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Layout of the Pierre Auger Observatory

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Abstract. The Pierre Auger Collaboration was formed to study the highest energy cosmic ray showers, focusing the attention on energies above $5{\cdot}10^{19}$ eV. The strong flux suppression at these energies and the need of reliable and full experimental measurements pose three conditions on the experimental layout: gigantic in size, hybrid in nature, and one observatory in each hemisphere. Each of the Pierre Auger Observatories extends over an area of 3,000 km^2 and comprise both a surface and a telescope component. On turn, these features impose restrictive conditions on the properties of the site. We will briefly discuss these properties, the relevant measurements and site tests performed, and focus on the final layout of the Southern Observatory, with a description of the surface detectors and fluorescence telescope systems.

1 Introduction

The Pierre Auger Project will study the highest known energy cosmic ray showers focusing the attention on energies above $5{\cdot}10^{19}$ eV. At these energies and, if these cosmic rays were to be from a universal distribution of sources, there would be a sharp flux reduction of these showers arriving on Earth, as described by Greisen (1965) and Zatsepin and Kuz'min (1966) (the GZK cutoff) due to energy degradation via interactions with the cosmic microwave background radiation. Such a cutoff has not been experimentally observed, as reported by the AGASA experiment [Takeda et al. (1998)], and therefore particles with energy above this cutoff must come from nearby, cosmologically speaking (less than 50 - 100 Mpc), and thus it may render possible to search for sources within the nearby universe.

Cosmic rays with the above mentioned ultra high energies have an extremely low flux, very roughly estimated to be 1/km^2/century/sr, and for this reason it was decided to build a gigantic observatory spanning an area of 3,000 km^2.

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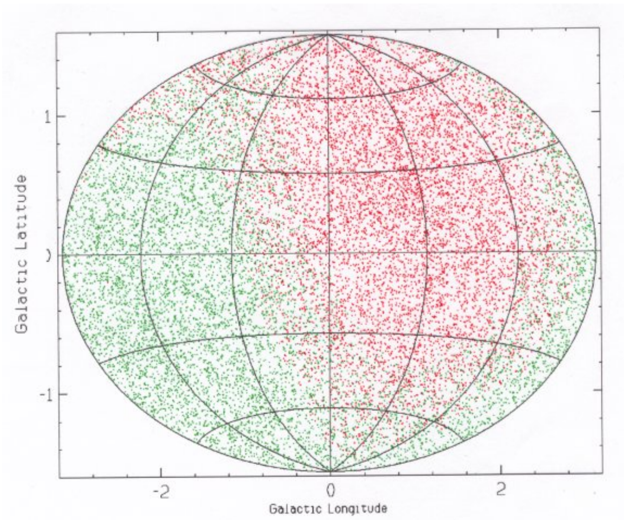

Fig. 1. Sky view simulation by the Auger Observatories in galactic coordinates. Showers with zenithal angle up to 60°, uniform source distribution.(North → red, South → green).

This is one of the three main distinct features of the Auger Observatory, the other two being: i) an observatory in each hemisphere and ii) a hybrid system.

Auger plans two observatories since anisotropy patterns in the distribution of point sources are much better studied collecting data on both hemispheres. Still, and since it was not possible to start construction of both detectors simultaneously, the project decided to build firstly the southern component since austral skies have not been explored at these energies yet, while there is data from northern skies (Volcano Ranch, Yakutsk, Haverah Park, AGASA, Fly's Eye/Hi-Res). If point sources are identified at the south, then a northern component will be in place as to have a full sky coverage (Fig.1). On the other hand, failing to identify sources will be a strong suggestion of new physics which will trigger a quest for a northern observatory from the Auger collaboration and others.

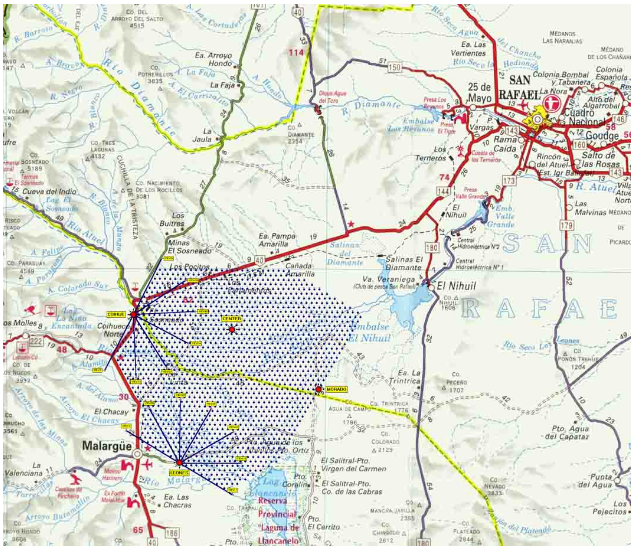

Fig. 2. Layout of the Observatory, where 1,600 surface detectors will be deployed in the dotted area and the telescope systems in the marked circles at Cerros Los Leones, Coihueco, Morados at the site periphery and a fourth one at the center. The lines encompass 30° angles which is the azimuth acceptance of each telescope. Two telescopes are being assembled at Los Leones and 40 tanks have already been deployed.

