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The distinctive features of anticoincidence detector system of the GAMMA-400 gamma-ray telescope

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Abstract

Some features of scintillation anticoincidence system (includes ACtop detector section located upper the converter-tracker and four AClat ones placed from its lateral sides) of the GAMMA-400 gamma-ray telescope, related to joint operations with another fast scintillation systems: SDC (scintillation detector system of calorimeter) and TOF (time-of-flight system) are considered. The main problem for high-energy (over 50 GeV) gamma-rays registration by gamma-telescopes is the presence of so-called «backsplash current» (BS) of particles from massive calorimeter when detecting of particles is provided. BS is a set of low energy particles, moving up from the calorimeter and producing triggering of the anticoincidence detectors, imitating detection of a charged particle. As an additional indicator of BS particles presence of in the ACtop detector, we offer the value of energy release in the S3 scintillation detector placing between two parts of the calorimeter (CC1 and CC2). Fast trigger signal in the main aperture for gamma-quanta is composed of analysis of TOF system signal, showing that charged particle or particles move in the direction from up to down, and ACtop energy deposition taking in to account specially designed for GAMMA-400 algorithms of backsplash rejection.

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Keywords: Gamma-ray astronomy; scintillation counters; time-of-flight; back-splash current

1. Introduction

The GAMMA-400 gamma-ray telescope [1] is designed for the detection of high-energy cosmic gamma-rays (up to 3 TeV). The layout and structure of this instrument is shown at Fig. 1. In this paper we consider the operation of

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fast scintillation counters AC, S1, S2, S3, that consist of two layers of Bicron-408 plastic scintillator bands viewed from both ends by groups of six silicon photomultipliers (SiPM) produced by SensL. Three apertures provide events registration from both upper and lateral directions. Fast trigger signal in the main aperture for gamma-quanta is composed of TOF system signal, showing that charged particle or particles move in the direction from up to down, and AC energy deposition taking in to account specially designed for GAMMA-400 algorithms of backsplash rejection.don't detect charged particles.

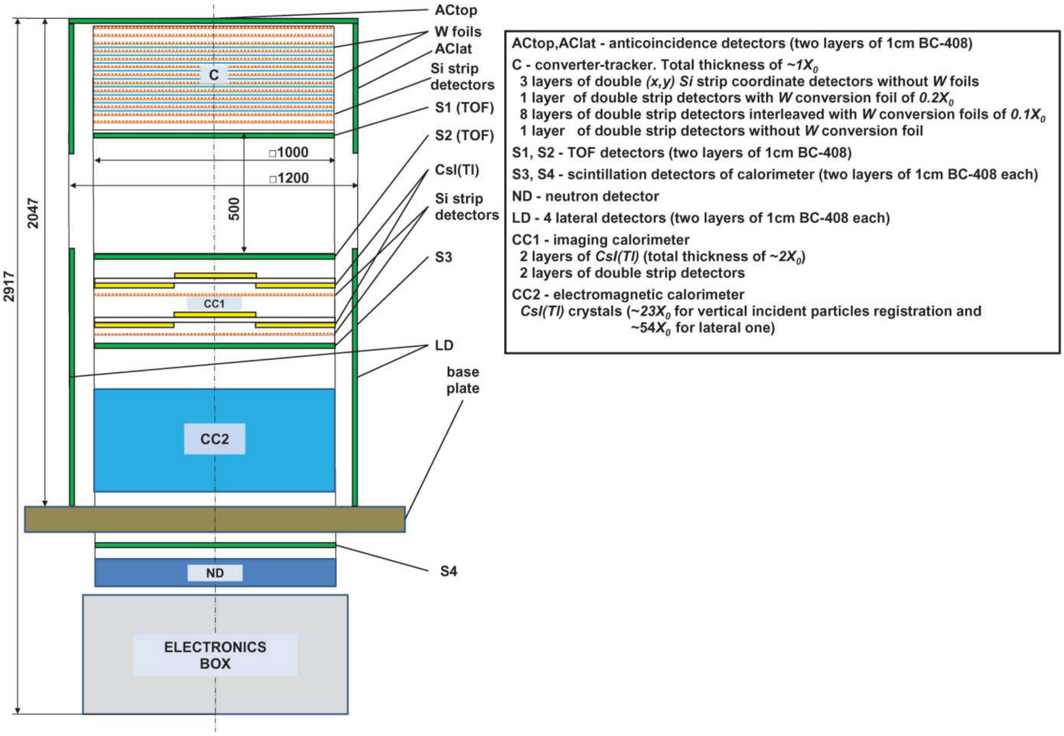

Fig. 1. The layout of the GAMMA-400 gamma-ray telescope.

