Additional aperture detectors of gamma-telescope GAMMA-400 calibrations on synchrotron “PAKHRA”: possibility of temporal profiles fractal analysis

GAMMA-400 (Gamma Astronomical Multifunctional Modular Apparatus) is gamma-telescope consists of three types of detectors: strips (used in the converter-tracker (C) and position-sensitive calorimeter CC1), plastic and non-organic scintillators. Following detectors based on BC-408 plastics: time-of-flight system TOF (2 sections S1 and S2), top (ACtop) and lateral (AClat) sections of anticoincidence system, scintillation detectors of the calorimeter (S3 and S4) and lateral detectors of the calorimeter (LD) (its installation required for particles registration from lateral directions). All detector systems ACtop, AClat, S1-S4 and LD consist of two sensitive layers of 1 cm thickness each. Two calorimeters made of CsI(Tl): position-sensitive (CC1) and electromagnetic (CC2) ones. CC1 contain of 2 strips layers and 2 scintillation layers. The thickness of CC1 and CC2 is \( 2X_0(\sim 0.1\lambda_0) \) and \( 20X_0(\sim 0.9\lambda_0) \) respectively (where \( \lambda_0 \) is nuclear interaction length). The total calorimeter thickness is \( 22X_0 \) or \( \sim 1\lambda_0 \) for vertical incident particles registration and \( \sim 54X_0 \) or \( \sim 2.5\lambda_0 \) for laterally incident ones. Silicon photomultipliers (SiPM) are used in all scintillation detectors instead of vacuum photomultipliers for minimization of weight and power consumption.

GAMMA-400 is optimized for the gamma-quanta and charged particles with energy \( 10^2 \text{ GeV} \) registration with the best parameters in the main aperture from upper direction. The main aperture created firstly due to converter-tracker (C): gammas converted in tungsten conversion foils are registered. Triggers in the main aperture will be formed using information about particle direction provided by TOF system and about presence of charged particle or backslash obtained from ACtop and AClat anticoincidence detectors in energy band \( 20 \text{ MeV} - 1 \text{ TeV} \) for gammas and \( E > 10^2 \text{ MeV} \) for electrons.

Other two apertures used for observation of transient events do not require best angular resolution as gamma-ray and bursts solar flares both from upper and lateral directions. Additional aperture allows to registered particles from upper directions which don’t interact with converter-tracker and don’t formed TOF signal. Particles detection in additional aperture starts with signal of CC1 fast discriminators in anticoincidence with lower TOF section S2. Energy band for gammas registration in this aperture is similar to the main one. In the lateral aperture low energy \( (0.2 - 10^2 \text{ MeV}) \) photons classified by using simple anticoincidence signals from the individual detectors of LD and CC2. Higher energies \( E > 10^2 \text{ MeV} \) recognized using energy deposition analysis in the individual detectors of S3, S4, LD and CC2.

Prototype of additional aperture functioning of GAMMA-400 contains two detectors. One of them AC/LD prototype based on BC-408 plastic scintillator with dimensions of \( 1280 \times 100 \times 10 \text{ mm}^3 \). Other is CC1 prototype composed of CsI(Tl) crystal with dimensions of \( 330 \times 50 \times 20 \text{ mm}^3 \). Electron and positron beams also used to gamma-detectors calibration because of high-energy gamma-quanta registered mostly after formation of electron-positron pairs. The positron beam with energies \( 100 - 300 \text{ MeV} \) was used for calibrations of prototypes of GAMMA-400 detectors on synchrotron “PAKHRA” of Lebedev Physical Institute (Russia).

For investigation of time series corresponding to solar flares, gamma-ray bursts and other transitive events fractal analysis often used. It has some features that allow it to be used to study sets with characteristics varying over a wide range: scaling (two events with similar temporal profiles but with different durations have a similar fractal dimension) and the possibility to process simultaneously the fractal dimension distributions obtained by using data from different detectors if the background fractal dimensions for these detectors are the same. Moreover, the fractal dimensions must be different for the temporal profiles of events caused by different physical processes. Thus background fractal dimension is useful characteristic of detector. Fluctuations of count rate registered in scintillation detector during satellite experiments caused due three reasons. The first
is the background fluctuations caused by gammas and charged particles of cosmic and magnetosphere origin. Statistical fluctuations of such background are described by Poisson or Gauss statistics outside the radiation belts and other disturbed regions of magnetosphere. The second reason is the fluctuations of produced scintillation photons and photoelectron number in photomultiplier after particle pass through it. Corresponding statistical fluctuations are poissonian or gaussian in the first approximation in the linear region of SiPM. Other reason is transient processes in electronic system. We calculate fractal dimension of temporal profiles measured during calibrations of AC/LD and CC1 prototypes. Preliminary results are $1.50 \pm 0.05$ and $1.48 \pm 0.08$ correspondingly. This is similar to Poisson statistics with coefficient of error in counting up to 10. Analogous values of fractal dimension were previously received for other instruments used for GRBs observation such as BATSE and BAT onboard CGRO and Swift satellites correspondingly.

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