The Pierre Auger Observatory

On the vast plain known as the *Pampa Amarilla* in western Argentina, the Pierre Auger Observatory is studying the highest-energy particles in the Universe, which hit the Earth from all directions, so-called cosmic rays. Cosmic rays with low to moderate energies are well understood, while those with extremely high energies remain highly mysterious. By detecting and studying these rare particles, the Pierre Auger Observatory is tackling the enigmas of their origin and existence.

**Area:** 3,000 km²  
(30 times the size of Paris)

**Surface Detector**  
1,660 surface detector stations  
(1,500 m apart from each other)

**Fluorescence Detector**  
27 fluorescence telescopes  
(in 4 different places)

**The Pierre Auger Collaboration**

- ~ 500 scientists  
- ~ 90 institutes  
- 16 countries

**Main Goals:**

Determination of the energy, direction and mass composition of cosmic rays with energies above $10^{18}$ eV to better understand the universe.

**Location:**

Malargüe, Province of Mendoza, Argentina

**Construction Budget:** US$ 54 million

**Published Papers:**

- 60 published peer-reviewed papers  
- > 7,000 citations

**Auger Spokespersons / Contact Persons**

Karl-Heinz Kampert (kampert@uni-wuppertal.de)  
Spokesperson of the Pierre Auger Observatory,  
Professor of physics and chair of astroparticle physics at the Bergische Universität Wuppertal, Germany.

Antonio Bueno (a.bueno@ugr.es)  
Co-spokesperson of the Pierre Auger Observatory,  
Professor of physics at the Universidad de Granada, Spain.

**Founding Fathers of Auger**

Jim W. Cronin  
Spokesperson Emeritus of the Pierre Auger Observatory,  
Professor Emeritus at the University of Chicago, USA.  
Nobel Prize in Physics in 1980 together with Val L. Fitch, for their discovery of the asymmetry in the behaviour of matter and antimatter.

Alan A. Watson  
Spokesperson Emeritus of the Pierre Auger Observatory,  
Professor Emeritus at University of Leeds, United Kingdom.  
Fellow of the Royal Society since 2000.
**Timeline**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tr>
<td>1992</td>
<td>Jim W. Cronin and Alan A. Watson suggest building a giant air shower array with much greater collecting power than had ever been considered previously.</td>
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<td>1995</td>
<td>Production of a design report – reference design and cost estimate – by the Design Group for the Auger Project hosted by Fermilab, Illinois, USA. This becomes the basis for funding proposals in 17 participating countries.</td>
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<td>1995 Nov</td>
<td>A meeting is held in Paris to form the collaboration. It chooses the site of Mendoza, Argentina in the Southern Hemisphere. The Observatory is named after the French physicist Pierre Victor Auger.</td>
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<td>1999 Mar</td>
<td>Signature of the International Agreement in Mendoza.</td>
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<td>2000</td>
<td>Beginning of the construction of the observatory.</td>
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<td>2001</td>
<td>The Engineering Array – a full-scale prototype of the first 32 SD stations and a single fluorescence telescope – is operated for 6 months. It is later integrated into the main setup and used for more detailed design choices and calibration.</td>
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<td>2003</td>
<td>The Observatory becomes the largest detector in the world for the detection of ultra-high energy cosmic rays.</td>
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<td>2004</td>
<td>First physics results are reported from more than 100 surface detector stations.</td>
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<td>2007 May</td>
<td>Release of 1% of the data to the public for outreach purposes. The data can be explored at the website of the Public Event Display (<a href="http://www.auger.org/event-display">www.auger.org/event-display</a>).</td>
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<td>2007 Nov</td>
<td>Preliminary results indicate that the directions of origin of the 27 highest-energy events are correlated with the locations of active galactic nuclei (AGNs).</td>
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<td>2008</td>
<td>Observation of the energy spectrum of cosmic rays confirms that the flux is strongly suppressed above $4 \times 10^{19}$ eV as predicted by the GZK theory.</td>
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<td>2009</td>
<td>Best present limits are set on the detection of photons with an energy of $10^{18}$ eV.</td>
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<td>2010</td>
<td>Observations of the depth of the maximum of air-shower profiles above $10^{18}$ eV give first hints on the composition of cosmic rays at ultra-high energy.</td>
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<td>2011</td>
<td>Solar physics with the Auger Observatory.</td>
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<td>2012</td>
<td>Measurement of the proton-proton cross section at a centre-of-mass energy of 57 TeV, complementing results from the LHC – always below 14 TeV.</td>
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<tr>
<td>2013</td>
<td>Best present limits on the detection of neutrinos with an energy of $10^{18}$ eV.</td>
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<td>2015</td>
<td>Observation of large-scale anisotropies: Arrival directions of cosmic rays are not evenly distributed, giving hints on the origin – whether galactic or extragalactic – of cosmic rays at ultra-high energy.</td>
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<td>2015</td>
<td>Observations of a deficit in the number of muons in air showers challenge predictions from hadronic interaction models.</td>
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<td>AugerPrime</td>
<td>AugerPrime – Celebrate 15 years of achievements and signature ceremony of a new International Agreement for the next ten years (<a href="http://www.auger.org/augerprime">www.auger.org/augerprime</a>).</td>
</tr>
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**AugerPrime**

The upgrade will consist of enhanced surface detector stations (SSD), faster electronics, dedicated underground muon detectors and optimized operations for the fluorescence telescopes.

