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Search for UHE gamma-ray short transients at Andyrchy EAS array

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Search for short transients of gamma-rays with E>60 TeV has been performed using data of the EAS array Andyrchy collected during 1996-2001. The arrays response for UHE gamma-rays was obtained with Monte Carlo simulation. The observed fluctuations in the event rate obtained in the sky survey are compatible with the statistical fluctuations of the cosmic-ray background. Search for correlations with known sources of gamma-rays has been performed. 147 GRBs observed by the BATSE during 1996-2000 occurred in the field of view of the Andyrchy. In the search for events coinciding with the BATSE's ones no significant signals have been observed.

1. Introduction

Registration of burst-like events of space γ - radiation was carried out at the Andyrchy EAS array. The array is located at 2060 m a.s.l. (atmospheric depth ~800 g/cm^2). [1]. It consists of 37 plastic scintillation detectors. Each scintillator is of 1m^2 square, 5 cm thickness and viewed by one PMT. The threshold of the detector is about 5 MeV (that is ½ of the most probable). The total count rate of the detectors of the array (37 m^2) is measured every second (~11500/s). Control over the stability is established through simultaneous measurements of the count rate for the four parts of the array (10, 9, 9, and 9 detectors) also every second. Each detector has an active thermoregulation. The temperature is kept within 1°C for the PMT (and electronic block) and within 3°C for the scintillator.

Search for burst-like events is performed using the Andyrchy EAS data. EAS were registered if four or more detectors triggered within 3.2 mks interval. The frequency of such events is 6.5 Hz. For each event arrival direction were calculated. Data period 1996-2001 (live time is ~1100 days) encloses $6.22\cdot10^8$ events. The effective angular resolution of the array for such events is $\sigma \approx 4.0°$. We use CORSIKA (v.6.03 model QGSJET) [2] to calculate a response of the BUST to primary gammas. The calculation was performed for zenith angle θ=(0°÷50°). The results are shown in figure 1.

To estimate the fluence we use a power law spectrum for gammas of burst-like events $I(E) \sim E^{-\gamma}$, where γ=2.0. Using this shape of spectrum we obtain an interval of the Andyrchy array sensitivity for primary gammas, $E_{0.95}$ –$E_{0.05}$, where we have registered 90% events, where $E_{0.95}$=60 TeV, $E_{0.05}$=1600 TeV. With the observed excess of events, *N*, inside an angular window in which a photon from a point source is detected with efficiency *ε*, and a power-law spectrum of photons of the burst-like event in the energy range $E_{min} < E < E_{max}$, the corresponding energy fluence in the energy range $E_{0.95} < E < E_{0.05}$ is given by [3]

$$W = \frac{N\int\limits_{E_{0.95}}^{E_{0.05}} E^{-\gamma+1}dE}{\varepsilon\cdot S\int\limits_{E_{\min}}^{E_{\max}} E^{-\gamma}P(E)dE} \qquad (1)$$

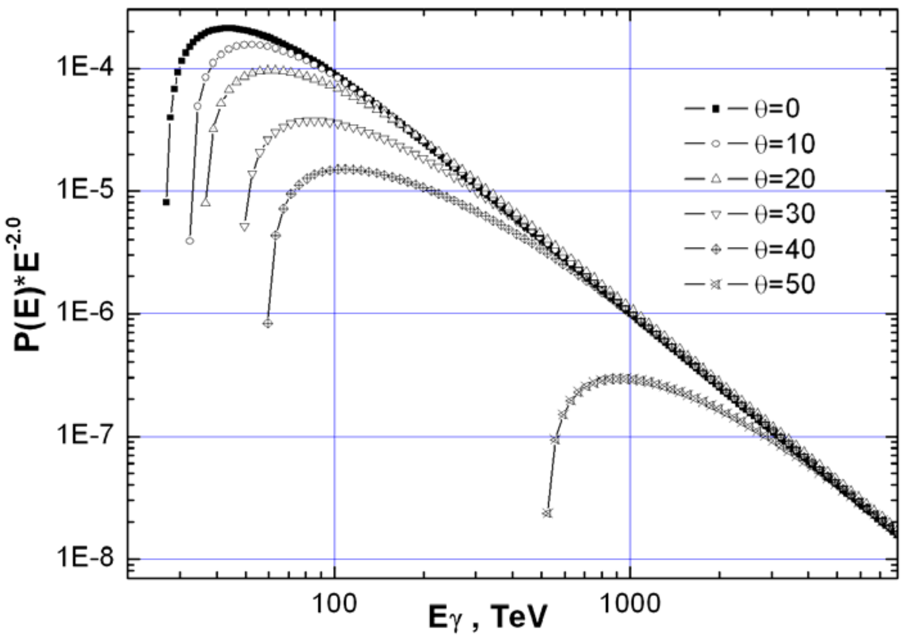

Figure 1. The response of Andyrchy array for primary gammas of power-low spectrum $I(E) \sim E^{-2}$ for different zenith angles.

