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ARGO-YBJ experiment in Tibet

P. Bernardini, on behalf of the ARGO-YBJ Collaboration

Dipartimento di Fisica, Università del Salento, and INFN, Sezione di Lecce, 73100 Lecce, Italy

E-mail: paolo.bernardini@le.infn.it

Abstract. The ARGO-YBJ detector is an extensive air shower array consisting of a carpet of Resistive Plate Chambers (RPCs). The main scientific goal of this Chinese-Italian experiment is the observation of very high energy (VHE) gamma-rays from astrophysical sources. High altitude and full coverage ensure a low energy threshold (few hundreds of GeV for gamma-initiated showers). High duty-cycle and large field of view allow a continuous sky survey. The data collected with the central carpet during the detector debugging have been analysed. First results about detector performance, gamma astronomy and cosmic ray physics are presented.

1. Introduction

The ARGO-YBJ (Astrophysical Radiation Ground-based Observatory at YangBaJing) experiment is located in Tibet at an altitude of 4300 m [1]. The detector consists of a single layer of RPCs operated in streamer mode, on a total area of about 110×100 m^2 (Fig. 1). The central part (78×74 m^2) is fully active and surrounded by a sampling ring with other 1000 m^2 (20% of the outer ring) equipped with RPCs. The experiment is in data-taking with the central carpet since June 2006. The sampling ring has been completely mounted and will be put in data acquisition quite soon. In the next months the RPCs will be covered with a layer of lead as photon-converter, in order to enhance the experimental sensitivity.

The detector is logically divided in 154 clusters, each made by 12 RPCs, with a dedicated Local Station for the DAQ. The digital read-out of the RPCs is performed by means of inductive strips (6×62 cm^2) well suited to detect small air showers. The fast-OR of 8 strips is called "pad" and defines the space-time pixel of the detector, with a time resolution of ~ 1 ns. In order to extend the measurable energy range, each RPC is equipped also with two large electrodes, called "big pads", which provide an analog signal proportional to the collected charge.

ARGO-YBJ collects data in shower and scaler mode. The first one works when the number of pads fired in a time-window of 420 ns exceeds the multiplicity required by the trigger condition. The event (arrival direction, core position and so on) is fully reconstructed looking at the space-time pattern (Fig. 2). The scaler mode does not require any trigger, it records the rate for four multiplicities (≥ 1, ≥ 2, ≥ 3 and ≥ 4) on each cluster in a time window of 0.5 s. The scaler mode allows the detection of low energy transient phenomena (e.g. GRBs and solar flares) observed as non-statistical fluctuations of the background [2].

The high altitude location, the full coverage with high space-time granularity, and the RPC time resolution allow an excellent angular resolution and reduce the energy threshold in shower mode to few hundreds of GeV. The continuous sky survey in the declination band from $-10°$ to $+70°$ is possible thanks to the duty-cycle close to 100% and the field of view greater than 2 sr.

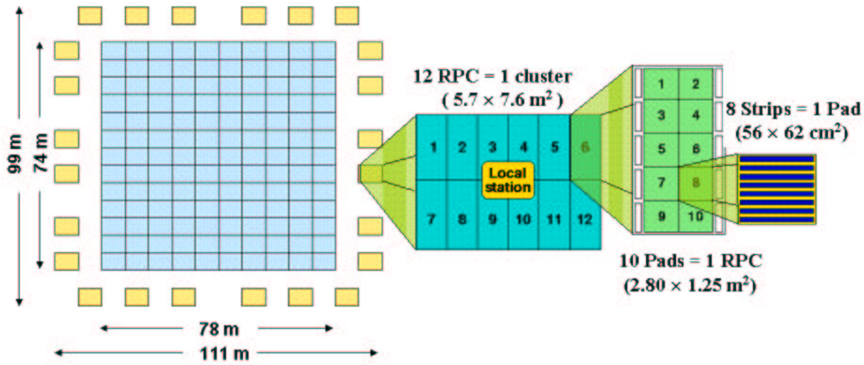

Figure 1. Detector setup. The present results are based on data collected with the 130 clusters (ARGO-130) of the central carpet.

2. VHE gamma-astronomy

The data collected with ARGO-130 have been analysed with the chess-board method after the timing-calibration of the pads [3]. The results confirm the simulations and the detector capability as a gamma-telescope with an angular resolution lower than 0.5° for internal events with more than 200 fired pads [4]. The Moon shadow in the cosmic ray flux has been observed (Fig. 3) with a statistical significance $n_\sigma \sim 10$ in 560 hours (T) with the Moon zenith angle (θ) lower than 45° [5]. The angular spread of the Moon shadow results compatible with the estimated angular resolution. Also the Sun shadow has been observed ($\sim 6\ \sigma$ in 208 hours of observation). As expected the ratio $n_\sigma/\sqrt{T}$ is the same for both the shadow sources.

