

ARGO-YBJ: a unique device for the EAS study

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Abstract. The ARGO-YBJ detector, installed at the Yangbajing Cosmic Ray Laboratory (Tibet, China), at 4300m a.s.l., is a full coverage layer of Resistive Plate Counters (RPCs) covering an area of about 5800 m². The high space-time granularity, the full-coverage technique and the high altitude location will make this detector a unique device for deeply investigating a large variety of astrophysical phenomena. In this work, the capabilities of ARGO-YBJ in imaging and reconstructing in detail some of the main atmospheric shower features will be presented.

1. Introduction

The ARGO-YBJ (Astrophysical Radiation with Ground-based Observatory at YangBaJing) experiment is under construction at the Yangbajing High Altitude Cosmic Ray Laboratory (4300 m a.s.l.), 90 km North to Lhasa (Tibet, P.R.China), as an Italian-Chinese collaboration project. It is partially operating since December 2004 and its primary aim is to study cosmic rays, mainly cosmic gamma radiation, at an energy threshold of few hundreds GeV, by detecting small size air showers at high altitude with wide-aperture and high duty cycle capability. This work will be focused on the peculiarity of this detector to reconstruct the main characteristics of shower events.

2. The detector

The apparatus has many features which make it a unique device for the study of EAS induced by cosmic radiation. It is made of a single layer of Resistive Plate Counters (RPC) fully covering an area of 74 x 78 m². In order to improve the apparatus performance in the detection of showers with the core near the edge of the full coverage carpet, the area surrounding the central detector will be partially instrumented with a guard ring of RPCs, up to 100 x 110 m², thus enlarging the fiducial area. A thick lead converter will cover uniformly the RPC plane to increase the number of charged particles by conversion of shower photons and to reduce the time spread of the shower front.

The detector is organized in modules of 12 RPCs, each RPC of dimensions 280 x 125 cm². This group of RPCs, called 'Cluster', is the basic detection and Data Acquisition unit in a logical subdivision of the apparatus. The percentage of active area in the central detector, made of 130 Clusters, will be 92%. At present about 2/3 of the central detector have been instrumented and 42 Clusters (about 2000 m²) are in data taking since December 2004 [1]. In particular, a 'shower mode' trigger for the cosmic ray shower detection is implemented.

3. Shower reconstruction

With ARGO-YBJ for the first time the digital readout allows to detect all particles in a shower inside the detector area down to very low densities (0.03 particles/m² in the present configuration). Moreover,

several detailed space-time information allows good performance in determining the main shower characteristics.

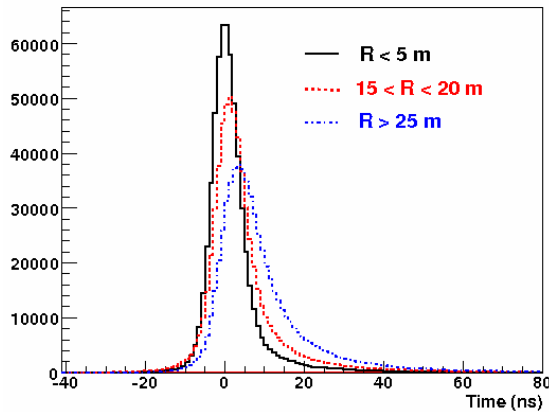


Figure 1. Time profile at different distances from the shower core

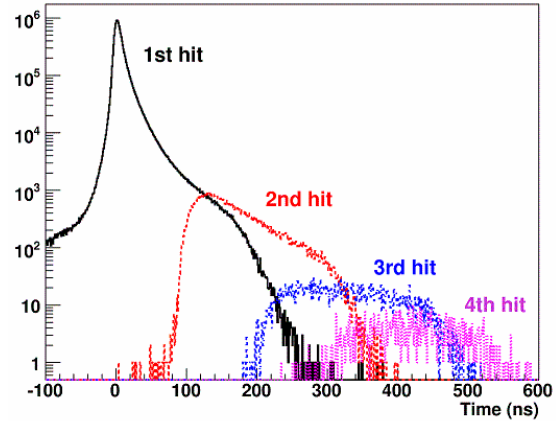


Figure 2. Time distribution of multiple hits

From the time information of each detector ‘pad’ (each one made by 8 strips of dimensions $6.7 \times 62 \text{ cm}^2$, in such a way that 10 pads cover one RPC), the time profile of the shower front is determined as shown in figure 1: the increasing time spread due to the shower front thickness as a function of the core distance is visible. The accuracy in determining the shower arrival direction depends on the time resolution. Each pad has an intrinsic time resolution due to the RPC, the signal propagation along the strip and the electronics. Relative time offsets among different pads are corrected by a proper ‘time calibration’ [2]. The device allows better than 1 ns time resolution [3].

