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Search for Gamma Ray Bursts at Sierra la Negra, Mexico

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We present results from a search for GRBs in the energy range from tens of GeVs to one TeV with an array of 6 water Cherenkov detectors located at 4500 m a.s.l. as part of the high mountain observatory of Sierra la Negra (N18^{o}59.1, W97 ^{o} 18.76) near Puebla city in Mexico. The detectors consist of light-tight cylindrical containers of 1 m ^{2} cross section filled with 750 l of purified water; they are spaced 25 m and have a 5” photomultiplier (EMI model 9030A) facing down along the cylindrical axis. We describe preliminary experimental results obtained by using a single-particle counting technique for a data taking period of one month.

1. Introduction

Gamma Ray Bursts (GRBs) are probably the strongest phenomena in the Universe. They are extremely energetic explosions that produce up to 10^{53} ergs in one second. They were discovered by military satellites in the 60´s, but their study started much more recently, when, in 1991, NASA launched the *Compton Gamma-Ray Observatory* (CGRO) to detect and study GRBs and other high energy phenomena. CGRO carried onboard 4 instruments: *BATSE, EGRET, COMPTE and OSSE*. In particular, *BATSE* detected more than 2700 GRBs with photon energies in the range from 20 KeV to 1 MeV. On the other hand, 7 GRB events have been observed with photon energies greater than 30 MeV by *EGRET,* with 6 of them having photons with energies greater than 1 GeV. The event named GRB940217 had the highest energy photon, 18 GeV [7]. It is important to mention that so far *BATSE* and *EGRET* have not observed a cut-off in the GRB energy spectrum; this suggests that the spectrum may extend up to high energy components, with TeV photons, or even greater as some models predict [4,10]. In this work we are interested in detecting GRBs with energies in the 10 GeV to 1 TeV range. For this purpose we use a ground-based detector array initially operating in a single-particle counting mode. We describe this water Cherenkov detector array located at the high mountain observatory of Sierra la Negra and we also describe this array´s capabilities in comparison with other ground-based observatories.

2. Ground-Based Experiments

Since gamma rays coming from outside the Earth can not penetrate the atmosphere, it is necessary to use satellites to detect them. However, as the photon energies increase, the photon flux decreases as a power law. Therefore, to detect small fluxes of gamma radiation or high energy photons in the range of GeV to TeV is necessary to construct more sensitive detectors with larger areas. Satellites with large collecting areas become impractical due to their cost. However, it is possible to detect gamma-ray photons with inexpensive ground-based experiments of large area. A simple possibility is to observe regular patterns in the rate fluctuations of single-particle counters, these regularties are signals for secondary particles produced by gamma photons interacting at the top of the atmosphere. Ground-based experiments around the world that are searching GRBs are: Chacaltaya at 5200 m a.s.l. in Bolivia [5]; Argo at 4300 m a.s.l. in Tibet, China; Milagro at 2650 m a.s.l. in New Mexico, USA; the Pierre Auger Observatory at 1400 m a.s.l. in Malargue, Argentina [1] and Sierra la Negra at 4550 m a.s.l.in Mexico. Of all these experiments only a prototype of Milagro called Milagrito has reported the possible detection of signals associated to a GRB, GRB 970417 [2]. Milagro is the largest area (60mx80m) water Cherenkov detector capable of continuously monitoring the sky at energies between 250 GeV and 50 TeV. Although designed to study ultra high energy cosmic rays, the Pierre Auger Observatory is also a very competitive high energy GRB ground-based detector due to its large area and the good sensitivity to photons of its water Cherenkov detectors.

The sensitivity increases strongly with the altitude of observation. Showers generated by primary photons of the same energy increase the size (number of secondary particles) with altitude. As an example, the mean number of particles generated by a photon of 16 GeV at 5200 m is 1 while at 2000 m (altitude of the EAS TOP experiment) is only 0.03, i.e., the sensitivity at Chacaltaya is better even though its detecting area (48m2) is considerable smaller than that of EAS·TOP (350m2).

3. Sierra la Negra Experiment

The high montain array prototype of Sierra la Negra is located near Puebla city, Mexico, at 4550 m a.s.l . At present, the array consists of 5 water Cherenkov tanks located at the vertices of a 25 m side penthagon, and one more placed only 14 m away from another to allow the possibility to detect secondaries in coincidence between them. Each tank has a cross secction of 1 m^2 . The tanks are filled with 750 l of ultra-pure water. The interior of each tank is covered with tyvek and all of them contain a PMT to collect the Cherenkov light produced in the water. The PMT signals are read out by a DAQ system that measures the rates of secondary particles each second. In the Sierra la Negra array we are sensible to GRBs of energies E > 200 GeV with this prototype and the single-particle technique represents only our first aproach to detecting GRBs. Figure1 shows that with water Cherenkov detector and a fast digitization system we can separate the muon component from the electromagnetic component. Further steps planned will optimize the single particle technique method of detection with higher levels of coincidence triggers and shower reconstruction.