Gamma Sources - The Crab Nebula has been observed with an evidence of $\sim 5\ \sigma$ in 50 days, requiring $\theta < 40°$ and a number of fired pads (N_{pads}) higher than 200 [1]. On the basis of this result the detector sensitivity is of the order of 0.3 Crab/year. The search has been performed also for Markarian 421 in the period July-August 2006, in coincidence with a flare in the X-band. In 80 hours the signal was detected with $n_\sigma = 5.5$ (Fig. 4). The analysis was performed requiring $N_{pads} \geq 60$, corresponding to a median gamma energy of 500 GeV.

Gamma Ray Bursts - The GRB spectra, well studied by satellite detectors in the keV-MeV range, are still quite unknown at higher energies. Only two observations indicate some emission in the GeV range [6]. By means of the scaler mode the ARGO-YBJ detector covers the range from 1 to 100 GeV. A first search for signals in coincidence with GRB satellite observations has been performed [7]. No significant emission has been detected and fluence upper limits ($\sim 10^{-3} \div 10^{-5}$ erg/cm^2) were set for GRBs in the ARGO-YBJ field of view.

3. Cosmic ray studies

The features of the ARGO-YBJ detector offer a unique chance to study deeply the hadronic component of cosmic rays in the energy range (1-1000 TeV) connecting direct and EAS measurements. Many analyses are in progress [8, 9]. The high space-time granularity allows unprecedented studies on EAS phenomenology (different topologies and time structures) [10].

The decrease of the shower frequency with the zenith angle, when primary energy and shower age are determined, gives a measurement of the flux attenuation at that energy. The flux attenuation is controlled by the absorption length, related to the interaction length. Therefore it is possible to estimate the proton-air cross section. Two sub-samples of events with mean energy of 3.9 and 12.7 TeV have been selected. The results of this analysis are shown in Fig. 5 [11]. Extension of this measurement to unexplored regions is possible, selecting higher energies by means of the charge analog read-out.

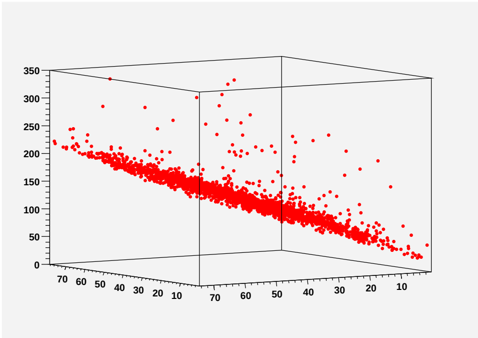

Figure 2. Space-time view of an extensive air shower.

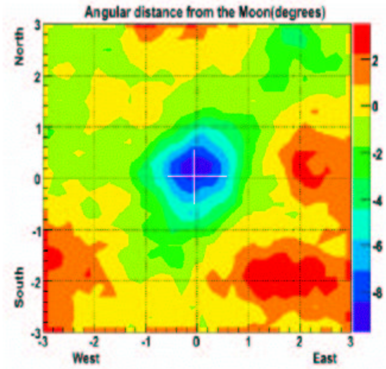

Figure 3. Moon shadow in the cosmic ray flux.

4. Conclusions

The ARGO-YBJ detector is almost completed (130/154 clusters are currently taking data). The data collected during the detector setting-up/debugging phase have been analysed. The detector performance is in agreement with the design requirements (angular resolution, energy threshold, sensitivity). Some preliminary results have been presented: Moon and Sun shadows, detection of the Crab Nebula, Markarian 421 flare observed in summer 2006, upper limits on the GRB fluence, proton-air cross section. Future implementations: guard ring in DAQ, Pb γ-converter, γ-hadrons discrimination [12].

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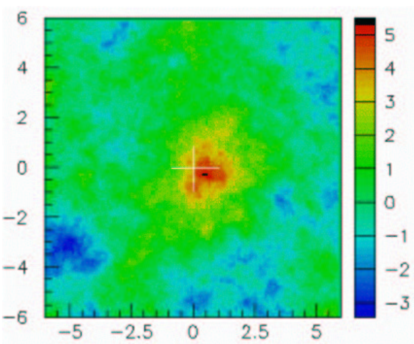

Figure 4. Markarian 421 signal during the summer 2006 flare.

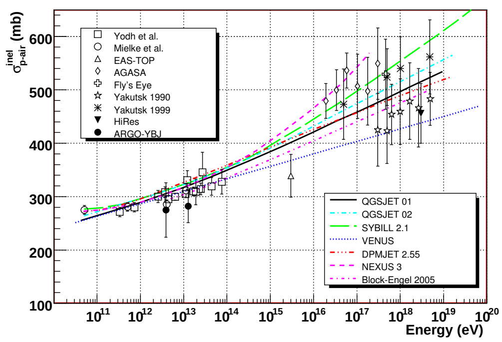

Figure 5. Proton-air inelastic cross section, the ARGO-YBJ measurements are the black dots.