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The ARGO-YBJ Detector and high energy GRBs

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Abstract. ARGO-YBJ is a detector optimized to study small size air showers. It consists of a layer of Resistive Plate Counters (RPCs) covering an area of $\sim$ 6500 m^2 and will be located in the Yangbajing Laboratory (Tibet, China) at 4300 m above the sea level. 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.

1. Introduction

The study of the high energy component of gamma-ray bursts is of great importance to understand the acceleration mechanisms and the sources physical conditions. 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 detailed space-time picture of the shower front, can succesfully measure arrival direction and primary energy of small showers, allowing the study of the unexplored range of gamma energies between 20 GeV and 300 GeV.

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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), sorrounded by an outer detector ($\sim$ 30% of

active area) for a total size of $\sim 100\times100$ m^2 (Bacci 1997). 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. 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 (Bacci 1997):

1) Gamma-astronomy at $\sim$ 100 GeV energy threshold, with a sensitivity to detect unidentified point sources of intensity as low as 10% of the Crab Nebula; detection of diffuse gamma-rays from the galactic plane, molecular clouds and supernova remnants.

2) Gamma-ray burst physics, extending the satellite measurements at energies E $>$ 10 GeV.

3) $\overline{p}/p$ ratio in the TeV energy range, not accessible to satellites.

4) The primary proton spectrum at 10$\div$ 200 TeV.

5) Sun and heliosphere physics, including cosmic rays modulations at $\sim$ 10 GeV threshold energy, and detection of gamma-rays from solar flares.

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 (Argo proposal 1996). 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 $\sim 5^{\circ}$.

To evaluate the sensitivity of ARGO-YBJ to detect GRBs, we considered a burst with a power law energy spectrum $dN/dE \propto E^{-\alpha}$ extending in the range 1 GeV $\div E_{max}$, a duration Δt=1 s, and a zenith angle θ=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}. Fig.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 $\sim$ 200 GeV with a slope $\alpha \leq 2$; 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,

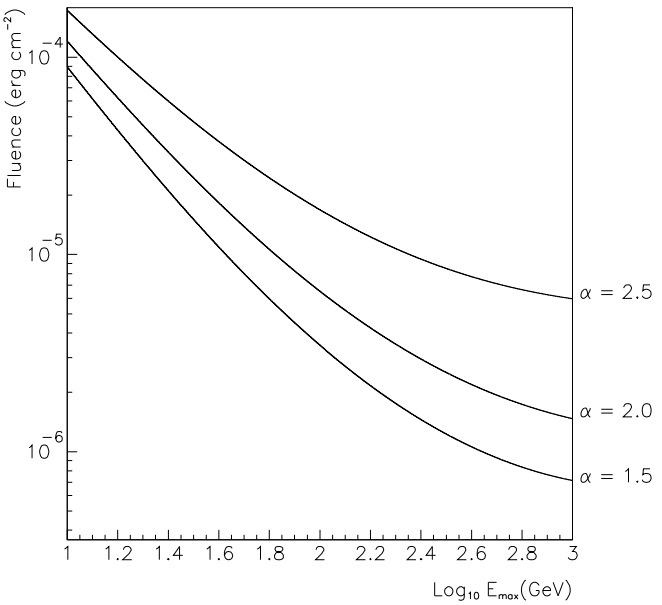

Fig. 1. The minimum energy fluence in the range 1 GeV$\div E_{max}$ of a GRB detectable by ARGO-YBJ as a function of the maximum energy of the spectrum E_{max} for 3 spectral slopes.

the high energy tail of the spectrum is affected by the $\gamma\gamma \rightarrow e^+e^-$ interaction of gamma-rays with low energy starlight photons in the intergalactic space. According to Salomon and 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.

4. Conclusions

The ARGO-YBJ detector is a gamma-ray telescope able to bridge the GeV and TeV energy regions. One of its aims is the detection of 10 GeV$\div$1 TeV GRBs. Its sensitivity allows the observation of events with energy fluence of a few 10^{-6} erg cm^{-2} above 1 GeV provided the spectrum extends up to $E_{max} \sim$ 200 Gev.

The detector assembling should start in 2000 and data taking with the first $\sim 750\ m^2$ of RPC's in 2001.

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