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# Search for gamma ray bursts with the ARGO-YBJ detector in scaler mode

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**Abstract**

The ARGO-YBJ experiment has been designed to decrease the energy threshold of typical Extensive Air Shower arrays by exploiting the high altitude and the full coverage, consisting of a 6700 $m^2$ carpet of Resistive Plate Chambers located at Yangbajing (Tibet, PR China, 4300 m a.s.l.). The lower energy limit of the detector ($\sim$1 GeV) is reached with the "Scaler Mode", recording the counting rate at fixed time intervals. Here we present results concerning the search for emission from Gamma Ray Bursts (GRBs) in coincidence with satellite detections.



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*Keywords:* Gamma ray bursts; Air shower arrays

## 1. Introduction

The ARGO-YBJ experiment is located at Yangbajing (Tibet, PR China, 4300 m a.s.l.) and consists of a single layer of Resistive Plate Counters (RPCs). The detector has a modular structure, the basic module being a CLUSTER ($5.7 \times 7.6\,m^2$), made of $6 \times 2$ RPCs. Each RPC is divided into 10 PADs, whose data acquisition is independent and which represent the high granularity pixel of the detector ($56 \times 62\,cm^2$). The whole RPC carpet is connected to two different DAQ systems, which work independently: in shower mode, for each event the location and timing of each detected particle is recorded, allowing the reconstruction of the lateral distribution and of the arrival direction [1]; in scaler mode, the counting rate of each CLUSTER is measured every 0.5 s, with no information on the space distribution and arrival direction of the detected particles. In the scaler mode DAQ, for each CLUSTER four scalers record the rate of counts $\geqslant 1$, $\geqslant 2$, $\geqslant 3$ and $\geqslant 4$ in a time window of 150 ns. The corresponding measured rates are, respectively, $\sim$40, $\sim$2 kHz, $\sim$300 and $\sim$120 Hz. The energy threshold is about 1 GeV, that is lower than the highest energies detected by satellite experiments. The modular structure of the detector allowed to collect data during the different mounting phases.

## 2. Search for emission from GRBs

Due to the longer setup and certification of the shower mode DAQ, the search for emission from GRBs could be performed up to now only with the scaler mode technique. The data presented in this paper have been collected from November 2004 (corresponding to the Swift satellite launch) to April 2007, with a detector active area increasing from 693 to 5632 $m^2$. The search for a signal is triggered by the events detected by satellites (mainly Swift) and is done for all GRBs with zenith angle $\theta < 45°$. For each event, the total number of counts in the T90 time window given by the satellite (corresponding to the detection of 90% of the photons) is compared with the number of counts averaged on a time interval corresponding to $10 \cdot$ T90 before and after the GRB. In case of no significant excess, the fluence

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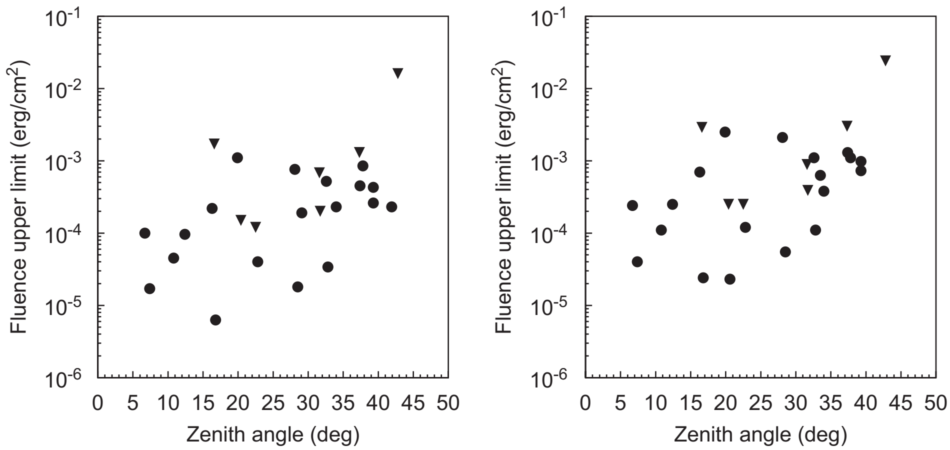


Fig. 1. Fluence upper limits as a function of the zenith angle in the 1–100 GeV range obtained extrapolating the measured keV–MeV spectra (left) or assuming a change to a photon index 2.5 at the energy 230 keV (right). For those GRBs with known redshift the upper limits are calculated taking into account the extragalactic absorption (triangles), otherwise $z = 0$ is assumed (dots).

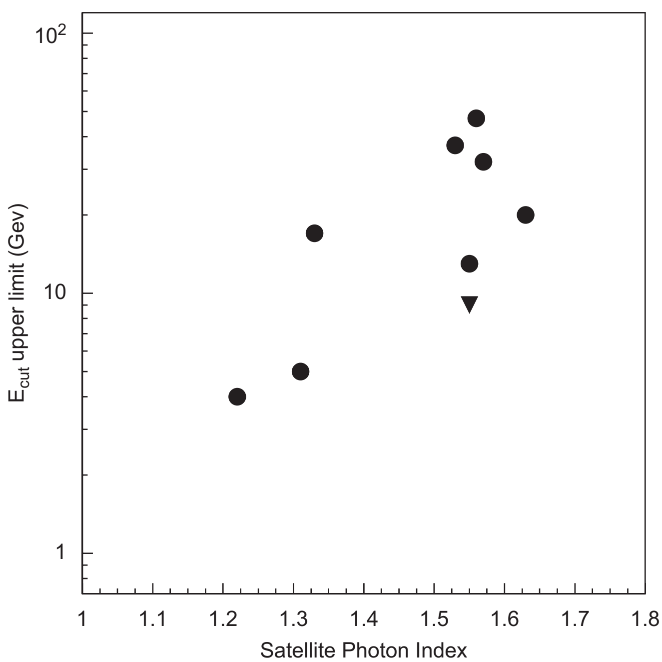


Fig. 2. Cutoff upper limits as a function of the spectral index measured by satellites. The triangle is obtained taking into account the extragalactic absorption.

