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Search for TeV burst-like events coincident with the BATSE bursts using the Tibet air shower array data

The Tibet ASγ Collaboration

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Abstract. Search for TeV counterparts to GRBs observed by BATSE has been made using the Tibet II/HD air-shower dataset. BATSE on board the Compton GRO, a wide field instrument sensitive to gamma-rays from 20 keV to 600 keV, detected 2704 bursts from 1991 to 2000. The analysed Tibet data were taken during the period from October 1995 through September 1999. BATSE detected 67 GRBs within the field of view of the Tibet array during this period. ¿From our analysis GRB971115a was found to be the most prominent GRB counterpart having the $Power$ of 6.05. Probability greater than this value expected by the statistical fluctuation was estimated by the Monte Carlo simulation, and was found to be 2×10^{-1}. Therefore, no significant TeV gamma-ray bursts associated with the BATSE GRBs were detected by Tibet II/HD air shower array from the present analysis.

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1 Introduction

Gamma-ray bursts(GRBs) are short flashes of high-energy photons which appear on average about once a day at an unpredictable time from unpredictable directions in the sky. GRBs have been the most mysterious astronomical phenomenon in the universe for about 30 years after the discovery. The discovery of X-ray afterglows and optical and radio counterparts to GRBs has enabled redshift measurement of GRB sources and hosts, thereby confirming the hypothesis that the origins of GRBs are cosmologically distant.[1] One leading model for the origin of GRBs involves a neutron star merging with another neutron star or with a black hole, but the production mechanism of gamma-rays in GRBs are not yet known at all. Currently GRBs are widely believed as dissipation of kinetic energy of relativistic motion produced by an expanding fireball with a Lorentz factor of $\sim 10^{2-3}$.[2] The possibility of very strong emission of TeV gamma-rays is considered to be synchrotron radiation of protons accelerated up to $\sim 10^{20}$eV.[3,4]

2 Experiment

The Tibet experiment located at Yangbajing in Tibet (4,300 m a.s.l.) consists of two overlap air shower arrays (Tibet II and HD)[5]. These arrays measure timing and density information of charged particles in an air shower induced by primary cosmic-ray and gamma-ray in the atmosphere, and then reconstruct the shower front to determine the arrival direction of primary particle into the celestial sphere. The Tibet II array is an array of 185 scintillation detectors of 0.5 m^2 each installed at lattice spacing of 15 m with an enclosed area of 36,900 m^2 and is designed to detect gamma-ray induced showers in the energy range above 10 TeV. The high-density (HD) array is installed at lattice spacing of 7.5 m on the inward side of Tibet II array and consists of 109 scintillation detectors shared some of detectors of Tibet II array with an enclosed area of 5,175 m^2. This array is designed to be covered gamma-ray induced showers in the energy range above multi-TeV. Each scintillation detectors has a lead plate of 5 mm thickness on the top side to improved fast timing data by converting gamma rays in the showers into electron pairs. This device is being increased the shower size by a factor of about 2 and being improved the angular resolution by about 30 %[6].

The performance of these arrays was examined using observing the shadow of the cosmic-ray flux masked by the Moon[7]. ¿From this result, the mode energies of primary protons to be detected are about 8 TeV and about 3 TeV for the Tibet II and HD arrays, respectively, and the angular resolution is estimated to be better than 0.9° for all events. The angular resolution is also proportional to the sum of the number of shower particles per m^2 detected in each detector ($\Sigma\rho$), as $0.8° \times ((\geq \Sigma\rho)/20)^{-0.3}(15 < \Sigma\rho < 300)$. These result was also confirmed that the parameter of $\Sigma\rho$ is independently of primary particle by the Monte Carlo simulation[8].

3 Observation and Analysis Method

The Tibet II and High Density (Tibet II/HD) air shower arrays have been operated from October 1995 until September 1999. Within the above observation period, 67 GRBs were observed by BATSE on board the CGRO in the field of view of the Tibet II array and 54 GRBs in that of the Tibet HD array. The field of view of the array was assumed to be less than 40° in zenith.

Error region of the BATSE GRBs with 90% confidence level including statistical and systematic errors is determined to each position. The error region of the 67 GRBs selected by the present analysis has radius from 4° to 20°. We searched for counterparts of the BATSE GRBs in this region with a view angle of radius 1°, which we call ON source circle hereafter, by shifting every 0.5° in right ascension and declination plane.

