Astron. Astrophys. Suppl. Ser. **138**, 597–598 (1999)

The ARGO-YBJ detector and high energy GRBs

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Received December 29, 1998; accepted April 21, 1999

Abstract. ARGO-YBJ (Astrophysical Radiation with Ground-based Observatory at YangBaJing) is a detector optimized to study small size air showers. It consists of a layer of Resistive Plate Counters (RPCs) covering an area of ~ 6500 m^2 and will be located in the Yangbajing Laboratory (Tibet, China) at 4300 m a.s.l. ARGO-YBJ will be devoted to a wide range of fundamental issues in cosmic rays and astroparticle physics, including in particular gamma-ray astronomy and gamma-ray bursts physics in the range 10 GeV $\div$ 500 TeV. The sensitivity of ARGO-YBJ to detect high energy GRBs is presented.

Key words: gamma-ray: bursts

1. Introduction

The study of the GeV – TeV component of gamma-ray bursts is of great importance to understand the acceleration mechanisms and the sources physical conditions. The detection of GeV gamma-rays by EGRET during some intense GRBs (Catelli et al. 1997) suggests the possibility that a high energy component could be present in all events. Furthermore several models predict GeV and TeV emission, sometimes correlated with UHECRs production (see Baring 1997, for a review). Due to the low fluxes and the small sensitive areas of satellite experiments, gamma-rays of energy larger than a few tens of GeV, must be detected by ground based experiments located at mountain altitude measuring the secondary particles generated by gamma-rays in the atmosphere. At energies $E < 10$ TeV the number of particles reaching the ground is to small to reconstruct the shower parameters using a standard air shower array, made of several detectors spread over large areas. On the contrary, a detector consisting of a full coverage layer of counters, providing a high granularity sampling of all particle showers, can successfully measure arrival direction and primary energy of small showers,

Send offprint requests to: S. Vernetto allowing the study of the unexplored range of gamma energies between 20 GeV and 300 GeV (Abbrescia et al. 1996).

2. The ARGO-YBJ detector

ARGO-YBJ is an air shower detector optimized to observe small size showers, to be constructed in the Yangbajing Laboratory (Tibet, China) at an altitude of 4300 m a.s.l. The experiment consists of a $\sim 71 \times 74$ m^2 core detector realised with a single layer of RPC's ($\sim 90\%$ of active area), surrounded by an outer detector ($\sim 30\%$ of active area) for a total size of $\sim 100 \times 100$ m^2. A lead converter 0.5 cm thick will cover uniformly the RPC plane in order to increase the number of charged particles by conversion of shower photons in e$^{\pm}$ and to reduce the time spread of the shower front (Bacci et al. 1998). ARGO-YBJ can image with high efficiency and sensitivity atmospheric showers initiated by primaries of energies in the range 10 GeV $\div$ 500 TeV. Its main physics goals are (Abbrescia et al. 1996): Gamma-astronomy at ~ 100 GeV energy threshold, with a sensitivity to detect unidentified point sources of intensity as low as 10% of the Crab Nebula; Gamma-Ray Burst physics, extending the satellite measurements at energies $E > 10$ GeV; $\overline{p}/p$ ratio in the TeV energy range; Sun and heliosphere physics. The detector assembling should start in 2000 and data taking with the first ~ 750 m^2 of RPC's in 2001.

3. Sensitivity to high energy GRBs

A high energy GRB is detectable if the number of air showers from the gamma-rays is significant larger than the fluctuations of the background, due to showers from cosmic rays with arrival directions compatible with the burst position. A good angular resolution is of major importance in order to reduce the background and increase the detection sensitivity. The angular resolution and the effective area of ARGO-YBJ to detect gamma-rays as a function of the energy have been obtained by means of simulations. For gamma-rays with energy as low as $E \sim 10-20$ GeV, the opening angle around the source direction in which 70% of the signal showers are contained is $\sim 5°$.

