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THE PIERRE AUGER PROJECT OVERVIEW

Martin Vlček

Joint Laboratory of Optics: Palacky University and Institute of Physics of the Czech Academy of Sciences, 17. listopadu 50, **772 07 Olomouc**, Czech Republic

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ABSTRACT: Cosmic particles with energies $\geq 10^{19}$ eV have been observed. This is a hundred million times more than can be achieved with terrestrial best accelerators. The nature of the primary cosmic particles, the mechanism of the cosmic acceleration and their locations are totally unknown. The sources are assumed to be close to our Galaxy, otherwise these particles could not have maintained such high energies due to their interaction with the cosmic microwave background radiation. The Pierre Auger Project aims to understand these important issues by the measurement of the energy spectrum, the arrival directions and the isotope composition of these particles.

1 Introduction

In the past 20 years, energies of up to 10^{20} eV in a single particle have been observed in different experiments. The Pierre Auger Project is dedicated to the study of cosmic rays at the highest energies ever observed [1]. It is named after Pierre Auger who discovered extended air showers and did the first observation and correct interpretation of this phenomenon in 1938 on the Jungfraujoch in Switzerland [2].

Atomic nuclei, mostly protons, hit the atmosphere with extraordinary energies and generate large cascades of secondary particles. Cosmic ray studies played an essential role for the birth of particle physics and a number of new particles were first observed in cosmic rays. Particle physics then concentrated on the use of accelerators. Since about a decade a renaissance of cosmic ray physics in a wide sense has occured. Particle astrophysics as a field in its own right has emerged out of strong synergies and broad interdisciplinary activities between elementary particle physics, astrophysics and astronomy. This is true for both theoretical and experimental work.

The Pierre Auger observatory is a hybrid detector consisting of a particle detector on the ground and an atmospheric fluorescence detector. The surface detector system covers an area of 3000 km^2 with 1600 water-Cherenkov detectors of $10\,m^2$ each, distributed on a grid of 1,5 km distance. Four optical detectors are compound from modified Schmidt telescopes with a mirror size of $13\,m^2$, an aperture of 1,7 m diameter and a pixel camera of 440 photomultiplier tubes in the focal plane. 3×6 telescopes are housed in observatories at the periphery of the array in the triangle apexes and twelve at the "eye" in the centre station.

The hybrid detector concept will provide an accurate measurements of the energy and directions of cosmic showers. It gives the Pierre Auger Observatory a clear advantage over similar experiments.

The Southern Pierre Auger Observatory is located in the Pampa Amarilla, near the town Malargüe in the province of Mendoza, in the Argentina, at an average altitude of 1400 m a.s.l. and is expected to be completed in 2004. It will for the first time register air showers in a large array of surface detectors and in clear dark nights simultaneously by their emission of fluorescence light in the atmosphere. In this way the collecting efficiency of a ground array is combined with a direct energy measurement and a reconstruction of longitudinal shower development. The nominal acceptance is $7000\,km^2 sr$ assuming a maximum useful zenith angle of 60° [3]. This will yield about one hundred events per year at or above the GZK threshold energy of $5 \times 10^{19}\,eV$. A second observatory is going to be installed in the Northern Hemisphere (Millard Country, Utah, USA) after the completion of the detector in Argentina. The Project is managed by a collaboration of 250 scientists, engineers and students of 53 institutes from 19 nations. It was officially launched in March 1999.

2 The surface detector

The surface detector (SD) consists of 1600 water Cherenkov tanks arranged on hexagonal grid with a 1,5 km pitch. The overall area is $3000\,km^2$ of which a sampling fraction of 4.5×10^{-6} is covered. Each tank is a cylinder of 1.20 m height and 3.60 m diameter, filled with about $10\,m^3$ of clean water. The inner walls are formed by Tyvec liner to achieve diffuse reflection of the Cherenkov light and ensure good homogenity of the response as a function of position and angle of penetrating particles. The water volume is viewed by three 8" photomultipliers (e.g. Hamamatsu R-5912). Prototype work has indicated a signal yield of 100 photoelectrons for vertically passing muons, and less for soft electrons in an air shower.

