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THE RUSSIAN VERSION OF A TELESCOPE TO RECORD THE DIFFUSE GAMMA RADIATION IN THE ENERGY RANGE 10-1000 GeV

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ABSTRACT

The GAMMA-400 gamma-ray telescope is designed to measure the energy spectrum of primary gamma radiation in the energy range 10-1000 GeV. The sampling calorimeter with fiber data readout, which energy resolution reaches 1-2% in this energy range, is projected to use as an energy instrument. In the GAMMA-400 gamma-ray telescope, the determination of particle incidence is realized by the system of scintillation counters with SiPM photon devices.

The gamma radiation recorded in the Earth’s orbit carries the information on processes occurring both on astrophysical objects of our Galaxy, and on extra-galactic objects, where the matter can be in extreme conditions of densities, temperatures, pressures, magnetic intensities, and other physical parameters.

Up to now, direct measurements of the cosmic gamma radiation spectrum were carried out in the wide energy range from tens and hundreds of keV up to 30-50 GeV. The energy range of cosmic gamma radiation from 30 to 1000 GeV up to the present remains unexplored. At the same time, measurements in this energy range will allow one to solve a number of the more important scientific problems, such as:

- the presence of a knee in the diffuse gamma radiation spectrum that should give the decision observational data to choice the model of origin of cosmic gamma radiation and cosmic rays as a whole;

- the view of the gamma radiation energy spectrum of discrete sources both of galactic, and metagalactic nature that will allow one to understand the mechanism of gamma-ray generation characterized by rather large energy release;

- the possibility to detect spectral gamma-ray lines occurring during annihilation of neutralino, hypothetical supersymmetric particles, probably, being the main component of “dark matter” in the Galaxy and the Universe as a whole.

At present, the AGILE and GLAST instruments are designed abroad. In Russia, the GAMMA-400 gamma-ray telescope is designed for measurements in the indicated energy range 10-1000 GeV [1]. One of versions of GAMMA-400 is shown in Fig. 1. The main structural elements of the telescope are two detector systems to separate primary particles and determine direction of their incidence (anticoincidence scintillators, time-of-flight systems, and systems of coordinate detectors), as well as a calorimeter to measure energy of primary particles. The presence of two systems of separation of incidence particles symmetrizes the telescope and allows one to double the instrument geometrical factor that is rather essential from the point of view of statistical reliability of results, because gamma-ray fluxes are small in the investigated energy range.

To measure the energy of recorded particles we project to use the sampling calorimeter of the “Shashlyk” type similar designed in Institute of High-Energy Physics for the PHENIX experiment carried out on accelerator in U.S. Brookhaven National Laboratory [2]. The calorimeter of the GAMMA-400 telescope is assembled of 25 separate modules, which structure is shown in Fig. 2. The module contains 180-200 layers, each of which consists of radiator (0.55-mm thick lead), active absorber (1.5-mm thick scintillation plastic), and two reflectors (0.12-mm thick white paper). Light occurring in scintillators by 144 wavelength shifter optical fibers penetrating all module layers falls on photocathode of the FEU-115M photomultiplier, and integral signal is fed to the electronic measurement system.

The performed simulation of gamma-ray energy measurement using this calorimeter of 18 radiation length in total thickness will allow us to obtain information about energy resolution and efficiency of photon detection in the energy range 100-1000 GeV. The energy resolution near 1 TeV is equal to 1.8%.

The engineering solutions included in the construction of the sampling calorimeter module allow us to construct a sample, which can be used to realize the experiment onboard spacecraft.

As indicated above, the system of separation of particles falling into the telescope includes coordinate detectors. The coordinate system consists of three identical units, in each of which there are two layers of detectors assembled from long scintillation tiles with section 10x10 mm^2. The axes of scintillators in two layers of the unit are mutually perpendicular that allows one to obtain the data in each of three units about two coordinates of charged particle track.

To record light flash created by charged particle in scintillator we project to use solid-state (silicon) photosensitive elements (SiPM), which at present are designed in our country by the SiPM collaboration (scientists from Moscow Engineering Physics Institute and “Pulsar” agency) [3]. Individual SiPM represents a set of large number (approximately 10^3 per 1 mm^2) of avalanche photodiodes (pixels) functioning not in proportional, but in Geiger mode, at which the recording even of one photon gives a standard signal of rather large amplitude at the output. The scheme of SiPM is shown in Fig. 3.

The output signal amplitude S proportional to the number of responded pixels N_r depending on total number of pixels m in photomultiplier, intensity of light flash N_{ph}, and the efficiency of photon detection ε is determined by the expression

$$S \equiv N_r = m\left(1 - e^{-\frac{N_{ph}\varepsilon}{m}}\right)$$

Solid-state SiPM is quite competitive on the parameters with usual vacuum PM that illustrates table.

Including the sampling calorimeter with good energy resolution in the GAMMA-400 gamma-ray telescope and the use of solid-state photon detectors SiPM designed in recent years noticeably improve the detector system of the gamma-ray telescope. At present, researches in development of corresponding systems of measurement and control of the telescope are continued.

