PROCEEDINGS OF SCIENCE

Outreach, Education and Communication Initiatives at the Pierre Auger Observatory

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The Pierre Auger Observatory in Argentina, built to study the physics of highest-energy cosmic rays, has a tremendous emotional appeal given the Pampa Amarilla environment at 1400 m asl in Mendoza, coupled with the aura of a pioneering experiment that explores the Universe. Here, we present some of the Outreach, Education, and Communication programmes carried out within the international collaboration. Since early times the Observatory has been communicating its existence and purpose through the Visitor Center, where guided tours with supporting presentations are frequently offered to make the experiment, astroparticle physics, and scientific research, in general, accessible to the public. The limitation of the on-site access by the ongoing pandemic fuelled the development of virtual tours and enlarged the number of international communication to the public. The use of high-school students' specific programs has been one of the elements of the Observatory upgrade. A part of the detectors used in the upgrade has been built in cooperation with students, setting the basis for a proficient citizen science program. A fraction of the data processed from the collaboration is made available to the public in a usable format. The collaboration developed special masterclasses, providing the resources to analyse the public data set together with special training sessions at teachers' or students' level. Finally, a glance at the worldwide inspirational activities, based on the mentioned emotional appeal of the Observatory and conducted by the International Collaboration members, will be given.

41st International Conference on High Energy Physics - ICHEP2022
6-13 July, 2022
Bologna, Italy

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PoS(ICHEP2022)386

1. Introduction

The Pierre Auger Observatory [1] is located in a large area of the Pampa Amarilla in Argentina, near the city of Malargüe. The Observatory is, to date, the largest astroparticle physics experiment to study the physics of highest-energy cosmic rays (UHECR) never realized. It uses a so-called hybrid detection system combining a ground array with an optical detector of atmospheric fluorescence. The key element of the ground array is constituted of more than 1600 water-Cherenkov stations arranged on an isometric triangular grid that covers an area of 3000 km^2. Four sites around this area, each with six fluorescence telescopes with elevation from 1° to 30°, form the fluorescence detector for measuring the light released by showers through the atmosphere. The scientific results [2] obtained by the Pierre Auger Collaboration cover different and complementary research fields. The research on the origin of the UHECRs is based on the energy spectrum and on the composition of the mass of the primary, on studies of neutral multi-messengers, such as photons and neutrinos, and on extensive research for anisotropy at large and intermediate angular scale. In addition to astrophysical studies, with the collected data, it is possible to explore the characteristics of hadronic interactions at energies that are unreachable at the accelerators and the existence of non-standard physics effects, such as potential violations of Lorentz invariance, or super-heavy dark matter signals. The Observatory has a tremendous emotional appeal given the Pampa Amarilla environment at 1400 m a.s.l. in the province of Mendoza, coupled with the aura of a pioneering experiment that explores the Universe. Moreover, the extension of the Observatory and its integration into the territory makes the interaction with the local population a top priority and duty of the collaboration.

2. Visiting the Observatory

Since early times the Observatory has been communicating its existence and purpose through the Visitor Center (VC), where guided tours with supporting presentations are frequently offered to make the experiment, astroparticle physics, and scientific research, in general, accessible to the public. The VC, located inside the Office Building of the Observatory (Fig. 1(a)), is a permanent exhibition dedicated to the evolution of astroparticle physics, playing a central role in the popularization of science initiatives conducted in the region. The Center is conceived as a public engagement hub to involve people with the main discoveries and the latest developments in technology and research fields. The VC opened its doors to the general public in 2001 and serves, on average, 8000 visitors annually (excluding the two "pandemic" years) (see Fig. 1(b)). In 2015, its focal point moved from giving presentations on the Observatory to a more interactive series of exhibits enabling the fruition of visitors arriving at almost all hours of the day. The in-person visits include the garden of the office building, which houses several pieces of art, as well as examples of several types of detectors that are used in the Observatory. During the COVID-19 pandemic, public visits were suspended, and science activities at the observatories were reduced and performed with minimum staffing and under strict safety measures. Therefore the collaboration started to offer 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 of one of the visits is also available online as a part of the material of the Frontiers-project [3]. As a side effect, the virtual tour has allowed reaching a global audience worldwide and is now considered an opportunity.

