

Outreach, Education, and Communication Initiatives at the Pierre Auger Observatory

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The Pierre Auger Collaboration has a long tradition of outreach that engages a wide range of people of all ages worldwide. In Malargüe, Argentina, the heart of the Pierre Auger Observatory, the Visitor Center offers a permanent interactive exhibition. Every November Collaboration meeting, we organize a Science Fair where Argentinian students from across the country can present their works and talk with the scientists at the site, motivating youngsters to pursue a career in Science. We also participate in the local parade, commemorating the foundation of Malargüe. We have developed numerous activities and interactive tools, including a 3-D event display. We have an open data policy and share them according to FAIR principles. Recently, we joined the International Masterclasses within the International Particle Physics Outreach Group, using a framework similar to the ATLAS and CMS Collaborations. In this contribution, we summarize all of our Outreach activities.

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1. Introduction

The Pierre Auger Observatory [1] is the world's largest facility for measuring the extensive air showers produced by ultra-high energy cosmic rays (UHECR) above 10^{17} eV. UHECRs offer the unique opportunity to investigate the nature of astrophysical sources and particle interactions in a kinematic and energy region well beyond that covered by current particle accelerators.

The Observatory is located on a high-altitude plain near Malargüe, Mendoza Province, Argentina, at a mean altitude of about 1400 m. It features an array of 1600 water-Cherenkov particle detectors covering 3000 km² on a 1500 m triangular grid. The array is overlooked by 24 air-fluorescence telescopes grouped at four sites. A low-energy extension with a denser surface array and three high-elevation fluorescence telescopes is also installed. Monitoring devices are constantly measuring the local properties of the atmosphere, which serves as a giant calorimeter. An extensive upgrade [2] program has been recently finalized, and the original layout has been complemented with new detectors (scintillators, underground muon detectors, and radio antennas) and equipped with faster electronics.

The rich data collected by the Collaboration covers different and complementary research fields from astroparticle to fundamental physics. The different devices involved in this research originate a large variety of data, which includes atmospheric data and low-energy events suitable to space-weather studies. The Pierre Auger Collaboration upholds the principle that data should be accessible and reused by the widest possible community. Since 2007, the [Pierre Auger Observatory Event Browser](#), with 1% of data from the surface detector, was created for educational purposes. In February 2021, the [Open Data Portal](#) [3] containing 10% of cosmic-ray data used at the ICRC19 conference and the associated analysis software has been published to engage professional and citizen scientists in worldwide research, educational, and outreach events.

Since the Observatory's foundation, the Pierre Auger Collaboration has developed a vast outreach program that involves the general public and students of all levels. This program spans from local initiatives, dedicated to enforcing the bindings with the local community, as the Malargüe parade, public events held at the Observatory's headquarters, and visits by the researchers to local schools, to global initiatives involving students connected from many countries worldwide. Moreover, initiatives on social networks and in the media, have generated a larger impact reaching tens of thousands of participants. All initiatives can be found at the official [Pierre Auger](#) page, under the Outreach card; see also [4, 5]. A selection of local and world-wide initiatives to disseminate the science behind the Observatory activity and the obtained results, is presented here in detail.

2. Local Initiatives

The Pierre Auger Visitor Center

The Pierre Auger [Visitor Center \(VC\)](#) has been installed at the Observatory headquarters in Malargüe since 2001 and offers a permanent interactive exhibition. Visitors can participate in regular guided tours and presentations to describe the detectors and introduce the general public to cosmic-ray physics. The main room is equipped with material related to the detectors with which the experiment



Figure 1: Collection of pictures from the Visitor Center in Malargüe (upper panels), the 8th Science Fair (lower-left panel) and the Malargüe Parade (lower-right panel).

works: models, videos, virtual reality devices, real-time detectors and detailed posters that allow visitors to understand the Observatory objective and work.

The Visitors Center has reached an average of about 10 000 visitors annually. During each visit, a number of questions arise that require a more detailed explanation. The selection of specific topics that recur in the public's questions and the search for the best answers were the starting point for the creation of "Auger in Focus", a bulletin available online on the VC page that helps to go deeper into topics related to science and technology at the Pierre Auger Observatory. A guest book is available to express comments and suggestions. Finally, virtual events are held from the VC in connection with particular days involving people world-wide. Two pictures from the Visitor Center in Malargüe are shown in Fig. 1, upper panels.

