ARGO-YBJ: A HIGH ALTITUDE DETECTOR FOR COSMIC RAY PHYSICS

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ARGO-YBJ is a full coverage detector of dimensions $\sim 74 \times 78 m^2$ realized with a single layer of RPCs (Resistive Plate Chambers) which is being installed at the Yangbajing Cosmic Ray Laboratory (Tibet, China) 4300 m a.s.l.. In the present work the performance and sensitivity of the apparatus are presented.

1 Introduction

The ARGO-YBJ experiment (Astrophysical Radiation Ground-based Observatory at YangBa-Jing) is under construction at the YangBaJing High Altitude Cosmic Ray Laboratory (4300 m a.s.l. equivalent to 606 g/cm^2) 90 Km North to Lhasa (Tibet, China). This experiment will be devoted to a wide range of fundamental issues in cosmic ray and astroparticle physics, including γ-ray astronomy and γ-ray burst physics at energies ≥ 100 GeV [1].

2 Detector Description

The apparatus consists of a full coverage array of dimension ($\sim 74 \times 78$ m^2) realized with a single layer of RPCs (Resistive Plate Counters), 280×125 cm^2 each. The area surrounding the central detector core, up to $\sim 100 \times 100$ m^2 (see figure 1), is only partially instrumented with RPCs. This outer ring improves the apparatus performance, enlarging the fiducial area for the detection of showers with the core outside the full coverage carpet.

A lead converter 0.5 cm thick will cover uniformly the RPCs plane. In this way the number of charged particles is increased by conversion of shower photons, thus lowering the energy threshold and reducing the particle time fluctuation on the shower front.

The basic element providing the time pattern of the shower is the logic PAD. It is defined as the fast-OR of 8 strips each 6 cm wide and 62 cm long used to pick up the signals of the RPCs [2]. These logic PADs (56×62 cm^2) define the time granularity of the detector (there are 15600 PADs in the carpet) while the space granularity is defined by the strips (124800 in the carpet).

The basic detection unit is the *cluster*, a set of 12 contiguous RPCs (see figure 1).

3 The ARGO-YBJ performance

To evaluate the performance of the detector in reconstructing the shower parameters an intense simulation activity has been performed. The development of the EAS in the atmosphere has been carried out using Corsika 5.624 [3] and EPAS [4] programs. A total of $\sim 10^6$ gamma and $\sim 10^7$