Phototube signals are continuosly digitized at 25 MHz sampling frequency with 10 bit resolution. Data are stored in a ring buffer memory and overwritten after $100\,\mu s$ or read out on receipt of trigger readout request. A typical trigger condition is ≥ 5 tanks above threshold within $20\,\mu s$ for which an efficiency of 98% at $10^{19}\,eV$ is obtained. At $10^{20}\,eV$ the average number of tanks hit is already 16.

The direction of incoming air showers is reconstructed from the arrival times in different detectors. Individual stations will be synchronized by a GPS (Global Positioning System). A time resolution of 5ns is expected.

All tank equipment is designed for extreme reliability and the electronics features extensive self-test capabilities as well as low power consumption. Communication is based on cellular phone technology. Electric power is provided by a solar panel and a buffer battery.

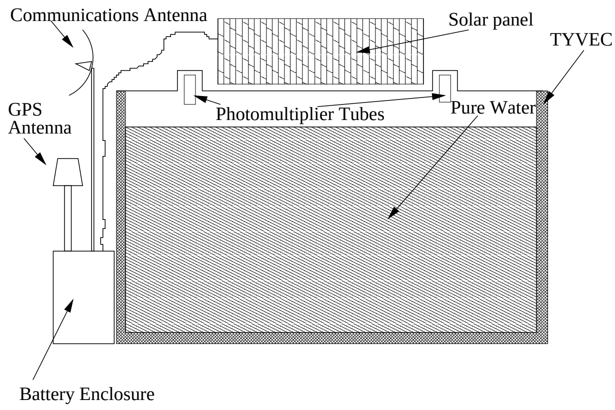

Figure 1: Water Cherenkov tank

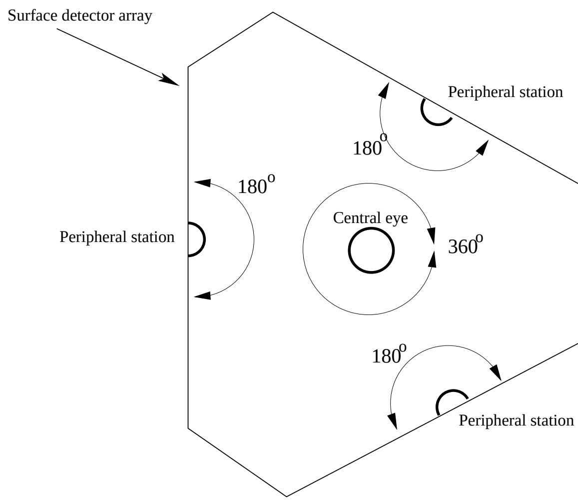

Figure 2: The Pierre Auger Project surface detector field with positions of fluorescence detectors eyes and their fields of view.

3 The Fluorescence Detector

The fluorescence detector will have two functions. It will serve as the energy calibration tool and as the independent detector. While the acceptance of a ground array can easily be computed this is not so easy for an optical detector and requires detailed knowledge of the atmospheric conditions. On the other hand, the energy measurement by means of fluorescence light is much more direct than from shower distributions at ground level. The fluorescence technique allows to reconstruct the longitudinal shower development in the atmosphere. This has been demonstrated by the pioneering work of the Fly's Eye collaboration [4].

The fluorescence detector consists of 30 individual wide-angle Schmidt telescopes grouped in four stations. Each telescope has a 30° field of view in azimuth and vertical angle. Three stations at the perimeter of the surface array consist of six telescopes each for a 180° field of view inward over the array. The central eye has twelve telescopes to unsure 360° azimuthal coverage. The vertical angular range is from slightly above 0° to 30°.

Each telescope will have a segmented spherical mirror with radius of curvature of 3.40 m and a total surface of 13 m^2. The aperture will have a diameter of 1.7 m without correction ring and 2.2 m with correction ring. In the focal surface a photomultiplier camera detects the light on 20×22 pixels. Each pixel covers $1.5° \times 1.5°$ and the total number of photomultipliers in the fluorescence detector system is 13200.

4 Our role in this project

Institute of Physics of the Czech Academy of Sciences in Prague and Joint Laboratory of Optics of Palacky University and Institute of Physics of the Czech Academy of Sciences in Olomouc are involved in this big and prestigious project. We play an useful role in the constructing of the fluorescence detector.

