# TRAGALDABAS

## A cosmic ray ground-based detector for the study of the solar activity; first observations (EGU2016-10137)

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**Introduction**: A new RPC-based cosmic ray detector, TRAGALDABAS (acronym of "TRAsGo for the AnaLysis of the nuclear matter Decay, the Atmosphere, the earth's B-field And the Solar activity") has been installed at the Univ. of Santiago de Compostela, Spain (N:42º52'34",W:8º33'37"). TRAGALDABAS will be able to monitor the cosmic ray low energy component strongly modulated by solar activity by means of the observation of secondary muons from the interaction between cosmic rays and atmospheric molecules. Its cadence and its angular resolution will allow to study in detail small variations in cosmic ray anisotropy. These variations can be a key parameter to understand the effect of solar disturbances on the propagation of cosmic rays in the inner heliosphere and, maybe, provide a new tool for space weather analysis. In this work first TRAGALDABAS observations of solar events are shown.

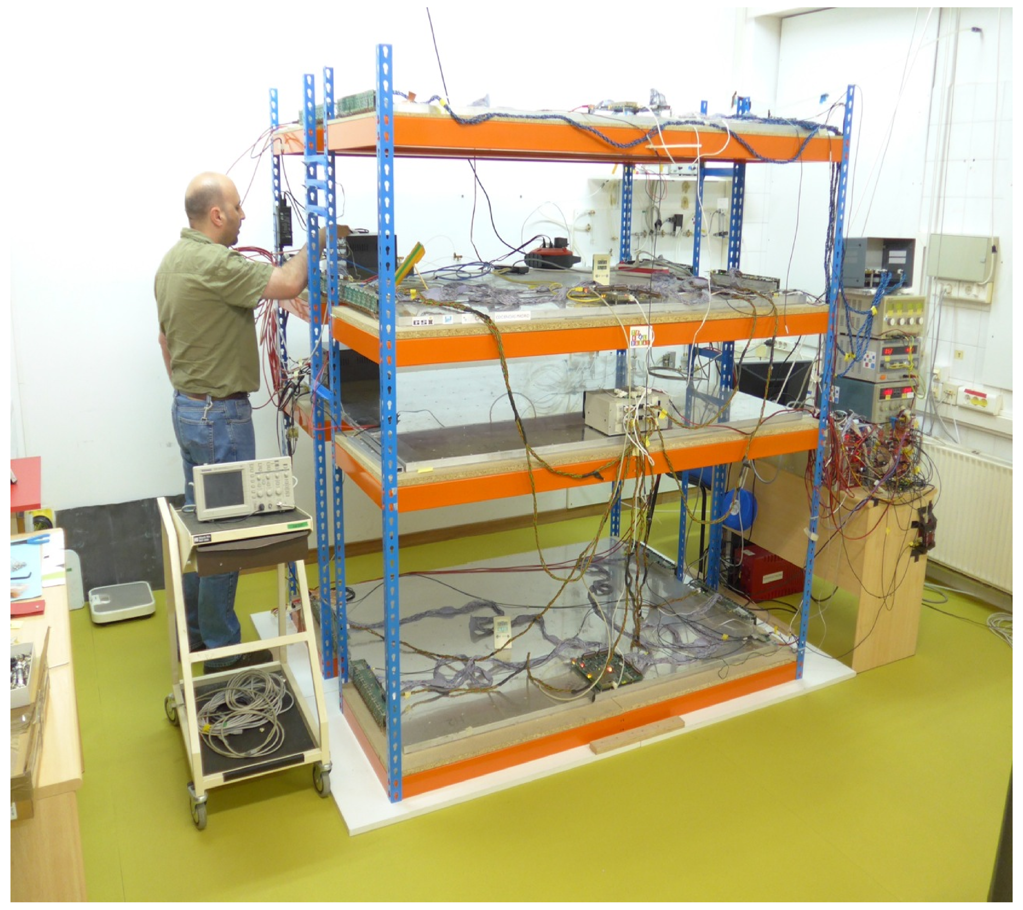


Fig. 1: TRAGALDABAS detector in its present layout. Only planes 1,2 and 4 are fully instrumented

### TECHNICAL FEATURES

**The detector:** In its present layout, TRAGALDABAS is composed by four 2-gap RPC planes. Each of them has an active surface of 1.2x1.5 m² and 120 cells, with a time resolution of ~300 ps. Such arrangement does allow to reconstruct tracks with a time resolution ~200 ps, an angular resolution <2º and a velocity resolution ~5%. Planes are placed at the heights: 180, 120, 90 and 0 cm.