2. Rejection of backsplash current

In the EGRET space experiment it appears that the efficiency at gamma-ray energy 10 GeV was twice lower in comparison with the 1 GeV energy and over 50 GeV the device became quite ineffective for gamma-rays [2].The reason of this effect is the presence of so-called “backsplash” (BS), the flux of the great number of low-energy electrons and gammas (characteristic energy 1 MeV), generated mainly in the heavy calorimeter and as a result of multiple scattering having the direction of movement opposite to the direction of the primary particle i.e. from the calorimeter to the anticoincidence detector (AC). Using the traditional method of the trigger generation the event detection will be prohibited if the energy release in AC detector overcomes the threshold for detecting the one-charged relativistic particle. In the presence of “backsplash” the flux of a great number of soft BS particles will lead to the energy over mentioned threshold and will exclude the detection of this useful event.

The segmentation is used when the BS particles are discriminated by energy release in one layer anticoincidence system, as in Fermi/LAT gamma-ray telescope [3], were the detector surface is composed of large number of sections. Therefore, the probability of sum of energy deposition from soft BS particles in each section to be higher than minimal energy release from one relativistic charged particle will be low.

For the separation of the events corresponding to the detection of charged particles and gammas taking into account the effects of backsplash we used the principles of double layer anticoincidence, AC detector segmentation, the separation of events with expected great amount of backsplash particles, the time-of-flight measurements and on-line treatment of energy releases using two-layer structure of detectors. Only signals from each detectors system individual detecting units without any summation applied for particle identification. The energy deposition and time delays' analysis provides by the counting and triggers signals formation system during onboard data processing due the specially designed thresholds combinations matrixes. The detailed analysis of each detectors system individual detecting unit energy deposition using for particles types verification during ground processing.

The sufficient energy deposition in S3 allows concluding possible high amount of BS. At the Fig. 2a, b simulated correlation between energy releases in ACtop detector (because of BS) and S3 for primary 10 and 1000 GeV gammas are shown. From this distribution was found that minimal energy release in S3 (shown by an arrow) corresponds to high BS amount expectation. The typical AC threshold of one charged particle (3 MeV for double layer) shown by horizontal dashed line).

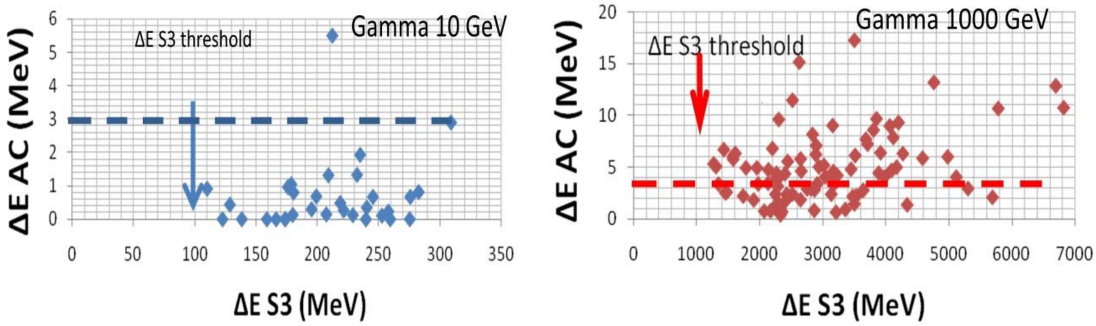

Fig. 2. Correlations between gammas energy release in ACtop and S3 detecting at the energies of 10 GeV (a) and 1000 GeV (b). Dashed line at 3 MeV corresponds to single charged particle threshold in AC.

