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ARGO Sensitivity to Detect GRBs with E>10GeV

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ARGO is a "full coverage" air shower detector currently under construction in Tibet, China. One of the main goals of this experiment is to search for possible GRBs with E>10GeV. The sensitivity in observing a GRB (with a certain significance) by ARGO is found to be depend on the flux, the zenith angle of the GRB, the slope and the energy cutoff of its spectrum.

1. Introduction

GRBs, a violent energy release at unpredictable time and from unpredictable sky direction, are still one of the most mysterious astronomical phenomena, though more than 30 years' time have been passed since their first discovery by VELA satellite in 1967. Lots of basic questions such as the emission mechanisms are still under study while some other such as the cosmological origination is convincingly established based on the observation results. The results from BATSE experiment on aboard of the CGRO (launched in April 1991) showed that the arrival directions of GRBs are highly isotropic which supports GRB originate at cosmological distances[1]. Further more the afterglow measurements of GRBs from satellite experiments manifested that at least part of GRBs originate from cosmological distances[2]. Now, several satellite experiments such as HETE, INTEGRAL and Swift are searching for GRBs with energies from keV to MeV. The EGRET experiment on board of the CGRO has detected GeV photons in coincidence with 3 BATSE GRBs. In general, high energy GRB on average showed a hard power- law spectrum with a slope (α) around 2[3] and no cutoff was seen at higher energies. According to which, it is possible for sensitive enough ground based detector to observe the high energy GRB. In past years, several ground-based experiments such as Milagro[4], Tibet Asγ[5]and L3+C[6] have devoted to search for high energy GRBs, but all reported negative results due to low GRB fluxes at GeV energies (comparing with the background flux from cosmic rays) . In addition, the attenuation of GeV gamma-rays via intergalactic absorption when they traveled through a cosmological distances may also be another cause to it.
The detection of GeV GRBs is very important to provide some information on the distances in origination and the emission mechanism of GRBs .The ARGO apparatus locates at Yangbajing in Tibet. Its high altitude (4,300m a.s.l.) , wide field of view, high duty cycle, high trigger rate and the lowest threshold energy (about 100GeV) make it the most suitable GeV GRB detector among the existing ground-based EAS experiments. The details of ARGO was described elsewhere[7]. In this note, we study the ARGO sensitivity for the detection of GRBs with E>10GeV.

2. Effective area of ARGO experiment

A_{eff}, the effective area of ARGO in detecting primary gamma-rays varies depending on energies of gamma rays and their zenith angles. We first determine A_{eff} by a full MC simulation. In this work, Corsika[8] was used to simulate the shower development in the atmosphere and ARGOG based on GEANT3[9] was used for the response of the detector. To account for the occasional hitting on ARGO detector by the very small shower events or by those secondary particles coming from the shower of which the majority are out side of the array, a noise rate of 380Hz per RPC pad which comes from the real measurement, was simulated. The trigger condition $N_{pad} \geqslant 20$, where N_{pad} is the number of fired pads of the detector, was required.

A sampling area of 210m × 210m, which is large enough under the trigger condition $N_{pad} \geqslant 20$ by simulation, was used to enclose ARGO at its center. The resultant effective area A_{eff} for recording gamma-rays from different zenith angles (θ) as the function of primary energies is shown in Fig.1.

At a fixed zenith angle and assuming a power-law GRB spectrum with an index α, the mean effective area $\langle A_{eff} \rangle$ of ARGO at the energy range from 10GeV to E_{max} can be calculated by

$$\left\langle A_{eff} \right\rangle = \frac{\int_{10\ GeV}^{E_{max}} A_{eff}(E).E^{-\alpha}.dE}{\int_{10\ GeV}^{E_{max}} E^{-\alpha}.dE} \qquad (1)$$

where E_{max} is the energy cutoff of the GRB (30-1000GeV, as considered in this work).