Fig. 3. Hauling of the water transportation trailer with 12 tons of pure water by two caterpillars at a difficult position with wet soil.

The other relevant feature of Auger is its hybrid nature by which it is meant that two different sorts of detectors are deployed: fluorescence telescopes overlooking an array of water Cherenkov detectors (WCD), spaced in an hexagonal grid 1.5 km apart from each other. As charged particles pass through the atmosphere, they produce fluorescence light in the range 300-400 nm and the telescopes collect this light onto phototube cameras, thus directly measuring the longitudinal profile. The surface array takes a sampling of the shower as it intercepts the ground, thus measuring the lateral profile. Auger is unique in this hybrid aspect and implies that for approximately for 10% of the showers (due to the telescope duty cycle), the shower energy, direction and primary particle composition will be independently measured providing valuable redundancy and cross checks. A hybrid device would reveal any systematic effects which might be inherent to either method. This cross calibration will certainly help to diminish doubts on the findings of Auger and in particular from any new physics that might arise from these studies. Based on the AGASA spectrum [Takeda et al. (1998)], each Auger observatory is roughly expected to measure 5000 and 50-70 showers per year at 10^{19} and 10^{20} eV, respectively, with the surface array; and 10% of them in the hybrid mode.

The selection of the observatory sites started with searches of candidate locations by scientific groups in several countries in both hemispheres. The local Auger group would identify them, develop the local scientific group and contact the relevant financing Agencies. A two-person team was chosen to survey all candidate sites with the help of local Auger collaborators. It performed a limited UBV photometry of selected stars for a few days and inspected the site by truck as thoroughly as possible.

The required properties for the telescopes were long attenuation lengths (i.e. many nights with clear skies) and appropriate ground altitudes to allow shower development (approximately 1,000 m above sea level, m.a.s.l.), while for the surface array the requisites were easy deployment and maintenance (low and scarce vegetation, availability of dirt tracks, few land owners), no extreme temperatures. There were also general conditions to be met: a nearby town with enough hotel lodgings and workshops, a thinly populated area to prevent anthropogenic pollution, support form the local community and government, a good infrastructure and an expeditious science and technology customs tax waiver. The International Collaboration chose ’Pampa Amarilla’ in the Departments of Malargüe and San Rafael, Province of Mendoza, Argentina, and Millard County, Utah, USA for the southern and northern observatory, respectively.

2 The Pampa Amarilla Observatory

Pampa Amarilla (35.0° to 35.3° S, 69.0° to 69.3° W, 1300-1400 m.a.s.l) lies in the southern portion of the Province of Mendoza, close to Malargüe city (pop. 18,000) and 180 km west of San Rafael (pop. 100,000) and encompasses an area of 3,100 km^2 (see Fig.2). Due to the sparse nature of the vegetation individual holdings are large and the total number of landowners is only 89. It has convenient hills in its periphery to place the fluorescence detectors and telecommunication towers.

Legally binding contracts have been signed with landowners, by which the collaboration gains access to the detectors over a period of 20 years, for deployment, commissioning and maintenance.

The site area is good for tank and water deployment inasmuch it is a “pampa” (i.e. a flat extensive area) with several gravel and dirt roads. Still, the soil distribution shows that a 30% of the site will have soft and wet grounds during winter and rainy periods, which may sink under weight (see Fig. 3).

Fig. 4. A WCD deployed at Auger Central Station.

In regards to light attenuation, luminosity of bright stars was measured for several elevations and three wavelengths for 22 nights from November 1997 to August 1998. Rather than using the drift-scan mode as during the site survey, the telescope was set to follow the star. The total atmospheric extinction coefficient for the UV band (365 nm) obtained was 0.485 ± 0.06 that gives an average attenuation length of 2.06 air masses, coherent with the value of 1.88 air-masses measured during the site survey. A CCD camera study showed horizontal attenuation lengths, centered at 440 nm, in the range (17 -37) km. Aerosol contents were obtained with a 3-channel (380, 500, and 1000 nm, each with FWHM = 10 nm) radiometer: the sunlight was measured over different sun angular positions, the Rayleigh attenuation was subtracted and the thus obtained three aerosol attenuations were fitted and parameterized with the Angström equation, $\beta\lambda^{-\alpha}$. The obtained value of β = 0.047 indicates a "clear" atmosphere ($\beta < 0.1$) while α=0.1 renders attenuation lengths fairly independent of wavelengths.