REFERENCES

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Table.

Parameter	Vacuum photomultiplier	Solid-state PM (SiPM)
Power supply	1-2 kV	25 V
Gain	10^6-10^7	10^6
Sensitivity threshold	1 photoelectron	1 photoelectron
Time resolution	30-100 ps	30 ps
Possibility of operation in the magnetic field	Limited	Limited

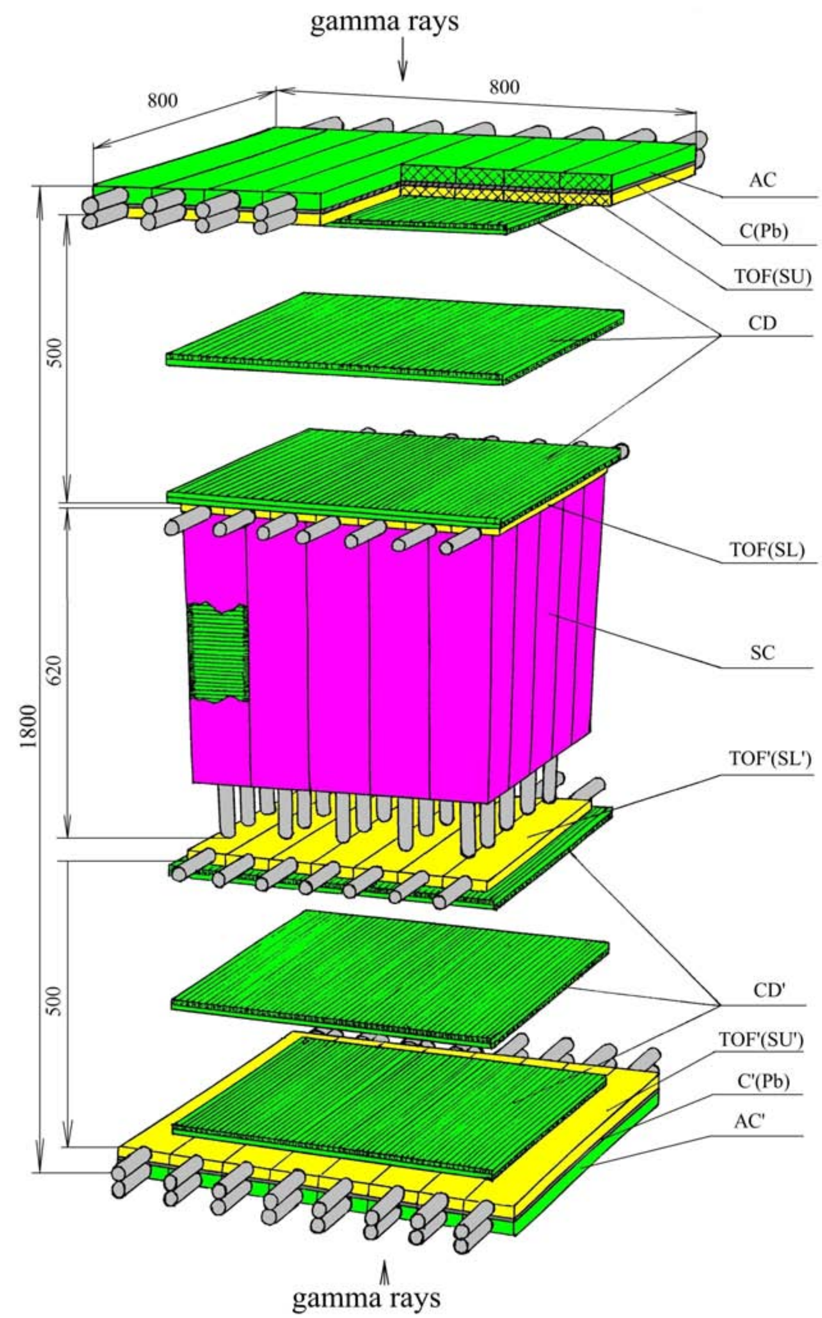

Fig. 1. Scheme of gamma-ray-telescope GAMMA-400.