**Monitoring**: A slow control system, based on NAGIOS, is supervising the following variables: the high voltage currents feeding the detectors, the pressure, humidity and temperature inside the detector boxe, the room temperature and the external pressure and temperature.

**Reconstruction software**: the reconstruction analysis of the detector is done within a specific framework based on ROOT (CERN) and written in C++. 10-min reduced ASCII files are built for some fast analysis.


Fig. 2: Setting of TRAGALDABAS respect CGUC in Coimbra and CaLMa neutron monitor in Guadalajara

### MAIN CAPABILITIES

**DAQ rate:** After a period of commissioning, TRAGALDABAS started to take regular data in March 2015 at a duty cycle of ~95% and at an approximate rate of 70Hz. In this early stage, only 3 planes were fully instrumented (Fig.1).

Around 40Hz correspond to events with multiplicity M=1, ~16Hz to multiplicity M=2 and ~14Hz to multiplicities M >2.

**Data corrections**: The main correction removes the dependence of the data on both, temperature and pressure.

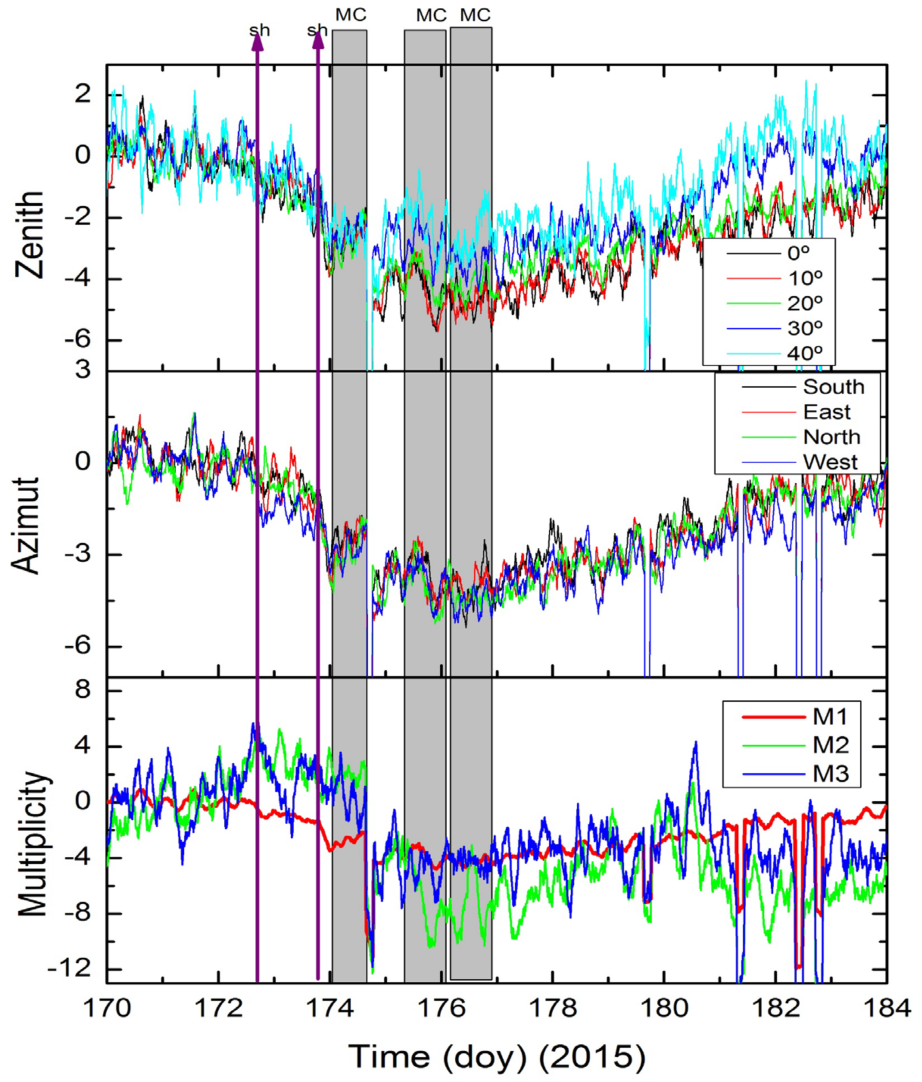



Fig. 3: Top&Center: Zenith and azimuthal angles distribution of TRAGALDABAS data around the FD on June 22nd 2016. Bottom: Multiplicities evolution.