2. Discussion

According to the sky survey method ultrahigh energy γ-radiation short transients were searched for as fluctuations in the event time distribution and spatial concentration inside a sky window of a size related to the angular resolution of the Andyrchy array. The search was performed in the sky region with zenith angle $\theta < 50°$. For each event *i* occurring at a time t_i and with arrival angles (θ,φ), we consider all clusters made up by events *i, i+1, ... i+N-1* whose arrival directions are inside a circular window centered on the event *i*, and satisfy the condition $\Delta t \equiv t_{i+N-1} - t_i$ <10 s. Search for clusters in simulating events was also performed. Comparing the simulated and experimental data one can conclude that all the experimental clusters could be explained as random coincidence. Each cluster has N events and duration Δt. The result of a search for such clusters is shown in figure 2.

Search for γ radiations of ultrahigh energy from the GRBs registered by the BATSE was carried both during T_{90} and 2 hours around a burst trigger. During the period of observations 147 GRBs registered by BATSE and described in the 4th catalogue [4], occurred in the field of view of the array (with zenith angle θ <50 °). For each event, during period T_{90}, the number of showers, *n*, coming from an angular cell centered at the GRB coordinates and with radius $\alpha_r = 4.0°$ was found. If duration of a burst in GCN circulars has not been found, the duration was put to 10s. Using data of the whole period of observation for each angular cell with radius $\alpha_r = 4.0°$ and the centre with coordinates (θ, φ), equal to coordinates of the burst, the expected (background) frequency of arrival of showers, *f*, was obtained. For each pair of numbers, i.e. number of showers, *n*, registered by the Andyrchy array from a cell (θ, φ) for interval T_{90} and expected number of showers, *f*, reciprocal Poisson distribution P(*n,f*) were calculated:

$$P(n,f) = \sum_{k=n}^{\infty} \frac{e^{-f} f^k}{k!} \qquad (2)$$

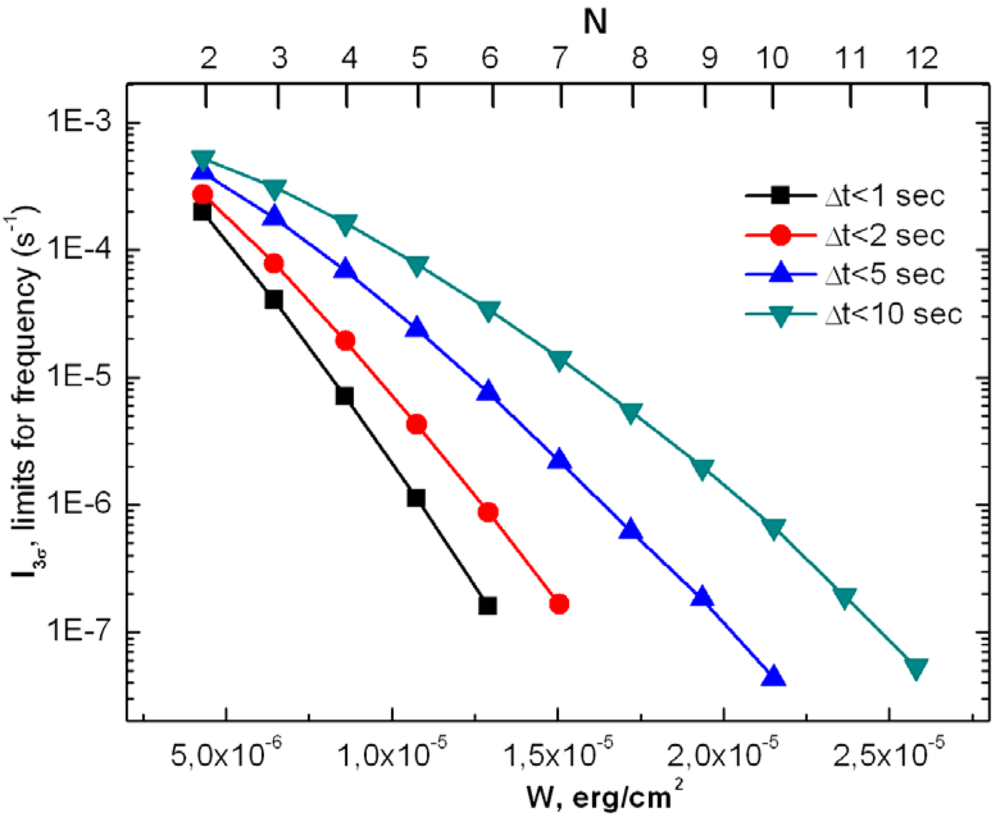

Figure 2. Limits for frequency of GRBs (at 3 standard deviations level) for various numbers of showers in a cluster, *N*, or for corresponding fluence, *W*.