(a) **(b)**

Figure 1: (a) Office building at the Pierre Auger Observatory; (b) Bar chart showing the number of people who visited the Visitor Center from its opening.

3. The Science Fair and the Parade

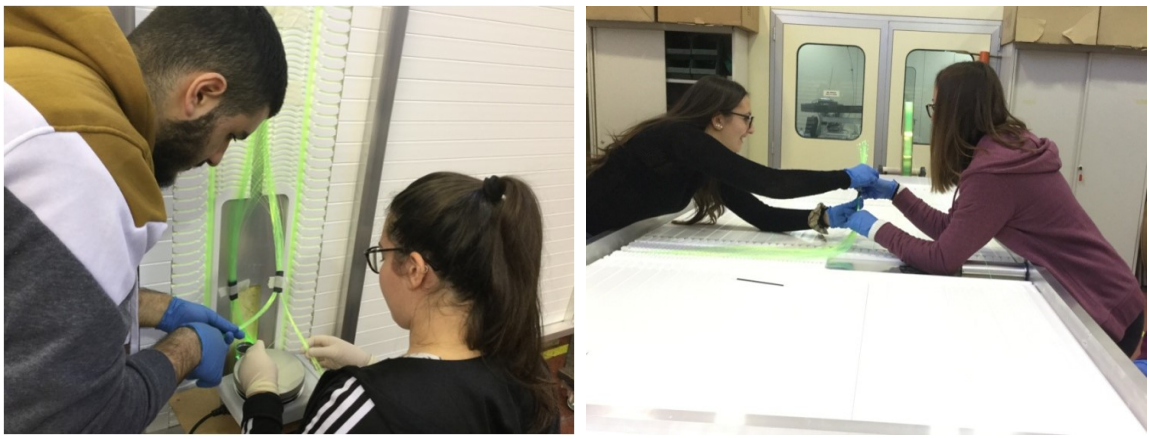
Since 2005 a Science Fair has taken place in November during the Collaboration meeting.. The Fair attracts the exhibition of science projects realized by school students from all over Mendoza Province and beyond (see Fig.2 (a)). A team of Auger collaborators is in charge of judging the projects on the basis of science content, oral and visual presentation, and a written report. The Fair is an opportunity for students to exchange ideas and opinions with the international scientific community. Every year in November, happens the Malargüe Day Parade. Students, (pre-)schoolchildren, teachers, nurses, dancers, all kinds of sport clubs, gauchos, as well as a team of the Pierre Auger Collaboration parade in the main street of the city (see Fig.2(b)).

(a) **(b)**

Figure 2: (a) A picture from the Science Fair at the Pierre Auger Observatory; (b) Auger Collaboration team in the Malargüe day parade (2015).

4. The Upgrade of the Observatory in cooperation with High School students

The Pierre Auger Collaboration is presently upgrading the Observatory [4], including, among others improvements, the addition of scintillation detectors on top of the the water-Cherenkov stations. Those detectors [5] have been built and tested in European sites and then sent to the Observatory where, after the completion of the assembly, they were deployed in the experimental area. The work to perform in this phase is systematic and repetitive and has inspired the idea of cooperation with the students from the High School, both at the Pierre Auger Observatory in Malargüe and INFN Lecce in Italy, one of the European sites where the detectors were built and tested. The program of activities is carried out thanks to Educational Programs active in the High Schools that allow the students to consolidate and expand the knowledge acquired with an internship in private or public working environments. In Italy, the students, organized in small groups tutored by scientists, participated in the construction, commissioning, calibration and testing of the detectors (see Fig.3). After a learning phase on the scientific case and detection methods, they had the opportunity to understand how to build a particle detector and to deal with the technical problems that arise. The various activities proposed, ranging from the assembly of mechanical parts to data analysis and programming, allowed the students to be directed towards activities more iin line with their aptitudes and to experience tasks and challenges not usual in school contexts. A similar program in Argentina allowed the students to be involved in the activities in the Assembly Building of the Observatory under the guidance of the staff. Here the focus was mainly on the methodological approach to scientific problems, cognitive flexibility and teamwork ability, as well as perseverance and a sense of responsibility.



