Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008
Vol. 2 (OG part 1), pages 491–494

30TH INTERNATIONAL COSMIC RAY CONFERENCE

ICRC'07
Mérida, México

Instrumentation and performance of the water Cherenkov detector array at Sierra La Negra site

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Abstract: We present results from the operation of the high mountain array of 4 water Cherenkov detectors located at 4550 m. a.s.l. located at the Sierra Negra mountain (N 18 59.1, W 97 18.76) near Puebla city in Mexico. The detectors consist of 4 light-tight cylindrical containers of 4 m^2 cross section. The vertices of the array form a triangle with one detector in the middle and an average spacing of 25m between neighboring detectors. The detector containers are filled with 5000 l of purified water and have one 5" photomultiplier (EMI model 9030 A) facing down along the cylindrical axis. The acquisition electronics consists of scalers counting the number of particles every 5 ms, and a digital oscilloscope used to fully record the traces of the four signals coming from the water Cherenkov detectors. The trigger signals correspond to photon candidates coming from a user-selected direction with an uncertainty lower than one degree. This detector array and the data-taking have been stable for the last six months; in this paper we describe the data and preliminary analysis corresponding to this period.

Introduction

Since gamma rays coming from outside the Earth can not penetrate easily 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, in order to detect small fluxes of gamma rays or high energy photons in the range of GeV to TeV it is necessary to construct sensitive detectors with large areas. Satellites with large collecting areas become impractical due to their high cost. However, inexpensive ground-based observatories of large area make it possible to detect the relativistic secondary particles induced by the interaction of GeV to TeV gamma-ray photons with the molecules of the upper atmosphere. Currently, a handful of ground-based observatories around the world are searching for gamma ray bursts (GRBs): Chacaltaya at 5200 m a.s.l. in Bolivia; Argo at 4300 m a.s.l. in Tibet; Milagro at 2650 m a.s.l. in New Mexico, USA; the Pierre Auger Observatory at 1400 m a.s.l. in Malargue, Argentina and Sierra La Negra at 4550 m a.s.l. in Mexico. Of all these observatories only the prototype of Milagro, called Milagrito, has reported the possible detection of signals associated to a GRB, GRB 970417 [1]. Milagro is the largest area (60m x 80m) water Cherenkov detector capable of continuously monitoring the sky at energies between 250 GeV and 50 TeV. Although it was designed to study ultra high energy cosmic rays, the Pierre Auger Observatory is also a competitive high energy GRB ground-based observatory due to its large area and the good sensitivity to photons of its water Cherenkov detectors [2-3].

We present results from the calibration and operation of the high mountain array of 4 water Cherenkov detectors located at 4550 m. a.s.l. in the Sierra La Negra mountain (N 18^o 59.1', W 97^o 18.76') near Puebla city in Mexico. The detectors consist of 4 light-tight cylindrical containers of 4 m^2 cross section. The vertices of the array form a triangle with one detector in the middle and an average spacing of 25m between neighbouring detectors as shown in Figure 2. The detector containers are filled with 5000 l of purified water and have a 5” photomultiplier (EMI model 9030 A) facing down along the cylindrical axis. The acquisition electronics consists of scalers counting the number of particles every 5 ms; a digital oscilloscope is used to fully record the PMT traces of the four signals coming from the water Cherenkov detectors. The trigger signals correspond to photon candidates coming from a user-selected direction with an uncertainty lower than one degree. In this paper we describe the data and preliminary analysis corresponding to the last six months when operation and data-taking have been stable.

The water Cherenkov detector array

Optimization of the cost/area detection has led us to deploy commercial 5000 litter containers of 2.2m diameter and 1.4m height.

Figure 1: The water Cherenkov detectors consist of light-tight cylindrical containers of 4 m^2 cross section.

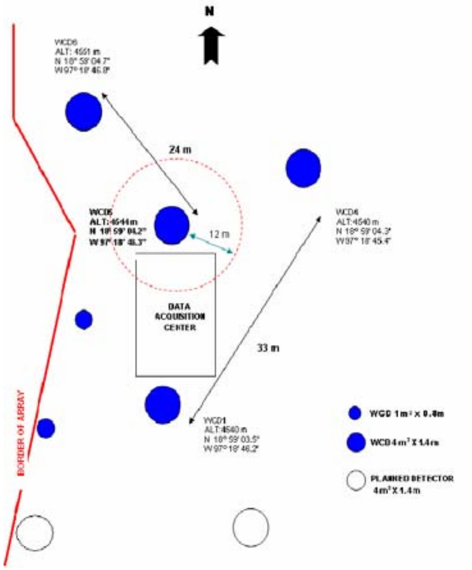

Figure 2: The detector array consists of 4 water Cherenkov detectors spaced as shown. The typical separation between detectors is 25m. Two additional smaller containers are also included.