### Data description:

**TRAGALDABAS:** Analyzed data have been reconstructed only using planes 1 and 3. Data were averaged in 10min intervals and smoothed with 12-point running average. Events have been classified in five 10º zenith angles and in eight 45º azimuthal angles. Regarding number of tracks, have been classified in multiplicities 1 (M1), 2 (M2) and >2 (M3) (Fig. 3)

**Neutron monitors**: 1h averaged data from NMDB.

**Solar Wind**: 1h averaged data from OMNIweb.

All the count-rates have been normalized to the mean count-rate of June 20th (doy: 171).

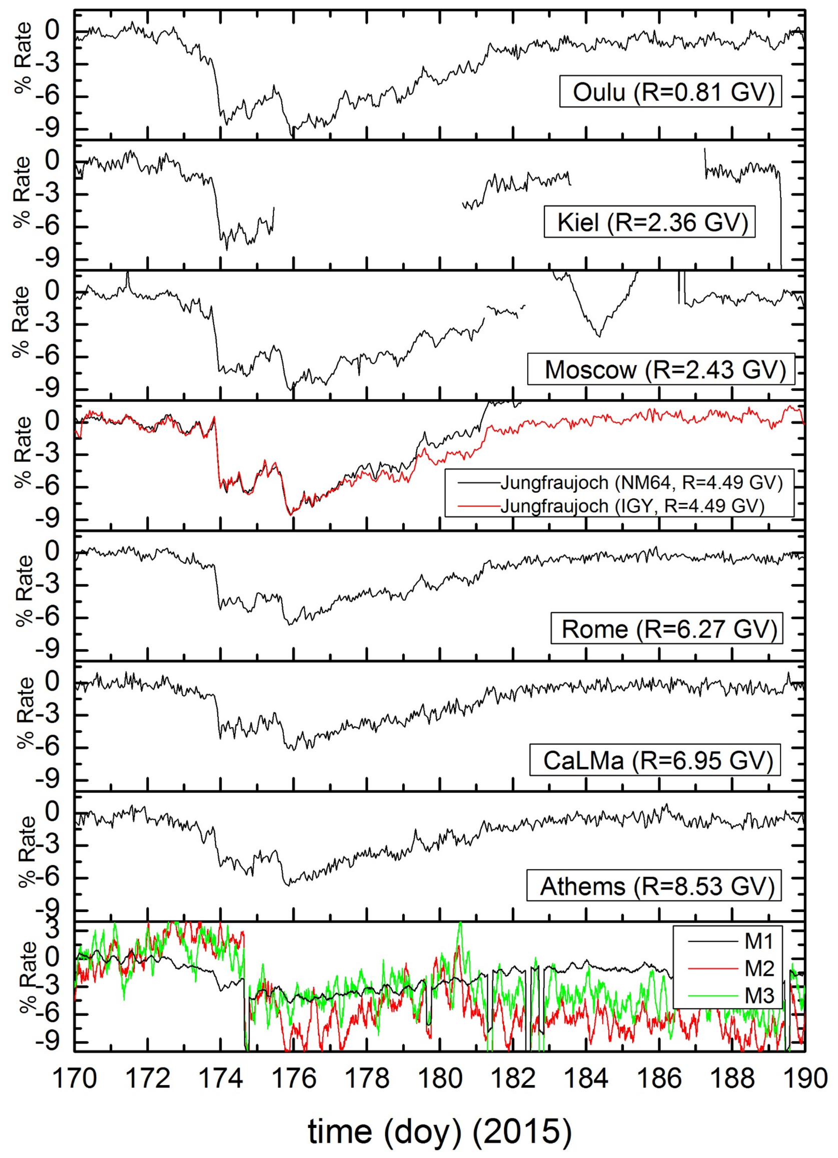
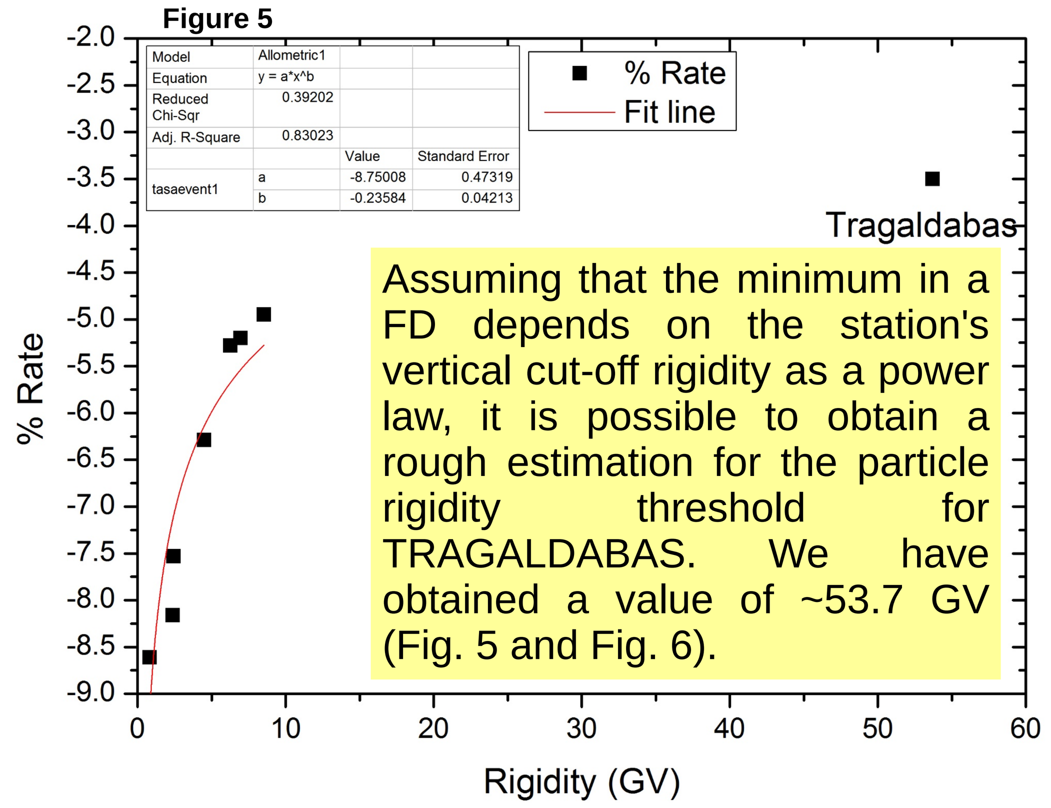



