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TRASGO: A proposal for a timing RPCs based detector for analyzing cosmic ray air showers

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ABSTRACT

The study of the properties of primary cosmic rays with energies above 100 TeV is only accessible indirectly through the use of detector arrays at the Earth surface. Despite the extremely high multiplicity of the air showers produced in their interactions at the highest layers of the atmosphere, only a fraction of those particles arrive to the ground over surfaces from ~ 0.1 to $\sim 100\ \text{km}^2$. The lack of information on the primary interaction and the low density of particles at the detection plane make the event by event analysis very complicated and usually only mean analysis are possible, sometimes with the help of simulation programs.

The necessity of covering big surfaces to gather a significant sample of information usually leads to the use of big volume detectors with limited performances, giving only access to a small part of the information carried out by the swarm of secondary particles of the shower. In this article, we propose the development of an affordable detector, the TRASGO, based on timing RPCs (Resistive Plate Chambers) offering at the same time very good timing and tracking performances. TRASGO would allow a better and more accurate reconstruction of the air shower properties either working stand-alone or in big surface arrays.

1. Introduction

The time–space structure of extensive air showers (EAS) has been extensively analyzed since the pioneering work of Bassi et al. [1]. They showed how it was possible to characterize the mean properties of EAS with a set of three small scintillators and fast timing techniques. They demonstrated that the shower front has a measurable thickness of a few meters close to the axis. Later works done by other experiments [2–4] extended the same study to broader air showers showing that, far away from the core, they reach a width of several hundreds of meters. The detailed simulations of Ambrosio et al. [5], compared with Haverah Park experiment data [3], contributed to improve the knowledge of the systematic properties of the showers concerning their shape, width and density of particles. Fig. 1 shows the most significant parameters defining the properties of an atmospheric shower front.

Using previous empirical models, Linsley proposed later [6] a low cost method to analyze them, using what he called "super mini arrays". The arrival time spread of the cosmic rays in a single detector would provide information about the distance of the detector to the core of the shower while the local density of particles would allow to estimate the energy of the primary cosmic ray. Linsley himself [7] and Bezbouah [8] did propose several parameterizations and approaches to characterize air showers with relatively sparse information.

Recently, the LAAS initiative [9] tries to look for large-scale coincidences between air showers over a network of small observatories distributed over the whole Japan. One of its groups at Okayama [10] has reported recently very promising results, using

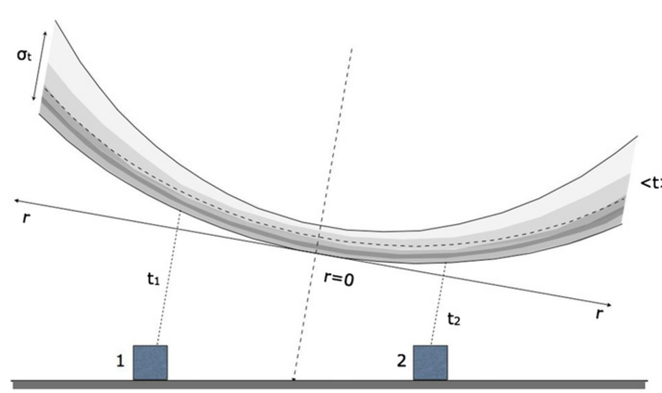

Fig. 1. Approximate shape of an air shower front (not at scale). σ_t: statistical time spread of the shower. $\langle t \rangle$: mean arrival time. r: distance to the axis (core) of the shower. t_1 and t_2: front arrival times measured by detectors 1 and 2 at different distances to the core.

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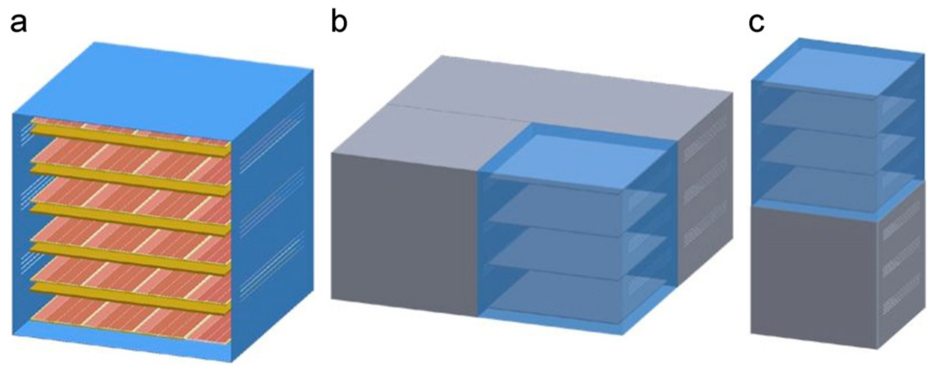

Fig. 2. Example of TRASGO with six active planes (a), arrangement of several TRASGOs to cover bigger surfaces (b) and arranged in columns to improve the efficiency and resolutions (c).