In order to calibrate our detectors, we used a muon telescope with scintillation paddles above and below one of our detector the water Cherenkov detectors.

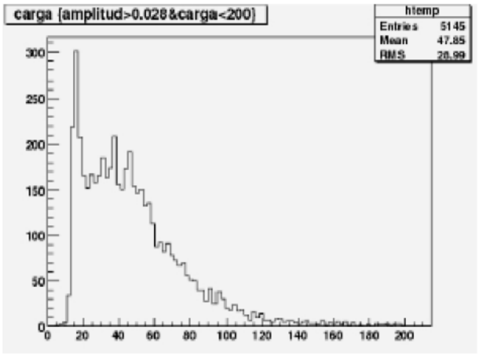

Figure 3: Calibration histogram for one detector obtained with a digital oscilloscope and a muon hodoscope.

We get histograms for the amplitudes and the integrated charges out of the PMT traces for vertical muons, as shown in Figure 3.

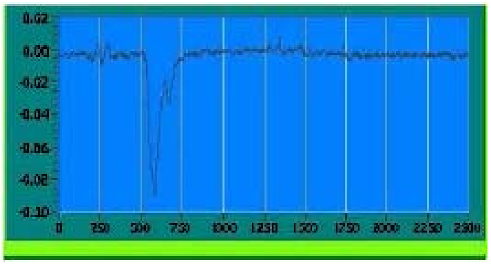

Figure 4: An example of the temporal profile of a vertical muon. The scale on the vertical axis is in volt and the horizontal scale in nanosecond.

We used these results to select the optimum threshold to get the number of particles detected by each detector every 5 milliseconds. To readout the data we are using one of the electronics local stations left over from the engineering array phase of the Pierre Auger Observatory [4].

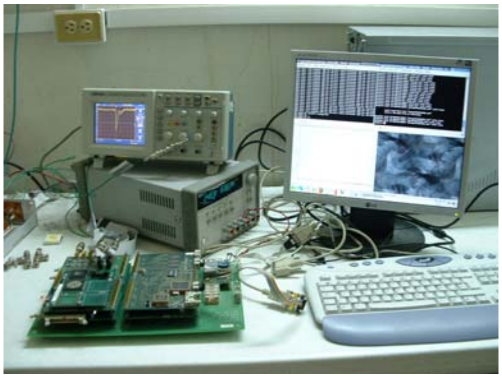

Figure 5: Readout electronics for the Sierra La Negra Array.

Results and Conclusions

As monitoring system we use scalers with different threshold levels. The average number of pulses for 5 millisecond intervals is evaluated in order to measure the mean value and the rms deviation. The average is evaluated with sixty thousand entries. The plot shown in Figure 6 corresponds to one day (January 25th, 2007). The average was taken for the lower threshold selected. As we can see the average is stable between 31 and 32 pulses each 5 millisecond period.

Since the detector system exhibits good stability, the low threshold scalers are used also to search for GRB's that have a component of high energy photons arriving at less than 30 degrees from the zenith al Sierra La Negra array. The results of several months of searches are discussed in the LAGO contribution to this conference.

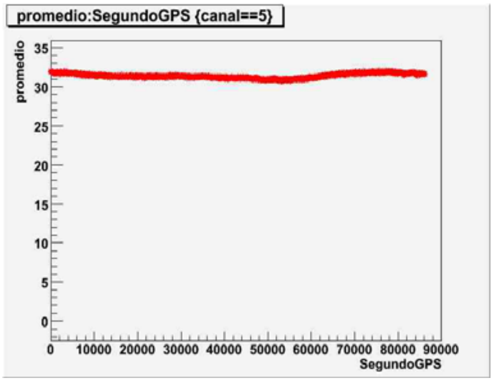

Figure 6: Average number of pulses for a 5 millisecond period. The average is evaluated with sixty thousand entries. The plot corresponds to one day (January 25th, 2007).

We use the precise time stamps (based on the GPS system) associated to the detection of the signals from each of our water Cherenkov detectors to determine the arrival direction of the extensive air showers with an accuracy of less than one degree. Since our calibration procedure provides the amplitude average of vertical muons, we are able to reject the showers with high muon contents (at least two of the detectors with higher signals. In addition, we use Monte Carlo methods along with measured fluxes of high energy photons from known astrophysical sources, such as the Crab Nebula, to study the efficiency of our observatory to detect these objects. For instance, theoretical calculations along with experimental measurements allow us to estimate a period of 6 months to detect the photon signal coming from the Crab Nebula with five standard deviations.

Acknowledgements

We thank INAOE, LMT and especially Eduardo Mendoza for all the technical facilities at Sierra la Negra that allow us to carry out this work.

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