Science Fair and Malargüe Parade

Each year in November, during the Pierre Auger Collaboration meeting, the Science Fair is organized, involving 170 teachers and their thousands of students from primary to secondary schools in the Mendoza and surrounding regions. The Science Fair, currently at its 9th edition, aims to provide a space where students can show their research skills and their understanding of how to achieve new knowledge through the scientific method.

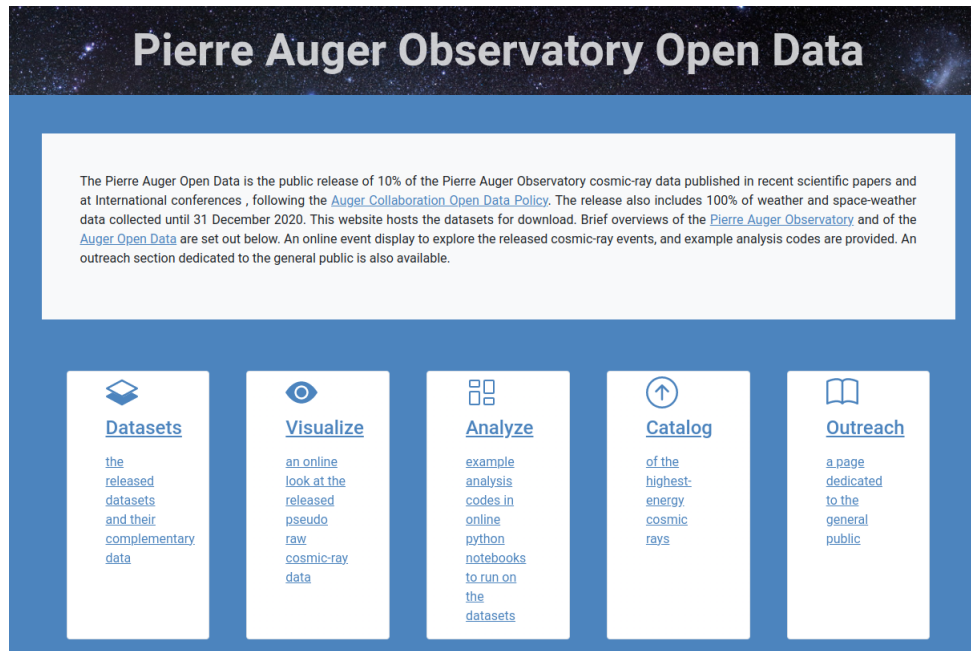


Figure 2: Screenshot of the main page of the [Open Data Portal](#), with the links to the five different sections of the page. For more details see [9].

The students exhibit the work developed with their classmates under their teachers' guidance and share their experiences in an environment where they will be guided in the way Science progresses, encouraging the exchange among the participating students and with the researchers of the Pierre Auger Observatory. A team of evaluators from the Auger Collaboration and the Faculty of Sciences of Malargüe select the best proposals. They visit the stands and share their experiences with the teachers and students. More than 500 visitors from the Malargüe community visit the fair each year.

Every year on November 16th, to celebrate the upcoming anniversary of the founding of Malargüe, the Pierre Auger collaborators and the Observatory staff participate in the Malargüe Parade, an event that is particularly meaningful to the local community. A section of the parade is dedicated to the Auger Observatory, with senior and junior collaborators marching together as a sign of the Observatory's multi-decade connection to the local community. Pictures from the 8th Fair of Science and the Malargüe Parade are shown in Fig. 1 on the lower-left and -right panel, respectively.

3. The Open Data Portal

Since February 2021, the [Open Data Portal](#) [3] was published, containing 10% of cosmic-ray data used at the ICRC19 conference and 100% of atmospheric measurements and low-energy data for space-weather studies. The portal is being continuously extended and updated in compliance with the *Data open-access policy of the Pierre Auger Observatory* [6]. Data are released under the [CC BY-SA 4.0](#) International License, and they have a unique Digital Object Identifier (DOI) always pointing to the latest version (<https://doi.org/10.5281/zenodo.4487612>). This format is following

the Berlin Declaration and the FAIR principles on data being Findable, Accessible, Interoperable, and Reusable [7]. The Pierre Auger Collaboration is committed to the principle that open access to the data and associated software is the only way to achieve the full scientific potential of the data in the longer term.

The portal contains a detailed explanation of the detectors and how the data are collected. Pre-selected data and high-level event info are available in a portable file format (JSON and CSV). 3D event visualization tools allow an immersive view of the atmospheric cascades. Python codes have been developed to allow easy data manipulation and to understand the recently published scientific results. Basic and advanced codes developed within the [Jupyter Notebook](#) platform allow the user to explore data and develop original ideas.

