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Search for high energy GRBs with EASTOP

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Abstract. A search for GRBs of energy $E > 10$ GeV has been performed by studying the single particle counting rate of the EAS array EASTOP. No candidates have been observed in coincidence with 292 BATSE GRBs and the typical upper limits obtained on the energy fluence are $F(10\ \mathrm{GeV} \div 1\ \mathrm{TeV}) \sim 10^{-4} \div 10^{-3}$ erg cm^{-2} for the events with zenith angle $\theta < 30°$. A single candidate has been observed in the "all sky" survey mode during 1.5 10^3 days.

Key words: gamma-ray bursts

1. Introduction

The high energy component of gamma-ray bursts can be measured by means of extensive air shower (EAS) arrays located at mountain altitudes. The e$^\pm$ generated in the atmosphere by gamma-rays with energy $E > 10$ GeV can reach the detector level; although the number of secondary particles is too small to reconstruct the primary direction, GRBs could be detected as a short time increase in the single particle counting rate. The background consists of e$^\pm$ and $\mu^\pm$ generated by low energy cosmic rays. All sources of background modulation have time scales (hours) much larger than the typical GRB duration (seconds), hence they do not affect the GRBs search.

The EASTOP experiment is running since 1991 at Campo Imperatore in Italy, at 2000 m a.s.l. The array is devoted to the measurement of the various components of extensive air showers. In the GRBs search only the detector of the electromagnetic component is used (Aglietta 1996). It consists of 35 scintillators of 10 m^2 each, spread over an area of $\sim 10^5$ m^2, operating at an energy threshold $E_{\rm th} \sim 3$ MeV. At the EASTOP altitude the single particle background is mostly due to muons and its measured rate is ~ 500 m^{-2} s^{-1}.

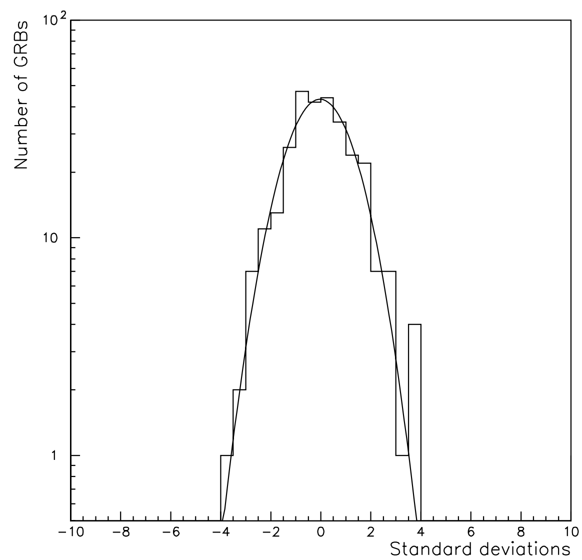

Fig. 1. Distribution of the excesses C − B, in unit of standard deviations, observed in coincidence with 292 BATSE GRBs

2. Data analysis and results

a) Coincidences with BATSE events

We considered 292 GRBs observed by BATSE (Brainerd 1998) during 1992 ÷ 1998 occurred in the field of view of EASTOP with a zenith angle $\theta \leq 60°$.

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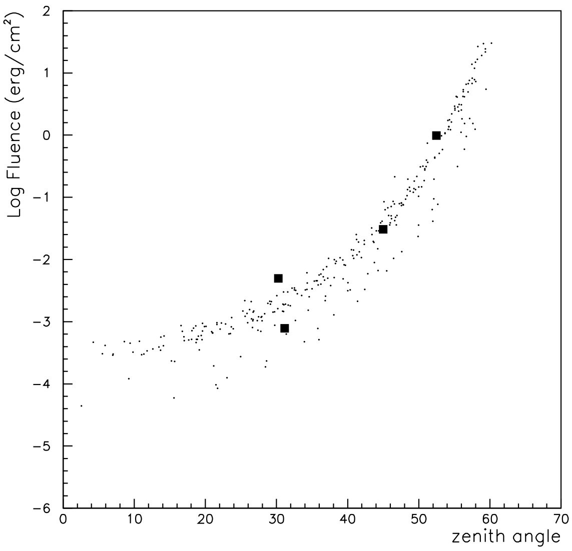

Fig. 2. Upper limits on the 10 GeV ÷ 1 TeV energy fluence obtained for 292 BATSE events, as a function of the zenith angle. Full squares correspond to 4 GRBs observed by Beppo-Sax (GRB 971214, GRB 970508, GRB 971227 and GRB 980703)

For each event the measured number of counts C during the Δt_{90} time interval in which BATSE detected 90% of the flux is compared with the average number of counts B expected from the background (evaluated in 600 s around the burst).