Two kinds of time ranges of the search was used in the present analysis. One was T90 which was determined by BATSE as a duration time of the burst. T90 ranged from 0.1 sec to 378 sec for the selected 67 GRBs. The other was time ranges with 5, 10, 20, 30, 40 and 50 sec started from the BATSE burst trigger.

Background event rate for each ON source circle was obtained by an equi-azimuth method in 240 sec for each time range. Poisson probability for each time range was calculated using the ON source events and the background events. Then $Power$ was calculated to evaluate the probability of occurrence as $Power = -log_{10}(Poissonprobability)$.

4 Results

The maximum power value $Pmax$ was calculated from the analysis of T90 and the six kinds of the time intervals for each GRB. Figure 1 shows $Pmax$ as a function of sequential numbers of the BATSE GRBs for Tibet II and HD respectively.

The maximum power value larger than 6 among these was obtained for the counterpart of GRB971115 for which the position determined by BATSE was (α,δ)=(84.6°, 41.7°) with an error circle with radius 17.1° at a 90% confidence level. There was no T90 data for GRB971115.

This counterpart was obtained for the time interval of 40 sec measured from the BATSE trigger for the Tibet II data. In the area of ON circle with a radius 1° of the view angle, there was 14 air shower events, whereas the estimated number of the background events was 2.7. Therefore, the $Power$ was calculated to be 6.05 for this counterpart.

The position where this value was obtained was (α,δ)=(86.6°, 31.2°), which was 10.6° apart from the GRB position determined by BATSE. This position is still within the error circle of 90% confidence level.

5 Conclusion

We searched for TeV counterparts to BATSE GRBs using the Tibet II/HD air shower array. ¿From our analysis GRB971115a was found to be the most prominent GRB counterpart having the $Power$ of 6.05. Probability greater than this value expected by the statistical fluctuation was estimated by the Monte Carlo simulation, and was found to be 2×10^{-1}. In this simulation 100 times of oserved events were generated to evaluate the significance of the candidate where zenith angle dependence of the air shower event rate was taken into account.

Therefore, we conclude that no significant TeV gamma-ray bursts associated with the BATSE GRBs were detected by Tibet II and HD air shower arrays from the present analysis.

In future we will search for the TeV counterparts from the data of the Tibet III array whose observation period is from November 1999 to June 2000. We will also search in different time intervals from those used in this analysis.

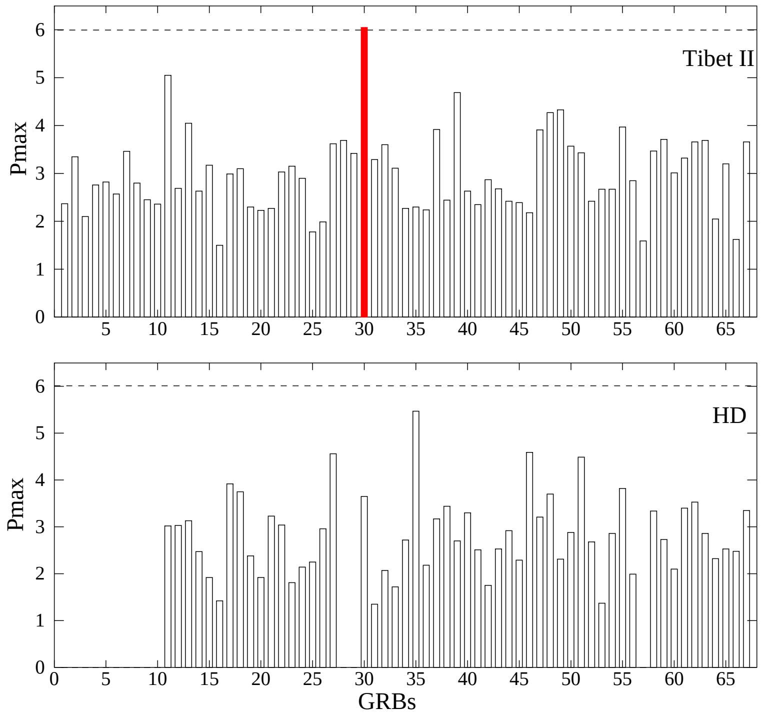

Figure 1. $Pmax$ distribution : The maximum values of the $Power$ obtained from T90 and the six time intervals is determined as $Pmax$. Top panel shows $Pmax$ for the Tibet II data and the bottom panel shows for the Tibet HD data. Sequential numbers of the BATSE GRB are shown in abscissa.