Similar detector concepts as those used in Auger have been previously implemented, namely in Haverah Park for the surface array and in Fly's Eye/Hi-Res for the fluorescence telescope system. But the Auger Collaboration has designed most of its equipment: telecommunication system and telecommunication control, Schmidt optics telescopes, new tank design and photovoltaic system, and the electronics have been customized to Auger.

An advantage of the WCD array is that is has a rigidly defined aperture which does not need to be estimated by means of a detector Monte Carlo, it is just set by the boundaries of the array. The Auger WCD's are 10 m^2 x 1.5 m tanks (see Fig.4) which are made of rotomolded polyethylene and each one has three 8" phototubes, a photovoltaic system, electronics and CPU, a telecommunication Yagi antenna (see Fig. 5), and a liner bag with a highly reflective and diffusive material

Fig. 5. A detail of a tank top positioned in the field.

(Tyvek(TM)) which is filled with 1.2 m of pure water (more than 3 MΩ·cm resistivity). Water tanks have a large solid angle sky coverage (eg the shower declination FWHM distributions were $\sim 75^\circ$ and $\sim 40^\circ$ for the water Cherenkov Haverah Park and scintillator Volcano Ranch arrays, respectively) and they efficiently detect γ rays since they produce relativistic electrons in the water by Compton scattering and pair production.

Two telescopes (see Fig. 6) are now being installed at Los Leones, one using slumped glass mirrors (only to be used in the current prototype phase) and other using a combination of aluminum mirrors and polished glass mirrors. The two telescopes will not only allow to evaluate the mirror design but will also enable us to match shower tracks that cross the field of view (FOV) of the two cameras. Each camera has 22 rows with 20 hexagonal 1.5° pixels. The prototype surface array is centered 10 km north and is viewed equally (in halves) by each telescope. They use Schmidt optics to eliminate the coma aberration by means of a diaphragm with nominal diameter of 1.7 m but which could be opened to 2.2 m by using a corrector ring. The designed spot size is of 0.5° and the FOV is 30° x 30°. Dead space between phototubes is eliminated by using reflective sloping walls at pixel boundaries to collect the light onto the active cathode areas.

Some tasks and responsibilities are inherent to the host country. Logistics have been a major concern since equip-

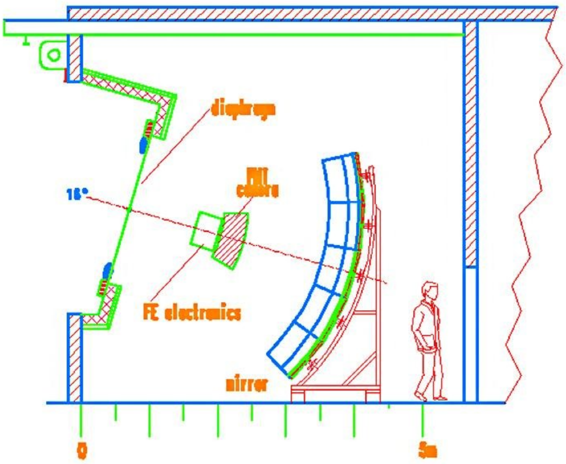

Fig. 6. A schematic view of a fluorescence telescope.

ment and detector parts come from many different countries and institutions, and need an expeditious customs clearance. Argentina has authorized Auger to use a diplomatic waiver, which after submission by the relevant country Embassy is approved within 5 days. San Rafael has a customs office which is quite efficient. The assessment of the infrastructure of the host country is also important since complex and huge scientific projects have not been frequent in it. Manufacturers have been or are being developed for rotomolded tanks and battery boxes, tank liners, aluminum solar panel supports, telecommunication antenna and towers, internet installation, water plant, etc. Buildings have been constructed (Figs. 7 and 8) and the budget allocated by the host is $ 15,000,000 out of the total cost of $ 50,000,000 for the Pampa Amarilla Observatory. By the end of 2001, Argentina will have spent or appropriated at least $ 4.880.000.

The overall schedule for the building of Pampa Amarilla is divided into two parts: the current prototype phase which is called Engineering Array (two years) and construction (three years). The Engineering Array work effectively got underway at the beginning of 2000. The plan is to finish the objectives of the Engineering Array by the end of 2001 and the complete observatory by the end of 2004. The next few years to come will be scientifically very exciting and it is expected that Auger will shed light on the mystery of the highest energy cosmic ray showers.

References

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Fig. 7. The assembly building, the internet dish, the 51 m telecommunication tower, and the pure water storage tank.

Fig. 8. The telescope building at Cerro Los Leones (12.5 km southeast of Malargüe city) with its six telescope bays.