Detection efficiency of small size showers by a full coverage RPC's carpet

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Abstract

Recent results, concerning both the observation of high energy gamma-rays from AGN's and the detection of a gamma ray burst with a spectrum extending up to $18\,GeV$, prompt the need of ground based detector covering a large angular acceptance and operating with high duty cycle. A "full coverage" RPC's carpet operated at high altitude could meet these requirements: its triggering efficiency for detection of small size showers initiated by photons of a few hundreds GeV has been calculated by a MonteCarlo simulation.

Introduction

The observation of high energy gamma-rays from several galactic (pulsars) and extragalactic (AGNs) sources by EGRET [1] and the detection of a few Gamma Ray Burst's (GRB) with a spectrum extending at least up to $\sim 20GeV$ [2] prompt the need of ground based detectors operating in the energy range from $100GeV$ to $10TeV$ and free of the traditional limitations of the Cerenkov technology. A full coverage RPC's carpet (ARGO [3]) operated at high elevation ($> 4000\,m\,a.s.l.$) could meet these requirements. The high variability of the extragalactic sources and the unpredictability of the GRB events determine severe limitations to the efficiency of narrow field air Cerenkov detectors which can only operate on dark nights and observe one potential source at a time for three or four months at the most for year. Though its sensitivity cannot compete with the performances expected for the next generation of air Cerenkov telescopes, ARGO should have the crucial advantage over them of a large angular coverage of the sky and a high duty cycle factor. Here we present results of simulations concerning the detection efficiency of this detector operated at an elevation of $4300\,m\,a.s.l.$ (corresponding to the altitude of the Cosmic Ray Laboratory of Yangbaijing, Tibet) for the observation of small size showers initiated by low ($< 1\,TeV$) energy photons.

Simulation of the detector response

The response of the RPC's carpet has been studied using MonteCarlo simulations. The EPAS code [4] is used to follow electromagnetic air showers initiated by gamma-rays. Photons with energies of $10 \div 10^3\,GeV$ are injected at 20^0 zenith angle from the top of the atmosphere and propagated up to a vertical depth of $606 g/cm^2$. Both electrons and photons with energy $\geq 1\,MeV$ are recorded at the sampling level. The dependence of mean size $\overline{N}_e, \overline{N}_\gamma$ on the primary energy is shown in Fig. 1 . Since the γ-component is about 7 times more abundant than electrons ($\sim$ 3.5 for distances $< 50\ m$ from the core), the conversion of low energy photons can be exploited to increase the number of charged particles. A lead converter 0.5 cm thick allows to increase the number of charged particles of a factor 1.6 . Particles are propagated through the converter by means of EGS4 code [5].

An RPC's carpet of $120 \times 120\,m^2$ has been considered with a 95% active area. Moreover a 95% efficiency has been take into account. Each RPC ($1 \times 2\ m^2$) is equipped with a read-out system of 3 cm wide, 50 cm long strips. Signals from the strips are OR-ed in order to get the time of the first particle and the number of particles hitting each $50 \times 50\ cm^2$ "pad". The information from these "logic pads" can be easily managed for triggering purposes. N shower events ($N \geq 10^3$ for each selected energy) have been simulated uniformly distributed over an area A of $200 \times 200\ m^2$ including the detector area. The effective area A_{eff} is obtained as $A_{eff} = A \cdot \frac{n}{N}$, being n the number of showers which meet the triggering conditions. Moreover, we define the efficiency ϵ for internal events as the fraction of showers with core hitting an area $100 \times 100\ m^2$ inside the detector satisfying the trigger.

Triggering schemes

Two types of trigger have been envisaged: a low multiplicity trigger (LMT), dedicated to the detection of very small size showers (a few "logic pads" fired) generated by low energy photons $< 100 GeV$ as expected in GRB's, and a high multiplicity trigger (HMT) addressed essentially to the gamma ray astronomy. LMT is obtained as follows: the whole carpet is subdivided in a matrix of $10 \times 10\ m^2$ logic sub-units. One logic sub-unit is ON if at least "two pads" are fired in a $50\,ns$ time window. The LMT is built requiring a coincidence of at least two logic sub-units in a time window of $450\,ns$ (corresponding to a maximum zenith angle of about 50^0) and a minimum number of 6 pads fired. Since the pad single rate at $4300\,m\,a.s.l.$ is estimated $\sim 200\,Hz$ (including the detector noise) the resulting frequency of accidental triggers is about $1\,KHz$, that is $\sim 1\%$ of the trigger rate. This logic is applied indepentently to another overlapping grid shifted of 5 meters in both x and y directions. The HMT is built simply requiring a coincidence of ≥ 20 pads in a $450\,ns$ time window.

The frequency of spurious triggers is a few tens Hz. These events could be processed in order to indentify the core location and recover the time profile of the shower by means of a cone-like or parabolic fit. On the other side, a simple plane-wave approximation could be applied to low multiplicity events ($N_{pad} < 20$) to determine the shower arrival direction (the angular resolutions are discussed in an accompanying paper [6]).

Results and conclusions

The solid line in Fig. 2 shows the triggering efficiency provided by HMT for showers with core hitting an area $100 \times 100\ m^2$ inside the carpet (for comparison the efficiency provided by LMT is also shown by a dashed line). It appears that about 20% of the showers initiated by $200\,GeV$ photons are imaged by the RPC's carpet with more than 20 "hits". Thus $200\,GeV$ is the energy threshold for *"well reconstructed internal events"* for which an angular resolution $0.4^0 \div 0.1^0$ (according to the number of fired pads) is expected. The effective area A_{eff} corresponding to LMT events is shown in Fig. 3 by a dashed line (for comparison, the effective area for events triggered by HMT is also shown by a solid line). The effective area increases from $\sim 20\ m^2$ at $10\,GeV$ up to $\sim 2 \cdot 10^3\ m^2$ at $100\,GeV$. Since the angular resolution for these events is expected to be $\sim 3^0$, this trigger should allow the detection of GRB's with fluence $\sim 10^{-5} \div 10^{-4}\ erg/cm^2$ provided that the spectrum extends up to $50\,GeV$ or beyond.

These results and those concerning the accuracy in the reconstruction of the arrival direction indicate that an RPC's carpet (ARGO) operating at high altitude could bridge very efficiently the energy region between GeV and TeV providing a continuous monitoring of gamma point sources and GRB's events.

References

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Figure Captions

Fig. 1: The average size $\overline{N}_e, \overline{N}_\gamma$ as a function of the photon energy.
Fig. 2: The triggering efficiency as provided by HMT (solid line) and by LMT (dashed line).

Fig. 3: The effective area corresponding to HMT events (solid line) and to LMT events (dashed line).