29th International Cosmic Ray Conference Pune (2005) **5**, 311–314

The ARGO-YBJ inclusive trigger

S. Mastroianni for the ARGO-YBJ collaboration
Dipartimento di Fisica and INFN Università Federico II University di Napoli, Italy
Presenter: S. Mastroianni (mastroianni@na.infn.it), ita-mastroianni-S-abs1-og27-poster

ARGO-YBJ is a ground-based cosmic ray telescope presently under construction at the Yangbajing High Altitude Cosmic Ray Laboratory (Tibet, People's Republic of China, 4300 a.s.l.). The detector will cover ∼5800 m^2 with a single layer of Resistive Plate Counters (RPCs), and will be surrounded by a partially instrumented guard ring.About 1900 m^2 of the central carpet are in data taking for science runs since December 2004.
The ARGO-YBJ experiment is devoted to gamma ray astronomy studies at an energy threshold of a few hundreds of GeV. The detection of small size showers is accomplished by means of an inclusive trigger able to record shower events with a minimum number of hits on the carpet. The logic of this trigger, its implementation and the expected performance are presented. These calculations are applied to the 42-cluster carpet presently in data taking and the results are compared to the experimental data.

1. Introduction

The ARGO-YBJ experiment (Astrophysical Radiation with Ground-based Observatory at YangBaJing) studies a wide class of phenomena in cosmic rays and astroparticle physics by observing the secondary particles of the atmospheric showers[1]. The energy spectra of the showers of interest span the GeV to TeV range.
The carpet is made of a single layer of RPCs that work in streamer mode and each chamber is read out by means of 80 pick-up strips. The ARGO-YBJ detector is divided into 15600 basic elements, the logic pads, which are defined by the fast-OR of 8 adjacent strips. Thus, the detector provides a space-time pattern of the shower front with a very high granularity.
All the trigger algorithms validate and select an event on the basis of the time distribution of the fired pads and their multiplicity on the carpet. In this paper we will investigate the performance of the trigger to select low energy showers in the range of a few hundreds GeV which are expected to fire less than 100 pads on the entire carpet. Beside this channel there are others triggers to select showers which have a much higher particle density [2].

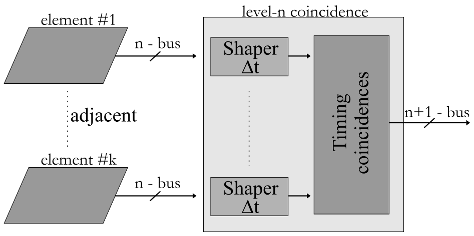
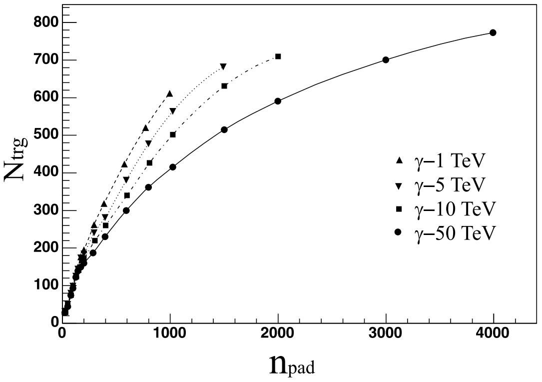


Figure 1. The level-n coincidence scheme: level-1 manages up to 4 Clusters ($\Delta t = 150\ ns$), level-2 up to 12 Clusters (250 ns), level-3 up to 65 Clusters (350 ns) and level-4 up to 130 Clusters (400 ns).



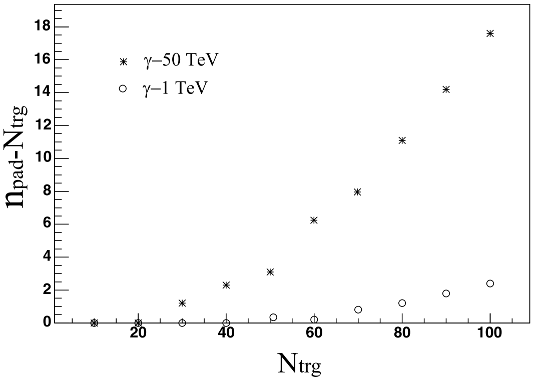


Figure 2. N_{trg} vs. n_{pad} for vertical gamma-showers with the core on the carpet at different energies.

Figure 3. The difference between n_{pad} and N_{trg} for vertical gamma-showers with the core on the carpet.

