

Home Search Collections Journals About Contact us My IOPscience

Gamma-quanta onboard identification in the GAMMA-400 experiment using the counting and triggers signals formation system.

This content has been downloaded from IOPscience. Please scroll down to see the full text. 2016 J. Phys.: Conf. Ser. 675 032015 (http://iopscience.iop.org/1742-6596/675/3/032015) View the table of contents for this issue, or go to the journal homepage for more

Download details:

IP Address: 46.39.49.101 This content was downloaded on 07/02/2016 at 08:28

Please note that terms and conditions apply.

# Gamma-quanta onboard identification in the GAMMA-400 experiment using the counting and triggers signals formation system.

I V Arkhangelskaja<sup>1</sup>, A I Arkhangelskiy<sup>1</sup>, E N Chasovikov<sup>1</sup>, A M Galper<sup>1,2</sup>, M D Kheymits<sup>1</sup>, A E Murchenko<sup>1</sup>, Y T Yurkin<sup>1</sup>

<sup>1</sup>National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe highway 31, Moscow, 115409, Russia <sup>2</sup>Lebedev Physical Institute, Russian Academy of Sciences, Leninskiy prospekt 53, Moscow, 119991, Russia

E-mail: irene.belousova@usa.net

Abstract. GAMMA-400 (Gamma Astronomical Multifunctional Modular Apparatus) will be the new generation satellite gamma-observatory. Gamma-telescope GAMMA-400 consists of anticoincidence system (top and lateral sections - ACtop and AClat), the converter-tracker (C), time-of-flight system (2 sections S1 and S2), position-sensitive calorimeter CC1 makes of 2 strips layers and 2 layers of CsI(Tl) detectors, electromagnetic calorimeter CC2 composed of CsI(Tl) crystals, neutron detector ND, scintillation detectors of the calorimeter (S3 and S4) and lateral detectors of the calorimeter (LD). All detector systems ACtop, AClat, S1-S4, LD consist of two BC-408 based sensitive layers of 1 cm thickness each. Three apertures provide events registration both from upper and lateral directions. The main aperture provides the best angular (all strip layers information analysis) and energy (energy deposition in the all detectors studying) resolution. Gamma-telescope GAMMA-400 is optimized for the gamma-quanta and charged particles with energy 100 GeV detection with the best parameters in the main aperture. Triggers in the main aperture will be formed using information about particle direction provided by time of flight system and presence of charged particle or backsplash signal formed according to analysis of energy deposition in combination of both layers anticoincidence systems ACtop and AClat individual detectors. For double-layer ACtop taking into account both amplitude and temporal trigger marker onboard analysis only 2.8 % photons will be wrongly recognized as electrons or protons for 100 GeV particles. The part of charged particles mistakenly identified as gammas is  $\sim 10^{-5}$  using described algorithms. For E~3 GeV less than 3% photons will be wrongly recognized as charged particles and fraction of wrongly identified charged particles will be also  $\sim 10^{-5}$ . In the additional aperture the particles identification is provided by analysis of signals corresponding to energy deposition in the individual detectors S2, S3 and fast signals from CC1 individual detectors discriminators. Low energy (0.2 - 10 MeV) photons in the lateral aperture recognizing by using simple anticoincidence signals from the individual detectors of LD. Gamma-quanta of higher energies are identified using energy deposition in the individual detectors of S3, S4, LD and fast signals from CC2 individual detectors discriminators. The results of anticoincidence system individual detectors thresholds modelling are discussed.

## 1. GAMMA-400 short description

GAMMA-400 (Gamma Astronomical Multifunctional Modular Apparatus) will be the new generation satellite  $\gamma$ -observatory. Its main scientific goals will be [1, 2]: discrete astrophysical sources observations, indirect dark matter origin study by the gamma-ray astronomy methods, diffuse background  $\gamma$ -emission investigations, high energy GRB emission research, research of high energy light nuclei fluxes, the study of high energy e–e+ fluxes. Also it is possible to study solar flares using GAMMA-400 lateral aperture. GAMMA-400 physical scheme is shown at figure 1.



Figure 1. The physical scheme of the GAMMA-400.