(a) **(b)**

Figure 3: Students working on the construction of a scintillator detector unit in Italy.

5. Open Data

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 producing examples of basic histograms of different data parameters and an 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]. Moreover, a first version of the Auger International Master Class was developed and tested on 9th May 2022 [9] based on the use of an Event Visualizer (see Fig.4) to perform data analysis.

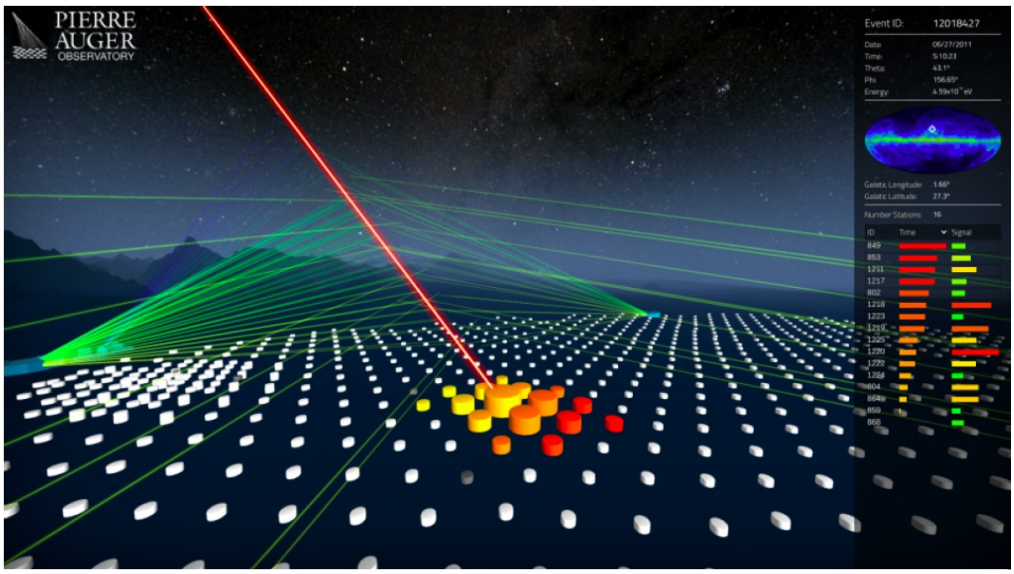


Figure 4: Event Visualizer for the Master Classes.

6. Worldwide Inspirational Activities

The emotional appeal of the Observatory has inspired several activities, and only a few are presented in this paper. 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/) (see Fig.5(a)). A gallery of artistic illustrations depicting the journey through the Universe of cosmic-ray particles [11] (see Fig.5 (b)) is included in one of the institutional sites of the collaboration.

A hand-made crochet mask, shown in Fig.6(a), has been created as a tool to introduce the Pierre Auger Observatory at Science Fairs and talks for students. The mask is built with decorative elements representing different parts of the detectors characterizing the upgrade. Finally, the web site of the Observatory [12] in Fig.6(a) contains a section devoted to Outreach as well as links to the other communication channels.

(a) **(b)**

Figure 5: (a) One of the educational videos on the YouTube platform, including the Pierre Auger Observatory; (b) Artistic illustration of the Pierre Auger Observatory - Credits to Lucian Muntean/Gina Isar/ISS.

(a) **(b)**

Figure 6: (a) "Observatorio Pierre Auger Aparecido"- Crochet Mask by G.Cataldi - Italy; (b) Web Page of the Observatory: on https://www.auger.org/.

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