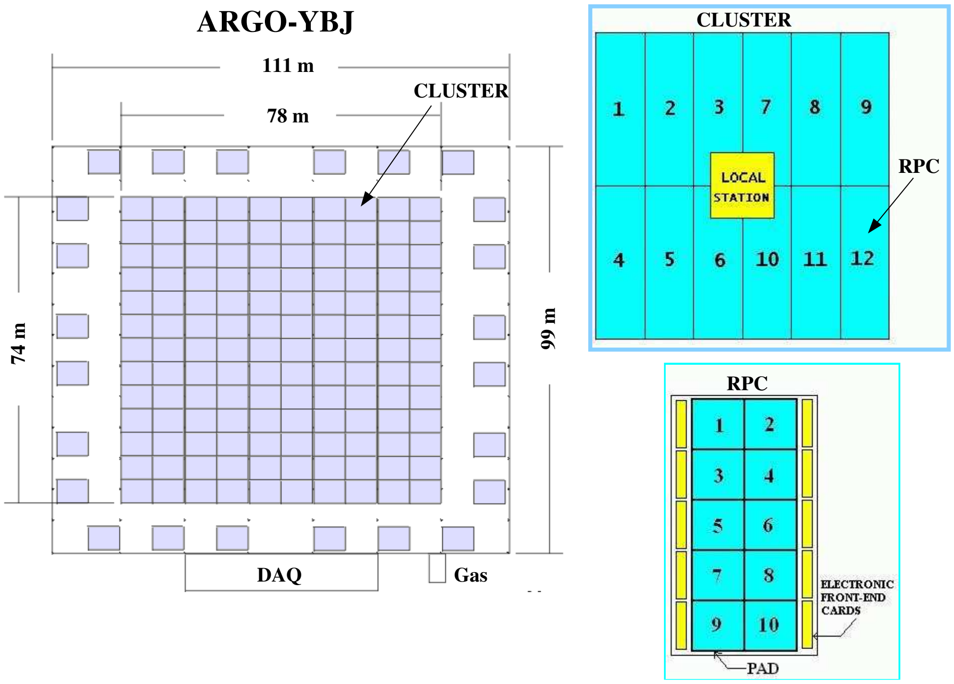

Figure 1: Schematic view of the ARGO-YBJ detector

hadron induced showers has been generated in the energy range $10 - 10^5$ GeV for gammas and $10^2 - 10^5$ GeV for hadrons.

The simulated EAS have been processed with a GEANT 3.21 [5] based Montecarlo program that contains a detailed simulation of the detector. The performance of the RPCs included in this Monte Carlo takes into account the results of a test held at the YangBaJing laboratory [6]

The apparatus performance in the shower reconstruction is strongly dependent on the pad multiplicity (see figure 2). Figure 2 shows the obtained angular aperture ψ_{70} (left panel) and the median energy of the reconstructed showers (right panel) versus the number of fired pads for a gamma ray source with the spectral index of the CRAB Nebula (-2.49) [7]. The aperture (ψ_{70}) is defined as the width of the angular bin that contains 70% of the showers produced by

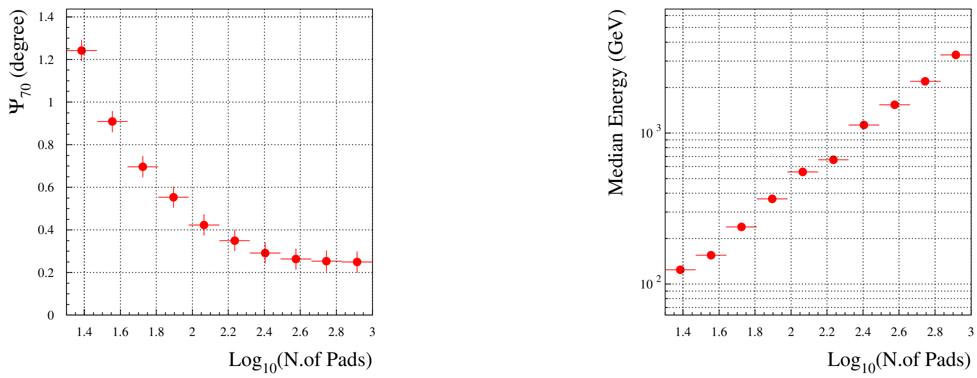

Figure 2: The opening angle ψ_{70} (see text) and the median energy as a function of the pad multiplicity. The shower core is selected in a fiducial area inside the carpet.

photons coming from a point source.

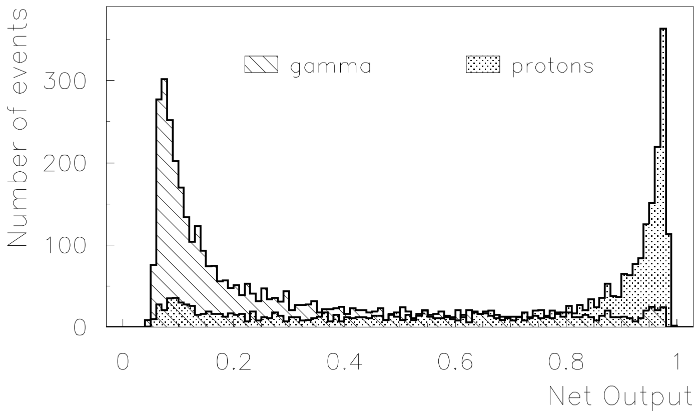

Figure 3: Gamma-hadron separation. Output of the neural network for events with $100 < n_{mult} < 150$.