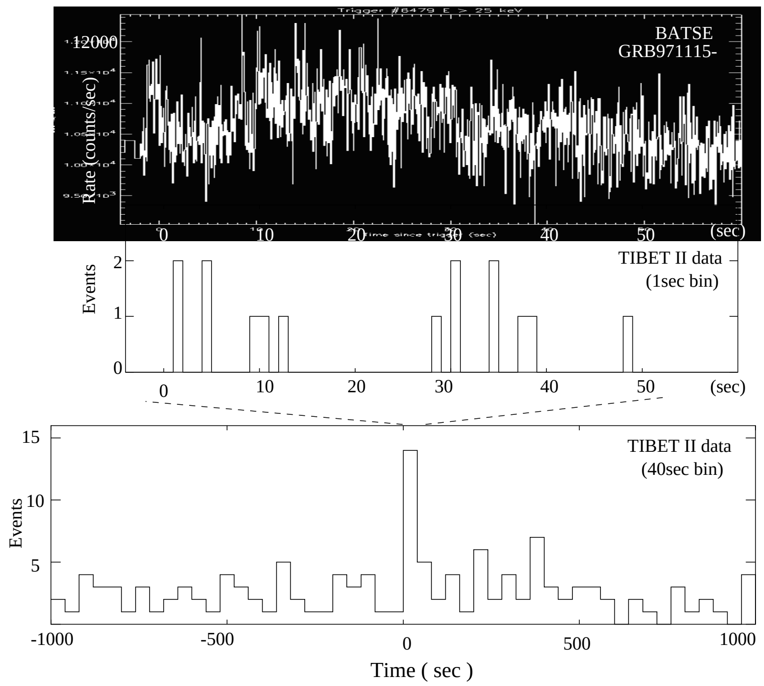

Figure 2. Variation of event rate : Top panel ; lightcurve obtained by BATSE, Middle panel ; Number of events in a sec as a function of time for Tibet II, Bottom panel ; Number of events in 40 sec bin in 1000 sec before and after the BATSE trigger for Tibet II.

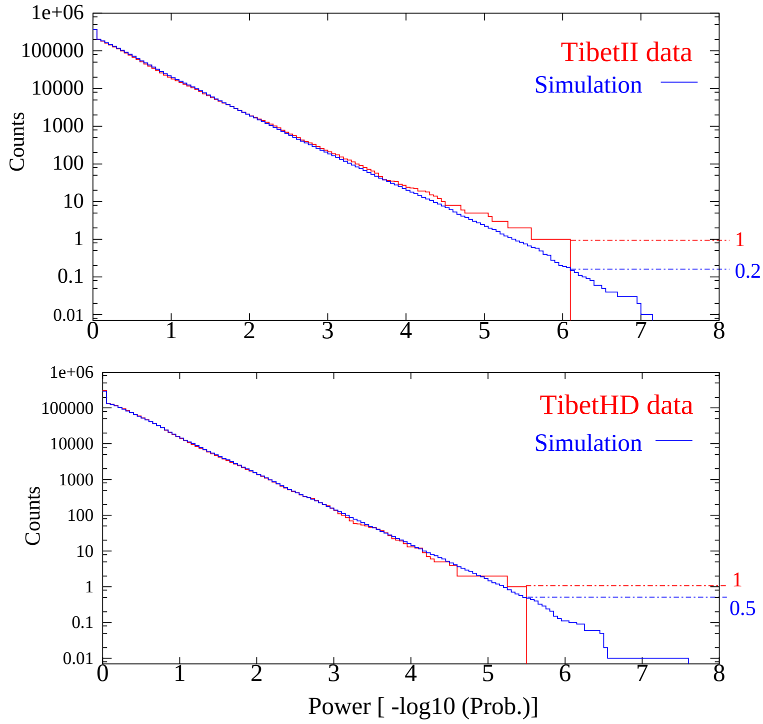

Figure 3. Integral power distribution obtained from the observation and the Monte Carlo simulation. Top panel : Tibet II. Bottom panel : Tibet HD

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