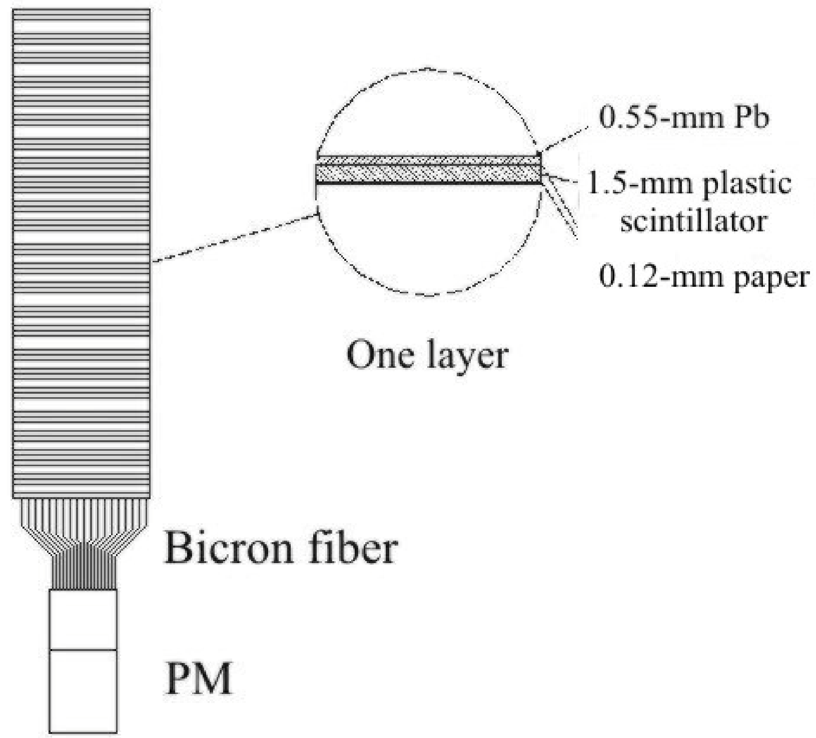

Fig. 2. Scheme of one module of the sampling calorimeter.

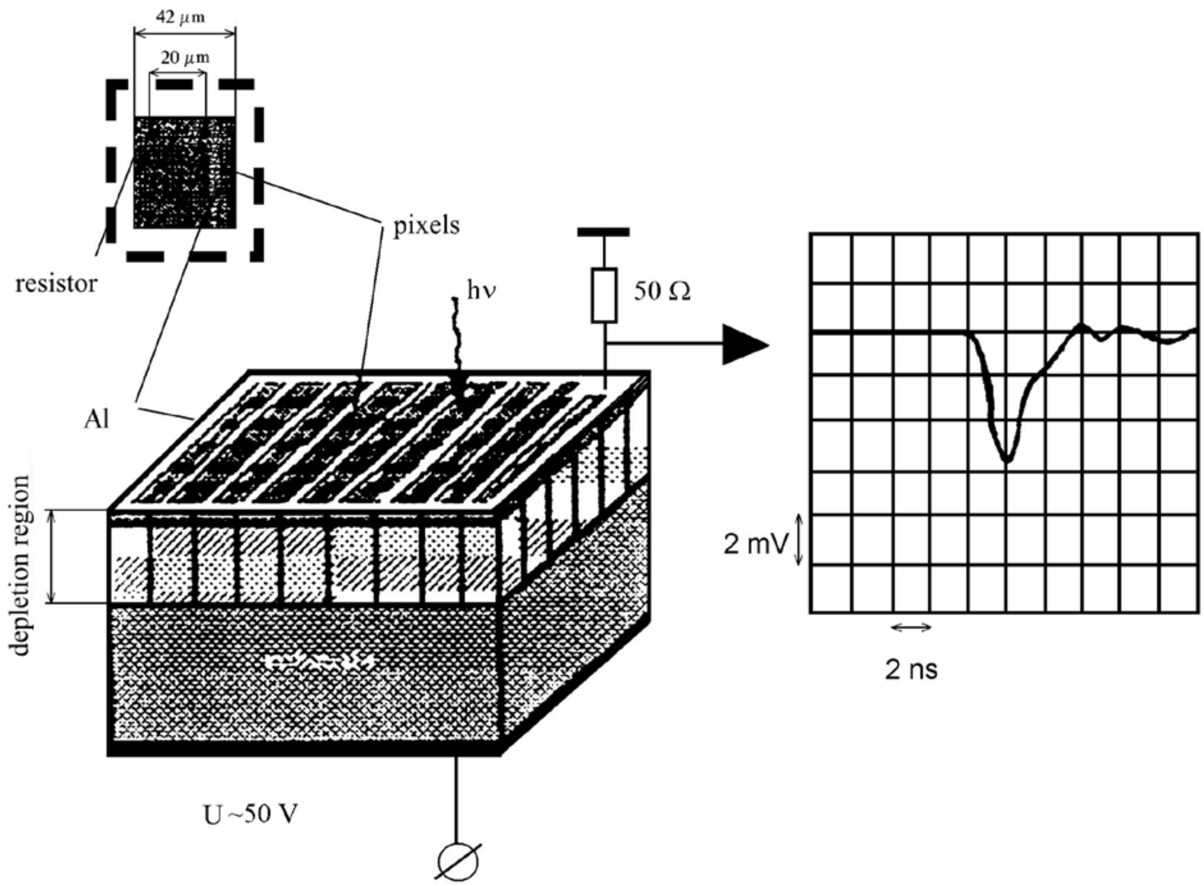

Fig. 3. Scheme of the solid-state photo detector (SiPM) for the coordinate system of the GAMMA-400 gamma-ray telescope.