Pointing accuracy of a full coverage RPC's carpet operating at high altitude

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Abstract

The detection at ground level of showers initiated by photons of a few tens-hundreds GeV is of a great importance for gamma-ray burst physics and gamma-ray astronomy since could allow to extend the energy range of the operating satellite experiments. The angular accuracy in reconstructing the arrival direction of small size shower by means of an RPC's carpet operating at an elevation of $4300 m a.s.l.$ has been evaluated by a MonteCarlo simulation.

Introduction

A ground-based full coverage detector operated at high altitude could record small size showers initiated by low energy photons of a few tens-hundreds GeV, in such a way bridging the energy regions accessible to satellite equipments and conventional EAS apparatus. Such a detector could complement efficiently the operation of high sensitivity Cerenkov telescopes by providing a continuous monitoring over a large angular acceptance $\sim 2\,sr$. These are valuable features in view of the extreme variability of the γ-ray sources and of the random (both in time and space) origin of γ-ray burst events (GRB's). Excellent performances are required from what concerns the detection efficiency at low energies, the angular resolution and the ability to distinguish photon/hadron initiated showers.

This paper is addressed to the pointing accuracy achievable by means of an RPC's carpet $120 \times 120\,m^2$ (ARGO [1]) operated at an altitude of $4300\,m a.s.l.$ as the ASγ array in Yangbaijing (Tibet). More details on the detector and results on the triggering efficiency can be found in an accompanying paper [2].

Simulation of the pointing accuracy

The time response of RPC's carpet has been studied by means of MonteCarlo simulations (for details see [2]). The EPAS code [3] has been used to simulate air showers initiated by photons of energies $10 \div 10^3\, GeV$. Both electrons and photons with energy $\geq 1\, MeV$ are recorded at the sampling level. Then, they are propagated through a $0.5\, cm$ lead converter by means of the EGS4 code [4]. This converter allows to shrink the time thickness of the shower front as shown in Fig. 1. The read-out of the RPC's carpet is obtained by means of strips $3\, cm$ wide, $50\, cm$ long. Signals from the strips are OR-ed in order to get the time of the first particle hitting each $50 \times 50\, cm^2$ "pad". This time is smeared out with the detector response and assigned to a conventional particle hitting the center of the "pad". The effect of the detector response is obtained by folding the "shower time" to a gaussian with $\sigma = 1\, ns$ (the typical RPC time resolution) and then adding the transit time in the strip (up to $2.5\, ns$ depending on the crossing point). Accidental signals are simulated by sampling hits from a Poisson distribution with $m = 6$, randomly distributed on the whole area in a time window of $450\, ns$.

Events are recorded according to two different triggers: a low multiplicity trigger (LMT) essentially requiring 6 fired "pads", and a high multiplicity trigger (HMT) requiring more than 20 "pads" [2]. A simple plane-wave approximation is applied to low multiplicity events ($N_{pad} < 20$) allowing for an iterative procedure to rejects spurious times due either to accidental hits or to extreme time fluctuations of shower particles. HMT events ($N_{pad} \geq 20$)are processed in order to identify the core location and recover the time profile of the shower by means of a cone-like fit. This procedure consists of the following steps:

(1) location of the core position from the center-of-gravity of the hits ($\sigma_x \simeq \sigma_y \sim 2\, m$);

(2) plane fit to hits at core distance $R < 30\, m$;

(3) rejection of out-lying times by means of a 4σ cut ($\simeq 10\, ns$) to the distribution of time residuals ($\Delta t = t_{plane} - t_i$);

(4) cone-like fit by fitting a conical shape to the survived times. This step is repeted applying a cut to a 3σ level. No weights are used. As a results $\sim 20\%$ of times are rejected.

This procedure is rather fast because makes use only of analytic formulae without requiring any information about shower features. The conicity parameter α is determined by data itself as well as the time offset and the direction cosines.

Results and conclusions

The angular spread in the reconstructed arrival direction is shown in Fig. 2 ($N_{pad} < 20$) and in Fig. 3 for events with $N_{pad} \geq 20$ and core reconstructed in an area $100 \times 100\, m^2$ included in the detector ("internal events"). The photon energy is $500 GeV$, however in the energy range we have explored ($10 \div 500 GeV$

for LMT, $100 \div 700\, GeV$ for HMT) results depends essentially on the number N_{pad} of fired "pads". Fig. 4 shows the opening angle $\psi(70\%)$ including 70% of events, for "internal events" with $N_{pad} \geq 20$. For comparison, the dependence of $\psi(70\%)$ on N_{pad} in the case of no-shielding is also reported. The opening angle $\psi(70\%)$ for events triggered by LMT ($N_{pad} < 20$) is $\sim 3^0$ as it results from Fig. 2.

These results show that an RPC's carpet operating at high altitude could achieve a pointing accuracy comparable to that obtained by Cerenkov telescopes in detecting small size showers with core enclosed in the carpet area and recorded with more than 20 hits ($E_\gamma \geq 200\, GeV$). The angular aperture appropriate for the detection of showers originated by photons of energies as low as $10\, GeV$ (as expected in GRB events) is $\sim 3^0$ sufficiently small to allow a remarkable rejection of the cosmic ray background.

References

[1] M. Abbrescia et al., Proc. 4th Int. Workshop on Neutrino Telescope, Venezia (Italy), 1992, p.349.

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Figure Captions

Fig. 1: Integral time distribution of electrons at distances $20 \div 30\, m$ from the shower core with and without $0.5\, cm\ Pb$ converter.

Fig. 2: The angular spread in the reconstructed arrival direction for events with $N_{pad} < 20$ ($\psi = \theta_{reconstructed} - \theta_i$).

Fig. 3: The angular spread in the reconstructed arrival direction for events with $N_{pad} \geq 20$.

Fig. 4: The opening angle $\psi(70\%)$ as a function of the number of fired pads for internal events with $N_{pad} \geq 20$.