Analysis of Single Particle Rates from the ARGO-YBJ Experiment

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Abstract

The ARGO-YBJ experiment is located in Tibet at 4300 m a.s.l.. The full coverage approach and the high altitude location allow us to study many physics items in the field of low energy cosmic rays. In particular, the search for gamma-ray burst and ground level enhancement at E>10 GeV can be done with the "single particle" technique, which consists in recording the counting rate of the detector at fixed time intervals. An excess is detected if it gives a counting rate significantly higher than the background. Moreover the same data can be used to check the detector stability. In this paper a preliminary analysis of the single particle rates collected every 500 ms is presented.

1. Introduction

Several physics items can be explored studying the cosmic rays with energy of tens of GeV. For GRBs, the detection of photons at these energies and moreover the measurement of the energy spectrum cut-off are very important to study the production and acceleration mechanism, as well as the propagation features in the extragalactic medium. For charged particles the observed phenomenon is the ground level enhancement (GLE), associated with solar flares with large coronal mass ejection. The observation of particles with these energies in GLE can improve our knowledge of the acceleration processes during solar flares, while the temporal and spectral information on particles associated with GLE can be used to infer some characteristics of the magnetic fields in the heliosphere. During last ten years shower array detectors have been used to detect both photon and proton primaries with the "single particle" technique, continuously counting the rates. This simple technique gives precious information at an energy much lower than the one needed to operate the shower array in coincidence, even if the arrival direction is not measured. Counting rate enhancements related with intense solar

pp. 2761–2764

flares have been measured by several shower detectors (as Baksan [1], AGASA [5], MILAGRITO [8] and L3+Cosmics [10]); MILAGRITO reports a possible GRB detection [2], even if with a low statistical confidence. All these observations suggest that primaries of energy > 10 GeV are present in the most powerful solar flares and GRBs. Dealing with transient phenomena, it is of great importance to have a detector with high sensitivity to monitor continuously the sky with large acceptance. A mountain detector is highly preferable since it allows us to detect cosmic rays of lower energy for both single particle and coincidence techniques, the latter giving information on the arrival direction (low multiplicity technique).

2. The experiment

The ARGO-YBJ detector is located in Tibet, China at the Yangbajing High Altitude Cosmic Ray Laboratory (30°.11 N, 90°.53 E, 4300 m a.s.l., 606 g/cm^2). It consists of a central carpet of a single layer of Resistive Plate Chambers (RPCs) operated in streamer mode, 74 x 78 m^2 size, with full coverage (active surface $\sim$ 92%). The detector has a modular structure, the basic element being a "cluster" of 12 RPCs, for a total area of about 44 m^2. The 130 clusters constituting the central carpet are organized in a 10 x 13 matrix. So far 36 clusters have been installed, while 16 of them are connected to the DAQ. For triggering purposes the signals coming from each cluster are organized by a front-end pre-processing electronics ("local station") to give the number of detected particles in a narrow time window (Δt = 150 ns) as pulses on different wires. In particular, 6 low multiplicity signals are available for each cluster, giving the multiplicity of at least 1 particle (≥ 1) to at least 6 particles (≥ 6) detected on the whole cluster surface. The single rate data acquisition system consists of a VME crate with a custom 80-channel scaler board. The absolute time is given by a GPS clock with an accuracy < 1 μs. A reference frequency of 10 MHz, provided by the GPS clock, is sent to the same board to check the counting duration, that can be software selected to 50 or 500 ms. The detector status is continuously monitored for what concerns the high voltage power supply, the current drawn by each RPC, the gas temperature and humidity, and the environmental parameters like atmospheric pressure and external air temperature [4].

3. Effective area for single particle operations

In order to define the sensitivity in the detection of low energy primaries, the effective area of the detector has been calculated using a detailed MC simulation. Since the information on the event multiplicity requires a scaler for each multiplicity of each cluster, this simulation is also useful to define the meaningful number of scalers needed. The simulation has been carried out with the CORSIKA [6] code and the EGS option for the electro-magnetic component; the

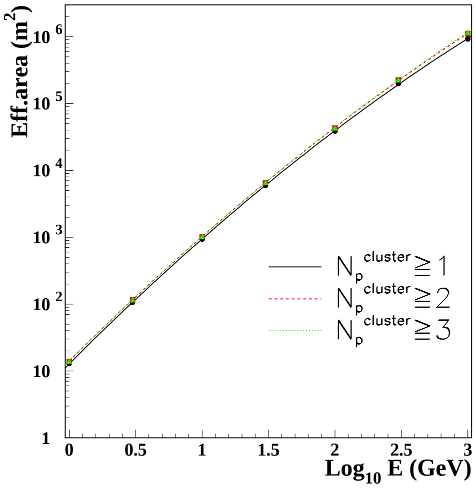

Fig. 1. Effective area of ARGO-YBJ to detect primary gamma-rays for different trigger requirements. The primary zenith angle is 20°.