Fig. 4: Counting rates of several monitors from the NMDB network. The two consecutive FDs explained in the text are clearly visible.

### Neutron monitor network observation

On June 21st (doy:172.70), a large Forbush decrease (FD) started with a shock arrival to the Earth. One day later, at doy:173.7, a sharp decrease began showing that the shock was followed by a magnetic cloud (MC). After the MC, the NMDB count-rates came in the recovery phase that was interrupted by the arrival of two consecutive (doy: 175.66, 176.25) MC, giving rise to a second decrease (Fig. 4.)

Figure 5



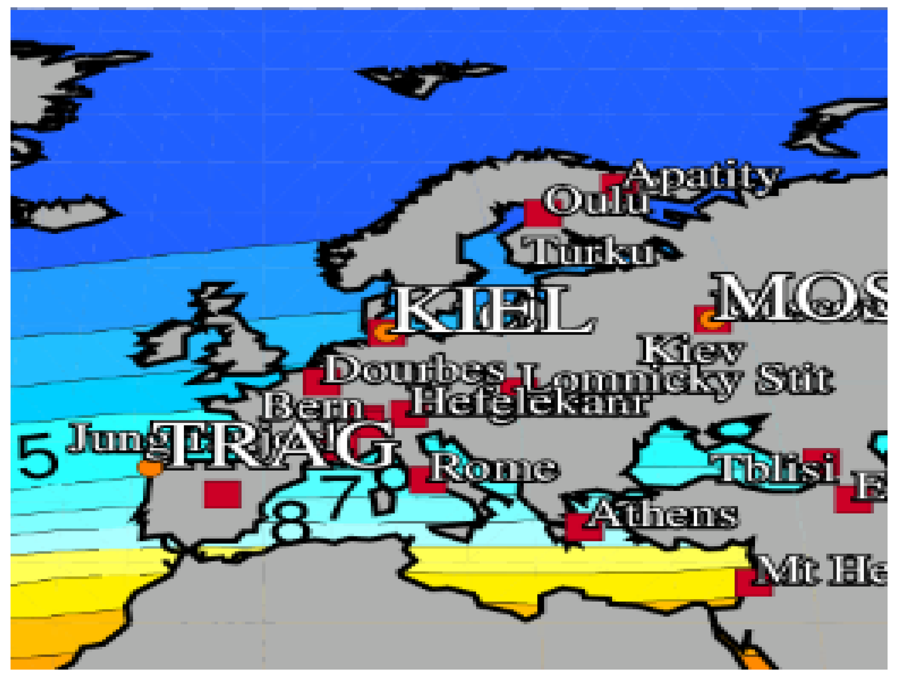




Fig. 6: Location on the map of some of the neutron monitors shown in Fig. 4.