A catalog of the highest-energy events [8] collected by the Observatory during the first phase of data taking has been published on the portal in 2023 under the UHECR catalog card. Finally, a simplified Outreach section dedicated to the general public and a help desk for contacting the Collaboration are also available. Since its opening, the Open Data Portal reached more than 40 000 visits and the public datasets have been downloaded more than 3000 times. A screenshot of the portal's main page is shown in Fig. 2. For more details, see [9].

4. Global initiatives

International Cosmic Day

The Pierre Auger Observatory participates in the [International Cosmic Day \(ICD\)](#), promoted by [DESY](#) within the [International Particle Physics Outreach Group \(IPPOG\)](#). ICD activities aim to bring together students, teachers, and researchers to discover and explore the properties and meaning of the information coming to us from the Universe via cosmic rays. Involved students become *scientists for one day* and try to find answers to questions such as: what are cosmic particles? Where do they come from? What messages do they bring us? How can we measure them?

The events include activities such as introductory discussions, news about the latest results, and direct measurement of cosmic particles with demonstration detectors. Guided analyses of the collected data and interactive online discussions between the participating groups are organized at each institution by the involved professors and researchers. The Pierre Auger Collaboration also offers video calls with guided tours of the Observatory and comments by experts. Finally, a booklet containing the written contributions of the participating students summarising their experience and the obtained results is produced and distributed online. A selection of pictures taken during the ICD events is shown in Fig. 3, left panel.

International Masterclasses

Since 2023, the Pierre Auger Observatory joined the [International Masterclasses \(IMC\)](#) program of the IPPOG with a dedicated initiative, the [Pierre Auger Observatory Masterclasses](#), held between February and April. The International Masterclasses involve more than ten thousand 15- to 19-year old students from 60 countries and take place in about 225 universities or research centers. The IMC provide an opportunity for students to discover particle physics and unravel its mysteries. Lectures by active scientists offer insight into topics and methods of fundamental research at the foundations of matter and forces and allow students to perform measurements on actual data from

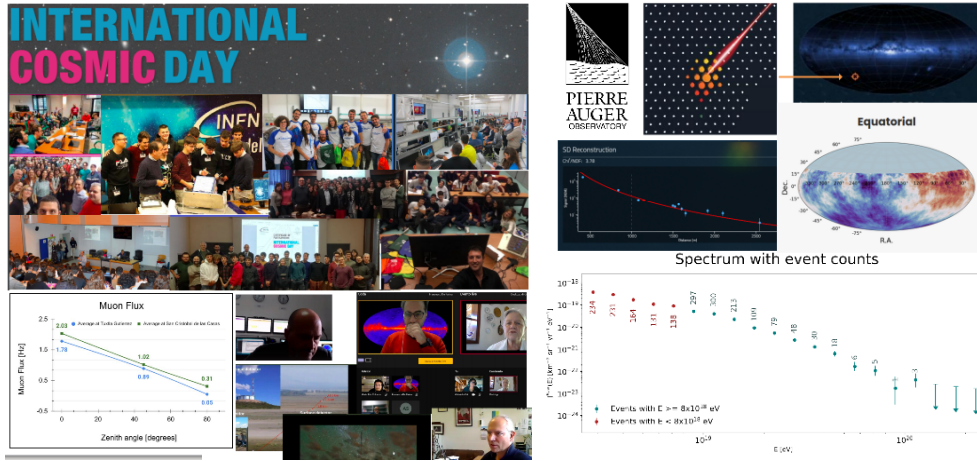


Figure 3: Collection of pictures from the international outreach initiatives: ICD (left panel) and Pierre Auger Observatory Masterclasses (right panel).

particle physics experiments. At the end of each day, as in an international research collaboration, the participants meet via video-conference to discuss and combine their results.

Under the IMC framework, the Pierre Auger Observatory organizes yearly dedicated events for high-school students worldwide. During this activity, high-school students spend a whole day at universities or research institutes learning about ultra-high energy cosmic rays and the Pierre Auger Observatory. The students analyze the Pierre Auger public data to look for answers to questions about the origin and the properties of ultra-high-energy cosmic rays. A selection of graphics obtained by the participating students using the data analysis interface is shown in Fig. 3, right panel. Afterwards, the students participate in a joint video-conference with their peers at other locations and with scientists at the Pierre Auger Observatory in Malargüe, to discuss their results and take a virtual tour of the Observatory. For further details see [5].

References

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