PROCEEDINGS OF SCIENCE

Advances on the Pierre Auger Outreach and Education program

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The Pierre Auger Observatory has implemented a novel method of astroparticle detection that combines various techniques and has an open data policy. The dissemination of information about the different astroparticle detection methods, ranging from surface water-Cherenkov detectors to underground scintillator detectors, is now possible due to access to specialized tools for data analysis. This allows for the introduction of the topic of astroparticles to teachers and students at different educational levels. This marks a significant moment for the Observatory. In this work, we will discuss the diverse outreach initiatives undertaken by the Observatory, which have facilitated interaction among members of the international collaboration and enabled collaborative actions between the permanent staff of the Observatory in Malargüe and other institutions worldwide through synchronous meetings. These programs provide visitors with the opportunity to explore the environment of secondary particle cascades produced by cosmic rays, leading to a record number of monthly visitors since the opening of the Observatory 25 years ago.

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(a) **(b)**

Figure 1: (a) A bar graph displaying the annual number of people who have toured the Visitor Center since its opening; (b) Students working on the construction of a scintillator detector unit in Italy.

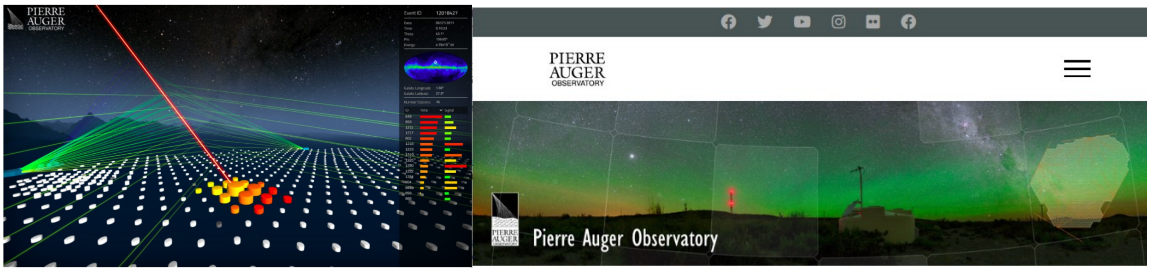
1. Introduction

Argentina's Pampa Amarilla, an expansive plateau close to the city of Malargüe, is where the Pierre Auger Observatory [1] is situated. The Observatory is currently the largest astroparticle physics experiment to investigate the physics of UltraHigh-Energy Cosmic Rays (UHECR). It makes use of a so-called hybrid detection system, which combines an optical detector for atmospheric fluorescence with a ground array, mainly consisting of more than 1600 water-Cherenkov stations distributed over a 3000 km^2 isometric triangular grid. The Pierre Auger Collaboration has produced scientific findings in a variety of related fields [2]. The energy spectrum and mass composition of the primary cosmic ray particle, the studies of neutral multi-messengers such as photons and neutrinos, and in-depth investigations of the UHECR anisotropy at large and intermediate angular scales are all used as the foundation for research into the origin of UHECRs. The information gained permits astrophysical studies and explorations of hadronic interactions at energies that are not feasible at accelerators, and the existence of unexpected physical effects, such as potential breaches of Lorentz invariance or superheavy dark matter signals. Interacting with the local population is a top priority and task for the collaboration due to the observatory's size and integration into the region.

2. Visiting the Observatory

The Visitor Center (VC), which offers regular tours and presentations to make the experiment, astroparticle physics, and scientific research accessible to the public, has always been the observatory's main method of communicating its existence and goals. The VC houses a permanent exhibition devoted to the advancement of astroparticle physics and serves as a hub for public interaction, educating the public on the most significant advancements in science, technology, and research. In 2001, VC opened its doors to the public and now receives an average of 8000 visitors per year, with the exception of two pandemic years (see Fig. 1(a)). The focus in 2015 was changed from giving presentations on the Observatory to a more interactive series of exhibits, allowing visitors to come at almost any time of the day. Since March 2023 virtual reality installations have been introduced that allow a deeper interaction with the experiment. The in-person visits include the office building garden, which houses several pieces of art, as well as examples of several types of detectors that are used in the Observatory. The COVID-19 pandemic resulted in the suspension of public visits and a decrease in science activities at observatories, with minimal staffing and strict safety measures. Therefore, the collaboration started offering virtual tours streamed online in English and Spanish, where the audience could explore the facilities and ask questions live. This activity was performed live and the recording is also available online as a part of the material of the Frontiers-project [3].

3. Scientific Citizenship programs and Open Data



(a) **(b)**

Figure 2: (a) Event Visualizer for the Master Classes; (b) Web Page on `https://www.auger.org/`.

The Observatory [4] is now being upgraded by the Pierre Auger Collaboration. The upgrade includes, among others improvements, the addition of scintillation detectors on top of the water-Cherenkov stations. These detectors [5] were constructed, evaluated, and brought from European locations to the Observatory, where they were put into use in the experimental area, after completion of the assembly. Both at the Pierre Auger Observatory in Malargüe and at INFN Lecce in Italy, one of the European sites where the detectors were developed and tested, high school students were involved in the upgrade. The activities are made possible by educational programs offered in high schools, which give students the chance to deepen and solidify their expertise through internships in public or private workplaces. The students in Italy took part in the building, commissioning, testing, and calibration of the detectors in small groups under the guidance of scientists (see Fig.1(b)). Following an educational phase covering the scientific case and detection techniques, they were able to comprehend the construction of a particle detector and address any associated technical issues. Students were able to focus on activities better suited to their skills and to take on jobs and problems that are not generally faced in a classroom context thanks to the many suggested activities, which ranged from assembling mechanical components to data analysis and programming.

A fraction of the data processed from the collaboration is made available to the public in a usable format [6] for the purpose of re-use by a wide community, including professional scientists, in educational and outreach initiatives, and by citizen scientists. A dedicated website is used to host the datasets that are available for download [7]. The collaboration has also developed the tools to analyse the public data, including a 'Ready-to-use' event display, a simple software package producing examples of basic histograms of different data parameters and analysis software demonstrating how to read the data and how to analyse them. The intention is to offer insights into how the results have been obtained. In parallel, several institutions and public events have offered special training sessions at the teachers' or students' level [8]. The creation and implementation of International Masterclasses [9] using the Auger public data has enhanced the Outreach and Education program at the Pierre Auger Observatory. The new activity made a successful premiere in 2023 with the organization of three events. It was incorporated into the International Particle Physics Outreach Group (IPPOG) program structure to reach high school students worldwide. The participants got the chance to study astroparticle physics and detection, examine the Auger public data, and talk with colleagues and scientists from other cities and nations about the data analysis that is performed with the help of an Event Visualizer (see Fig.2(a)). Many educational videos including the Observatory are available on online platforms, e.g. "Cosmic Ray Scientists and Experiments" on YouTube [10], produced for the 10th anniversary of the International Cosmic Day (`https://icd.desy.de/`). Finally, the web site of the Observatory [11] in Fig.2(b) contains a section devoted to Outreach as well as links to the other communication channels.

References

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