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The Pierre Auger Observatory Upgrade Program

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Abstract

The Pierre Auger Observatory has been taking data since 2004 and with the complete set of detectors since 2008, with an efficiency above 95%, with very low downtime. Our accurancy in the results have had a deep impact on the area of ultra-high energy cosmic rays and new questions and open challenges call for an upgrade of the Observatory. The planned detector upgrade is presented and the expected performance and improved physics sensitivity of the upgraded Auger Observatory are discussed.

Keywords:
astroparticle physics, cosmic rays, instrumentation: detectors,

1. Introduction

In the last ten years the Pierre Auger Observatory [1] has been addressing the most fundamental questions about the nature and origin of the highest-energy cosmic rays.

The extremely low flux of the ultra-high energy cosmic rays (UHECRs) requires that the Observatory covers an overall area of 3000 km^2 to collect enough statistics. Using simultaneously two complementary techniques to detect the extensive air showers they induce in the atmosphere, the Pierre Auger Observatory has reduced significantly the systematics on the energy scale [2]. The 1600 water Cherenkov surface detectors (SD) are deployed on a triangular grid of 1500 m spacing and measure the lateral distribution of air-shower particles on the ground. The 27 fluorescence telescopes overlook the atmosphere above the SD from four sites located on the periphery of the array. They measure the longitudinal profile of the number of shower particles, through the nitrogen fluorescence light emitted along the shower axis.

In this report, we first present a brief summary of some important Auger results, then we make the case to motivate an upgrade to the Observatory. Following this, the proposed scintillator detector is described, representing the upgrade of the water Cherenkov detector, and the underground muon detector is described as well. Finally, the upgrade performance is also illustrated in detail.

2. Pierre Auger Observatory results

Unquestionable evidence for a cosmic-ray flux suppression above 50 EeV is observed after 10 years of the Auger operation as shown in figure 1 [3]. Strong limits have been placed on the photon and neutrino components of the flux indicating that top-down source processes, such as the decay of super-heavy particles, cannot account for a significant part of the observed particle flux [4, 5]. The spectrum and the X_{max} data together favor a scenario where the suppression is partly a source effect [6] rather than the GZK process. The limited data on X_{max} above 40 EeV is available where the trend towards heavier composition appears [7, 8], and this is due to the low duty cycle of the fluorescence detection

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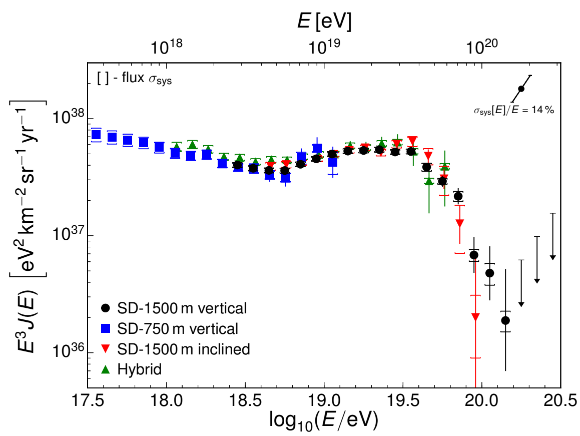

Figure 1: The Auger energy spectra obtained from hybrid events, from SD data obtained with the 1500 m array for vertical and inclined events (SD-1550), and from vertical events with the infilled SD array (SD-750).

technique. The SD has the statistic but it's not able to discriminate the composition on event-by-event basis.

A detailed report on the Auger Collaboration results was also presented at this conference [9] and therefore will not be repeated here.

3. Motivations for an upgrade

The Auger Collaboration upgrade program called Auger PRIME: (**P**rimary cosmic **R**ay **I**dentification with **M**uons and **E**lectrons) has defined the following aims for the upgrade proposal:

- to clarify the mass composition and the origin of the flux suppression at the highest energies, i.e. the differentiation between the energy loss effects due to propagation, and the maximum energy of particles injected by astrophysical sources;
- to reach a sensitivity to a contribution of protons as small as 10% in the flux suppression region; this will be crucial to predict the flux of secondary gamma rays and neutrinos due to proton interactions for future cosmic-ray, neutrino, and gamma-ray detectors;
- to investigate extensive air showers and hadronic multiparticle production, including the exploration of fundamental particle physics at energies today not accessible with accelerators, studying the constraints on new physics phenomena, such as Lorentz invariance violation or extra dimensions.

To reach these aims with high statistics and mass composition discrimination capabilities the Auger Collaboration is proposing an upgrade program with additional detectors and an extension of its operation until 2024.

4. Auger PRIME: the upgrade program

The main upgrade will be the Surface Scintillator Detector (SSD). It consists in the installation of 4 m^2 scintillator detectors on top of the existing water-Cherenkov surface detectors, providing the capability to distinguish between the electromagnetic and muonic components of air showers, which will provide information about the composition of the primary particles. The upgrade also includes the substitution of the current electronics allowing for an improved performance, the completion of the array of the AMIGA muon detectors, and the extension of the duty cycle of the fluorescence telescopes by allowing measurements during nights with more background light. A detailed description of these components of the upgrade program appears in the following subsections.

4.1. The Surface Scintillator Detector

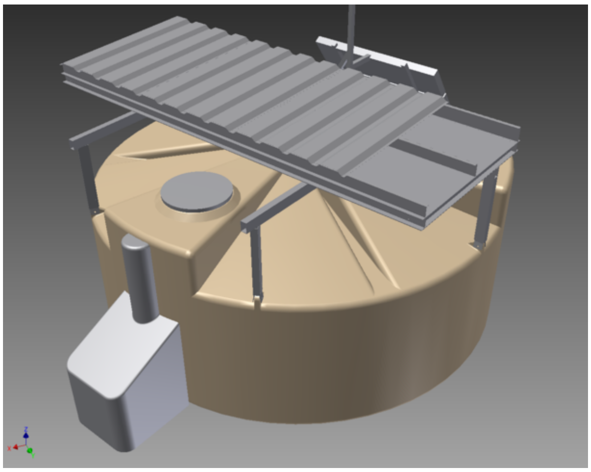

Figure 2: 3D view of a Surface Scintillator Detector mounted on a water-Cherenkov detector.

The SSD provides the complementary measurement and is made of a plastic scintillator plane mounted on the existing water-Cherenkov detectors (WCDs) as shown in figure 2.

The shower particles will be sampled by the two detectors that respond in different ways to muons and electromagnetic particles as shown for the SSD in figure 3 and for the WCD in figure 4.

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