2. The inclusive trigger logic

The DAQ and Trigger basic elements are structured in modules made of 12 RPCs, called Clusters. The central carpet includes 130 Clusters. Each Cluster has its own modular read-out and local trigger electronics housed in a Local Station (LS) [3]. The 120 pad signals of each Cluster are stretched to 150 ns in order to guarantee that particles of the same shower are in coincidence. The LS outputs a 6-bit Low Multiplicity (LM) weighted bus (when $\geq$1, $\geq$2, $\geq$3, $\geq$4, $\geq$5, $\geq$6 pads are fired). This read-out saturates effect when the pads fired in coincidence on the same Cluster are greater than 6.

A simple yet powerful algorithm to select shower events is achieved just adding the multiplicities of all Clusters corresponding to the same shower across the entire carpet in $\sim$ 400 ns. This logic produces an output when the total number of hits exceeds the programmed threshold. The spurious signals of the detector ($\sim$400 Hz/pad) represent the noise for the shower events. To keep them as low as possible, a four-level coincidence scheme has been implemented in order to correlate only pad signals pertaining to adjacent areas. This logic offers a good noise rejection. In Fig. 1 the level-n coincidence scheme is shown. In order to guarantee the coincidence across all the input elements even with the worst hit timing case, the algorithm stretches the signal widths to the pertaining time window Δt and then sums them up, handling the bus outputs. The level-n coincidence splits the central carpet in an opportune number of blocks of adjacent Clusters managing their coincidence time[2].

In the following we will describe the response of the inclusive trigger to the selection of the showers, evaluating the trigger probabilities, the particle fluxes and the expected trigger rates. The estimate will be compared with the experimental results for the 42 cluster carpet.

3. The inclusive trigger performance

The shower development in the atmosphere has been simulated by means of the CORSIKA/QGSjet code [4]. The response of the detector, including the pad noise, has been taken into account by using a GEANT3-based code, that gives position and time of all the fired pads for every shower hitting the detector. We have developed a dedicated software to simulate the trigger logic. A large number of showers induced by gamma, protons and Helium nuclei have been simulated at different zenith angles up to 50° and in the energy range from a few GeV to 100 TeV with the core on a sampling area $A_{fid} = 800 \times 800\ m^2$.

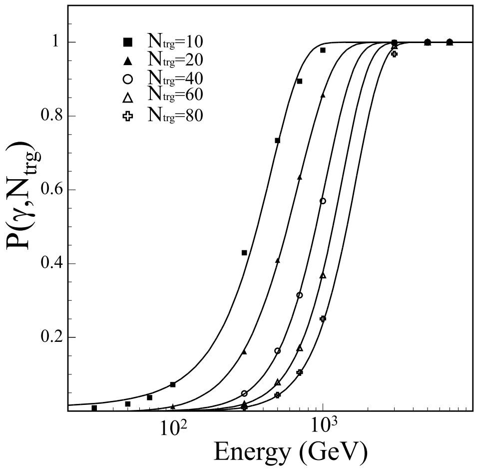


Figure 4. Trigger efficiency $P(\gamma, N_{trg})$ vs. energy for γ-induced showers at zenith angle=20° ("internal events").

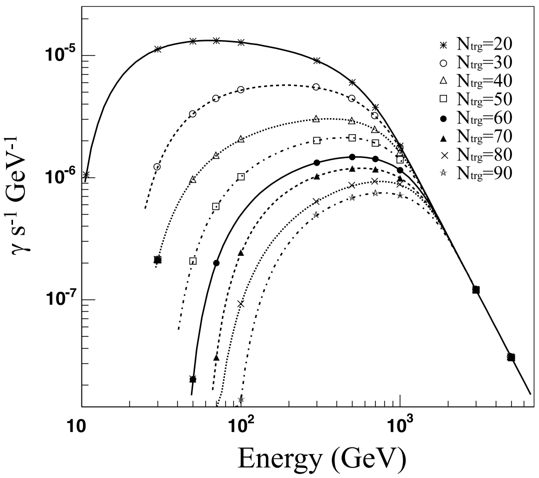


Figure 5. The energy spectrum sampled at different trigger thresholds. The median energies range from 490 GeV for $N_{trg} = 20$ to 1650 GeV for $N_{trg} = 90$.

We define N_{trg} as the number of fired pads required to satisfy the trigger conditions while n_{pad} is the number of pads fired on the detector when the trigger is issued. These two quantities are generally different because: a) the maximum number of pad signals for each Cluster recorded by the trigger system is 6 with respect to a total of 120; b) the coincidence time Δt (see Fig. 1) does not select delayed particles belonging to the shower tail. To evaluate this effect we compare N_{trg} with n_{pad} for vertical $\gamma-$showers with core on the carpet. We observe a good linearity up to $n_{pad} \sim 100$ for showers of energies less than a few TeV. The difference $n_{pad} - N_{trig}$ is shown in Fig. 2 for 1 TeV and 50 TeV $\gamma-$induced showers. For the envisaged trigger level ($N_{trg} \leq 50$) the difference is negligible also for showers with energies as high as 50 TeV.