4. Sensitivity of Sierra la Negra to GRBs

GRBs can be observed with ground-based detectors if the secondary particles produced by their interactions with the atmosphere give rise to an excess in the counting rate that is significantly larger than the statistical fluctuations of the background. This excess can be in temporal coincident with satellite GRB detection, for example, *SWIFT*. Therefore, GRBs can be detected with a statistical significance of n standard desviations if [9] $N_s/\sigma_b > n$, where N_s is the signal detected by the array. This signal is proportional to the area and to the flux of secondary particles; σ_b is the background noise and goes as the square root of all the secondary particle produced by cosmic rays. In general, n is taken as 4.

The background variation with the altitude is described in Vernetto [9]. According to this description, the background at Sierra la Negra altitude corresponds to ~1600 part/ s/m^2. Using this number and $N_s/\sigma_b > n$ we can calculate the minimum flux of particles detectable by an array of a given area located at a given altitude produce by a GRB. Likewise, for Sierra la Negra this minimum flux detectable correspond to about 70 part/ m^2 for an area of 6 m^2. The same calculation for Chacaltaya in Bolivia, which is the highest altitude array in the world , 5.2 Km a.s.l. gives a minimum flux of ~26 part/ m^2, for an effective area of 48 m^2 and a background of ~2100 part/s/ m^2 (Figure 3 in Vernetto [9]). By the geographic coordinates of Sierra la Negra (N 18º59.1, W 97º18.76) we have the advantage of the almost zenithal transit of the Crab Nebula every day. The Crab Nebula is a constant source of gamma rays that can be used as a calibrator [6]. The estimated flux from this source is 2.68 X 10^{-7} $E^{-2.59}$ photons/s/ m^2 /TeV [2,3] . The Crab Nebula has been detected at high energies by ground-based experiments as Milagro located at New Mexico (2630 m a.s.l.) and ARGO located in the Tibet, China (4300 m a.s.l.). The minimum energy of photons required to produce the flux of secondary particles mentioned above is ~240 GeV for Sierra la Negra and ~195 GeV for Chacaltaya.

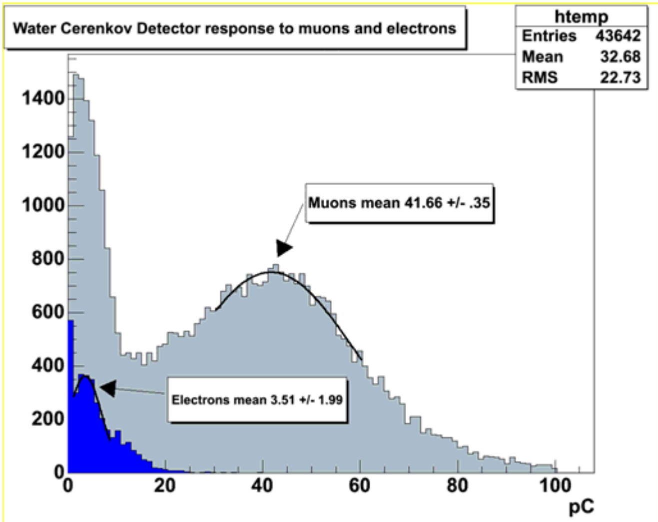

Figure 1. Water Cerenkov detector response to muons and electrons. The deposited charge ratio from muons and electrons is 41.7/3.5 =12, which is consistent with muon energies around 1 Gev crossing 70 cm of water and electons with energies around 10 Mev.

5. Data Analysis and Results

We present data taken by 3 water Cherenkov detectors that are already operating in Sierra la Negra. Figure 2 shows the distribution of the rate with an standard desviation 31 part/s/ m^2 and a mean rate of 514 part/s/ m^2 and the coincidence rate/sec for the two closer detectors. It is to worth to mention that this rate is about a factor of 3 smaller than that predicted by Vernetto [9] at the Sierra la Negra altitude (about 1600 part/ m^2 /s). This disagreement is due to the higher particle counting threshold in our detector at the initial runs. Out of the total background [9], aproximately 41 % corresponds to the electromagnetic component (electrons, positrons and photons), 33 % corresponds to the muon component and all the rest is due to the hadronic component. Notice that at low altitude places, < 3.5 Km, the muon component is dominant while at higher altitudes the electromagnetic component is dominant. After this analysis, and the experimental data from muon/electromangnetic separation (Sierra la Negra experiment section, Figure1), we fix a new threshold to include electromagnetic and muonic component. The new results are presented in Figure3.

