The Auger Observatory for high-energy cosmic rays (GAP-2002-061)

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The Southern Observatory of the Pierre Auger project for the study of cosmic rays of very high energy, above 10^{18} eV, is now under construction in Argentina. Some examples of the first data are shown.

1. INTRODUCTION

The Auger Observatory [1] is a *large acceptance "hybrid" system.* Large acceptance is needed because in the energy region close to 10^{20} eV the flux of the primaries is extremely low, of the order of one particle/km^2/sr/century. The hybrid concept, combination of a surface array for detecting the shower front at ground level and telescopes to observe the longitudinal profile of the shower from the fluorescence light produced in the atmosphere, is a unique feature of the Auger project. It allows control of the systematic uncertainties and cross-calibration of the measurement of the energy.

The energy region above 10^{20} eV is of special interest because of the GZK cut-off caused by the interaction of the primary particles with the microwave background. Evidence was reported [2] for the presence of events in the region which is expected to be depleted if a uniform distribution of sources is assumed. This evidence is controversial [3], because of problems in the determination of the energy scale. If confirmed, a natural implication is that the very high-energy particles come from distances which are relatively small on astrophysical scale, less than about 100 Mpc. Being very energetic, these particles, if protons, are magnetically rigid enough to point back to their sources which could then be identified.

In any case the accurate study of the energy, direction and mass composition of the primary particles in the region above 10^{18} eV with statistics at least one order of magnitude larger than present experiments, will provide important information for the understanding of the origin and acceleration mechanism of these particles.

2. THE OBSERVATORY

In the Auger project two Observatories are foreseen, in the Northern and Southern hemispheres. At present the Southern Observatory is being constructed in Argentina, in the province of Mendoza, near the small town of Malargüe (Fig.1). The site, Pampa Amarilla, covers an area of 3000 km^2 at the altitude of 1400 m (atmospheric depth of 875 g/cm^2). It is almost flat with very low population density and favourable atmospheric conditions in terms of man-produced light and aerosol pollution. The detector data is transmitted by radio technology in a network and collected at the central data acquisition system in the Observatory central building in Malargüe.

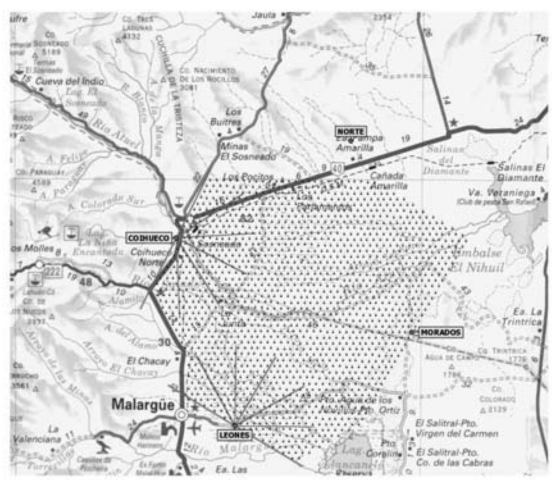


Figure 1. Map of the site. The fluorescence telescopes overlook the site from four small hills on the perimeter.

2.1. The Surface Detector (SD)

The Surface Detector is a grid of 1600 water Cherenkov counters spaced at a distance of 1.5 km. Each counter (Fig.2) is a polyethylene tank of cylindrical shape and size of 10 m^2 x 1.2 m, filled with purified water. The internal wall is lined with diffuse reflector. The Cherenkov light produced by the shower particles in the water is detected by three 9" photomultipliers looking downward. Each unit is autonomous with a battery and a solar panel.
The time structure of the photomultiplier signals is analyzed by Flash ADCs and these data are transmitted together with the timing provided by a GPS receiver. Cosmic ray muons provide the calibration which is expressed in terms of "vertical equivalent muons" (VEM).

Figure 2. Picture of a water Cherenkov tank installed on the site. The solar panel and the antenna are visible

2.2. The Fluorescence Detector (FD)

The Fluorescence Detector (FD) consists of 24 telescopes located in four stations ("eyes"). Each station is on top of a small elevation on the perimeter of the site and contains 6 telescopes.
A sketch of a telescope is shown in Fig.3 where from left to right we see the shutter, the circular diaphragm with a UV filter transmitting in the spectral region of the fluorescence light from nitrogen, the camera and the large spherical mirror with curvature radius of 3.4 m.
The sensitive element of the camera is a matrix of 440 hexagonal photomultipliers placed on the focal surface. The pixel size is 45 mm, corresponding to the angular size of 1.5^o. The field of view is 30^o in azimuth and 28.6^o in elevation. The PMT signals are sampled by Flash ADCs.

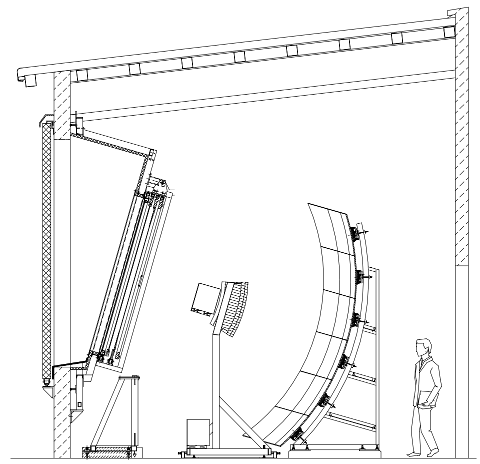


Figure 3. Sketch of a fluorescence telescope.

