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Search for GRBs of energy E > 10 GeV with the air shower detector ARGO-YBJ

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Abstract. ARGO-YBJ is an air shower detector under construction at the Yangbajing Laboratory (Tibet, China) at 4300 m a.s.l., consisting of $\sim$6500 m^2 carpet of Resistive Plate Chambers. One of the aims of the experiment is the observation of GRBs of energy E > 10 GeV. According to simulations, ARGO-YBJ could detect GRBs with energy fluence as low as $\sim 10^{-6}$ - 3 10^{-5} erg cm^{-2} in the energy interval 1 GeV - E_{max}, with E_{max} ranging from 10 GeV to 1 TeV.

At the end of 2002 a subset of the detector ($\sim$1500 m^2) has been installed, ready to take data in spring 2003.

1. Introduction

The EGRET detection of GeV photons during few intense gamma-ray bursts suggested the idea that a large part of events could have a high energy component so far not observed because under the current instrument sensitivities (Catelli, Dingus, & Schneid 1997). The study of the high energy region of GRB spectra would be of great importance to understand the physical conditions in the burst source, setting limits on magnetic fields, densities and bulk Lorentz factors.

The observation of high energy GRBs can be performed by ground based experiments, as air shower detectors, recording the secondary particles produced in the atmosphere by primary gamma-rays. Their large field of view ($\Omega \sim \pi$ sr) and their duty cycle of almost 100% make them suitable to observe unpredictable events as GRBs.

However, due to the cosmological distances of the GRB sources, high energy gamma-rays are strongly absorbed during their travel towards the Earth by pair production on visible and infrared photons in the intergalactic space. According to Salamon & Stecker (1998) the optical depth at redshift z=1 (0.2) becomes equal to 1 for photons of energies as low as 40-70 (200-400) GeV. The distribution of GRBs hosts and afterglows redshifts so far measured (over 30 events in late 2002) spans the range from 0.25 to 4.5 (excluding the peculiar GRB 980425 with z=0.0083 probably associated with SN 1998bw) with a median around $z \sim$1. This implies that the study of the GRBs high energy component is limited to the region E < 1 TeV or even less, depending on the distance of the source. On the other hand the study of the features of the 1 GeV - 1 TeV GRBs spectrum, could give important information on the intergalactic photon field and its evolution.

Air shower detectors can operate at energy E < 1 TeV satisfying the two following conditions:

a) by disposing of a "full-coverage" large active area, in order to detect the small showers produced by low energy gamma-rays;

b) by operating at very high mountain altitude, in order to increase the number of the detectable particles (as an example, the mean number of charged particles reaching the detector level from a 100 GeV primary gamma-ray increases by a factor ∼20 going from 2000 m to 5000 m).

2. The ARGO-YBJ detector

The ARGO-YBJ experiment has been conceived to detect small size atmospheric air showers. It consists of a central carpet made by a single layer of Resistive Plate Chambers (RPCs) fully covering an area of 78 × 74 m^2, sorrounded by a guard ring partially instrumented with RPCs, for a total sensitive area $A_d \sim$ 6400 m^2 (Fig.1 left). The detector is divided in 18480 logic "pad" , each of area 56 × 62 cm^2, able to give a detailed space-time picture of the shower front. The detector will be uniformely covered by a layer of lead 0.5 cm thick, to convert a fraction of secondary photons in charged particles, and to reduce the time spread of the shower front. A detailed description of the experiment is given by Abbrescia et al.(1996) and Bacci et al.(1998).

ARGO-YBJ is under construction at the Yangbajing High Altitude Cosmic Ray Laboratory (Tibet, China), at an altidude of 4300 m a.s.l. At late 2002 about 1/3 of the central RPC carpet (∼1500 m^2) has been installed, ready to take data in spring 2003. The full experiment is planned to start operating in late 2004.

3. Detection of gamma-ray bursts

One of the main field of research of ARGO-YBJ is gamma-ray astronomy above few hundreds GeVs and gamma-ray bursts physics above 10 GeV. The ARGO-YBJ detector could observe high energy gamma-ray bursts with two different modes of operation (Vernetto et al. 1999):

a) the "single particle" technique (SP);

b) the "low multiplicity" technique (LM).

Air showers induced by gamma-rays of energy E <100 GeV give a very small number of particles at the detector level (e.g. the mean numbers of charged particles reaching the ARGO-YBJ level produced by a vertical gamma-ray of energy E = 10 and 100 GeV are respectively 0.35 and 15). Hence in this energy region it is convenient to operate in "single particle" mode (SP), i.e. recording all single secondary particles hitting the detector, not requiring any coicidence between the particles arrival times.

In this operation mode a GRB is detectable if the secondary particles from gamma-rays give a short time excess larger than the statistical fluctuations of the all-sky cosmic rays background (Aglietta et al. 1998; Cabrera et al. 1998; Vernetto 2000). The background single particle rate measured at Yangbajing is $B_{SP} \sim 1500$ s^{-1} m^{-2}.