For the reduction of proton admixture in GAMMA-400 gamma-ray telescope will be used additional discrimination of events according the time-of-flight between ACtop and S1 detectors. This method can considerably suppress the number of events from charged particles with high BS which can be interpreted as gammas.

For more precise calculation of timing properties of ACtop detector the simulation was fulfilled. The results of this simulation is shown at Fig. 3 representing the example of time-interval distribution the number of particles between particle detection in S1 and AC for 1000 gammas of 10^3 GeV incident parallel to the telescope axis.

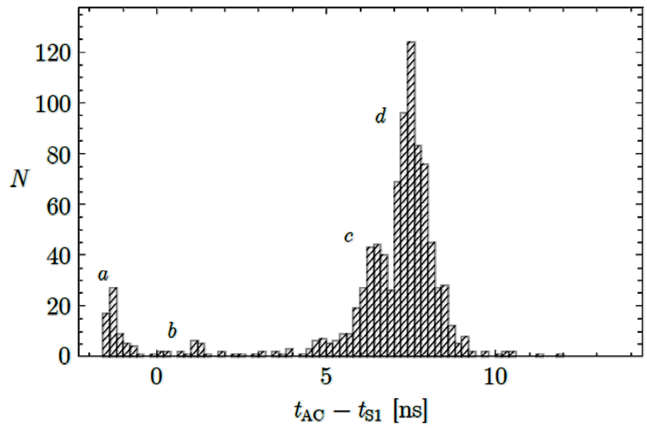

Fig. 3. Time-interval particles distribution between particle detection times in S1 and ACtop for 1000 GeV gamma-rays.

This simulation was confirmed by the detailed analysis of detection time in different layers of gamma- telescope anticoincidence scintillation detectors. The peaks at the distribution correspond to the following events:

a – gamma conversion in ACtop, the same time interval charged particles will presents;

b – events with backsplash from the converter;

c – cases with backsplash from CC1;

d - situations with back-plash from CC2.

So, the negative values of time-of-flight will correspond to charged particles detection and all the other events will correspond to gammas with BS.

For the further cleaning from the charged particles events at the onboard analysis in the counting and triggers signals formation system [4] the use of double-layer construction is foreseen.

Each BS particle has low probability to give the signal in both layers of ACtop detector. The BS electrons will be fully absorbed in one layer and the probability for the gamma-ray to produce electron-positron pair in both layers will be very low. Therefore, we can consider the interaction of BS particles in two detector layers as independent in the first order of approximation.

When the backsplash is high (i.e. the signal in S3 exceed corresponding threshold – see Fig.2) and the event is unconditionally detected we use the following scheme of event separation for charged particles and gammas.

The event is considered to be identified as charged particle only when energy release in ACtop simultaneously in individual detectors of both two layers lying at the reconstructed trajectory of primary particle will exceed the threshold for charged particle in each layer (typically 1.5 MeV, but 2.5 MeV for protons and electrons with E>10 GeV) [4].

Basing on the simulation it was shown that using this method for gamma-quanta with $E>10^2$ GeV the number of events with BS, which can be interpreted as charged particles and rejected does not exceed 3%.

3. Conclusion

The main problem for high-energy (over 50 GeV) gamma-quanta registration due gamma-telescopes is the presence of BS formed in massive telescope calorimeter. BS is a low energy particles flux, moving up from the calorimeter and producing triggering of the anticoincidence detectors, imitating the charged particle registration. For the separation of the events caused by charged particles and gammas taking into account the BS effects we used the AC detectors sections segmentation, on-line treatment of energy releases using individual anticoincidence detectors two-layer structure and the special processing of events with expected great amount of backsplash particles due S3 signal analysis. Besides, it is used additional discrimination of events according the time-of flight between ACtop and S1 detectors. This method can considerably suppress the number of events from gammas with high BS, which can be interpreted as charged particles and rejected. This value is less than 3% for photons with $E>10^2$ GeV.

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