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TRAGALDABAS: a new RPC based detector for the regular study of cosmic rays

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ABSTRACT: Cosmic rays of a wide range of energies are arriving permanently to the Earth coming from the Sun or beyond our solar system. Their study is of interest for many fields of research. A high granularity and high time resolution cosmic ray tracking detector, TRAGALDABAS, based on timing RPC cells, has been recently installed at the Faculty of Physics of the Univ. of Santiago de Compostela, in Spain, in order to go deeper into the understanding of the cosmic rays arriving to the Earth surface. In this article, the layout and the main performances of the detector are shown together and some of the expected research fields are discussed.

KEYWORDS: Particle tracking detectors (Gaseous detectors); Timing detectors; Large detector systems for particle and astroparticle physics

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Contents

1 Introduction

More than one hundred years after their discovery, there are still a lot of unknowns related with the properties of the cosmic rays arriving to the Earth and with the processes that do affect them before they collide with the atoms on the top of the atmosphere. Except by the suppression of some nuclei lighter than the carbon due to spallation processes, cosmic rays have roughly the same composition that the mean composition of the Universe. They are dominated by protons and light nuclei that may reach energies up to several joules; a huge amount of energy for single nuclei!

Violent phenomena on Sun surface, as flares and coronal mass ejections, are able to accelerate particles up to some GeV, i.e. energies about the low energy component of galactic cosmic rays. These solar energetic particles constitute the solar cosmic rays and, usually, they are measured using detectors located in satellites. Above a few GeV, primary cosmic rays come mainly beyond the limits of the Solar System and do interact in the high atmosphere where they produce showers of up to billions of particles, called secondary cosmic rays. At the ground level, those are mainly electrons, gammas, neutrons and, specially, high energy muons able to reach more than one kilometer deep on the ground. These ones are mainly measured by ground level stations such as neutron monitors and muon telescopes. Figure 1 shows both the estimated flux of primary cosmic rays arriving to the Earth's atmosphere and the measured fluxes of the main species of secondary cosmic rays arriving to the sea level.

Before and after arriving to the Earth atmosphere, cosmic rays are affected by different effects, as the interplanetary magnetic field induced by the Sun, the solar wind, the Earth's magnetic field or the atmosphere. All these effects, on the one hand, make more difficult to measure the properties of the primary cosmic rays but, on the other hand, may provide valuable information about their behavior and characteristics. For all these reasons, currently, many stations are deployed in the Earth surface that permanently measure the arrival of cosmic rays. Most of them are neutron monitors, sensitive to the integrated fluxes of cosmogenic neutrons, and muon detectors, offering some directional and energy threshold capabilities, that provide complementary information.

Recently, a new generation timing-RPC-based detector, TRAGALDABAS, has been installed in the Univ. of Santiago de Compostela for the regular survey of cosmic rays. Its development has been inspired by the encouraging results [1] obtained during the analysis of the cosmic ray data

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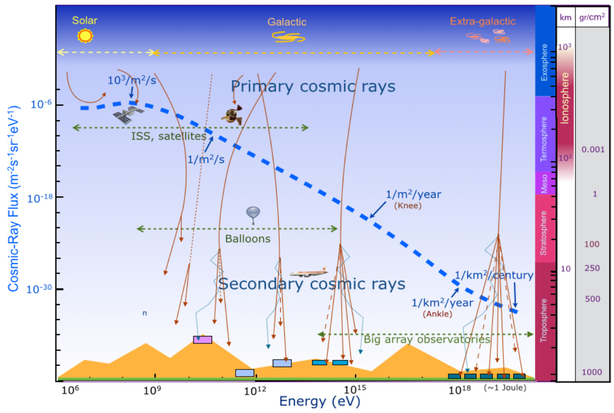

(a)

Mean Flux of Cosmic Rays at the Sea Level (I: Flux in $m^{-2}s^{-1}sr^{-1}$)

