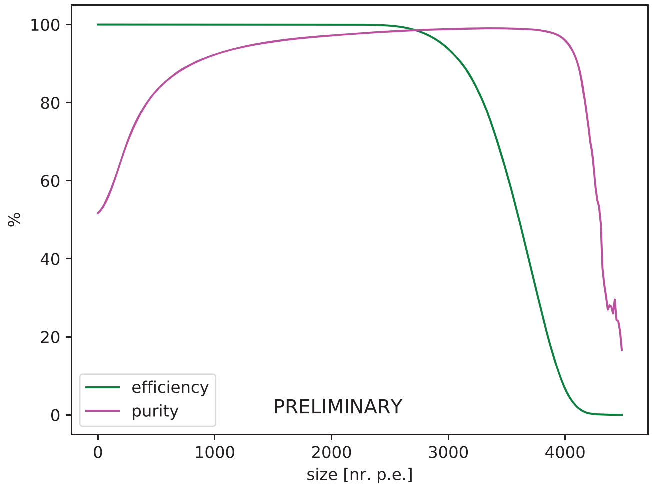

Fig. 2. – Selection efficiency and purity for LSTs.

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