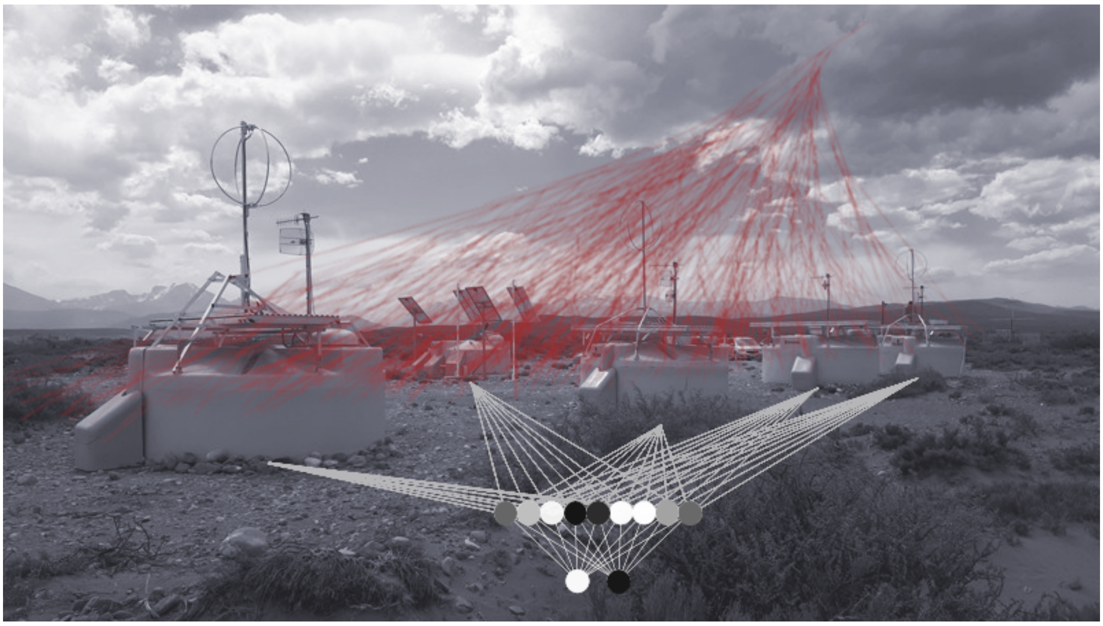
Karlsruhe Institute of Technology

PIERRE AUGER OBSERVATORY

Harry Potter and the Neural network triggers at the Pierre Auger Observatory: A plausibility study



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Review and Declaration

This thesis has been accepted by the first reviewer of the master thesis.

Karlsruhe, TBD

Prof. Dr. Ralph Engel

I declare that the work in this thesis was carried out in accordance with the requirements of the university's regulations and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, the work is the candidate's own work. Work done in collaboration with, or with the assistance of, others is indicated as such.

Karlsruhe, TBD

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Contents

1 Introduction

2 Physical background

This chapter aims to introduce the general physical principles underlaying the analysis presented in this work. For this purpose, an overview of the origin, composition and energy spectrum of cosmic rays is given in section 2.1. Their interactions with other matter, and consequently possible detection methods are listed in section 2.2.

2.1 Cosmic rays

2.1.1 History

A first hint at the existance of high-energy particles in the upper atmosphere was given by Hess in 1912, who found that the discharge rate of an electroscope is altitude-dependant. Millikan coined the term cosmic "rays" for these particles, as he argued the ionizing radiation must be part of the electromagnetic spectrum [1]. This was later - at least partially - falsified with the discovery of the east-west effect [2]. Hess' observation however withstood the tests of time and was ultimately recognized with the Nobel prize in physics in 1936 [3]. Two years later, in 1938, Pierre Auger showed via coincidence measurements that cosmic rays originate from outer space, and gave a first description of extensive air showers. Another 60 years later, the Pierre Auger collaboration would adopt his experimental setup and name in their search for cosmic rays of the highest energies.

Numerous other discoveries have helped advance our knowledge in both astro- and particle physics in the meantime. These include (but are not limited to)

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2.1.2 Origin

Cosmic rays whose kinetic energy far exceeds their rest energy must originate from some of the most extreme environments in space. In particular, regions with a large (either in field strength or spatial extent) electromagnetic field, where charged particles are accelerated to speeds very close to the speed of light, , via e.g. the Lorentz force.

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Acceleration mechanisms

2.1.3 Composition

2.1.4 Energy spectrum

2.2 Extensive air showers

Consider an incident particle of sufficiently high energy such that

2.2.1 Heitler Model

2.2.2 Heitler-Matthews Model

3 The Pierre Auger Observatory

Located on the argentinian high-plains of Pampa Amarilla, the Pierre Auger observatory is a hybrid detector designed to detect and study cosmic rays of the highest energies. With an effective area of $3000\,\mathrm{km}^2$ it is by far the largest experiment of its kind [4].

This chapter offers a brief look into the measurement principle and setup of the observatory. The surface detector (SD) is described in section 3.2 and critical in understanding the analysis presented in chapter 4. For a more complete overview on the experiment, information regarding the fluoresence detector can be found in section 3.1. Notes on the event reconstruction are found in section 3.3. If not explicitly stated otherwise, information is adpoted from the Pierre Auger observatory design report [4].