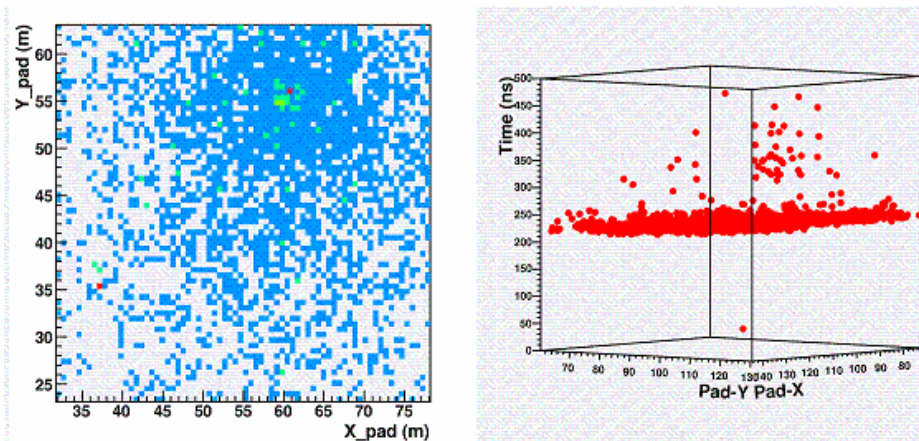


Figure 3. A wide shower hitting the detector

Due that for particles within several tens of meters from the shower core the front shape is expected to appear conical, in the procedure used to reconstruct the arrival direction the space-time coordinates (positions and times of all pad hits in the event) are fitted to a cone, with conical correction $\alpha R_i/c$, where R_i is the distance of the i -th pad from the reconstructed core and $\alpha/c=0.03 \text{ ns/m}$. An algorithm based on the Maximum Likelihood method allows to find out the core position also near the edge or outside the carpet within few meters [4].

The pad signals for the TDCs are shaped to 90 ns, thus allowing the possibility to detect ‘multiple hits’ due to several particles hitting the same pad, as shown in figure 2. Very delayed particles in the

cascade can be recorded, up to a maximum time delay of about $1.3 \mu\text{s}$ with respect to the shower front, so that the complete time development of the cascade can be fully inspected.

4. Shower phenomenology

The high space/time granularity of ARGO-YBJ detector gives the opportunity to detect several kinds of events, characterized by different topologies and time structures.

As an example, figure 3 shows a wide shower, induced by a very energetic (likely of several TeV) cosmic ray primary. On the other side, figure 4 shows the images (both space pattern at pad level and space-time profile) of two quite localized showers, probably generated by an interaction in the atmosphere not far from the detector. In this case a strong conical shape is evident.

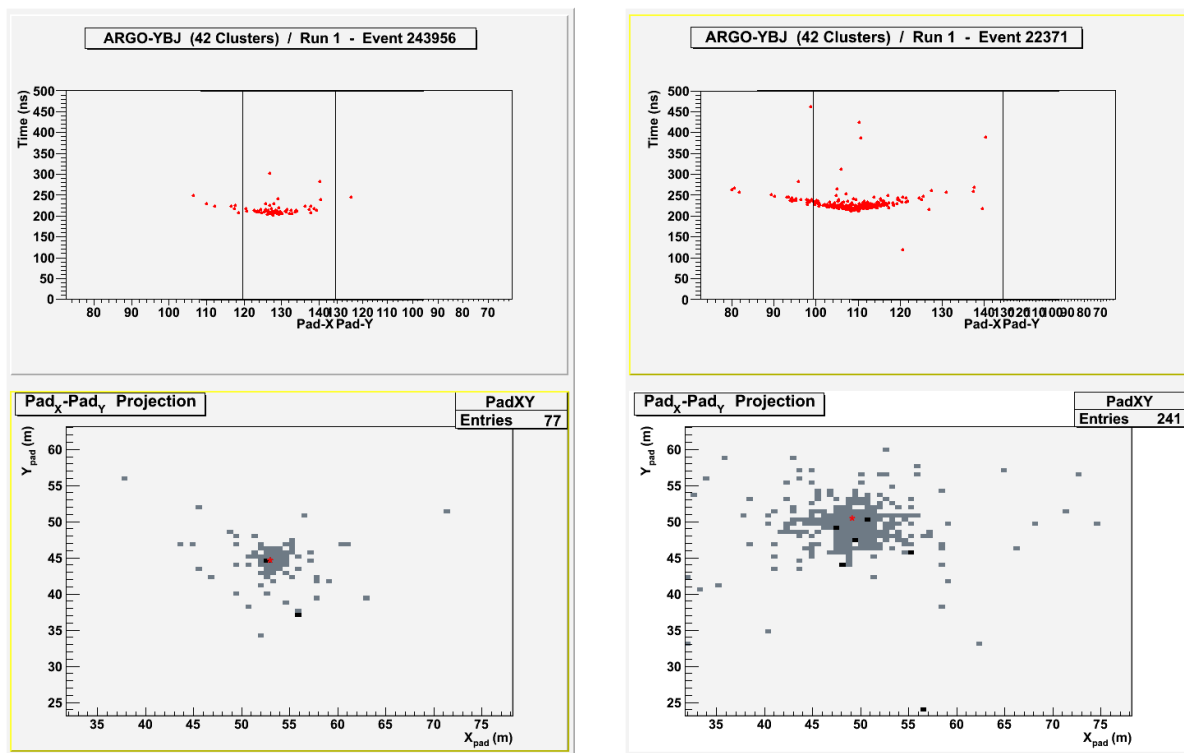


Figure 4. Two small size showers. A strong conical shape is evident.

5. Conclusions

Taking into account its most relevant features and peculiarities, the ARGO-YBJ detector has the capability to image the air shower front with unprecedented detail and to fully reconstruct the time structure of the cascade in its development in the atmosphere. This will allow to deeply investigate a wide and possibly unexpected EAS phenomenology.

Moreover, the same capabilities could be useful in discriminating gamma-initiated from hadron-initiated showers, thus providing an important quality factor in the gamma ray astronomy searches.

References

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