Integrated distribution of number of bursts depending on 1/P (integration from 1/P up to +∞) was calculated. In this distribution only those bursts were used during which (i.e. T_{90}) at least one shower came from a cell. Integrated distribution of events N (1/P) considering only random process in double logarithmic scale is depicted with a straight line of a slope k = -1. The agreement of the experimental distribution with the expected one was obtained. For each event that came in the field of view of the Andyrchy array, a limit on fluence, W, was obtained (for the direction of the burst and number of showers registered during T_{90}). All obtained limits are in a range from $2.5 \cdot 10^{-6}$ erg/cm^2 up to $5 \cdot 10^{-5}$ erg/cm^2.

To detect delayed or leading ultrahigh energy γ-rays the search for clusters during two hours around the registered onboard GRB was carried out with a method of a sliding interval. Duration of intervals, Δt, was 1, 2, 4, 10, 50, 100 seconds, the step is equal to half of the interval. The number of the showers that came from an angular cell with radius α_r = 4.0° and centre of the GRB, was counted up each second. Then summation in an interval of duration Δt was performed. The expected (background) number of events for each GRB and each interval Δt was obtained after processing the information collected during 1 day before the GRB. Then for each pair of number - number of showers n, registered by the Andyrchy array from a cell (α, δ) for an interval Δt and expected number of showers, *f*, reciprocal Poisson distribution, P(n,f), was calculated. In figure 3, dependence of the number of intervals, Δt, in which at least one shower is registered, on the probability, P, for intervals before and after the moment of burst is shown. Thus, no excess of showers over a background in time windows around GRBs was found.

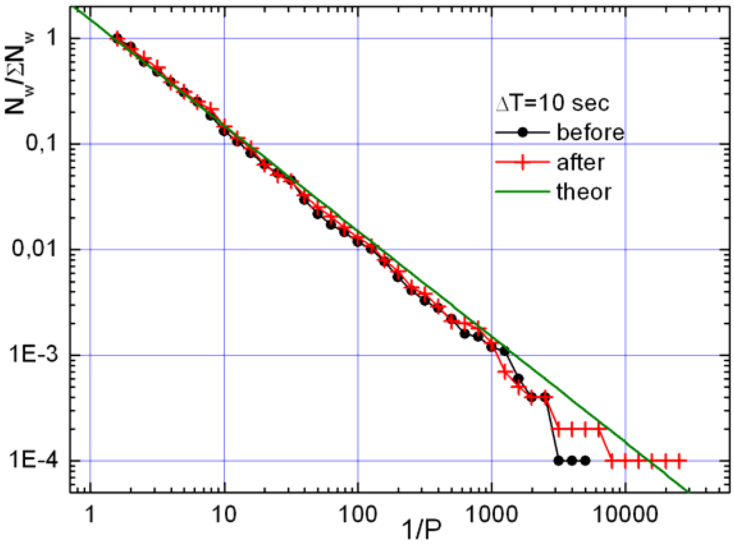

Figure 3. The dependence of the integrated distribution of number of time windows, N_w, on random coincidence probability in observation of *n* showers from an angular cell with background *f* (e.g. Δt=10s) during a time window.

3. Conclusions

Search for the short transients of ultrahigh energy γ-rays (Eγ>60 TeV) in a sky survey and ultrahigh energy γ-radiations from GRBs registered by the BATSE was carried out using data of the Andyrchy EAS array for 1996 – 2001 years. Limits on frequency of short transients of ultrahigh energy γ-radiation with duration from 1 to 10 seconds and fluence range of ($4\cdot10^{-6} \div 2.5\cdot10^{-5}$) erg/cm^2 were obtained at 3 standard deviation confidences level: $\Omega_{lim}=(5\cdot10^{-4} \div 5\cdot10^{-8})$ s^{-1}. Search for ultrahigh energy γ radiation from GRBs registered by the BATSE was carried out both for the observed duration of the burst, and for the time interval ±2 hours around the burst. No significant excess above a background of random coincidences was observed. Obtained limits on fluence which is carried away in γ-rays of ultrahigh energy at the time of bursts ranges from $2.5\cdot10^{-6}$ erg/cm^2 to $5\cdot10^{-5}$ erg/cm^2.

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