Ten more years of operation is planned to double the data set and to particularly study:

- The origin of the flux suppression at ultra-high energy,
- The proton contribution at highest energies ($E > 6 \times 10^{19}$ eV), leading to a so-called "particle astronomy"
- New particle physics beyond the reach of the LHC

**What is it made of?**

- **How does it get to us?**

**Where does it come from?**

**How does the airshower of billions of particles develop?**

**How can we improve the detector?**

More information at www.auger.org
Enhancements and further developments to the Observatory

**AERA – Auger Engineering Radio Array**
- 153 radio detection stations spread on an area of 17 km²
- radio-station array completed in April 2015
- detects the radio emission from cosmic-ray showers in the frequency range of 30-80 MHz
- measures the cosmic-ray composition beyond $3 \times 10^{18}$ eV

**AMIGA – Auger Muons and Infill for the Ground Array**
- an infilled area of 61 surface detector stations, deployed on a 750 m triangular grid of 23.5 km², each paired in the future with a 30 m² plastic scintillator and buried 2.3 m underground
- first 7 stations with muon detectors have been deployed in an engineering array called the Unitary Cell (UC), completed in Feb. 2015
- measures the muon content of air showers

**HEAT – High Elevation Auger Telescopes**
- 3 FD telescopes with elevated field of view – being tilted by 29°
- designed to cover the elevation range from 30° to 58°, which lies above the field of view of the standard FD telescopes
- extends the energy range of cosmic air-shower measurements down to $10^{17}$ eV

**Funding agencies**

**Argentina**
- Comisión Nacional de Energía Atómica
- Agencia Nacional de Promoción Científica y Tecnológica (ANPCyT)
- Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)
- Gobierno de la Provincia de Mendoza
- Municipalidad de Malargüe
- NDM Holdings and Valle Las Leñas, in gratitude for their continuing cooperation over land access

**Australia**
- The Australian Research Council

**Brasil**
- Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)
- Financiadora de Estudos e Projetos (FINEP)
- Fundação de Amparo à Pesquisa do Estado de Rio de Janeiro (FAPERJ)
- São Paulo Research Foundation (FAPESP)

**Czech Republic**
- Ministry of Education, Youth and Sports

**France**
- Centre de Calcul IN2P3/CNRS
- Centre National de la Recherche Scientifique (CNRS)
- Conseil Régional Ile-de-France
- Département Physique Nucléaire et Corpusculaire (PNC-IN2P3/CNRS)

**Germany**
- Bundesministerium für Bildung und Forschung (BMBF)
- Deutsche Forschungsgemeinschaft (DFG)
- Helmholtz-Gemeinschaft Deutscher Forschungszentren (HGF)
- Ministerium für Wissenschaft und Forschung, Nordrhein-Westfalen
- Ministerium für Wissenschaft, Forschung und Kunst, Baden-Württemberg

**Italy**
- Istituto Nazionale di Fisica Nucleare (INFN)
- Istituto Nazionale di Astrofisica (INAF)
- Ministero degli Affari Esteri e della Cooperazione Internazionale (MAE)
- Ministero dell’Istruzione dell’Università e della Ricerca (MIUR)

**Mexico**
- Consejo Nacional de Ciencia y Tecnología (CONACyT)

**Netherlands**
- Ministerie van Onderwijs, Cultuur en Wetenschap
- Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO)
- Stichting voor Fundamenteel Onderzoek der Materie (FOM)

**Poland**
- National Science Centre

**Portugal**
- Portuguese national funds and FEDER funds within Programa Operacional Factores de Competitividade through Fundação para a Ciência e a Tecnologia (COMPETE)

**Romania**
- Ministry of National Education and Scientific Research
- Romanian Authority for Scientific Research and Innovation ANCSI (NDII-UEFISCEDI)
- Programme for research - Space Technology and Advanced Research (STAR)

**Slovenia**
- Slovenian Research Agency

**Spain**
- Comunidad de Madrid
- Ministerio de Educación y Ciencia
- Xunta de Galicia

**USA**
- Department of Energy
- National Science Foundation
- The Grainger Foundation

**International**
- European Particle Physics Latin American Network
- European Union 7th Framework Program
- UNESCO