

Upgrades to the Fluorescence Detectors of the Pierre Auger Observatory



THE UNIVERSITY
of ADELAIDE

Tristan William Sudholz

School of Physical Sciences
University of Adelaide

This dissertation is submitted for the degree of
Doctor of Philosophy

July, 2018

Abstract

Acknowledgements

Contents

Nomenclature	ix
Introduction	1
1 Cosmic-Rays	3
1.1 History of Cosmic-Rays	3
1.2 Energy Spectrum and Mass composition	3
1.3 Production Method and Sources	3
2 Detections of Cosmic-Rays	5
2.1 Extensive Air Showers	5
2.2 Fluorescence Production	5
2.3 Atmospheric Effects	5
2.4 Detectors and History	5
3 Pierre Auger Observatory	7
3.1 Hybrid Detector	7
3.1.1 Surface Detector	7
3.1.2 Fluorescence Detector	7
3.2 Communication System and CDAS	7
3.3 Event Reconstruction	7
3.3.1 Surface Detector	7
3.3.2 Fluorescence Detector	7
3.4 Enhancements and future upgrades	7
4 Conclusion	9
4.1 Future Work	9

Nomenclature

Introduction

- Define Cosmics Rays.
- The origins of the highest energy cosmic-rays still unknown.
- First detection by Pierre Auger in 1937 and the current detector looking at these energies is the Pierre Auger Observatory.
- Hybrid experiment containing both surface detectors and fluorescence detectors
- Surface detector has nearly 100% up-time while the fluorescence detectors only have 15% up-time.
- Proposal to extend the fluorescence detector up-time. To achieve this will have to operate while the moon is above the horizon. This will increase the level NSB and will have the PMTs run under a reduced gain to compensate.
- Photomultiplier Tubes are used as pixels within the camera of the fluorescence detectors and the aim of this thesis is to quantify the characteristics of the PMT under the reduced gain and increased.
- Outline a Summary of each chapter.

Cosmic-rays are particles that originate outside of the Earth atmosphere. These particles can be photons, hadronic or leptonic in nature [ref?]. In this thesis, when mentioning cosmic-rays I will mean the hadronic component unless specified otherwise. Cosmic-rays have been measured over a large range of energies (over 6 decades in energy) and it has many interesting features have been observed in this energy spectrum. One of the longest running mysteries is what happens at the highest energy. Since the first detection of extensive air showers by Pierre Auger in 1937 [ref], many different experiments have endeavoured to solve this mystery. The Pierre Auger Observatory [ref] is currently in operation to observe cosmic-rays at the highest energies.

The Pierre Auger Observatory is a hybrid experiment consisting of both surface detectors and fluorescence detectors. (Outline location) The surface detector has a nearly 100% operation up-time [ref] while the fluorescence detectors only 15% operation up-time [ref]. (Outline how PAO detects cosmic-rays, just need a brief summary).

A current proposal to extend the fluorescence detector operation up-time. Extended up-time would be beneficial as the fluorescence detectors image the entire extensive air shower and would increase the number of showers observed throughout yearly observation. To achieve the extended operation the fluorescence detectors would have to operate while the moon is above the horizon. While the moon is up, this would increase the Night Sky Background level and to compensate the Photomultiplier Tubes acting as the camera pixels would have to be run under reduced gain.

The aim of this thesis is to quantify the characteristics of the Photomultiplier Tubes operating under this reduced gain and outline any operation strategies. Outline of each chapter is as follows:

- Chapter 1: Cosmic-rays
Does this work as a new line
- Chapter 2: Detection of Cosmic-Rays
- Chapter 3: The Pierre Auger Observatory
- Chapter ??:
- Chapter ??:
- Chapter ??:
- Chapter ??:
- Chapter ??:

Chapter 1

Cosmic-Rays

1.1 History of Cosmic-Rays

First detection of ionizing radiation.

1785: Coulomb found that electroscopes can spontaneously discharge by the action of the air and not by defective insulation

1835: Faraday confirms the observation by Coulomb, with better insulation technology

1879: Crookes measures that the speed of discharge of an electroscope decreased when pressure was reduced

1.2 Energy Spectrum and Mass composition

1.3 Production Method and Sources

Chapter 2

Detections of Cosmic-Rays

2.1 Extensive Air Showers

Use Earth's atmosphere as an interaction medium. Primary particle interacts with the molecules in the atmosphere to produce a cascade of secondary particles. This cascade of particles is referred to as an Extensive Air Shower (EAS). Hadronic primaries can produce pions, muons and other stuff. Mixture of a hadronic core with an electromagnetic component from the decay of π^0 .

Shower profile has particles produced until energy on individual secondary particles drop below the ionization threshold. Therefore the shower will reach a point of maximum particle number then will drop off.

2.2 Fluorescence Production

The charge particles of EAS interact with the nitrogen molecules in the atmosphere. This interaction turns the nitrogen molecule dipole like and when the nitrogen returns to a ground state, a photon is emitted. This emitted photon is termed fluorescence light. Fluorescence light is can be emitted isotropically and typically in the UV band (between 300 and 400 nm). ***
Show wavelength profile ***

2.3 Atmospheric Effects

2.4 Detectors and History

Chapter 3

Pierre Auger Observatory

Science Goals

Location

3.1 Hybrid Detector

3.1.1 Surface Detector

3.1.2 Fluorescence Detector

3.2 Communication System and CDAS

3.3 Event Reconstruction

3.3.1 Surface Detector

3.3.2 Fluorescence Detector

3.4 Enhancements and future upgrades

Chapter 4

Conclusion

4.1 Future Work