Systematic Uncertainties in Cosmic Ray Energies Measured by the Auger Fluorescence Detectors

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Thesis submitted for the degree of

Doctor of Philosophy

The University of Adelaide

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September 2011

Contents

Abstract

This work investigates the processes used to reconstruct extensive air showers induced in the atmosphere by ultra high energy cosmic rays. It contributes to the efforts of the Pierre Auger Collaboration, whose members are working to solve many mysteries behind the phenomenon of these particles. Specifically my work has focused on the use of the Pierre Auger Observatory's fluorescence detectors to determine cosmic ray energies. I have investigated ways to reduce the systematic uncertainties involved in the reconstruction process.

To accurately reconstruct an extensive air shower in order to determine properties of the primary cosmic ray, we need to be able to model how the atmosphere will affect its production and propagation. A precise knowledge of how to interpret the signals received at our detectors is also needed. Inaccurate models or incorrect assumptions may lead to large errors in the shape and magnitude of the true energy spectrum of the cosmic rays which we observe at Earth. We wish to use the information that we gather from this experiment about the energy spectrum, anisotropy and composition of cosmic rays to help locate and study sources, and the acceleration mechanisms that produce their incredible energies. If we are inaccurately reconstructing these extensive air showers then this could lead to incorrect theories being developed. The systematic uncertainties that I have investigated and are presented in my thesis are:

- An unexplained halo of light around the shower track at the fluorescence detector which led me to develop a parameterisation for singly scattered Cherenkov light that we receive at the fluorescence detectors. This parameterisation is a function of

shower evolution, distance to the shower, scattering probability and angular distance from the tracks centre.

- Uncertainty in the nitrogen fluorescence yield due to the humidity dependence of collisional quenching. To take this dependence into account I constructed monthly vapour pressure profiles using data acquired from radiosonde launches conducted above the Pierre Auger Observatory. As the fluorescence detectors are unable to detect air showers on overcast days, launches conducted in overcast conditions were identified and excluded, using infra-red cloud camera data and sky temperature measurements. Methods to reduce the uncertainty on the vapour pressure profiles uncertainties were also investigated.

- Uncertainty in the methods used to interpret the light seen by the fluorescence detectors. When comparing two methods, I found that they differed in their approach to take into account the lateral shower width at large shower ages. This was because the initial parameterisation was only constructed up to shower ages of 1.2. I used the simulation package CORSIKA to check whether the original parameterisation was still valid at ages up to 1.5, and to check its validity down to primary particle energies of 10^{17}eV.

In addressing these systematic uncertainties, we now have a better understanding of the light that we receive at the Fluorescence Detectors, and of how to collect this light for use in reconstructing extensive air showers to determine the cosmic ray energy spectrum, cosmic ray composition and their arrival directions.

Statement of Originality

I, Vanessa Catherine Holmes certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to thee provisions of the Copyright Act 1968. I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library catalogue and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

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Acknowledgements

I would like to thank my Supervisors for their guidance and patience, my friends for their ongoing support, my family for their unwavering belief in my abilities, and the Pierre Auger Collaboration for giving me the chance to be a part of such an amazing experiment. But most of all, I wish to thank my husband-to-be Brad for absolutely everything.

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