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Search for gamma-ray bursts at energy $E_\gamma \leq 10$ GeV

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Abstract.
For the purpose to register gamma-ray bursts (GRB) the single secondary particle counting rate of the EAS "Andyrchy" array was used. The EAS array "Andyrchy" has been operating since 1996, the study is performed by searching for short increases of counting rate. The results obtained in sky survey (10° < δ < 70°) for 1996 – 1999 years (793.6 days of live time) are presented.

1 Introduction

The search for high-energy gamma rays from GRB is of great importance for the understanding of the nature of the GRB. In the GeV energy range positive observations was reported by EGRET aboard the CGRO (B.L.Dingus et al.,1997) and, as it was noticed in (M.Aglietta et al., 1996), the detection of an 18 GeV gamma ray delayed 1.5 hr after the onset of the GRB 940217 (Hurley et al., 1994) shows that the phenomena can even be more complicated with increasing energy.

Observations beyond few GeV can be performed by means of large area ground-based detectors operating at mountain altitude at "single particle" mode (M.Aglietta et al., 1996). It means the total count rate of the all array's detectors is measured. Because of the cosmic ray spectrum steepness, most of the events detected in this mode of operation are in fact due to solitary particles from small showers generated by 10 - 100 GeV cosmic rays.

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2 The apparatus

The EAS array "Andyrchy" (E.N.Alexeyev et al., 1993; E.N.Alexeyev et al., 1994) is located at altitude 2060 m a.s.l. (atmospheric depth 800 gr·cm^{-2}) and consists of 37 plastic scintillation detectors. Each scintillator has an area of 1 m^2, with thickness of 5 cm and is viewed by one PMT. Each detector has an active thermoregulation. The temperature is within 1°C at the PMT (and electronics block) and within 3°C at the scintillator. A data used for search of gamma bursts was obtained in "single particle" mode operation. The measurements like this one are performed with large cosmic-ray background. It demands a high stability and reliability of all devices. The count rate of "Andyrchy" array detectors is measured once per second (~11500/(sec·37 detectors)). A check of stability is provided by means of simultaneous measurement (also once per second) of the count rates of four parts of array (10,9,9 and 9 detectors).

3 Data processing

For preliminary analysis two parameters - Φ_ι and Δ_ι - were used. The Φ_ι is a deviation in units of the Poisson sigma of the count rate N_ι in the ιth second of a 15 minute interval from the rate N averaged over the interval:

$$F_i = (N_i - N)\big/\sqrt{N} \qquad (1)$$

Because the variations of cosmic ray intensity in 15 minutes are negligible and average count rate is a large enough ($\overline{N}$ =11513 for whole array, for four years information), the quantity Φ_ι is expected in first approach to be Gaussian with mean value ς=0 and rms σ=1.0. To characterize the deviation in counting rate we use Δ_ι as:

$$D_i = \frac{1}{4}\sum_{j=1}^{4}(F_i^{\,j} - \overline{F}_i)^2 \qquad (2)$$

where $F_i^{\,j}$ is the deviation for φth part of array and $\overline{F}_i$ is an average of four values $F_i^{\,j}$.

In following analysis only points (countrate/sec) with

$$D_i \le D_{bound}(F_i) \qquad (3)$$

were used. The values of $D_{bound}(F_i)$ were obtained by means of Monte-Carlo simulation assuming Gaussian distribution for F_i. The condition (3) gives a possibility to eliminate points with contradictory deviations between parts of array, i.e. to eliminate the apparatus faults. Four years information (~$6.86 \cdot 10^7$ points) was analyzed using condition (3) and only 0.01% events were eliminated.

4 Results

Experimental distribution on parameter Φ_ι is shown in Fig.1. The data are fitted by Gaussian with mean value ς=–0.0026 and σ = 1.012. Deviation from ideally expected ς=0 and σ = 1.0 is accounted by Poisson behavior of counting rate, but it is unimportant for our purposes. The data show for lack of large deviations, it can be interpret as the lack of gamma-ray bursts. But nevertheless it can be assumed that the gamma-ray bursts give contribution for events with not so large Φ_ι (for example, $\Phi_\iota \ge 4.5$). Fluence $W(F_i)$ corresponding to deviation Φ_ι can be calculated as:

$$W = F_i \cdot \sqrt{\overline{N}} \cdot \frac{\overline{E}_0}{S} \qquad (4)$$

where $F_i \cdot \sqrt{\overline{N}}$ is the number of gamma rays in the burst, $\overline{E}_0$ (≈ 50 GeV) is the mean energy of gammas, S = 37 m^2 – the total area of detectors. Assuming a power-law differential spectrum of photons in the burst $I(E_0) \sim E_0^{-\gamma}$ (with $\gamma = 2.0$), the mean energy was calculated as:

$$\overline{E}_0 = \frac{\int_0^\infty I(E_0)E_0 dE_0 \int_0^{90} P(E_0,\theta)d\theta}{\int_0^\infty I(E_0) dE_0 \int_0^{90} P(E_0,\theta)d\theta} \qquad (5)$$

$P(E_0,\theta)$, the probability to detect a signal in hypothetical "Andyrchy" scintillator of infinite area from gamma ray with primary energy E_0 and zenith angle θ, is the result of a simulation of electromagnetic cascades in the atmosphere and in the detectors.

In this analysis the expected number of events for each Φ_ι was obtained by assuming a Gaussian with ς=0 and σ=1. The limit on excess of measured events above the expected one $\Delta M(F_i)$ was obtained at 3 sigma level. The limits on frequency of gamma-ray bursts (at 99.7% C.L.) for declination band [10°, 70°] in 793.6 days of live time are presented in table 1.

Table 1.

Fluence, erg·m^{-2}	Frequency, sec^{-1}
$2.2 \cdot 10^{-2}$	$<7.4 \cdot 10^{-7}$
$2.4 \cdot 10^{-2}$	$<3.1 \cdot 10^{-7}$
$2.7 \cdot 10^{-2}$	$<1.0 \cdot 10^{-7}$

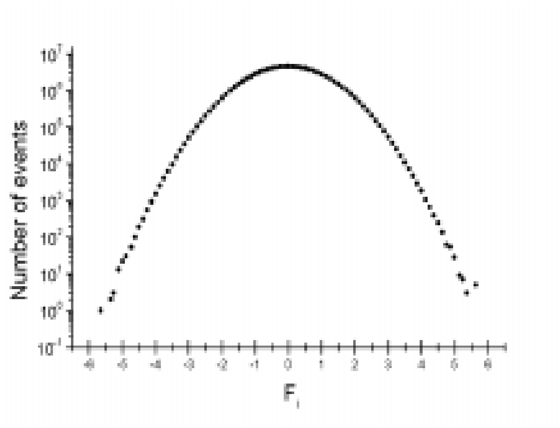

Fig.1. Distribution on F_i.

5 Conclusions

The method of search for gamma-ray bursts with $E_\gamma \ge 10$ GeV performed by operated in "single particle" mode "Andyrchy" EAS array is presented. Our data show for lack of large deviations in counting rate that can be interpreted as the lack of gamma-ray bursts. The limits on frequency of gamma-ray bursts as function of fluence were obtained (table 1).

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