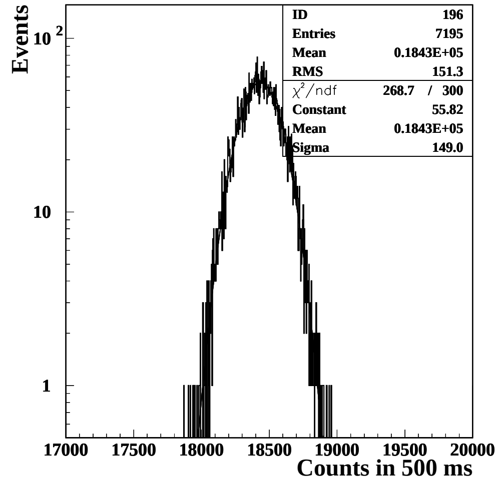

Fig. 2. Counting rate distribution for cluster #166.

hadronic interaction model used is QGSJET [7]. Primary photons and protons have been simulated with fixed energy ranging from 1 GeV to 1 TeV at a zenith angle of 20°, with an energy cut at 50 KeV for both electrons and photons.

Figure 1 shows the effective area for primary photons for different scaler configurations (≥ 1 means using 1 scaler only per cluster; ≥ 2 means 2 scalers per cluster and so on). As expected the difference is negligible at low energy while becomes relevant in the higher energy region, where the single particle mode is less sensitive with respect to the low multiplicity technique. Using 2 scalers per cluster the effective area loss is ≤ 2 % up to 100 GeV and becomes ~ 12 % at 1 TeV. For these reasons 2 scalers per cluster will be used for the whole ARGO-YBJ detector. From the same plot we can see that the effective area is quite large even at the lowest energies, being ~ 100 m^2 at 3 GeV. Similar considerations apply to the effective area for primary protons also.

4. The data

Preliminary data from cluster #166 have been collected from 2nd to 5th April, 2003. During this period the cluster was kept in stable conditions while the other 15 were under test and calibrations. Single particle rates have been collected with a gating time of 500 ms, for a total number of 341668 readings; having 80 scaler channels available, for this first trial the multiplicities from ≥ 1 to ≥ 4 have been collected. Figure 2 shows the counting rate spectrum, added on the 4 multiplicities. Since the correlation with the environmental and detector parameters has not been yet implemented, the plot refers to 1 hour of data taking, to check the detector stability in constant external conditions. The resulting mean counting rate is 910 Hz/m^2, slightly lower than the one measured during the ARGO test ($\sim$ 1200 Hz/m^2) [3]; the sigma of the gaussian fit is almost compatible with a "statistical" detector, being only 10 % greater than what expected from poissonian fluctuations. Finally, a rough measurement of the mean primary energy can be done comparing the ratio of ≥ 2 to ≥ 1 counting rates with that from MC simulation. Because the ratio depends on primary energy, even if slightly, going for protons from 5.8 % at 10 GeV to 6.8 % at 100 GeV and 12.9 % at 1 TeV, the measured ratio of 5.4 %, confirms the expected mean energy of primary particles. The counting time duration has been checked using the GPS data. The resulting dead time of the DAQ is 392 μs, corresponding to 0.08 % for a 500 ms integration time, with a total time jitter (counting plus dead time) of 1.6 μs.

5. Conclusions

From this very preliminary data set we have verified that the DAQ system is reliable, having a very stable and uninterrupted counting time. The detector, at least for short periods, acts nearly as a "statistical" detector, fulfilling the fundamental requirement for single particle technique. In addition, the mean energy of the primary particles seems coherent with what expected. Obviously much more statistics on more clusters, measuring and applying corrections for environmental parameters, must be collected to verify the long term stability. 16 clusters are ready to work and hopefully some more results will be presented at the Conference.

6. References

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