The Pierre Auger Observatory Open Data

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ICRC 2021
THE ASTROPARTICLE PHYSICS CONFERENCE
Berlin | Germany
37th International Cosmic Ray Conference
12–23 July 2021

Outline

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The Pierre Auger Observatory Open Data - February 2021 release

- The Observatory
- The Data
- Visualization
- Tools for analysis
- Outlook

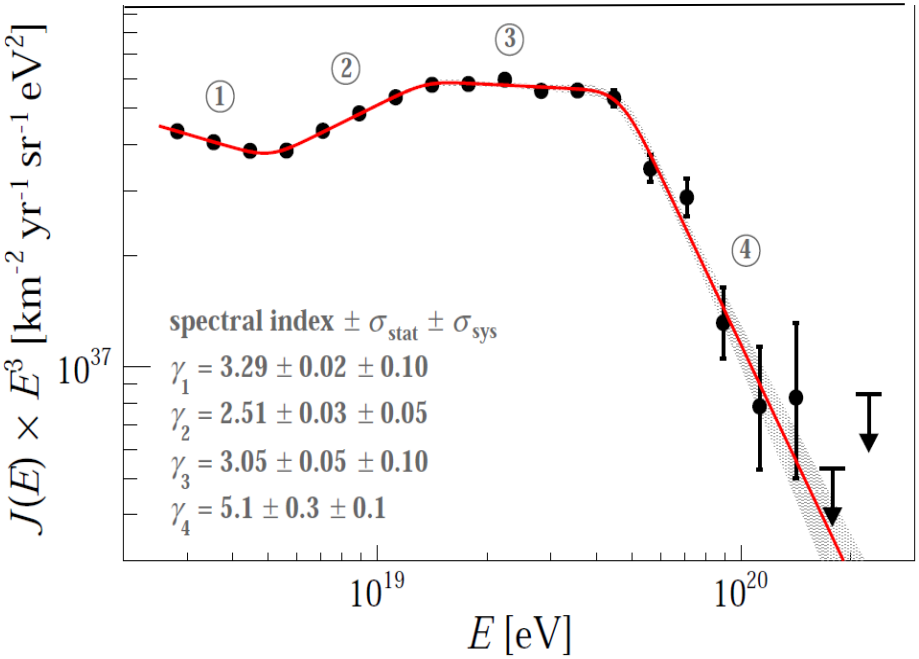
The Observatory

The scientific case

nature and origin Ultra-High Energy Cosmic Rays

- Energy spectrum
- Arrival directions
- Composition
- Search for photon and neutrinos as primary cosmic rays
- Hadronic physics

Auger Collaboration PRL 2020 arXiv 2008.06488



The Collaboration

~400 scientists from 18 Countries

for a summary of Auger achievements see:

R. Engel highlight talk at this conference

The Observatory

The hybrid concept

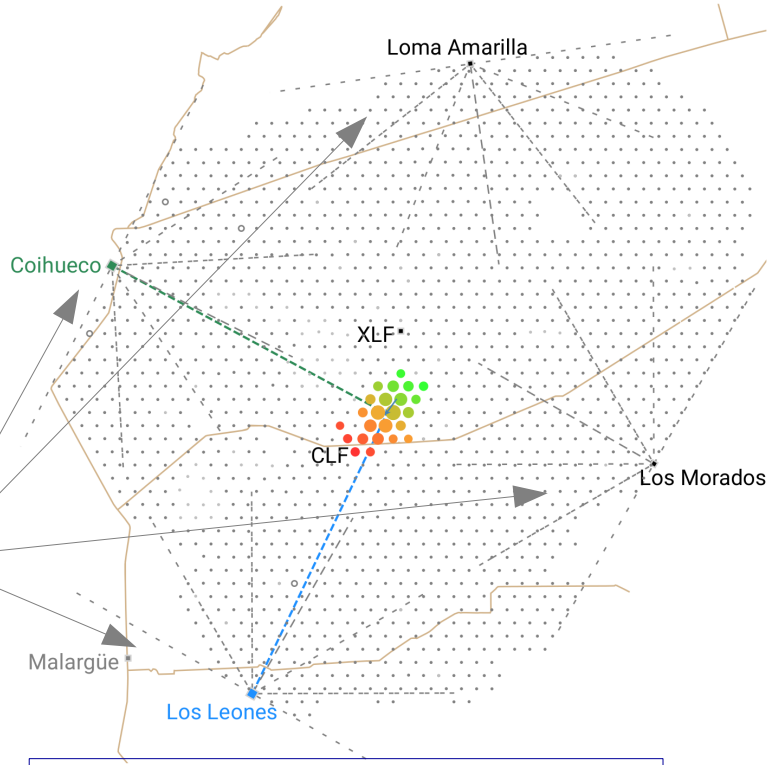
Surface Detector (SD)
Density of particles at the ground:
duty cycle ~ 100%

