

Monte Carlo simulations for the Pierre Auger Observatory using the VO auger grid resources

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4. VO auger

Established in 2006 by the Czech group
Cooperation with CESNET

- 32 members
- 11 countries
- 23 sites
 - 1.3 M files
 - 210 TB disk space

1.4 PB
storage capacity!

-  **metacentre** cesnet
 - Provides and maintains central resources
 - Registration portal
 - VOMS server
-  **DIRAC** THE INTERWARE
 - Job management
 - File Catalog

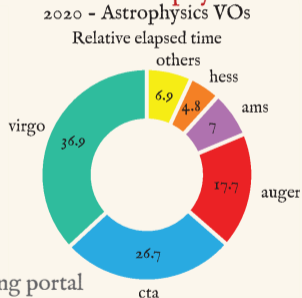
5. VO auger - 2020 Yearly statistics*

Usage comparable with other astrophysics VOs

Single-core jobs

- ~ 100000 jobs
- 5 Regions
- 6 Sites
- 60 million CPU hours
- Year average
 - 562 cores
 - > 200 TB

*From the EGI accounting portal



3. Auger Monte Carlo libraries



Multipurpose simulation libraries

CORSIKA

- ~ 700 k files
- $\lg(E/eV) = 15.0 - 20.2$
- 5 species (γ , H, He, O, Fe)
- 3 hadronic interaction models
- 10^{-6} thinning

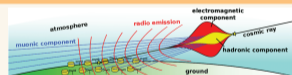
Auger Offline

- > 1 M files
- CORSIKA as input
- 5 – 30 \times resamplings
- Hybrid reconstruction
- SD reconstruction

And also hybrid time dependent simulations

7. In the pipeline...

- Multi-messenger studies
 - Neutrino simulation libraries
- Hadronic studies; muons
 - Inclined air shower libraries
- AugerPrime
 - Upgrade existing libraries



- Many radio simulations
 - Computationally expensive



MPI needed!



Eva Santos¹, on behalf of the Pierre Auger Collaboration²

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OBSERVATORY

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1. Pierre Auger Observatory

Largest cosmic ray detector in the world
More than 1500 events with $E > 10^{19.5}$ eV!



Pierre Auger Observatory schematic sketch.

- $E > 10^{16}$ eV
- Surface Detector (SD)
 - 3000 km²
 - 1660 water-Cherenkov detectors
- Fluorescence Detector (FD)
 - 4 sites
 - 27 fluorescence telescopes

2. AugerPrime

Enhanced measurements at the highest energies

- Surface Scintillator Detector
- Radio Detector
- Underground Muon Detector
- SD extended dynamic range
- SD Electronics Upgrade
- FD extended duty cycle



AugerPrime surface detector station.

New simulation libraries needed!

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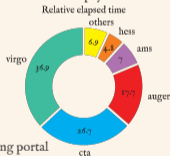
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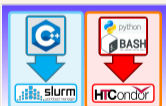


6. Production framework

Local clusters and grid

Farm

- Productions:
- CORSIKA & Offline
- Job submission:



Grid

- Productions:
- CORSIKA
- Job submission:



8. References:

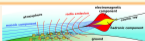
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6. S. Arribó et al., *Nucl. Instrum. Meth. A* 910 (2007) 2487-2496, [0707.1652].
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9. Acknowledgments:

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• DIRAC server:



<https://dirac.france-grilles.fr/DIRAC/>



CVMFPS for software distribution



iRODS - preferred data access

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Executive Summary



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What is this contribution about?

We describe the usage of the Virtual Organization (VO) auger for the production of reference shower and detector simulation libraries used in a handful of analyses, ranging from photon searches to the studies of hadronic interactions within the Pierre Auger Collaboration. On demand, the grid is also used for extensive simulation libraries which cannot be produced on standard local computing farms.

Why is it relevant/interesting?

AugerPrime, the Pierre Auger Observatory upgrade, is swiftly progressing and the demand for new simulation libraries for the new detectors is high. The production of simulation libraries including the radio component of air showers is the most challenging endeavor as it requires studies regarding the possibility of using the Message Passing Interface of the CORSIKA code on the grid which may be of relevance for the current and next generation cosmic-ray experiments exploiting this detection technique.

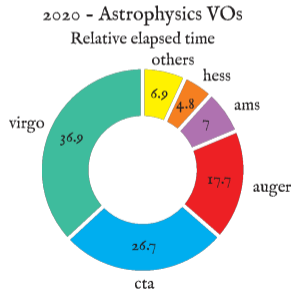
What has been done?

A Monte Carlo simulations task was established to coordinate, plan, and produce extensive simulation libraries for the Pierre Auger Collaboration. The bulk of the simulations are produced in the grid using the VO auger. The reference simulation libraries serve as a baseline for numerous Auger analyses spanning over several research topics. The task works in close collaboration with the Auger Offline team, helping to debug, improve and develop new features. We also worked on a standard set of scripts that allow all Auger members to produce CORSIKA air shower and Offline simulations with the reference settings for the specific analyses.

What is the result?

Reference and on-demand Auger libraries are used in tens of analyses, several of them serving as a base for full author list papers. Five contributions presented in this conference are based on these simulations.

In 2020 we doubled the grid usage in Auger and had comparable relative elapsed time with regards to other Astrophysics VOs. Given the high demand in simulations for AugerPrime, we aim to increase the production of extensive simulation libraries and consolidate our position among the leading Astrophysics VOs.





**Many thanks
for your attention!**