3.1 Fluoresence Detector (FD)

The fluoresence detector consists of a total of 27 fluoresence telescopes at 4 different sites (compare Figure 3.1). Each telescope monitors a 30° x 30° window of the night sky. This results in an effective FOV of roughly 180° x 30° per FD station, with an exception of Coihueco, where three additional telescopes - HEAT (**H**igh **E**levation **A**uger **T**elescope) - are installed to enable monitoring of higher zenith angles ($30° \leq \theta \leq 60°$) and increase sensitivity for showers of lower energies (compare chapter 2).

The individual telescopes consist of 3.6 m by 3.6 m, curved mirrors, which reflect light onto 440 photomultipliers (PMTs) each, that make up the pixels of the photo sensor. Since the setup needs to be extremely sensitive to UV light in order to see flouresence caused by extensive air showers, its operation is limited to moonless astronomical nights ($\measuredangle(\text{Sun, Horizon}) \lesssim -18°$).

FD photo?

3.2 Surface Detector (SD)

the surface detector consists of a multitude of individually operating stations. Each station is made up of a 12 000 L tank filled with highly purified water and equipped with three PMTs that detect Cherenkov light. Onboard electronics, the **U**nified **B**oard (UB) or **U**pgraded **U**nified **B**oard (UUB) read out measurement

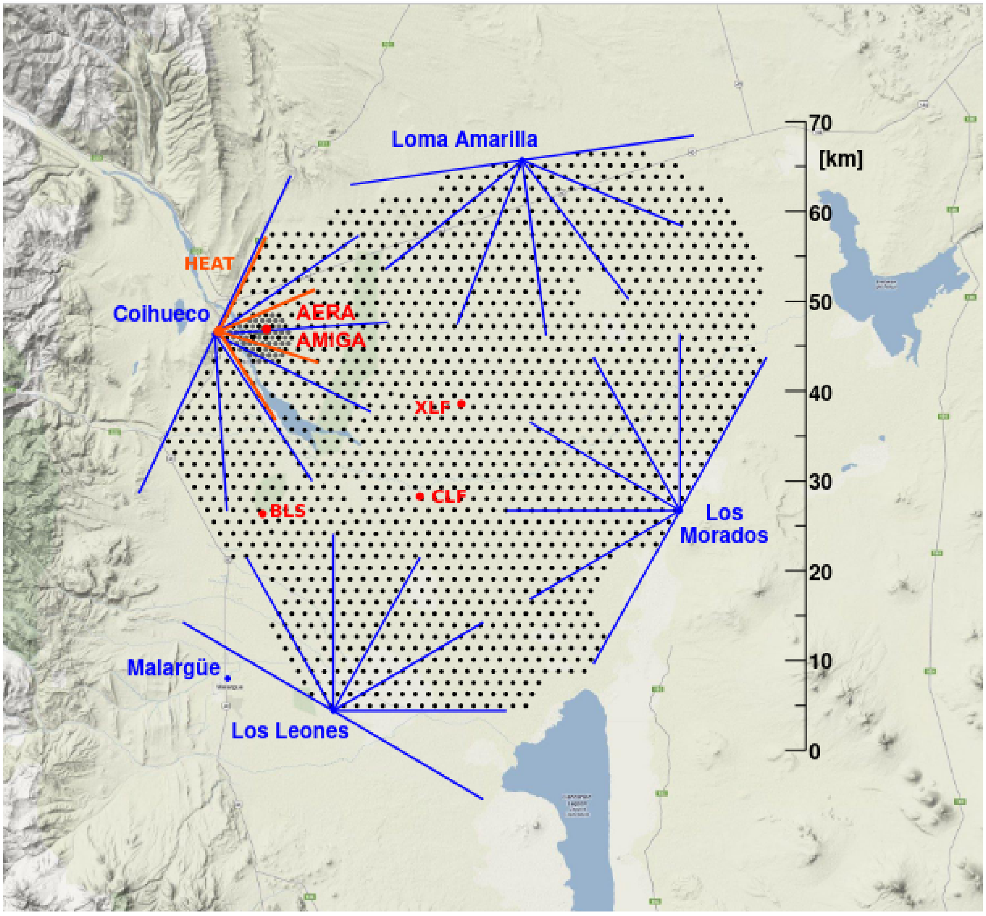

Figure 3.1: Overview of the Pierre Auger observatory. The four different FD sites (respective FOV shown with blue lines) sit at the edge of the detector area and monitor the night sky above the SD array consisting of 1600 water tanks (black dots). Two laser facilities, the e**X**treme (XLF) and **C**entral **L**aser **F**acility (CLF) are located in the middle of the array to measure atmospheric properties. A denser spacing of stations near Coihueco is equipped with additional electronics such as e.g. radio antennas (AERA) and muon detectors (AMIGA).

3.3 Trigger Procedure and Event Reconstruction

4 SD Station Triggers

Bibliography

[1] Robert A Millikan and G Harvey Cameron. "The origin of the cosmic rays". In: *Physical review* 32.4 (1928), p. 533.

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[3] Nobel Media AB. *Press release*. `https://www.nobelprize.org/prizes/physics/1936/summary/`. Accessed: 18th Jul. 2022. 1936.

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