1600 stations @ 1.5 km, 3000 km^2
61 stations @ 0.75 km, 25 km^2

Fluorescence Detector (FD)
Longitudinal profile:
duty cycle ~ 15%

24 FD Telescopes @ 4 sites,
1°- 30°FoV
3 High Elevation Tel. (HEAT),
30°- 60° FoV

Malargüe, Mendoza Argentina



most energetic multi-eye event in the sample (E ~ 6 x 10^{19} eV)

The Open Data

The February 2021 release

10% of data used for physics results presented at ICRC2019

Aim: re-use by a wider community
including professional and citizen scientists and
in world-wide educational & outreach initiatives

- Close-to-raw data & higher level reconstructed information
- Surface and Fluorescence Detectors
- JSON and summary CSV files
- Event visualization tools
- Python code for data analysis

PIERRE AUGER OBSERVATORY

`https://opendata.auger.org`

`DOI:10.5281/zenodo.4487613`

The Data: SD

Surface Detector data:

over 20000 events

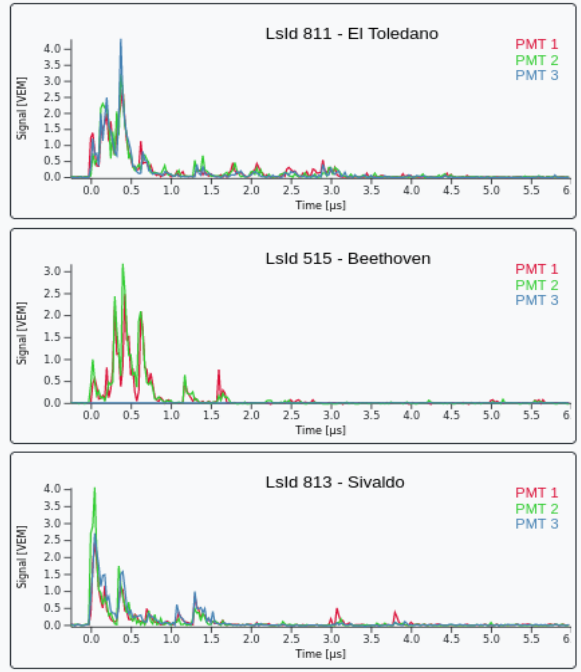
Data taking 2004-2018

Full Efficiency: E > 2.5 x 10^{18} eV and θ < 60°

Feb 2021 release	SD, all events 22731	Hybrid, all events 3156		
	Full efficiency	Spectrum	Calibration	X_{max}
Number of events	21564	1539	414	3057
Data taking period	2004-2018	2004-2017		
Threshold energy	2.5 EeV	1 EeV	2.5 EeV	0.6 EeV
Zenith angle range	0 – 60°	0 – 60°	0 – 60°	0 – 90°

Table 1: Details of the event samples of the 2021 Open Data release.

Recorded PMT traces



The Data: FD

Fluorescence Detector data:

over 3000 events

Data taking 2004-2017

specific selection criteria / energy thresholds:

→ **X_{max} , energy spectrum and calibration**

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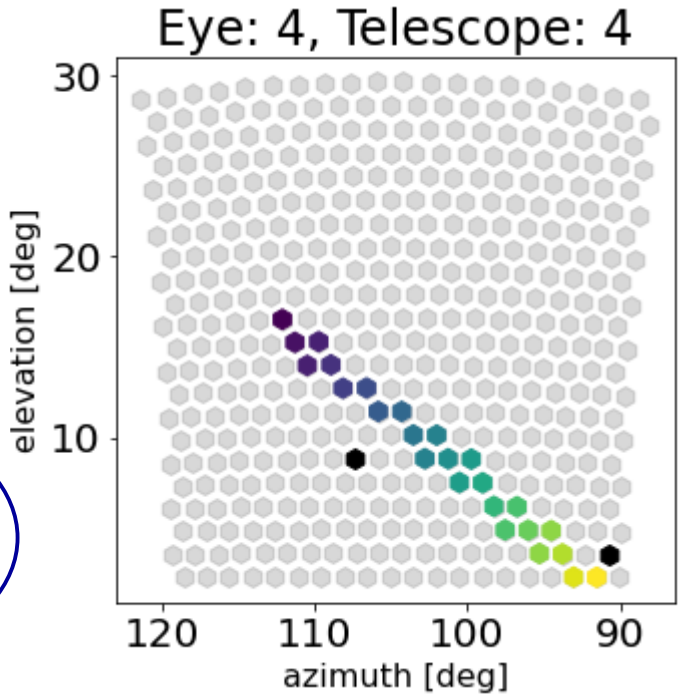
Fluorescence track view