E(GeV)	Muons	Electrons	Photons	Protons	Neutrons
0.01	100	28	60	2.1	30*
0.1	99	6	8	1.9	10*
0.5	86	1	1.1	0.9	1.5
1	69	0.4	0.4	0.5	0.7
2	46	0.1	0.1	0.25	
5	20	0.02	0.02	0.1	
10	8.6			0.03	
50	0.58	* Estimated values			
100	0.14				
1000	$5\ 10^{-4}$				

(b)

Figure 1. a) Energy spectrum of primary cosmic rays together with their corresponding estimated sources and the main detection techniques. b) Summary of the main flux of secondary cosmic rays at the sea level; adapted from [3].

obtained during the commissioning of the RPC ToF wall of the HADES experiment at GSI [2]. Unlike other small size cosmic ray monitors, the detector provides outstanding timing resolution (∼300 ps), high granularity (120 cells over a surface ∼1.8 m^2) and a tracking capability of high energy charged particles with a resolution of 2-3°. All these features allow it to reconstruct the front region of the air showers and, as a consequence, to estimate the arrival direction and the energy of the primary cosmic ray having generated the air shower.

In section 2 we will describe the main features of the detector. In section 3 we will describe the front-end electronics, FEE, used to instrument the detector and summarize the main performances the detector offers with its present layout. In section 4 we overview the main research goals of the facility.

2 The TRAGALDABAS detector

TRAGALDABAS (TRAsGo for the AnaLysis of the nuclear matter Decay, the Atmosphere, the earth B-Field And the Solar activity) is a cosmic ray detector, based on the timing RPC technology [4] offering both high granularity and high time resolution together with tracking capability. It is the first prototype of the Trasgo concept [5] that was proposed for the study of cosmic rays at the Earth's surface as an affordable alternative to other existing techniques.

The left panel of figure 2 shows a picture of the detector in its present layout. It is composed by two RPC planes with an external size of 1.285×1.650 m^2 each one, placed horizontally at a distance of ∼ 1.2 m and oriented in the E-W direction. It is installed on the first floor of a two-floor building, that will reject part of the electromagnetic component of the showers, in the geographical coordinates (N 42° 52' 34", W 8° 33' 37") and at ∼ 260 m over the sea level. In the future two additional planes will be added until complete a 4-plane detector. The right panel of figure 2 shows the geographical location of the detector together with the location of all the laboratories that have participated in the development of the detector and that will collaborate in the analysis of the data.

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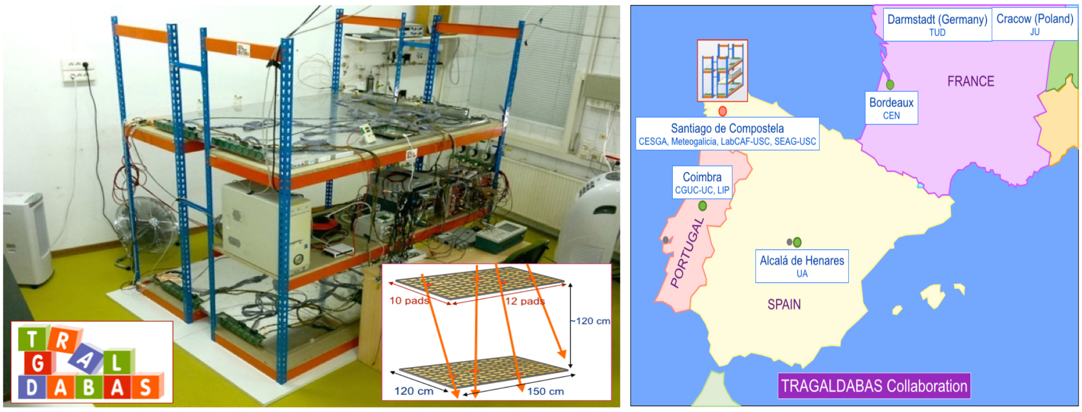
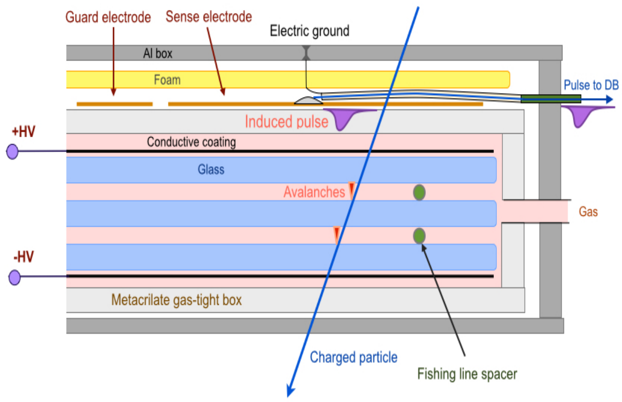