### TRAGALDABAS First observation

The arrival of a interplanetary shock on June 21st followed by a MC on June 22 was observed by TRAGALDABAS as a slight decrease in its M1 count-rate (doy 172.2). An sharp decrease started once a second shock driven by a MC arrived to the Earth at doy: 173.7. After the MC passage, the count-rate started to recover both in neutron monitors and TRAGALDABAS but the arrival of a second MC produced a new decrease in the count-rates of all the neutron monitors and TRAGALDABAS (Fig. 7).

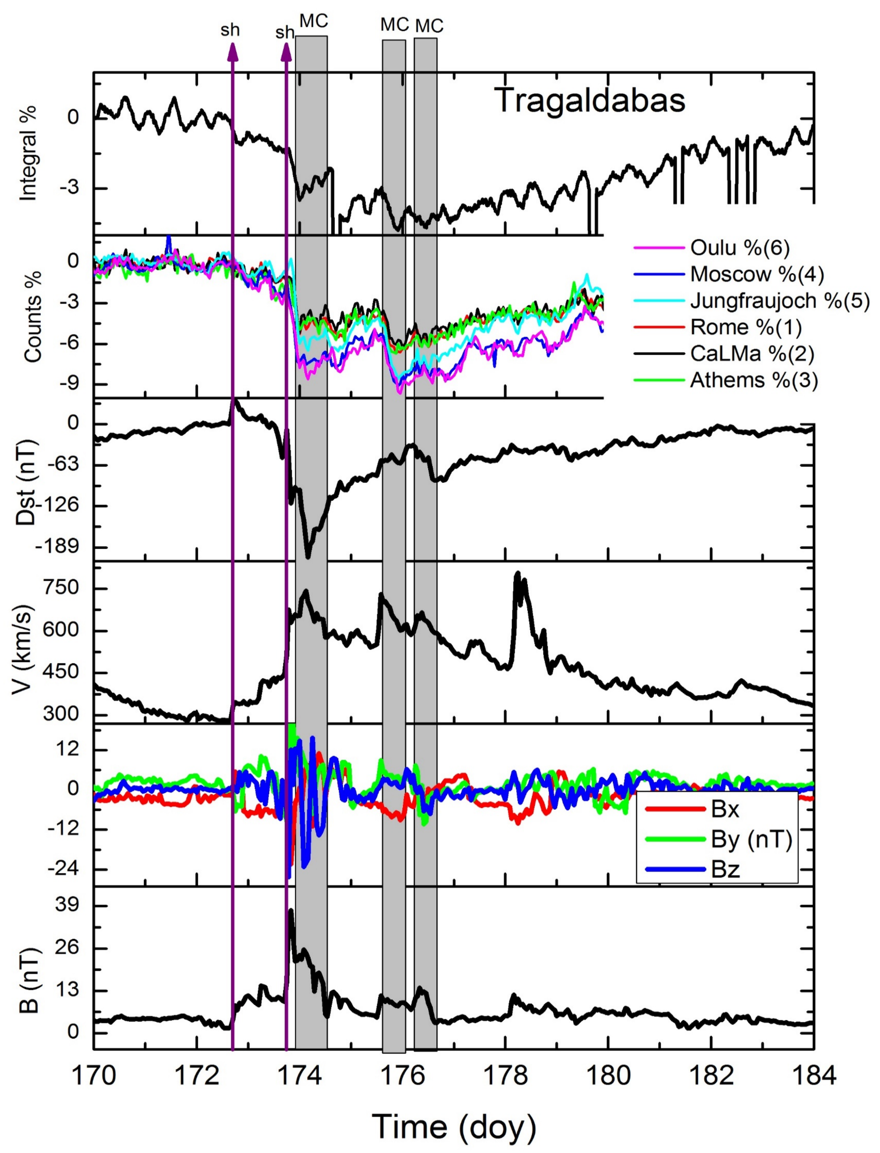



Fig. 7: Several cosmic ray count-rates and other space weather variables measured before and during the FD of June 22nd.