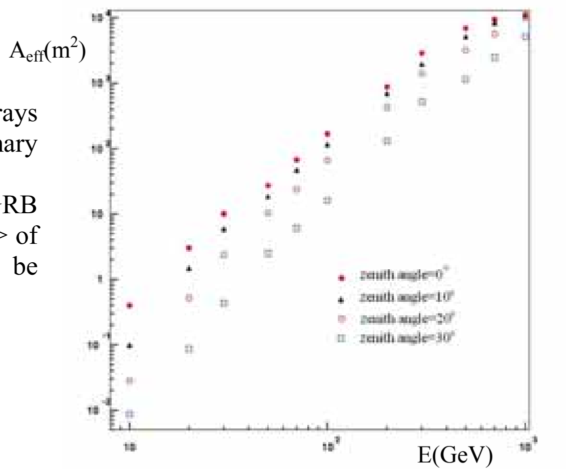

Figure1. The A_{eff} of ARGO for gamma-rays from different zenith angles, as a function of primary energies

3. Minimum number of signals making a GRB observable by ARGO

A simulated GRB appears as a shower cluster in a given small sky window and a time interval (△t) with an appropriate significance. In the following 5σ was taken as the necessary significance indicating a GRB observable. To estimate the minimum number of signals that makes a GRB observable by ARGO, the angular resolution, 1.65° under the trigger condition $N_{pad} \geqslant 20$ [10] was considered. Any simulated signal showers coming from a fixed direction have to be smeared by a Gaussian distribution with an variance of 1.65°. Correspondingly, the optimal angular radius of the on-source window 2.6° (a factor of 1.58 of the angular resolution) was chosen.

It was known that the background event rate for ARGO is 21.7kHz[11]. Taking this value, the experimentally measured zenith angle and azimuth angle distributions into account, the number of events in the background windows(also with 2.6° angular radius) is determined by the "equi-zenith-angle" method.

In general, any value can be used as the time duration of a GRB. In the following a typical value 1s was used. In this case the $\langle N_b \rangle$ distribution at different zenith angles was shown in Fig 2.

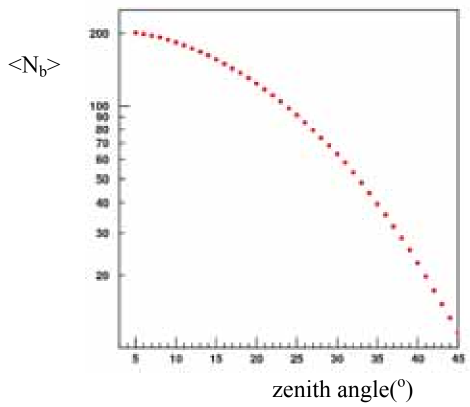

Figure 2. The background rate $\langle N_b \rangle$ within 1s as a function of zenith angles

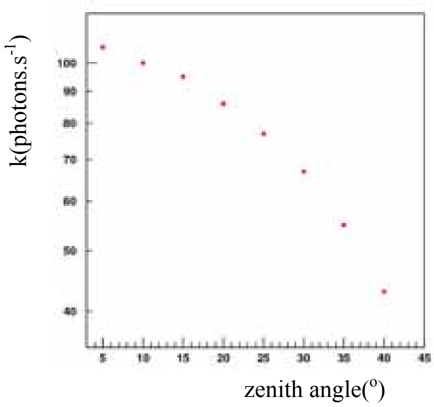

Figure 3. The minimum signal intensity k as a function of zenith angles

Then the minimum number of signals N_{on} , as well as the minimum signal intensity k within 1s that gives a significance of 5 σ can be obtained. In Fig 3 is shown the k (△t =1s) distribution at different zenith angle. For a general time duration △t, the minimum signal intensity is evaluated by the formula:

$$k = k_0 / \sqrt{\Delta t} \qquad (2)$$

Where k0 is the minimum signal intensity when △t=1s.

4. ARGO sensitivity to E>10GeV GRBs

To compare with the results from other experiments and theory predictions, only knowing the minimum signal intensity k is not enough. The minimum signal flux F_{min} outside the earths' atmosphere could be calculated by $F_{min}=k/<A_{eff}>$, where F_{min} depends on the slope of the gamma-ray spectrum, the energy cutoff E_{max}, the time duration △t and the direction of the GRBs. Assuming a zenith angle 20^o and △t=1s, the curve 1,2 and 3 in Fig. 4 show the F_{min} as a function of E_{max} for the values of the spectrum slope 2.5, 2.0, 1.5, respectively. We can see that, in case of the slope =2.0 and E_{max} =1TeV, F_{min} is about 7×10^{-5}phontons/cm^2.s.