(a) (b)

Figure 2. a) Picture of the TRAGALDABAS detector. b) Location of the detector in Santiago de Compostela and location of all the laboratories participating in the TRAGALDABAS collaboration.



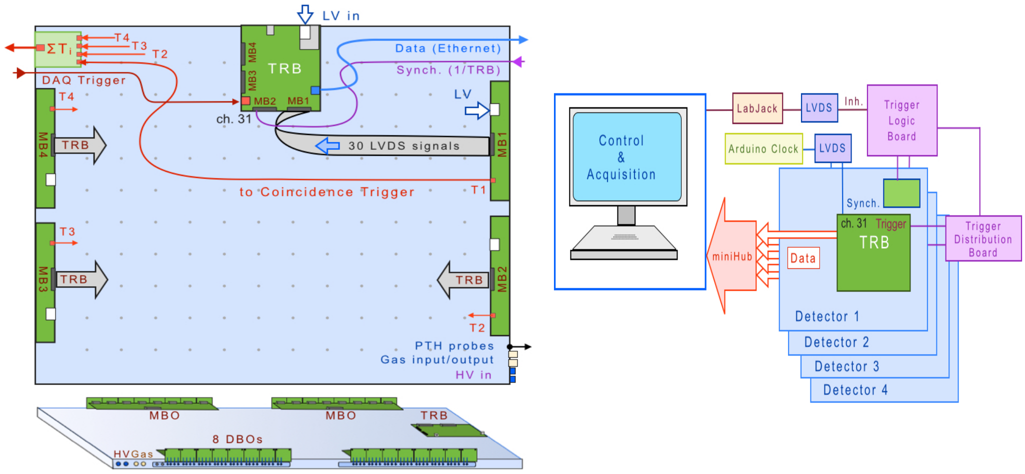
RPC layout	Width(mm)	X_0(cm)	ΔX_0
Al	3	8,9	0,034
Foam(dens=0.3)	8,7	142,0	0,006
Cu	0,03	1,4	0,002
PCB (FR4)	1,57	31,8	0,005
Metacrilate	1	40,8	0,002
Glass	1,9	3,2	0,059
Gas: R134a	1	26,5	0,004
Glass	1,9	3,2	0,059
Gas: R134a	1	26,5	0,004
Glass	1,9	3,2	0,059
Metacrilate	1,0	40,8	0,002
Al	3	8,9	0,034
Total	26		~0,27

(a) (b)

Figure 3. a) Cut structure of each RPC plane. b) Width and equivalent radiation length of each of the different layers of a RPC plane.

The internal layout of each of the RPC planes is shown in the right side of figure 3. The RPC planes were built at LIP-Coimbra with the same technology they are using in some prototypes that are being tested in the P. Auger observatory [6], in Argentina. Each plane is made by 3 slides of 2 mm glasses with a 1mm-gap in between, placed inside a gas tight metacrilate box. A small flux of R134a type freon is kept flowing to compensate the gas losses. The external sides of the external glass plates are covered by a conductive coating where a $\pm$ 5600 V high voltage is applied. The read-out is done by 120 Cu pads placed in the outer side of the metacrilate box at 10 mm distance of each other. Pads are separated by straight guard-electrodes 6 mm wide to prevent the crosstalk, that is almost negligible. The size of the pads is 111 $\times$ 116 mm^2 and the active size of each plane is near 1.2 $\times$ 1.5 m^2.