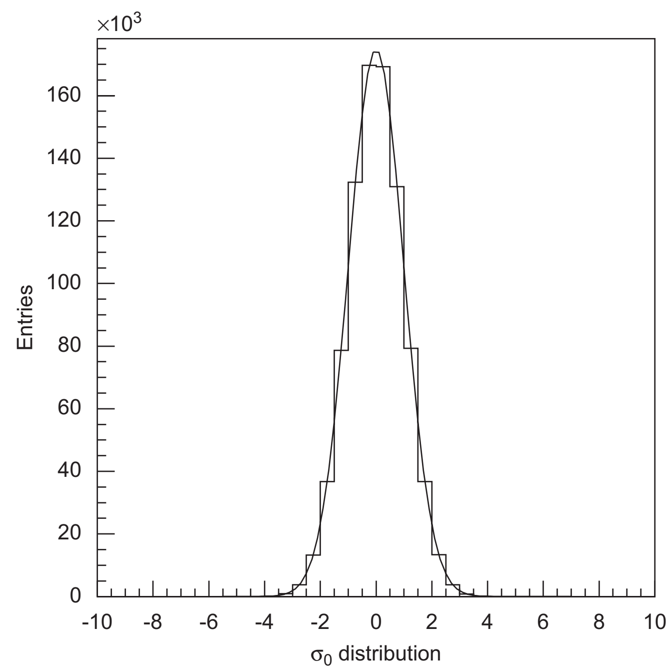


Fig. 3. Distribution of the statistical significances of our set of GRBs in a $\pm 1$ h interval around the GRB start recorded by satellites using different time windows $\Delta t$ (see text), compared with a standard normal distribution.

upper limit (with a $4\sigma$ significance) is calculated using the detector effective areas and assuming a power law spectrum up to $E_{\max} = 100$ GeV. For this calculation two different assumptions were made for the power law spectrum: (a) extrapolation of the keV–MeV spectrum measured by satellites; (b) sharp index change from the satellite spectrum to a photon index 2.5 at the break energy 230 keV (peak value of the BATSE distribution [2]). Fig. 1 shows the upper limits to the fluence in the 1–100 GeV energy range, obtained for the two different spectra as a function of the local zenith angle. For those GRBs for which the redshift is known, the upper limit is calculated including a model for the $\gamma\gamma$ absorption by the Extragalactic Background Light [3] and represented with a triangle in Fig. 1. For the other GRBs $z = 0$ is assumed, since below 100 GeV the $\gamma\gamma$ absorption is almost negligible for $z < 0.5$.

Using the same two models for the GRBs spectra, an upper limit to the cutoff energy $E_{\mathrm{cut}}$ can be determined at least for some GRBs in the following way. The extrapolation of the fluence measured by satellites is plotted together with our fluence upper limit as a function of the cutoff energy. If the two curves cross in the 2–100 GeV energy range, the intersection gives the upper limit to the cutoff energy for the assumed spectrum. Fig. 2 shows the distribution of these cutoff upper limits as a function of the spectral index measured by satellites. If the spectra of these GRBs extended up to $E_{\mathrm{cut}}$, a signal of $4\sigma$ would have been produced.

Since the high energy emission could happen with features very different with respect to the low energy signal, another search is made for delayed or anticipated signals of fixed duration. We considered time windows $\Delta t = 0.5$, 1, 2, 5, 10, 20, 50, 100, 200 s and T90 shifted by steps of $\Delta t$ inside a $\pm 1$ h interval around the GRB start recorded by satellites. The distribution of all the excesses for all the GRBs is shown in Fig. 3, compared with the expected standard normal distribution. It results that for our set of GRBs no statistically significant excess is found in any time window. Fig. 3 also shows the statistical behaviour of the detector and the correct determination of the significances.

Finally, a search for a signal from stacked GRBs has been made by adding up in phase all the GRBs with $\mathrm{T90} \geqslant 5$ s (thus belonging to the long GRB population), scaling their total duration. In this way we can test the hypothesis that the high energy emission occurs at a certain phase of the low energy burst, is present for the stack of GRBs, but is lower than the sensitivity of our detector for each single GRB. Considering 10 phase bins, also in this case no evidence of emission has been detected so far, the overall significance of the GRB stack with respect to the background fluctuations being $1.14\sigma$.

## 3. Conclusions

Until now, the search for emission from GRBs with the ARGO-YBJ detector has given no positive result. The simple scaler mode has shown a good sensitivity, with $4\sigma$ fluence upper limits down to $\approx 10^{-5}\,\mathrm{erg/cm^2}$ in the 1–100 GeV energy range. The directional capability of the shower mode at energies of a few hundreds of GeV allows the ARGO-YBJ experiment to study the GRB high energy tail in the whole 1 GeV–1 TeV range.

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