During its livetime, EGRET detected GeV phontons from 3 BATSE GRBs. From BATSE to EGRET their slopes are known as 2.24(GRB910503)[12], 1.97 (GRB930131) and 2.53 (GRB940217)[13,14]. Extrapolating their power law spectra to E_{max} (30GeV<E_{max}<1TeV) ,the integral fluxes of these 3 GRBs from 10GeV to E_{max} can be obtained. The points and circles in Fig. 4 are the fluxes for GRB930131 and GRB910503, respectively. The flux of GRB940217 is much lower than the ARGO sensitivity.

We can see from Fig.4 that ARGO can observe GRB930131 if E_{max}>300GeV. If E_{max}>700GeV, GRB910503 can also be observed by ARGO. It means that 2 of these 3 GRBs can be observed by ARGO if their spectra could extend to E_{max} and if they appeared in the view field of ARGO.

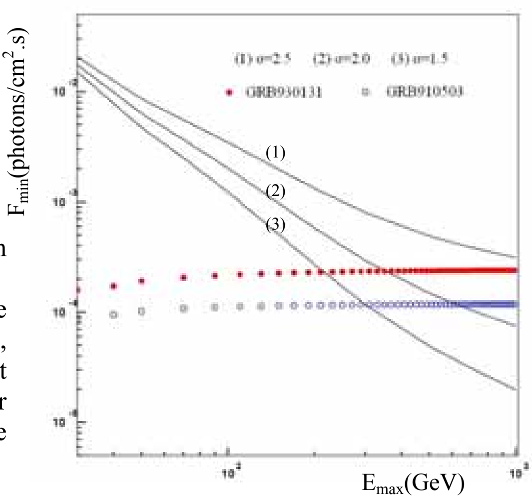

Figure 4. The F_{min} of ARGO and the extrapolating fluxes of 3 EGRET GRBs as the function of E_{max}

5. Conclusion

The ARGO sensitivity in detecting GRBs depends on the GRB's direction , the slope of spectrum and energy cutoff. When a zenith angle 20^o, a spectrun slope 2.0, the minimum signal flux outside the earths' atmosphere is about $10^{-5}\sim10^{-4}$photons/cm^2.s assuming the energy cutoff up to a few hundred GeV. Since we are considering the experimental sensitivity of ARGO, the attenuation of gamma-rays during their propagation from the source has not been considered. If we want to get the minimum signal flux at the source of a GRB, the intergalactic absorption should be considered[15].

References

[1] Meegan C A et al. Nature, 1992, 355:143-145.
[2] Metzger M R. et a. Nature,1997; 387:878-880.

[3] Dingus B.L.,Catelli J.R. and Schneid E.J.,1997,Proc. 25th ICRC,30-32
[4] J.E.McEnery et al.,1999,Astro-Ph-9910549
[5] Xunxiu Zhou,et al.,2003,Proc.28th ICRC,2757-2760
[6] Adriani O et al. Nucl. Instr. and Methods in Physics Research,2002,A488(1-2):209-225
[7] A.Surdo,et al. 2003,Proc.28th ICRC,5-8
[8] http://www-ik.fzk.de/~heck/corsika/
[9] http://www.fisica.unile.it/~argo/analysis/argog/index.html
[10] Cui S W et al. HEP&NP,2005,29(1):62-67
[11] Huihai He,et al.,2003.Proc. 28th ICRC,773-776
[12] M.Abbrescia, et al., 1996, Proposal of the ARGO experiment
[13] J.R.Catelli,B.L.Dingus,E.J.Schneid:AIP Conf.Proc.，1997，309：428
[14] K.Hurley et al.,Nature.,1994,372: 652-661
[15] Salamo,M.H. and Stecker,F.W.,ApJ,493-547(1998)