Gamma-telescope GAMMA-400 consists of the converter-tracker (C), time-of-flight system (2) sections S1 and S2 composed of BC-408 detectors), anticoincidence system (BC-408 based top and lateral sections - ACtop and AClat), position-sensitive calorimeter CC1 makes of 2 strips layers (pitch of 0.08 mm) and 2 layers of CsI(Tl) detectors, electromagnetic calorimeter CC2 composed of CsI(Tl) crystals, BC-408 based scintillation detectors of the calorimeter (S3 and S4), BC-408 based lateral detectors of the calorimeter (LD), neutron detector ND [3, 4]. All BC-408 based detector systems consist of two sensitive layers of 1 cm thickness each. The converter-tracker is composed of 13 layers of double (x, y) silicon strip coordinate detectors (pitch of 0.08 mm) [1]. The first three and final one layers are without tungsten while the middle nine layers are preceded with tungsten conversion foil each: the first one with thickness 0.2 X<sub>0</sub> and the next eighth with 0.1 X<sub>0</sub> one (where X<sub>0</sub> is radiation length). The thickness of CC1 and CC2 is 2 X<sub>0</sub> (0.1  $\lambda_0$ ) and 23 X<sub>0</sub> (1.1  $\lambda_0$ ) respectively (where  $\lambda_0$  is nuclear interaction length). The total calorimeter thickness is 25  $X_0$  or 1.2  $\lambda_0$  for vertical incident particles registration and 54 X<sub>0</sub> or 2.5  $\lambda_0$  for laterally incident ones. Together with the  $\gamma$ -telescope GAMMA-400, the space observatory will include non shown at figure 1 devices: two star sensors for determining the GAMMA-400 axes with accuracy of approximately 5", two magnetometers, and the KONUS-FG gamma-ray burst monitor (4 position and 2 spectrometric detectors) [4].

### 2. Gamma-quanta onboard identification in different apertures

Three apertures provide events registration both from upper and lateral directions. Photons distinguish provides by the system of counting and triggers signals formation [5]. The main aperture supply the best angular (all strip layers information analysis) and energy (energy deposition in the all detectors studying) resolution. Gamma-telescope GAMMA-400 is optimized for the gamma-quanta and charged

particles with energy  $\sim 1.0 \times 10^2$  GeV detection with the best parameters in the main aperture [4]: the angular resolution  $\sim 0.01^\circ$ , the energy resolution  $\sim 1\%$ , and the proton rejection factor  $\sim 5 \times 10^5$ . In the main aperture triggers will be formed using information about particle direction provided by TOF system due special TOF signals matrix [5] and presence of charged particle or backsplash. Figure 2 shows trigger creation scheme and detectors response analysis matrix for triggers and trigger markers signals formation for the main aperture. In this aperture gamma-telescope operated in event by event registration mode.



**Figure 2.** Trigger creation scheme and detectors response analysis matrix for triggers and trigger markers signals formation for the main aperture. Backsplash particles marked by red lines, primary gamma-quantum and its produced shower marked by magenta color.

GAMMA-400 is able to registered gamma-rays and electrons (positrons) in the energy range from  $0.1-3.0\times10^3$  GeV in the main aperture. Also this aperture allows investigating high energy light nuclei fluxes characteristics. The GAMMA-400 effective area in the main aperture is ~4000 cm<sup>2</sup> at E $\gamma > 1$  GeV. Both additional and lateral apertures energy resolution is ~2% for electrons, positrons, light nuclei and gamma-quanta in energy range E>10 GeV.

Most part of backsplash produced in calorimeters and conversion foils. Results of backsplash from calorimeters modelling for the main aperture are presented at figure 3. Also at some situations backsplash formation region is located in ACtop lower layer just below of upper layer individual detector on which particle is impinged. The energy deposition in ACtop upper layer from such kind of events is less than 1 MeV. Moreover, part of backsplash particles absorbed in conversion foils, all detectors' supports and TOF detectors. Also the backsplash electrons could be absorbed or produced photons in the first conversion foil and only sufficiently lower energy gamma component propagate through ACtop lower layer. Additionally, sufficient amount of backsplash particles tracks are outside ACtop detector system due to long distance between ACtop and calorimeters. Usually backsplash particles delayed at individual time  $\Delta t$ \_BS correspondingly twice distance between ACtop and place of backsplash production. For GAMMA-400 this time is approximately 3.5 ns for most particles.

Results of gamma-quanta direct interaction modeling for energies 100 GeV and 3 GeV are shown at figure 4. Data examination has shown only 2.8 % photons will be wrongly recognized as electrons or protons for double-layer ACtop taking into account both amplitude and temporal trigger marker onboard analysis for 100 GeV particles. The part of charged particles mistakenly identified as gammas is ~10<sup>-5</sup> using described algorithms. For E~3 GeV less than 3% photons will be wrongly recognized as charged particles and fraction of wrongly identified charged particles will be also ~10<sup>-5</sup>.



**Figure 3.** Results of backsplash from calorimeters modelling for the main aperture: for electrons (a), protons (b) and gammas (c) with energy 3 GeV.



**Figure 4.** Results of gamma-quanta direct interaction modeling for energies 100 GeV (a) and 3 GeV (b). Lines indicates thresholds for electrons and protons with the same energies than gammas. Areas marked (1) and (2) contains events with energy deposition less than 1 keV in both ACtop layers constituted ~60% and ~70% correspondingly.