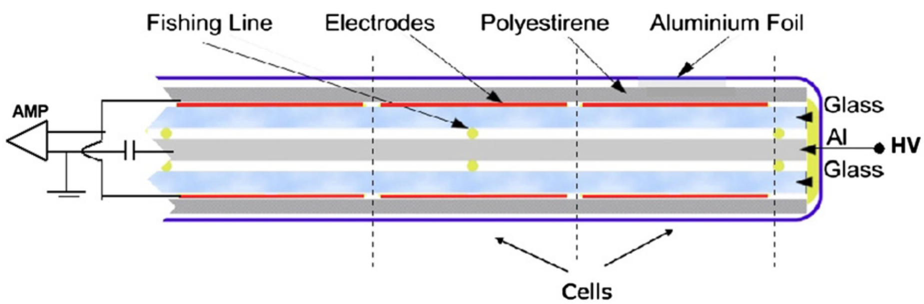

Fig. 3. Structure of the proposed 2-gaps cell. HV distribution and signal readout are also drawn.

the technique proposed by Linsley, with an array of eight detectors and they are able to identify air showers with energies up to $E=10^{18.75}$ eV.

They also analyzed some data taken with a second array in coincidence with a low acceptance magnet spectrometer able to measure almost vertical atmospheric muons with an angular resolution of about 1 mrad [11]. The arrival direction of the muon is highly correlated with the one reconstructed with the scintillators array [11, Fig. 5], suggesting that the shower arrival direction can be determined using that of one muon.

The availability of detectors providing accurate and correlated information could be of big interest for an event by event analysis of extended air showers. This is why we propose here an innovative RPC-based detector arrangement, the TRASGO. As discussed in the following, each single TRASGO would be able to offer, besides the mean time and density of particles, accurate measurements of the arrival directions, arrival time profile and also some particle identification (PID) capabilities, as well as all their correlations.

2. The TRASGO

The TRASGO (TRAck reconStructinG mOdule) concept we are proposing faces the goal of developing an affordable detector offering at the same time very good timing and tracking performances. It can work either stand-alone or arranged in sets of several TRASGOs covering big surfaces or volumes. The detector is based on most of the achievements done by the groups participating in the development of the HADES low angle TOF wall [12]. In the following, its main features are presented.

2.1. The detector

TRASGOs will use timing RPC cells as detectors. The very good time resolution they provide [13] will contribute to achieve both good arrival time and arrival direction resolutions. It will also allow to reach better reconstruction efficiencies at high rates and outliers rejection capabilities.

A TRASGO is devised to work as stand-alone detector but offering the capability of building bigger structures putting several TRASGOs together or pilling them up on top of each other (Fig. 2). The basic design we propose is a cube shaped detector with at least four active tRPC planes.[2] We propose to develop cells with a few cm wide strips (the exact width is related with the total number of channels) with readout at both ends. In this way, each plane provides two perpendicular coordinates: the coordinate corresponding to the strip position and the transverse coordinate measured by the time difference at both ends.

As each acquisition board (see Section 2.2) has 128 readout channels, we suggest basic TRASGOs having one board and 5 cm $\times$ 80 cm cells. A configuration with two TRBs and four planes would allow to reduce the strip size to 2.5 cm $\times$ 80 cm cells. Geometrical acceptance can be increased making smaller the height of the detector but making worse the angular and the velocity resolutions.

To get an efficiency close to 1 in the detection of cosmic rays, cells with at least four gaps are needed. But, in order to cover big surfaces at an affordable price, a compromise solution could be to develop RPC cells with only two narrow gaps, offering an efficiency of $\sim 90\%$ and a slightly worst time resolution. Fig. 3 shows a cut of the proposed tRPC structure with two gaps of 0.3 mm width, using two plates of 2 mm-glass and one plate of 2 mm-aluminum. HV (100 kV/cm in the nominal case) is applied to the center Al plate, and signal is collected in the readout strips through a capacitor. The detector would use the standard gas mixture for

[2] We suggest a maximum size of 80 cm $\times$ 80 cm $\times$ 80 cm (equivalent to 0.64 or 0.5 m^3) for each TRASGO, otherwise the weight of the cells and of each module would be too high for an easy handling.