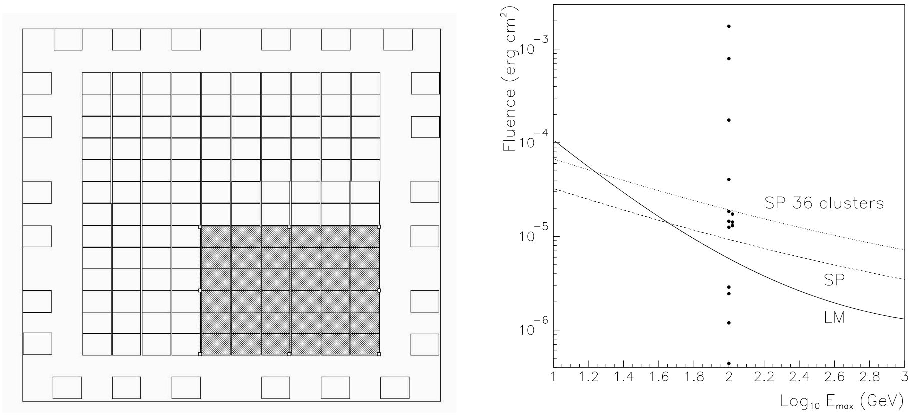

Figure 1. *Left* - Scheme of ARGO-YBJ, showing the central RPCs carpet and the guard ring. The rectangles (clusters) are logical subsets of the detector of area $\sim$42 m^2. The shaded area ($\sim$ 1500 m^2, 36 clusters) has been installed in 2002. *Rigth* - Minimum observable GRB energy fluence in the range 1 GeV-E$_{max}$, as a function of the maximum energy of the spectrum E$_{max}$, for the low multiplicity technique (LM), single particle technique (SP) and single particle technique with the detector configuration of 36 clusters. The points represent the fluences above 1 GeV of 14 EGRET bursts, obtained by extrapolating their spectra up to 100 GeV.

Using the single particle technique the directions and energies of gamma-rays obviously are not measurable, however it is possible to estimate the high energy flux and to study the temporal behaviour of the high energy emission.

The low multiplicity technique (LM) consists in the detection of very small air showers, by requiring at least $\sim$10 particles in coincidence. In this case the measurement of the arrival direction is possible, and according to simulations the angular resolution (defined as the opening angle around the source containing the $\sim$ 70% of the signal events) for such small showers is $r \sim 5^\circ$ (Abbrescia et al. 1996). The number of background events with arrival directions in a cone of radius $r = 5^\circ$ and zenith angle θ=20° is expected to be $B_{LM} \sim 160$ s^{-1}.

4. Sensitivity of SP and LM techniques.

To evaluate the detector sensitivity to GRBs we have simulated the response of the detector to showers induced by gamma rays and cosmic rays of different energies and zenith angles. We assumed for semplicity a GRB power law spectrum $dN/dE = KE^{-\alpha}$ photons m^{-2} extending up to a cutoff energy E_{max}, with E_{max} >10 GeV. This assumption is supported by EGRET observations, reporting power law spectra extending with no visible cutoff up to the maximum observable energy (in some cases in the GeV region). The energy cutoff can be due to an intrinsic cutoff in the emission region or/and to the absorption of gamma-rays in the intergalactic space. Obviously a sharp cutoff at $E = E_{max}$ is not realistic, but for our purposes this simple parametrization can be adopted. The average spectral slope measured in the 30 MeV-10 GeV region is $\alpha = 1.95 \pm 0.25$ (Dingus, Catelli, & Schneid 1997).

We espress the sensitivity in terms of F_{min}, defined as the minimum energy fluence in the energy range 1 GeV$\div E_{max}$ necessary to make a GRB observable by ARGO-YBJ with a statistical significance of 4 standard deviations.

Fig. 1 (right) shows F_{min} as a function of E_{max}, using the SP and the LM techniques. The curves are given for a GRB duration Δt=1 s and a spectral slope $\alpha = 2.0$. The minimum fluence for a different duration Δt scales as $\sqrt{\Delta t}$. The GRB zenith angle is assumed 20°.

The SP mode is more sensitive for GRB spectra with a low energy cutoff. For $\alpha = 2$ the SP technique is better than LM for $E_{max} < 50$ GeV. This limit ranges between 35 and 70 GeV if the slope α varies from 1.5 to 2.5. The sensitivity in SP mode simply scales with the square root of the geometrical area of the detector. The SP sensitivity for the 1500 m^2 RPC carpet already installed is about 0.5 the full sensitivity, as shown in the same figure.

To compare the ARGO-YBJ sensitivity with what can be reasonably expected from real bursts, we reported in the same figure the fluences in the 1-100 GeV energy range obtained extrapolating up to 100 GeV (with their measured slope) the spectra observed by EGRET during 14 events (Catelli, Dingus, & Schneid 1997). As can be seen in the figure, a large fraction of the events has an energy fluence greater than the ARGO-YBJ limits.

5. Conclusions

The ARGO-YBJ detector can observe GRBs in the energy range $E > 10$ GeV using the "single particle" technique (SP) and the "low multiplicity" technique (LM). Adopting the SP method for GRBs with the maximum energy of the spectrum $E_{max} < 50$ GeV and the LM method for higher values of E_{max}, ARGO-YBJ could detect GRBs with energy fluence as low as $\sim 10^{-6}$ - 3 10^{-5} erg cm^{-2} in the energy interval 1 GeV - E$_{max}$, with E$_{max}$ ranging from 10 GeV to 1 TeV, if the spectral slope is $\alpha \sim$2.

References

Abbrescia, M., et al. 1996, in www1.na.infn.it/wsubnucl/cosm/argo/argo.html
Aglietta, M., et al. 1996, in ApJ, 469, 305
Bacci, C., et al. 1998. in www1.na.infn.it/wsubnucl/cosm/argo/argo.html
Cabrera R., et al. 1999, in Astr. and Astroph. Suppl.Series, 138, 599
Catelli, J.R., Dingus, B.L., & Schneid, E.J. 1997, in AIP Conf.Proc., 428, 309
Dingus, B.L., Catelli, J.R., & Schneid, E.J. 1997, in Proc. 25th ICRC, 3, 30
Salamon, M.H., & Stecker, F.W. 1998, in ApJ,493, 547
Vernetto, S. 2000, in Astrop.Phys, 13, 75
Vernetto, S., et al. 1999, in Proc of 26th ICRC, Vol.4, 28