The TRAGALDABAS is taking test data with 2 RPC planes since Sept. 2013 in the Univ. of Santiago de Compostela, with coincidence trigger between both planes, at a rate of about 7 million



(a) (b)

Figure 4. a) Layout of the FEE electronics of a single plane. Four MBs get the amplified and digitized signal coming from the DBs and are readout by a TRB that send the data to the acquisition computer via Ethernet. pads of a RPC plane of the TRAGALDABAS detector. b) Readout electronics and trigger logic scheme foreseen for the final detector.

of registered events per day (∼ 80 triggers/s). In its present layout, the main performances of the detector are:
- Granularity: 120 pads / plane; pad size: 130 cm^2.
- Acceptance: ∼5 sr.
- Angular resolution: 2°- 3°
- Time resolution: ∼280 ps.
- Hit efficiency: ∼1

3 Front end electronics, data acquisition and performance

As read-out FEE, the TRAGALDABAS uses the well known and well tested design done for the HADES spectrometer at GSI, Darmstadt [7]. RPC signals are first amplified and integrated and then digitized in LVDS format in 4-channels daughter boards (DB). Every 8 DBs are connected to a motherboard (MB), that provides them the low voltage and the output for both the digital read-out and the trigger signals. The four MBs collecting all the signals of a RPC plane are read-out by a TDC based read-out board (TRB) [8]. The TRB.V2 is instrumented with 4 HPTDC ASICs, developed at CERN. The board is controlled by an ETRAX processor that sends the data to an external computer via an ethernet port. The detector-acquisition electronics chain provides a joint time resolution of ∼280 ps and an efficiency close to 100%. Figure 4 shows the general structure of both the readout electronics and the box chart of the forthcoming control and acquisition philosophy. Data are collected in the acquisition computer and are regularly sent to the supercomputing center CESGA,[1] for their definitive storage.

[1] www.cesga.es

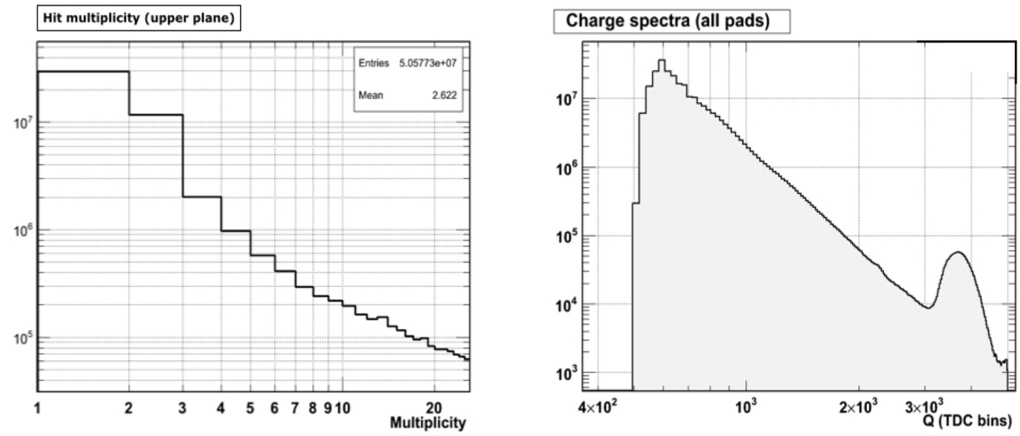


Figure 5. Left panel) Hit multiplicity distribution in the upper plane for a week of data collection. Right panel) Charge distribution in TDC units. The big charge bump at the right corresponds to streamer events .

Figure 5 shows the hit multiplicity distribution, in the whole upper plane, for ~week of data together with the charge distribution in all the cells, obtained at a HV of 5600 V. A mean multiplicity of ~ 2.5 is obtained that correspond to about 200 particles/s in a 1.8 m^2 detector. The big bump observed in the right side of the charge spectra may correspond to streamer signals. They correspond to an almost negligible amount of data ($< 1\%$ of the data).