Another important element in order to estimate the sensitivity of ARGO-YBJ is its capability to discriminate between gamma induced and hadron induced showers. Thanks to his very high space granularity, ARGO-YBJ can discriminate between these two types of showers looking at the spatial distribution of the particles.

A neural network [8] has been adopted to perform such a discrimination. Four input neurons for each pad with measured multiplicity N_{pad} are used. They are given by N_{pad}, N_{pad}^2, $W = \mid (N_{pad} - < N_{pad} >) \mid / \sqrt{< N_{pad} >}$, and W_{max}. $< N_{pad} >$ and W_{max} are calculated by dividing the detector in circular coronas, 1m wide, around the core position: $< N_{pad} >$ is the mean value, calculated event by event, of N_{pad} in the corona to which the considered pad belongs and W_{max} is the maximum value of W in the same region. An example of the output of the neural network is shown in fig. 3 for events with total multiplicity $100 < n_{mult} < 150$ and the core generated in the center of the carpet. In this case a rejection factor of the order of 80% is obtained, which means a factor 3 improvement in the sensitivity.

4 The ARGO-YBJ Sensitivity

The sensitivity of ARGO-YBJ in detecting a point source of gamma rays depends on its angular resolution, its effective area for gamma and hadron induced showers, $A_\gamma(E,\theta)$ and $A_h(E,\theta)$, and on the quality factor of the γ/hadron separation $Q(E,\theta)$. However, since all these quantities are functions of the energy, the sensitivity depends on the spectrum of the gamma ray source itself.

The CRAB spectrum has been used as a test for the calculation of the ARGO-YBJ sensitivity which can be expressed by the following formula, representing the significance of the signal in terms of the background fluctuation:

$$S = \frac{0.7 \cdot T \cdot \int\int \Phi_\gamma(E) A_\gamma(E,\theta) f'(\theta) Q(E,\theta) dE d\theta}{\sqrt{T \cdot \int\int \Phi_h(E) A_h(E,\theta) f'(\theta) \Delta\Omega(E,\theta) dE d\theta}}$$

where T is the total detection time, $\Phi_\gamma(E)$ and $\Phi_h(E)$ are respectively the gamma ray source flux and the cosmic ray flux (background), $f(\theta)$ is the fraction of time the source spends under the zenith position θ and $\Delta\Omega(E,\theta)$ is the bin in the sky defined by the angular resolution of the detector.

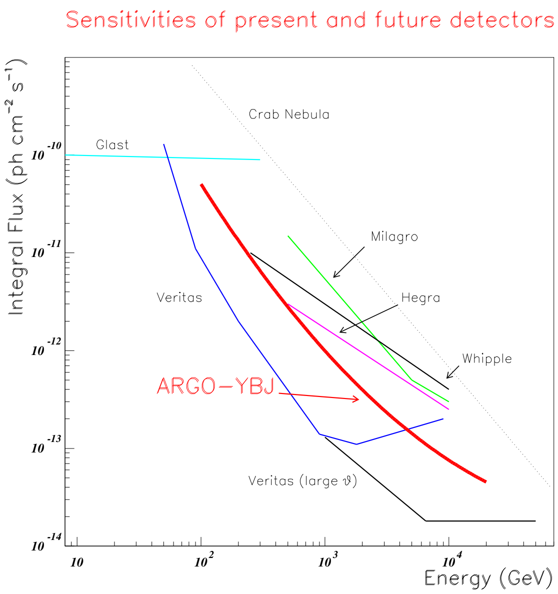

Figure 4: Sensitivity of ARGO-YBJ to the CRAB Nebula compared with other experiments ([9−12])

The sensitivity we obtain, expressed as the minimum integral flux from the Crab, detected with a 5 σ significance in 1 year, is shown in figure 4 and compared with the quoted sensitivity of other present and future experiments.

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