The scaler mode at the Pierre Auger Observatory to study solar activity modulation of galactic cosmic rays

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Motivation: Galactic Cosmic Rays (GCRs)

The time variability of the GCR flux on Earth has been systematically recorded since the 1950s by neutron monitors:

- very slow variations (years) \rightarrow solar cycle
- slow variations (days) \rightarrow daily modulation and Forbush decreases
- fast variations (seconds) \rightarrow gamma-ray bursts

The heliosphere presents a variety of dynamical structures not yet well understood:

- solar wind observations from spacecrafts
 - \rightarrow provides direct measurements of magnetic field,
 - \rightarrow difficulties to get global magnetic structures.
- ground observations of cosmic rays at low energies
 - \rightarrow measurement through a long period of the GCR flux at different locations,
 - \rightarrow nice complement to *in-situ* experiments,

Combination of observations from **Space** and from **Earth** provides a good opportunity to make detailed studies on solar modulation to GCRs

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The Pierre Auger Observatory – Province of Mendoza, Argentina



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Extensive Air Showers



Extensive Air Showers



The Surface Detector / SD



 \rightarrow 10 m² of effective area per tank,

 \rightarrow 12 tons of high purity water in a reflective bag,

 \rightarrow signals recorded @ 40 MHz [25 ns],

 \rightarrow Cherenkov radiation produced by the passage of charged particles in water.



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The Pierre Auger Observatory and GCRs counting

The scaler mode, or "single particle technique"

- counts the number of signals per second in each tank with an energy deposited as 15 MeV ≤ E_d ≤ 100 MeV,
- average rate of \sim 200 m⁻²s⁻¹ for a collection area of 16600 m² \rightarrow 2 × 10⁸min⁻¹,
- originally dedicated to monitor the long-term stability of the detector.

Atmospheric correction



Atmospheric pressure variations are known to modify the flux of secondaries at ground

 \rightarrow variation of mass of atmosphere above the detector,

 \rightarrow flux anti-correlated with pressure,

 \rightarrow atmospheric pressure monitored at Auger.

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Scaler mode

MC simulation – secondaries at ground level

Set of low energy shower simulations by CORSIKA (GHEISHA/QGSJetII-03)

- all nuclei in the range $1 \le Z_p \le 26$, with zenith angles $0^\circ \le \theta_p \le 88^\circ$,
- simulated as a power law in primary energy E_{p} with empirical exponents,
- energy range: $(10 \times Z_p) \leq (E_p / \text{GeV}) \leq 10^6$,
- detector response simulated by the Auger data analysis framework.



Flux of secondaries is dominated by γ (68%), μ^{\pm} (21%) and e^{\pm} (10%)

MC simulation – detector sensitivity to primaries



 \rightarrow geomagnetic rigidity cut off at Malargüe is 9.5 GV,

 \rightarrow 10 GeV \leq E_p \leq 2 TeV : 90% of the counts in the instrument,

 \rightarrow largest sensitivity of the detector to primary particles in the range 10 GeV–100 GeV.

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Scaler data set – daily modulation



ightarrow average scaler rate over 6 months before and after pressure corrections,

\rightarrow nice agreement with the expected trend.

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Scaler data set – solar transient phenomena



ightarrow comparison of Auger scaler data with Neutron Monitor based at Rome,

 \rightarrow Forbush decrease observed in both of the instruments.

Scaler data set – Forbush decrease @ 15 May 2005



 \rightarrow data compared with Neutron Monitor at Los Cerrillos (Chile) where a similar rigidity cut off is observed,

 \rightarrow a 2.9% decrease in the flux is recorded in the Auger scaler data.

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http://auger.colostate.edu/ED/scaler.php



Summary

- the Pierre Auger Collaboration has accumulated more than 6 years of scaler data,
 - \rightarrow useful for long-term monitoring of the detector
- daily modulation and solar transient events are well recorded,
 → comparison to neutron monitors show a nice agreement
- a new method based on a selection in deposited energy is now in development,

 \rightarrow all the energy ranges are affected in the same way during a Forbush decrease ?

 \rightarrow leads to a sensitivity to primary energies and secondary particles

Scaler data are publicly available on the web !

http://auger.colostate.edu/ED/scaler.php

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References

- The Pierre Auger Observatory scaler mode for the study of solar activity modulation of galactic cosmic rays P Abreu et al [Pierre Auger Collaboration], JINST 6 (2011) P01003
- The scaler mode in the Pierre Auger Observatory to study heliospheric modulation of cosmic rays *S Dasso, H Asorey for the Pierre Auger Collaboration, arXiv:1204.6196 [astro-ph.SR]*

Backup slides

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Solar activity @ Auger

AMS workshop – Grenoble 2 / 3

Histogram mode (preliminary)



- bump produced mainly by muons,
- averaged histograms over 20 MeV bands of E_d,
- Forbush decrease clearly visible in all energy bands.