The triggering efficiency as a function of the shower energy is shown in Fig.4 for different trigger conditions. For $N_{trg} = 10$ we observe a "tail" due to a spurious contribution from the pad noise. Accordingly, a "noiseless" trigger is obtained by setting $N_{trg} \geq 20$. The curves of the Fig.4 have been folded to the Crab-spectrum[5] to get the effective energy spectrum sampled by different trigger conditions. The result is shown in Fig. 5. A median energy of about 500 GeV is achieved by using the most inclusive triggers ($N_{trg} \leq 30$). Similar calculations have been carried out to evaluate the trigger rate to be sustained by the DAQ system. The present estimate takes into account only proton and helium induced showers. The proton and helium fluxes are from [6]. After integration on energy up to 100 TeV and over the solid angle up to $\theta_{max} = 50°$ we obtain the trigger rate shown in Fig. 6 as a function of the inclusive threshold N_{trg}. In the figure the proton and helium contributions from "internal" and "external" events (cores inside and outside the carpet) are singled out. Taking into account the contribution of heavier nuclei, we can state that the trigger rate with the most inclusive thresholds should not exceed 10 kHz. A check of these calculations has been performed by simulating the expected trigger rate for the 42 clusters presently in data taking. The measured trigger rate is compared in Fig. 7 with the calculated values. The agreement is remarkable, the slight difference at high trigger thresholds likely being due to the contribution of the cosmic ray heavy components.

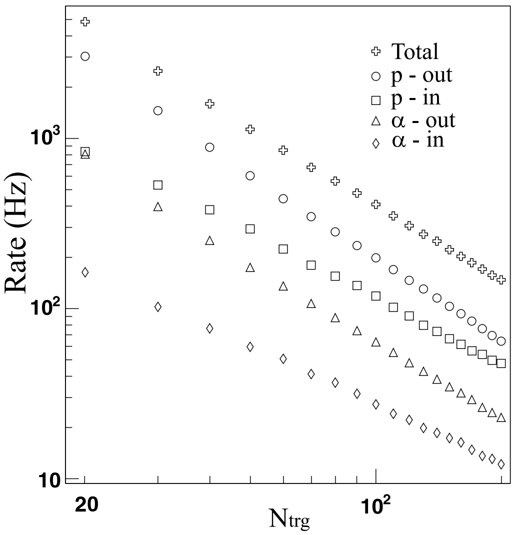


Figure 6. Trigger rate (full ARGO carpet) induced by protons (p) and Helium nuclei (α): in=internal events and out=external events.

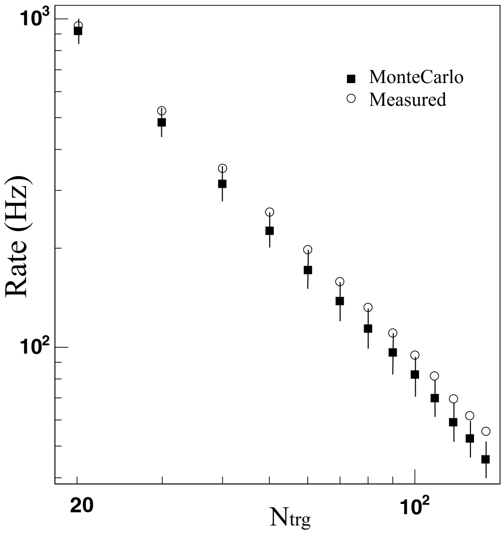


Figure 7. Trigger rate vs. trigger threshold for the 42-Cluster carpet.

4. Conclusions

The detection of small size showers is one of the main task of the ARGO-YBJ experiment. An inclusive trigger able to record a minimum number of hits has been implemented, based on a four-level coincidence scheme which correlates only signals pertaining to adjacent areas. This trigger will allow to sample photon-induced showers down to energies of a few hundreds GeV. The expected trigger rate due to the cosmic ray background is less than 10 kHz.

References

[1] M. Abbrescia et al., *Astroparticle Physics with ARGO*, Proposal (1996).
C. Bacci et al., *The ARGO-YBJ Project*, Addendum to the Proposal (1998).
[2] A. Aloisio et al., IEEE Trans. Nucl. Sci. 51, 1835 (2004).
[3] R. Assiro et al., Nucl. Instr. and Meth. A 518 (2004).
[4] D.Heck et al., Forschungszentrum Karlsruhe FZKA 6019 (1998).
[5] A.M.Hillas et al., ApJ 503,744 (1998).
[6] J.R. Horandel et al., Proceedings of the 27th ICRC (Hamburg 2001).