Trasgos: Analysis of the atmospheric properties with a high resolution cosmic ray detector

Irma Riádigos, Damián García-Castro, Diego González-Díaz,
J. A. Garzón-Heydt, and Vicente Pérez-Muñuzuri
TRAGALDABAS Collaboration, Faculty of Physics, Universidad de Santiago de Compostela,
15782 Santiago de Compostela, Spain

Cosmic rays constantly reach the Earth and collide with the nuclei of atmospheric atoms creating billions of secondary particles. The measurement of such particles reaching the surface may provide very valuable information about the properties of the atmosphere.

A strong correlation exists between different variables of the atmosphere and the arrival of the secondary particles called muons. For several years, studies of the influence of temperature have been performed for muons of different energies and angles of incidence [1, 2, 3]. However, modern cosmic ray detectors are mostly committed to the study of solar activity and other astrophysical phenomena, and therefore their intention is to remove those effects using simple techniques, or to use them to coarsely assess the instrument response. Our work is concerned with a deeper comprehension of such atmospheric effects.

For this purpose, a medium-size tRPC detector (1.2×1.5 m^2) of high resolution ($\sigma_{x,y} \sim 3$ cm, $\sigma_t \sim 300$ ps, $\sigma_\theta \sim 2.5°$) of the TRASGO family, called TRAGALDABAS, was installed in the Physics Department of the University of Santiago de Compostela (Spain). Timing resistive plate chambers (or tRCPs) are prime detectors when aimed at large area coverage with ultimate time-of-flight resolution. Due to its granularity and versatile trigger, this instrument is able to select high and low multiplicity events, by individually identifying and reconstructing each of its constituent tracks. In addition, ECMWF reanalysis datasets provide the temperature profiles up to several kilometers, as required for our research.

Current techniques take into account the temperature effect by using an approximation of the integral method for muons, which requires, on the one hand, having the temperature profiles above the detector and, on the other hand, the theoretical distribution of temperature coefficients [4]. However, in our case we have to deal with multiplicities instead of energies and the presence of the soft component in our data as well. Therefore, we need to study the dependence of our data grouped by multiplicities with the several parts of the atmosphere [5]. However, the variations of temperature of the different atmospheric layers are strongly correlated and as a consequence, the study of this dependence turns out to be quite complicated. We perform some statistical methods for analyzing multicollinearity.

Supposing that each multiplicity gives us information about the temperature of different parts of the atmosphere, we could develop an inverse method which allow us to obtain the temperature at different heights using the measured variations in our multiplicity rates.

[1] M. Ambrosio, R. Antolini, G. Auriemma, R. Baker, A. Baldini, G. C. Barish, G. Battistoni, R. Belloti, C. Bemporad *et al.*, Seasonal variations in the underground muon intensity as seen by MACRO, Astropart. Phys. **7** 109-124 (1997).

[2] S. Osprey, J. Barnett, J. Smith, P. Adamson, C. Andreopoulos, R. Armstrong, D. J. Auty, D. S. Ayres, B. Baller *et al.*, Sudden stratospheric warmings seen in MINOS deep underground muon data, Geophys. Res. Lett. **36**, L05809 (2009).

[3] S. Tilav, P. Desiati, T. Kuwabara, D. Rocco, F. Rothmaier, M. Simons, H. Wissing *et al.*, Atmospheric variations as observed by IceCube, arXiv:1001.0776.

[4] A. N. Dmitrieva, R. P. Kokoulin, A. A. Petrukhin, and D. A. Timashkov, Corrections for temperature effect for ground-based muon hodoscopes, Astropart. Phys. **34**, 401-411 (2011).

[5] J. A. Garzón *et al.*, TRAGALDABAS. First results on cosmic ray studies and their relation with te solar activity, the Earth's magnetic field and the atmospheric properties, XXV ECRS 2016 Proceedings, arXiv:1701.07277.