We have also analyzed the behavior of the detector during a very stable period between March 21st. and April 27th. 2014. The evolution of the dark current and the room temperature as a function of time is displayed in figure 6. We observe a very clear correlation between the current and the room temperature although we had quite big fluctuations along some days during that period. We also observe that the relationship between both magnitudes has a non-negligible quadratic component. For this reason we decided to improve the isolation of the detector's room and to install air-conditioning able to keep the temperature stable in the range ($20 \pm 0.5\ ^\circ C$). The mean value of the current is of the order of ~600 nA for the upper plane, slightly higher than the one reported in [9] for a quite smaller detector and with narrower gaps. Nor correlations neither dependences have been observed between the dark current of the detector and both the pressure and the ambient humidity.

4 Main research goals and aims of the facility

The TRAGALDABAS may be included among the small size cosmic ray detectors, based in the measurement of the arrival direction of secondary muons coming from the decay of mesons produced in the chain of nuclear collisions induced by the first cosmics ray. Unlike other detectors, TRAGALDABAS has a very small size, close to 2 m^2. For example the MUSTANG detector [10] at Greifswald, Germany, has a surface of 4 m^2 and the detector at Mount Norikura [11], in Japan, based on proportional tubes, has a surface of close to 20 m^2. Another important difference is that those detectors have lead absorbers for absorbing the electromagnetic soft component of the cosmic rays. Although the detector in Greifswald is close to the sea level, the Japanese detector is at a very high altitude, near 2770 m.

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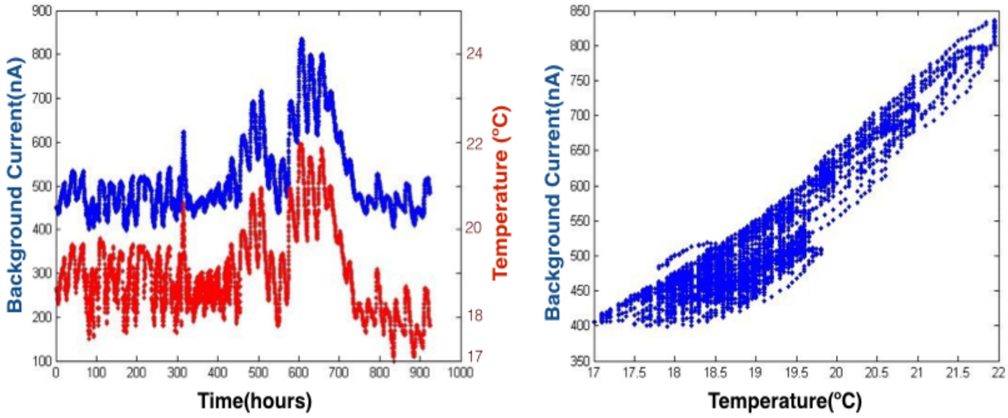

Figure 6. Left panel) Background current and ambient temperature as a function of time for the analyzed period, ∼40 days. Right panel) Behaviour of the dark current as a function of the temperature. A non-negligile quadratic component is apparent with some "hysteresis" effects.

The main strength of our detector lies in its high granularity and its outstanding time resolution. Previous preliminary results obtained in the analysis of the cosmic ray data taken during the commissioning of the HADES RPC wall at the GSI, Darmstadt [1] seem to show that those features would help to overcome to some extent the small size, and, as a consequence, the lack of statistics problem. The high granularity does allow to measure the multiplicity of the swarm of particles belonging to the same air shower and the good time resolution offers many advantages: on the one hand it reduces the tracking ambiguity in high multiplicity environments and, on the other, it allows to select the first arriving particles of a cluster that are those that keep a better memory of the direction of the primary cosmic ray; for this purpose gammas and electrons existing in the air shower may be very helpful. Also, a good measurement of the time profile of high multiplicity events may allow for an estimation of the energy of the primary cosmic ray [13].

