First measurements with the ARGO-YBJ detector

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Abstract

The detection of small size air showers at high altitude allows the search for γ-ray point sources at few hundreds GeV energy threshold. The ARGO-YBJ experiment, currently under construction at the Yangbajing Cosmic Ray Laboratory (4300 $m\ a.s.l.$), has been designed to meet these requirements by exploiting the RPC technology and a dedicated DAQ system based on a custom high-speed read-out architecture. About 1600 m^2 of detector have been instrumented and put into operation for calibration runs devoted to test the performance of the individual components and their integrated operation. Events collected with a 'shower mode' trigger have been recorded to check the consistency of physics data. We present the current status of the experiment and report on future prospects.

1. Introduction

The experiment ARGO-YBJ (Astrophysical Radiation with Ground-based Observatory at YangBaJing) is under construction at the Yangbajing High Altitude Cosmic Ray Laboratory (4300 $m\ a.s.l., 606\ g/cm^2$), 90 km North to Lhasa (Tibet, P.R.China), as an Italian-Chinese collaboration project. It will be operating over the next years with the aim of studying cosmic rays, mainly cosmic γ-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.

The apparatus, a full coverage detector of dimension $\sim 74 \times 78\ m^2$, is made of a single layer of Resistive Plate Counters (RPCs). In order to improve the apparatus performance in the detection of showers with the core outside the full coverage carpet, the fiducial area will be enlarged by partially instrumenting the area surrounding the central detector core with a guard ring of RPCs, up to $\sim 100 \times 110\ m^2$. A lead converter 0.5 cm thick 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 site location (longitude $90^\circ\ 31'\ 50''\ E$, latitude $30^\circ\ 06'\ 38''\ N$) will allow the monitoring of the Northern hemisphere in the declination band $-10^\circ < \delta < 70^\circ$.

The test operated in 1998 on a full coverage carpet of $\sim 50\ m^2$ at the YBJ Laboratory demonstrated the good performance of RPCs at 4300 $m\ a.s.l.$ and their capability of sampling the shower front of atmospheric cascades at high altitude with excellent space and time resolutions [2, 3].

2. Detector layout, Trigger and Data Acquisition System

The detector is organized in modules of 12 RPCs, each RPC having dimensions $280 \times 125\ cm^2$. This group of chambers ($5.7 \times 7.9\ m^2$ of area), called 'Cluster', represents a logical subdivision of the apparatus: the detector consists of 130 Clusters in the central part and 24 Clusters in the guard ring (Fig.1 in [3]). The active area in the central detector is $\sim 92\%$ the total. The signals from each RPC are picked-up with 80 read-out strips. The 'Fast-OR' of 8 strips defines a logic unit called 'pad' ($56 \times 62\ cm^2$). The pad signal is used for timing and trigger purposes. The trigger and the DAQ systems are built in a two level architecture. The signals from the Cluster are handled by Local Stations which in particular provide the pad multiplicity information. At any trigger occurrence, the space and time information from each Local Station is collected and elaborated in the Central Station for event building and storage. According to this logic a module of 12 RPCs (the Cluster) represents the basic detection unit.

Two main kinds of triggers have been designed for the ARGO-YBJ detector: (1) 'scaler mode' trigger and (2) 'shower mode' trigger. The 'scaler mode' trigger is based on the measurement of pad single rate from each Cluster, with the aim of (a) monitoring the apparatus and (b) detecting unexpected increases of cosmic ray fluxes mainly related to Solar flares or Gamma Ray Bursts. The 'shower mode' trigger is based on the requirement that a minimum number of pads are fired in the central carpet with the proper space-time pattern.

Both single pad rate measurements ($\sim 300\ Hz$) and expected event rates make us confident to be able to run with a relatively low multiplicity (≥ 50 hits) trigger on the entire carpet. From Monte Carlo simulations we infer that this means to explore a Crab-like γ-ray source spectrum with threshold $E_{th} \sim 200\ GeV$ and median energy $\sim 500\ GeV$, by selecting the events with a reconstructed core inside the detector area. With such multiplicity threshold ARGO-YBJ can achieve a pointing accuracy better than 1° and a sensitivity to such a point source of at least $10\ \sigma$ in 1 year of data taking (without considering any quality factor coming from the γ/hadron primary discrimination).

A detailed description of the trigger and DAQ setup can be found in [5], the operation in 'scaler mode' is described in [6], while the expected physics performance of the detector is discussed in [4, 7].

3. Experiment status and detector performance

Presently, 36 Clusters of the central detector carpet (corresponding to a total instrumented area of $\sim 1600\ m^2$) have been installed and partially put into operation for debugging and certification.

Each Cluster has been individually run by using 'shower mode' triggers of low (≥ 3) and medium (≥ 16) pad multiplicity, to test the performance of the individual components, the uniformity of their response and the time alignment of all electronics channels. Several runs with higher multiplicity triggers have been devoted to the single Cluster calibration.

The integrated operation of the detector components has been tested by running 16 Clusters with a 'shower mode' trigger ≥ 16. Fig. 2 shows the space-

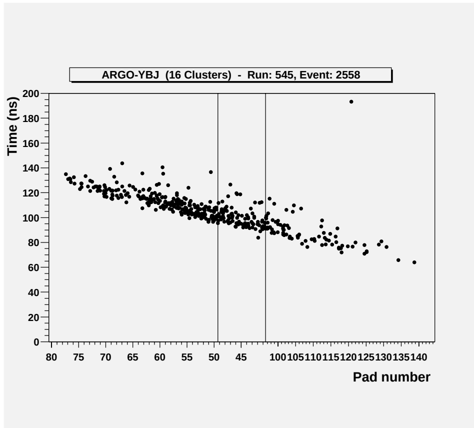

Fig. 1. Space-Time projected view of an event (the full scale of the horizontal axis corresponds to $\sim 30\ m$).

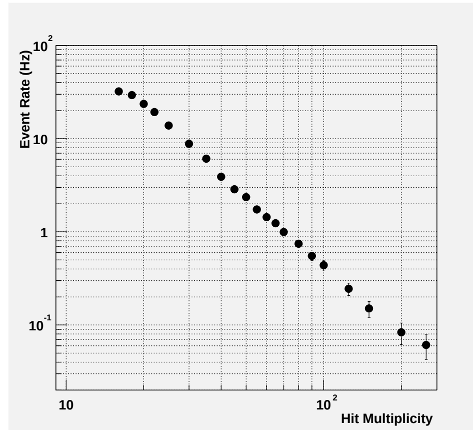

Fig. 2. The event rate as a function of the hit multiplicity (trigger: ≥ 16 hits on 16 Clusters).

time projected view of an event with hit multiplicity = 444. In Fig. 3, the rate of events is represented as a function of the hit multiplicity: the linear shape with slope $\cong 2.5$ on a bi-logarithmic plot demonstrates the physics consistency of the detected showers. Also the trigger rate is in agreement with the expected one.

The experiment schedule foresees the installation of 80 Clusters by the end of 2003 and the completion of the whole carpet during 2004. As a first step, a stable data acquisition will be performed with 36 Clusters ($\sim 1600\ m^2$), which means a detecting area large enough for Solar flare and GRB searches.

4. Conclusions

The status of the ARGO-YBJ detector, currently under construction at the Yangbajing Cosmic Ray Laboratory, has been presented. The data collected by 16 Clusters (about one tenth of the final active area), with several 'shower mode' triggers, allowed us to check the individual and integrated operation of the detector components. Both the absolute trigger rates and the shape of the hit multiplicity distribution are in agreement with our expectations.

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