No significant excess has been observed and the distribution of the excesses $C - B$ is fully explained by poissonian fluctuations (see Fig. 1). Looking for possible delayed or anticipated excesses with respect to the BATSE event, the same analysis procedure has been performed in a 2 hours interval centered on the BATSE time, changing the width of the time window from 1 to 200 s. Also in this case no excess was found.

Figure 2 shows the obtained upper limits on the energy fluence in the range 10 GeV ÷ 1 TeV for the 292 bursts analyzed, in the time window Δt_{90}, as a function of the zenith angle. The fluence upper limits have been calculated at 5 standard deviations level, assuming a GRB spectrum $\mathrm{d}N/\mathrm{d}E \propto \ E^{\alpha}$ with $\alpha = -2$, extending up to 1 TeV.

The gamma-ray absorption in the intergalactic space through $\gamma + \gamma \rightarrow \mathrm{e}^{+}\mathrm{e}^{-}$ pair production affects the high energy part of the spectra of GRBs located at cosmological distances. According to Salomon & Stecker (1998) the gamma-ray flux from a source at redshift $z = 1$ is reduced by a factor ~ 3 at $E = 50$ GeV and by a factor ~ 30 at $E = 100$ GeV. Assuming the GRB sources at $z = 0.5(1.0)$, the obtained fluence upper limits have to be increased by a factor $\sim 8(16)$.

b) All sky survey

GRBs can be searched as short duration increases ($\Delta t \leq$ 1 s) in the flux of secondary charged particles. In each second, the counting rate C is compared with the expected background B calculated averaging the counting rate in 15 minutes around. Figure 3 shows the distribution of the differences C − B in unit of standard deviations, obtained assuming poissonian fluctuations, for a total time of measurement of 3.6 10^{4} hours. The data are well fitted by a Gauss distribution with $\sigma = 1.17$, showing the stability and good performance of the detector over a long time exposure.

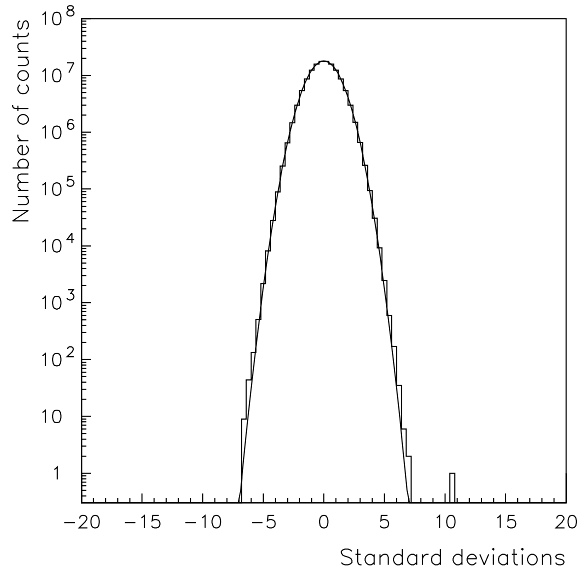

Fig. 3. Distribution of the excesses of duration $\Delta t = 1$ s in units of standard deviations, obtained in the "all sky" survey

A single statistical significant excess (10.6 standard deviation) has been observed on 1992 July 15 at 13:22:26 UT (Aglietta 1993). Assuming this excess due to a gamma-ray burst with a zenith angle $\theta = 30°$, the correspondent 10 GeV ÷ 1 TeV energy fluence is 1.5 10^{-3} erg cm^{-2}.

3. Conclusions

Operating in "single particle mode" with the electromagnetic part of the EASTOP detector, typical upper limits of $\sim 10^{-4} \div 10^{-3}$ erg cm^{-2} have been obtained on the 10 GeV ÷ 1 TeV energy fluence for BATSE events occurring in the EASTOP field of view with zenith angles $\theta < 30°$.

A single statistical significant excess has been observed in the "all sky" survey mode during a total live time of 1.5 10^{3} days.

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