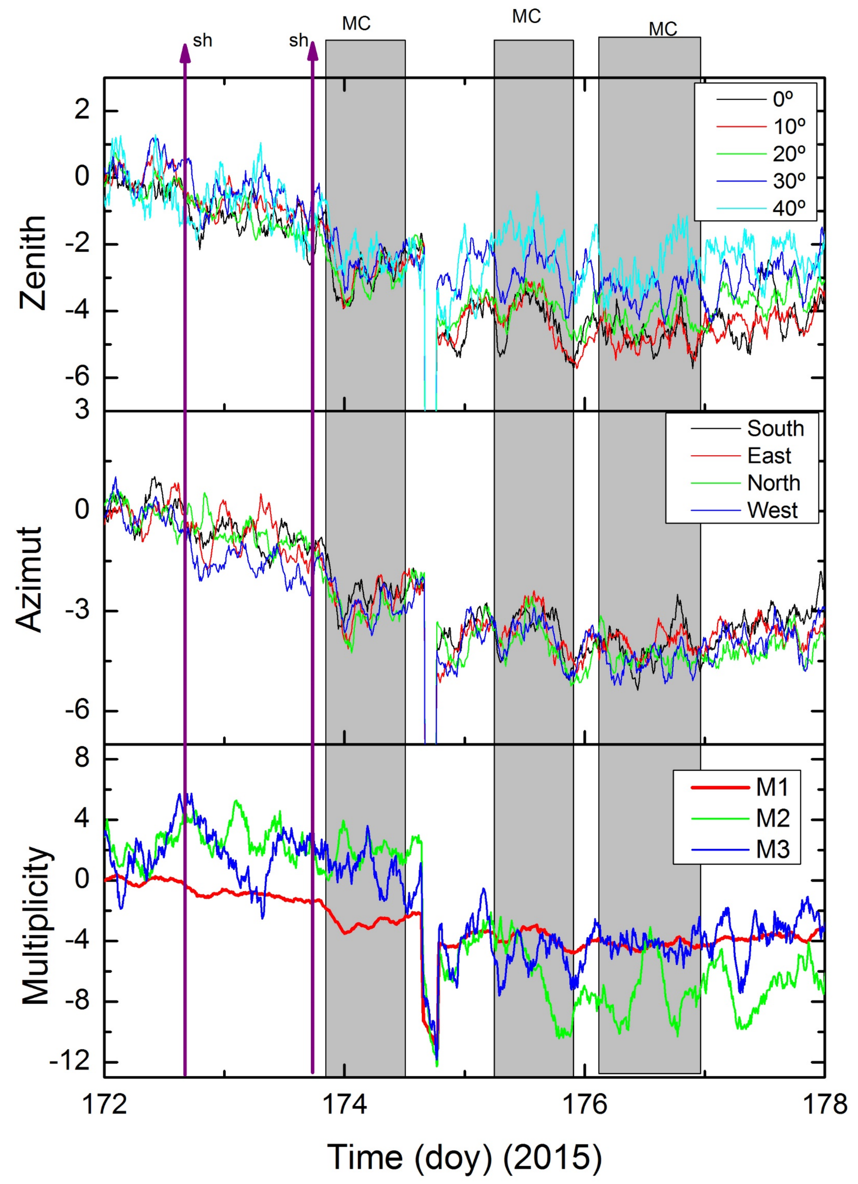



Fig. 8: Evolution of some of the variables measured by TRAGALDABAS compared to the arrival of the MCs reported on the text.

### Conclusions:

- The analyzed data show that TRAGALDABAS, with a size of barely 2 m², even in a low angular resolution mode using just two planes, is sensitive to the solar activity.

-TRAGALDABAS is providing reliable information about cosmic ray anisotropies. This property can be used to study Forbush Decreases and the effect of solar wind structures on cosmic ray transport. This feature is evident in the FD observed in June 22nd 2015.

- The highest variations in count-rate are observed at low zenith angles. This effect can be related to the energy of primary cosmic rays.

- Regarding to azimuthal angles, the highest fluctuations are observed before the MC arrival in the region between the first and the second shocks, reflecting, perhaps, a turbulent solar wind region (Fig.8).

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