According to our data , 4 estandard desviations corresponds to 196 part/s/ m^2 , then a GRB will be detected if it shows and excess in the counting of at least this number of single particles. Figure 3 shows the measured single-particle rate as a function of time for one of the water Cherenkov detector and and its distribution fitted by a gausian function We can appreciate a small variation in the rate counting due to the change of pressure during the night in agreement to expectations [8]. The time scale of these modulations are much larger than the typical time duration of a GRB and therefore, do not affect the GRB search.

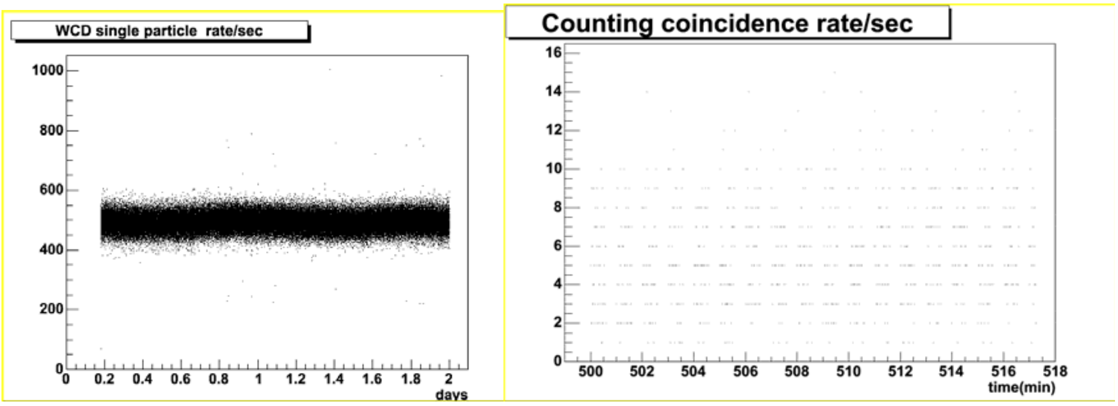

Figure 2. Single particle rate/sec for muons and high energy electrons(left). Coincidence rate/sec for the two water Cherenkov detectors with a separation of 14 m.

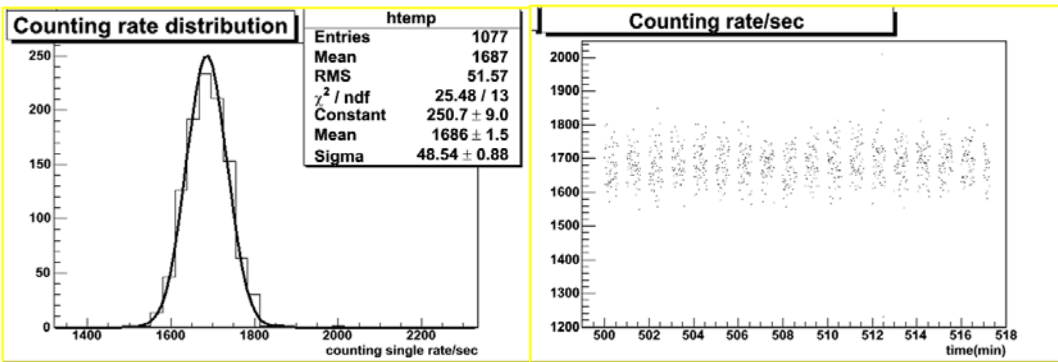

Figure 3. Rate distribution observed in Sierra la Negra with a mean value of 1686 part/ s/ m^2. The typical dispersion rms/mean was lower than 3%. Small variations in the counting rate can be observed (right).

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References

[1] D. Allard et al Proceedings of ICRC (2005)
[2] R. Atkins et al. ApJ, 533**,** L119, (2000)
[3] R. Atkins et al. ApJ, 595, 803, (2003)
[4] M. G. Baring, astro-ph/9711256
[5] R. Cabrera et al. A&A 138, 599, (1999)
[6] A. M. Hillas et al., ApJ, **503**, 744, (1998)
[7] K. Hurley et al., Nature **372**, 652–654, (1994)
[8] A. Mahrous et al. Proceedings of ICRC (2001), P 3477
[9] S. Vernetto astro-ph/9904324
[10] M. Vietri astro-ph/9705061