To evaluate the sensitivity of ARGO-YBJ to detect GRBs, we considered a burst with a power law energy spectrum $\mathrm{d}N/\mathrm{d}E \propto E^{-\alpha}$ extending in the range 1 GeV $\div E_{\max}$, a duration $\Delta t = 1$ s, and a zenith angle $\theta = 20°$. The burst will give a signal with a significance larger than 4 standard deviations if the energy fluence in the range 1 GeV $\div E_{\max}$ is larger than a minimum value $F_{\min}$. Figure 1 shows $F_{\min}$ as a function of $E_{\max}$ for 3 spectral slopes. For a generic duration Δt the minimum fluences detectable are given by $F_{\min}\sqrt{\Delta t}$.

In the energy range considered the sensitivity is strongly dependent on the maximum energy of the spectrum $E_{\max}$. ARGO-YBJ can observe GRBs with energy fluences of a few 10^{-6} erg cm^{-2} if the energy spectrum extends at least up to ~ 200 GeV with a slope

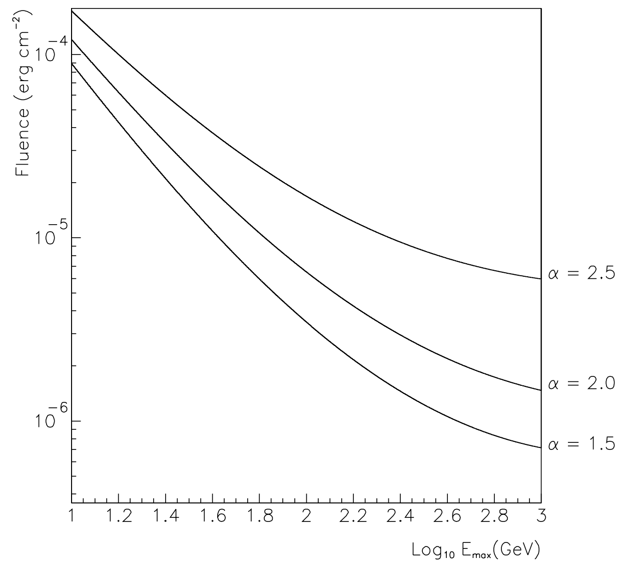

Fig. 1. The minimum energy fluence in the range 1 GeV $\div E_{\max}$ of a GRB detectable by ARGO-YBJ as a function of the maximum energy of the spectrum $E_{\max}$ for 3 spectral slopes

$\alpha \le 2$; the minimum detectable fluence is $\sim 10^{-5}$ if $E_{\max} \sim 30$ GeV.

This is of particular importance, since if GRB sources are located at cosmological distances, the high energy tail of the spectrum is affected by the $\gamma\gamma \to e^+e^-$ interaction of gamma-rays with low energy starlight photons in the intergalactic space. According to Salomon & Stecker (1998), at a distance corresponding to a redshift $z = 0.1$ the absorption is almost negligible, while at $z = 0.5\,(1.0)$ the absorption becomes important for photons of energy $E > 100$ (50) GeV. These values give an idea of the possible maximum energy of the GRBs spectra as a function of their distance, and from Fig. 1 one can infer the maximum sensitivity of ARGO-YBJ to detect cosmological GRBs. The minimum observable fluences can be compared with the fluences measured by EGRET in the 1 MeV $-$ 1 GeV energy range: $F \sim 10^{-5} \div 10^{-4}$ erg cm^{-2} (Catelli et al. 1997). Since EGRET spectral slopes α are mostly ~ 2, one could expect fluences of the same order of magnitude at energies above 1 GeV. From Fig. 1 one can conclude that ARGO-YBJ could detect GRBs with the same intensity of those observed by EGRET provided that the energy spectrum extends up to few tens of GeVs; the sensitivity increases by a factor $\sim$10 for spectra extending up to $E_{\max} \sim 200$ GeV.

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