On our optical workshops glass mirrors were made which create one half of the prototype fluorescence detector. The second half of the prototype telescope reflective surface is covered by aluminum mirrors, which was manufactured in the Forschungszentrum in the Karlsruhe, in the Germany. Prototype mirrors were already moved into Argentina and there rebuilt and tested. This tests were successful and we will make mirrors for the whole project together with our German colleagues from Karlsruhe. 12 detectors will be covered by mirrors manufactured in Joint Laboratory of Optics of Palacky University and Academy of Sciences of Czech Republic and the rest of detectors by mirrors manufactured in Germany. You can see mounted prototype mirrors in Germany on the picture 3 and the proposal of the telescope covered by our mirrors on the picture 4.

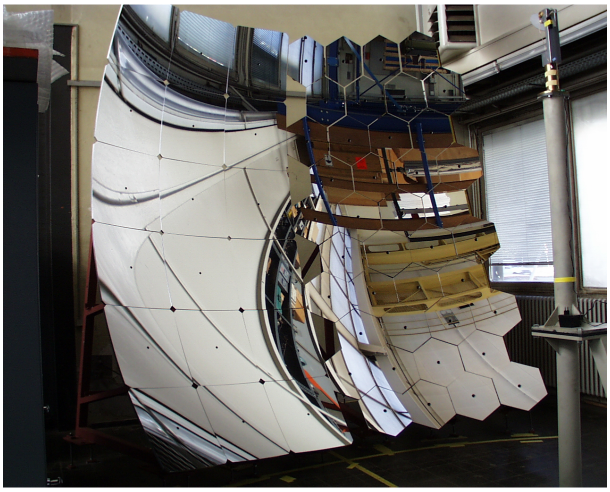

Figure 3: Mounted czech-german prototype mirrors in Karlsruhe (Germany), October 2000.

Next acquisition of our laboratories in Auger collaboration is the proposal and computing of the right shape of the correction ring which enlarge the aperture

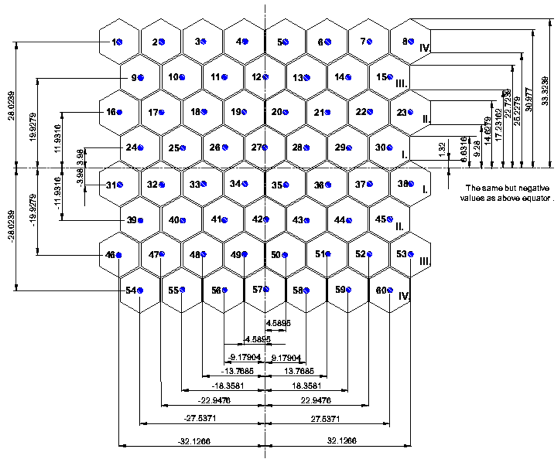

Figure 4: The proposal of the telescope covered by glass mirrors from the Czech Republic.

of each fluorescence detector [5], [6], [7]. We have discussed some production processes and prove qualities of manufactured pieces of correction ring in our laboratories. Results of our computations were discussed on many workshops and finally corrector rings will be made in the shape as we proposed.

We also tried to make optical filters for this project in UV region. Useful range is 300-420 nm and we developed evaporated and bonded filters which both provide satisfying solution meeting the required transmittance in the wavelenght range 300-420 nm as specified by Auger Project [8].

5 Acknowledgement

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SUMMARY
THE PIERRE AUGER PROJECT OVERVIEW

This article want to introduce to the readers basic characteristics of The Pierre Auger Project and show the acquisition of our physicists for this project. The Pierre Auger project is a very important step in explanation of existence ultra-high energy cosmic radiation. Potencial results will have fundamental importance for ultra-high energy physics and astrophysics.

SOUHRN
PIERRE AUGER PROJEKT

Tento článek chce představit čtenářům základní charakteristiky projektu Pierre Auger a přiblížit přínos našich fyziků pro tento projekt. Projekt Auger je velice důležitým krokem pro vysvětlení existence vysokoenergetického kosmického záření. Předpokládané výsledky budou mít základní význam pro fyziku vysokých energií a astrofyziku.

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