In the additional aperture gamma-telescope operated in event by event registration mode too (see panels (a) at the figures 5 and 6). Particles registration starts with signal of CC1 fast discriminators in anticoincidence with TOF pulse. Up-down particle direction indicates due fast signals from detectors CC1 and S3, anticoincidence in this aperture provides by S2, LD and S4. The angular resolution is provided by strip layers in the CC1 and for gamma-quanta is from  $\sim 5^{\circ}$  to  $\sim 4^{\circ}$  in energy range 1.0 MeV - 0.1 GeV and from  $\sim 4^{\circ}$  to  $\sim 0.7^{\circ}$  for 0.1 - 1.0 GeV one. For particles with E >1.0 GeV the angular resolution is  $\sim 0.7^{\circ}$ . The additional aperture energy resolution provides due to energy deposition analysis in S2, S3, S4, LD and calorimeters (CC1 and CC2).

Gamma-quanta, electrons/positrons and light nuclei with energy E>10 GeV also registered in the lateral aperture. This aperture allows detecting of low-energy gammas in the range 0.2 - 10 MeV and photons with energy of 10 MeV – 10 GeV. The energy resolutions in these cases are 8% - 2% and 2% correspondingly according to GAMMA-400 "Technical Project" stage results.

In the lateral aperture gamma-telescope operated in event by event registration mode only for particles with E>100 MeV.

Journal of Physics: Conference Series 675 (2016) 032015

doi:10.1088/1742-6596/675/3/032015



Figure 5. Trigger creation scheme for the additional (a) and lateral (b) apertures. Backsplash particles marked by red lines, primary gamma-quantum and its produced shower marked by magenta color.



Figure 6. Detectors response analysis matrix for triggers and trigger markers signals formation formation matrixes for the additional (a) and lateral (b) apertures.

Event detection in its aperture begins with signal of CC2 individual detectors fast discriminators in anticoincidence with TOF pulse and CC1 individual detectors fast discriminators. Higher energies  $\gamma$ -quanta recognised using energy deposition in the individual detectors of LD, S3, S4 and fast signals from CC2 individual detectors discriminators (see panels (b) at the figures 5 and 6).

Low energy photons recognizing by using simple anticoincidence signals from the individual detectors of LD and registered in spectral mode with acquisition timescales depends on detectors count rate. Angular resolution will  $\sim 5^{\circ}$  for only for gamma-quanta with energies 0.2 - 10 MeV in the lateral aperture obtained due individual detectors of CC2 count rate analysis only for non-stationary events (GRB, solar flares and so on). The applied method looks like BATSE (Burst And Transient Source Experiment) detector onboard Compton Gamma Rays Observatory algorithm for transient sources (see [6] and references therein) differ from occultation analysis technique using in this experiment too.

### 3. Conclusion

Three apertures provide events registration both from upper and lateral directions. The main aperture provides the best angular (all strip layers information analysis) and energy (energy deposition in the all detectors studying) resolution. Gamma-telescope GAMMA-400 is optimized for the gamma-quanta and charged particles with energy 100 GeV detection with the best parameters in the main aperture.

Triggers in the main aperture will be formed using information about particle direction provided by time of flight system and presence of charged particles or backsplash signal formed according to analysis of energy deposition in combination of both layers anticoincidence systems ACtop and AClat individual detectors due the system of counting and triggers signals formation [5].

For double-layer ACtop less than 3% photons will be wrongly recognized as electrons or protons for  $\sim$ 3-100 GeV particles. The part of charged particles mistakenly identified as gammas will be  $\sim$ 10<sup>-5</sup> using described algorithms.

In the additional aperture the particles identification is provided by analysis of signals corresponding to energy deposition in the individual detectors S2, S3 and fast signals from CC1 individual detectors discriminators. Low energy (0.2 - 10 MeV) photons in the lateral aperture recognizing by using simple anticoincidence signals from the individual detectors of LD. Gamma-quanta of higher energies are identified using energy deposition in the individual detectors of S3, S4, LD and fast signals from CC2 individual detectors discriminators.

### Acknowledgments

This work performed within the framework of the Center FRPP supported by MEPhI Academic Excellence Project (contract No. 02.a03.21.0005, 27.08.2013).

### References

- [1] Topchiev N P et al. 2015 Bull. Russ. Acad. Sci. Phys. 79(3) 417
- [2] Galper A M et al. 2015 Physics Procedia 74 177
- [3] Galper A M et al. 2013 Bull. Russ. Acad. Sci. Phys. 77(11) 1339
- [4] Galper A M et al. 2013 Advances in Space Research. 51 297
- [5] Arkhangelskaja I V et al 2015 Physics Procedia 74 212
- [6] Hakkila J 1990 BATSE software for the analysis of the gamma ray burst spatial distribution. Alabama Univ. Research Reports: 1990 NASA/ASEE Summer Faculty Fellowship Program 5p. SEE N91-18967 10