2.3. General features

Various trigger schemes have been devised using the SD and FD either independently or combined together.
The efficiency of a trigger requiring a coincidence of at least 3 adjacent tanks reaches 100% at $3x10^{18}$ eV. Requiring a coincidence of at least 5 tanks, the efficiency is 40% at $3x10^{18}$ eV and becomes 100% at 10^{19} eV.
The FD may provide a trigger with threshold at the level of a few 10^{17} eV.
The expected number of events for one year operation of the Observatory is shown in the Table.

Energy	Number of events
E > $3x10^{18}$ eV	∼ 35,000
E > 10^{19} eV	∼ 5,000
E > $5x10^{19}$ eV	∼ 500
E > 10^{20} eV	∼ 50-100 ?

The FD duty cycle is 12-15% due to the requirement of operating in moonless nights.
For hybrid operation the error on the shower energy and direction is less than 5% and 1^o, respectively, while the position of the shower axis at the ground level is determined with accuracy of about 50 m. The depth of the shower maximum is measured by the FD with error of 15-20 g/cm^2.

3. THE ENGINEERING ARRAY

The first element of the Observatory, the "Engineering Array",was completed in 2001 and has taken data for several months. It consists of 40 tanks overlooked by 2 telescopes installed on the top of the hill of Los Leones on the southern boundary of the site. The Engineering Array is only a small fraction of the final system but it contains all basic elements of the SD, FD, communication network and data acquisition.
About 80 hybrid events were collected in 3 months using the hybrid trigger combining the information from both SD and FD.
In Fig.4 the observed signals for an event with 11 active tanks are shown. A preliminary analysis [4] of this event indicates that the energy of the shower is $(2.5\pm0.4)\mathrm{x}10^{19}$ eV and the zenith angle about 54^o.

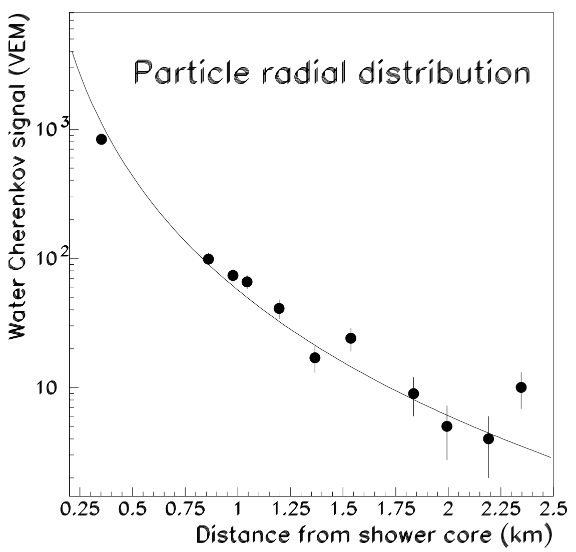
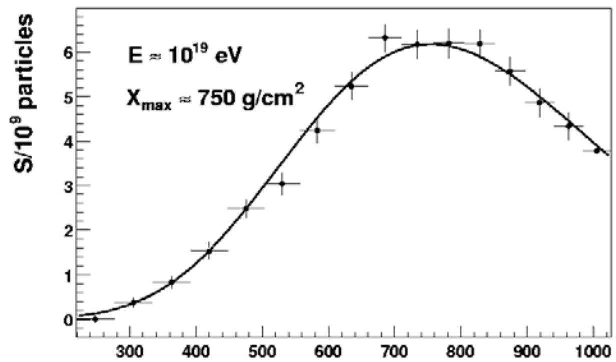


Figure 4. Radial distribution of particles observed by the SD for a 11-tank event with $E\simeq2.5\mathrm{x}10^{19}$ eV. The data are expressed in terms of vertical equivalent muons (VEM). The solid line is the result of a fit using a standard form.

Two examples of longitudinal profiles measured by the FD are shown in Fig.5 and 6. The observed number of charged particles is presented as a function of the atmospheric depth together with the result of fitting using the Gaisser-Hillas form. A preliminary estimate of the energy is also given together with the depth X_{max} where the development of the shower reaches its maximum.



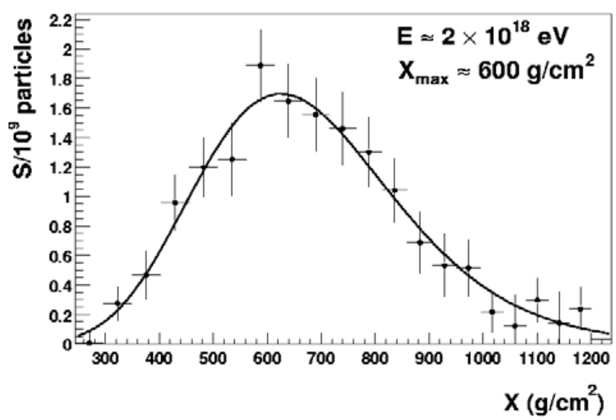


Figure 6. The profile of a shower of relatively low energy which appears to be fully contained in the atmosphere.

4. CONCLUSIONS

The successful operation of the Engineering Array has been extremely useful to assess the properties and reliability of all components and the feasibility of operating the hybrid system. The construction is going on with the aim of completing the Observatory by the year 2005.

REFERENCES

1. J.W.Cronin, Proc. of ICRC 2001, Hamburg.
2. N.Sakaki et al.(AGASA), Proc. of ICRC 2001.
3. D.R.Bergman (HiRes), Proc. of this Conference.
4. M.Ave et al., Auger technical note GAP-2002-020.