

Calibration and Analysis of the GCT Camera for the Cherenkov Telescope Array

Jason J. Watson

Brasenose College
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*A thesis submitted for the degree of
Doctor of Philosophy*

Trinity 2018

Abstract

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Acknowledgements

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Abstract

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Abbreviations

ASIC Application-Specific Integrated Circuit.

CHEC Compact High Energy Camera.

CHEC-M Compact High Energy Camera (CHEC) using Multi-Anode Photomultiplier Tubes (MAPMTs) as the detector.

CHEC-S CHEC using Silicon Photomultiplier Tubes (SiPMTs) as the detector.

CTA Cherenkov Telescope Array.

MAPMT Multi-Anode Photomultiplier Tube.

SiPMT Silicon Photomultiplier Tube.

TARGET5 TeV Array Readout with GSa/s sampling and Event Trigger(version 5).

1

Introduction

1.1 Plan

1.1.1 Topics

- High Energy Astrophysics
 - Fermi
 - Fermi Bubbles
 - HAWC
- IACTs
- CTA
- CTA Science
 - Science Cases
 - Use "Science with CTA" paper
- SSTs
- SST Science
 - What do we contribute?
 - What can't be done without us?
- GCT
- CHEC
 - What makes us better?
 - Advantages of Schwarzschild-Couder
 - * Increased FoV
 - * Size
 - * Cost
 - Advantages of full waveform readout
 - Other Advantages?
 - * Trigger
 - * Energy/power/voltage Requirements
 - * Commonalities (SCT)

1.1.2 Questions

- ?

2

Camera Design & Mechanics

Contents

1.1 Plan	1
1.1.1 Topics	1
1.1.2 Questions	1

2.1 Plan

2.1.1 Topics

- Introduce TARGET architecture & Wilkinson ADC
- Different TARGET versions
- FEE
- MAPMs
- SiPMS
 - How they work
 - Comparison investigations
 - Property trade-offs
- CHEC-M
- Changes for CHEC-S
- Future - MUSIC ASICs

2.1.2 Questions

- ?

2.2 Introduction

3

CTA Architecture

Contents

2.1	Plan	2
2.1.1	Topics	2
2.1.2	Questions	2
2.2	Introduction	2

3.1 Plan

3.1.1 Topics

- Requirements
- Data Levels

3.1.2 Questions

- ?

4

Software

Contents

3.1	Plan	3
3.1.1	Topics	3
3.1.2	Questions	3

4.1 Plan

4.1.1 Topics

- TargetIO/TargetDriver
- TargetCalib
- ctapipe
- gammapy/CTOOLS

4.1.2 Questions

- ?

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Calibration

Contents

4.1	Plan	4
4.1.1	Topics	4
4.1.2	Questions	4

5.1 Plan

5.1.1 Topics

- Pedestal subtraction
- Transfer functions
- Gain Matching
- SPE
- Flat fielding
- Time correction
- Future
 - Live calibration

5.1.2 Questions

- TARGET architecture diagram, Wilkinson ADC
- How much detail about all the TF approaches do I go into?

5.2 Introduction

In order to obtain meaningful and reliable results from the camera, a number of calibrations must be applied to the waveforms read. A primary objective of my DPhil is to investigate the most optimal and efficient approaches for these calibrations (in

accordance with the Cherenkov Telescope Array (CTA) requirements described in Chapter 3), and to determine if additional calibrations are required.

The calibrations applied have evolved during the course of the prototyping of CHEC (Compact High Energy Camera); the calibrations applied to CHEC using MAPMTs as the detector (CHEC-M) waveforms are not the same for CHEC-S (CHEC using SiPMTs as the detector). Additionally, the calibration applied for the on-sky pipeline can differ slightly to the calibration used to obtain results such as the charge resolution.

In this chapter I will outline the each of the calibration steps in the general order that they are applied.

5.3 TARGET Calibration

The calibrations described in this section relate to the TARGET5 (TeV Array Readout with GSa/s sampling and Event Trigger(version 5)) module. As detailed in Chapter 2, the TARGET5 (TeV Array Readout with GSa/s sampling and Event Trigger(version 5)) Application-Specific Integrated Circuit (ASIC) is responsible for the sampling and digitisation of the waveforms, and therefore

5.3.1 Electronic Pedestal Subtraction

The most important, but also the simplest calibration to apply is the subtraction of the electronic pedestal

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Pipeline Reduction

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6.1 Plan

6.1.1 Topics

- Charge Extraction Methods
- Image cleaning
- Shower reconstruction
 - Hillas
 - Impact
 - model
 - Neural Nets
 - ++
- Energy Reconstruction
- Direction Reconstruction

6.1.2 Questions

- ?

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Camera Performance

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6.1.1	Topics	7
6.1.2	Questions	7

7.1 Plan

7.1.1 Topics

- Charge Resolution
- TF Investigations
- Different NSB
- MC Validation
- MC Performance

7.1.2 Questions

- What other criteria?
 - Trigger performance - even though I haven't contributed

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On-Sky Pipeline

Contents

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7.1.2 Questions	8

:

8.1 Plan

8.1.1 Topics

- Decided upon reduction methods
- Potentially different than for performance chapter
- CHEC-M campaign
- MC CHEC-S
- Future observations
- Jupiter observations (Beyond cherenkov?)

8.1.2 Questions

- ?

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Summary

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