Visualization

public event display:

- event selection

  ID, energy, Zenith angle, GPS time

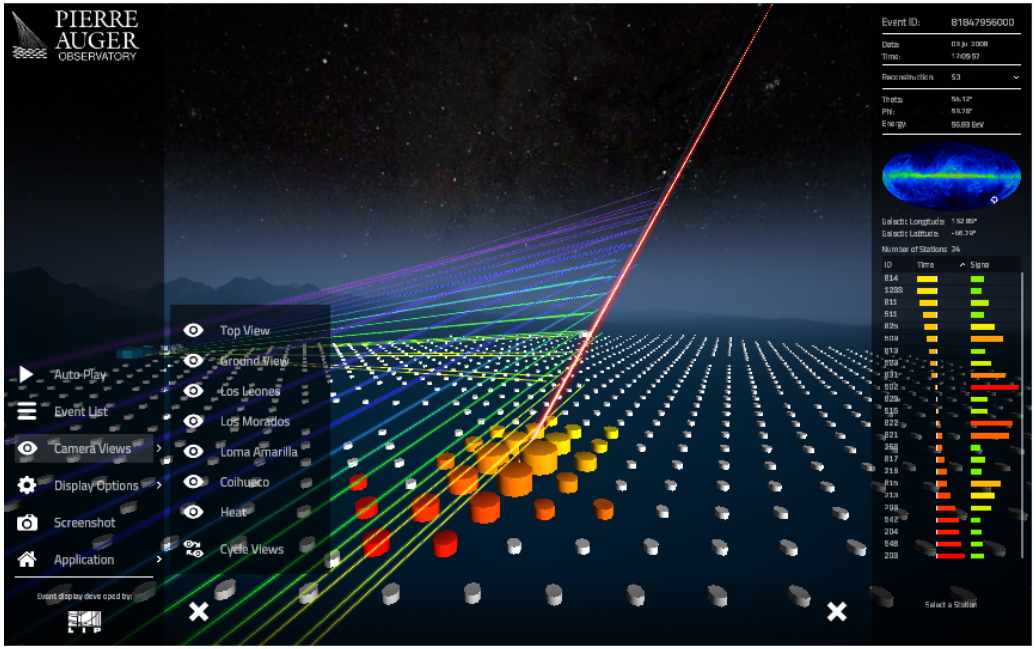
  multiple visualization tabs: SD/FD

- exemplary events

  most energetic event, multi-eye events …

interactive 3D display:

animated, interactive, views of the Observatory



Developed @ LIP Portugal

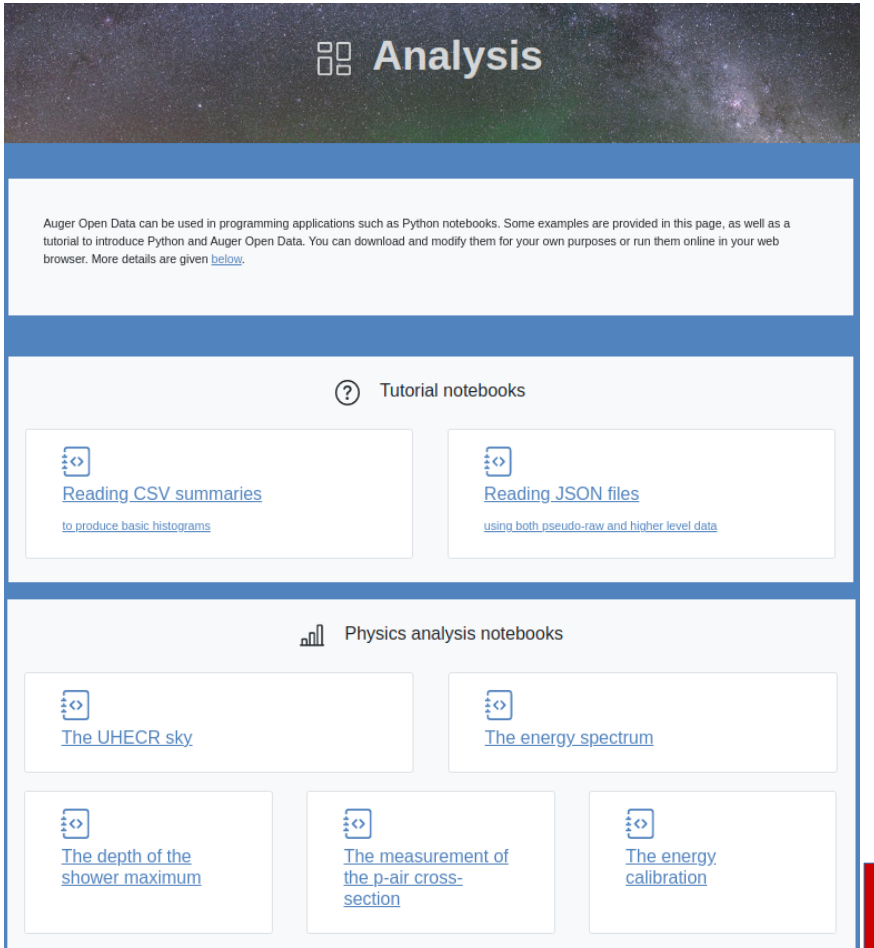
Tools for analysis

Science python notebooks

- **Tutorial notebooks**
  - to handle JSON and CSV files
  - plot variables, histograms, trends
- **Advanced analysis notebooks**
  - energy calibration
  - energy spectrum
  - Xmax analysis
  - cross section
  - UHECR sky

use Auger Open Data

understand physics results



Sep 2021 release

“Other than cosmic-ray data”:
Environmental and space-weather data:

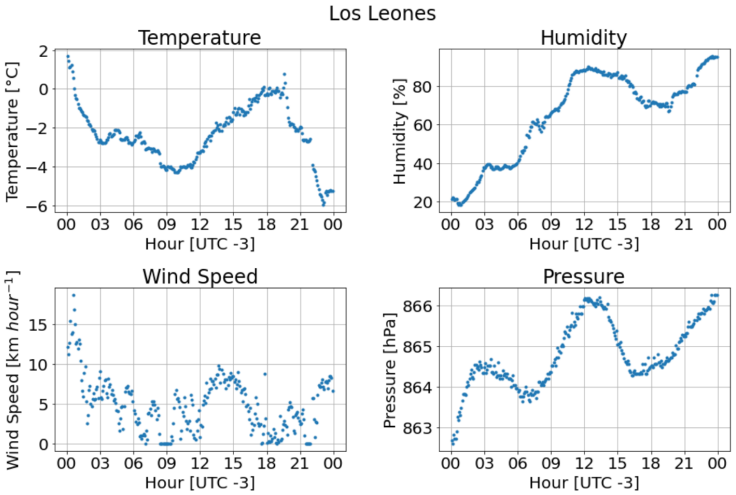
- temperature, humidity, pressure and wind speed at the Pierre Auger Observatory site → weather corrections

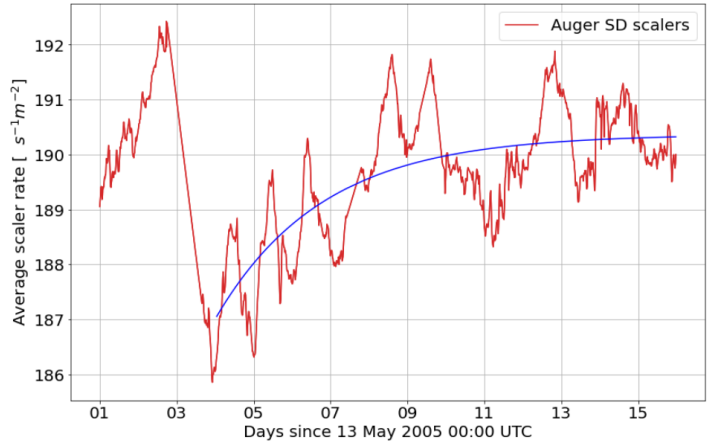
- scaler mode particle counters for low energy cosmic ray studies → forbush decrease event

Open Data web portal:
- new notebooks
- outreach & education section:
  - → for students: play with our data!
  - → for educators: tutorials & exercises
  - → for citizen scientists and the general public

many years of outreach activities @ Auger:

K. S. Caballero Mora talk in the E&O session





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10% data from 2004-2018 (ICRC19): over 20000 showers from SD and 3000 from FD, event visualization and analysis tools

Sep 2021 release: More science data, Outreach & Education section

Next release in 2022: Extended data sample (ICRC 2021), MC simulations

please stay tuned at `https://opendata.auger.org`