Another very interesting and unusual circumstance is that, around the detector, at less than 500 km distance, there are other important observatories looking at the Earth's surrounding with different instrumentation: the *Observatorio Magnético da Univ. de Coimbra*[2] in Coimbra, devoted to the regular registration of the magnetic field of the Earth, and *CaLMa: Castilla-La Mancha neutron monitor*[3] [12] in Guadalajara, near Madrid, that monitors permanently the solar activity in the range of energy between 6 and 20 GeV.

As the information of cosmic rays arriving to the Earth's surface is of interest for many research fields, a collaboration of about 20 experts coming from 10 european laboratories, the TRAGALDABAS collaboration, has been organized for extracting as much information as possible from the measured cosmic ray data. Some of the research fields of interest are:

- Analysis of the microstructure of the front edge of the cosmic ray air showers and search of new cosmic ray identification signatures.

[2] www.uc.pt/fctuc/Investigacao/unidades_id/CGUC.
[3] www.calmanm.es; this facility is integrated into the neutron monitors network (NMDB).

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- Study of the solar activity and possible early detection of clouds of solar plasma and magnetic storms.
- Analysis of the Earth's magnetic field behavior and detection of possible short time big fluctuations.
- Analysis of the dependence of the rate of high energy cosmic rays and the temperature of the stratosphere.
- Study of the possible existence of correlations between cosmic ray flux and the cloud cover.

Other foreseen steps to be undertaken in the future include to double the detector size, for improving both the statistical resolution and the acceptance, and to install another detector outdoors in order to avoid the unmanageable effects of the building walls, roof, etc.

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References

[1] D. Belver et al., *Analysis of the space-time microstructure of cosmic ray air showers using the HADES RPC TOF wall*, 2012 *JINST* **7** P10007.

[2] D. Belver et al., *The HADES RPC inner TOF wall*, *Nucl. Instrum. Meth.* **A 602** (2009) 687.

[3] Kaye&Laby, *Tables of Physical & Chemical constants*, www.kayelaby.npl.co.uk/general/physics/2_7/2_7_7.html.

[4] ALICE collaboration, P. Fonte, A. Smirnitsky and M.C.S. Williams, *A New high resolution TOF technology*, *Nucl. Instrum. Meth.* **A 443** (2000) 201.

[5] D. Belver et al., *TRASGO: A proposal for a timing RPCs based detector for analyzing cosmic ray air showers*, *Nucl. Instrum. Meth.* **A 661** (2012) S163.

[6] P. Assis et al., *R&D for an autonomous RPC station in air shower detector arrays*, *Proc. 32th. Int. Cosmic Ray Conf.* **V3** (2011) 133.

[7] D. Belver et al., *Performance of the low-jitter high-gain/bandwidth front-end electronics of the HADES tRPC wall*, *IEEE Trans. Nucl. Sci.* **57** (2010) 2848.

[8] I. Fröhlich et al., *A General Purpose Trigger and Readout Board for HADES and FAIR-Experiments*, *IEEE Trans. Nucl. Sci.* **55** (2008) 59.

[9] L. Lópes et al., *Study of RPCs for autonomous field stations in cosmic ray research*, PoS(RPC2012)043.

[10] R. Hippler et al., *First Spaceweather Observations at MuSTAnG - the Muon Spaceweather Telescope for Anisotropies at Greifswald*, *Proc. 30th. Int. Cosmic Ray Conf.* **1** (2008) 347.

[11] K. Munakata et al., *A "loss cone" precursor of an approaching shock observed by a cosmic ray muon hodoscope on October 28, 2003*, *Geoph. Res. Lett.* **32** (2005) L03S04.

[12] J. Medina et al., *Castilla-La Mancha neutron monitor*, *Nucl. Instrum. Meth.* **A 727** (2013) 97.

[13] J.A. Garzón et al., *Measuring the atmosphere properties with a high resolution Cosmic Ray detector*, *Proc. 7 ª Asamblea Hispano-Portuguesa de Geodesia y Geofísica* **S05** (2012) 287.

2014 JINST 9 C09027