HIGH ALTITUDE WATER CHERENKOV DETECTOR PERFORMANCE

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Abstract: Experimental data on the temporal profile of signals from a Water Cherenkov Detector (WCD) of the CHARM Observatory (High Altitude Cosmic Radiation Monitor) are presented. CHARM is a hybrid array of Water and Air Cherenkov detectors located at 4300 meters under construction. The observatory is designed to study high-energy cosmic rays in the range of 10^{16}-10^{18} eV, with the advantage of observing the maximum of the secondary particles shower generated by cosmic rays. This paper presents the results of temporal structure studies of two Water Cherenkov Detectors, one at 2200 m (at laboratory) and another one at 4300 m (at the CHARM site). We study the time rise parameter, peak amplitude and integrated charge of the signals obtained from the detector. This study is performed using secondary particles from the background. In both detectors we are using a photomultiplier tube (EMI-9530A) on the top. The WCD containers are covered in the inner walls with a high UV reflectivity material called Tyvek and filled with pure water.

Keywords: New experiments, WCD, calibration, performance.

1 Introduction

According to experimental data from Kaskade [1], at energies above $3{\cdot}10^{15}$ eV, there is a decreased flow of protons and an increase in heavy nuclei of primary cosmic rays. This change in the count rate reaches the heavy component of cosmic rays with energies above $5{\cdot}10^{17}$ eV, decreasing the flow of heavy nuclei. Currently, it is not yet clear what causes the breaks in the experimental energy spectrum of cosmic rays. What it is expected is that to energies higher than 10^{17} eV, cosmic rays from other sources such as extragalactic, should contribute the most on primary cosmic rays flow.

The CHARM observatory is a hybrid array of Water and Air Cherenkov detectors under construction, located at the Pico de Orizaba volcano in Mexico. The principal goal of this observatory will be to determine the origin and mass composition of the primary particles of the cosmic rays with energy between 10^{16} to 10^{18} eV using the capabilities and advantages of its location.

Using the WCDs, we analyze their performance at two different altitudes, one at 4300 m a.s.l. (at CHARM site) and another one at 2200 m a.s.l. (at the laboratory) whit the goal to study differences on the temporal profile, peak amplitude and integrated charge of signals from two Water Cherenkov Detector (WCD) at different altitudes.

2 The array

CHARM is a high altitude observatory near Puebla City in Mexico. The observatory is located at 4300 m.a.s.l and at (N 18°59:1, W 97°18:76). The detectors will consist of 25 light-tight cylindrical containers of $10 m^2$ cross section filled with 12000 l of purified water, covered in the inner walls with Tyvek. Those detectors will be distributed in 3 hexagonal rings, with 330, 600 and 866 m apothem size respectively and rotated by 60° to have a more dense array. In the first stage the array have six tanks, in one of then was performed the measurements of the background. Each station consist in a PMT including the DAQ and power supply electronics. In the CHARM site, the electricity is generated by a aeolic generator and the water for the tanks is collected from rain or snow.

On the other side, in the Campus of the University of Puebla (at 19°N, 90°W, 2200 m.a.s.l.) we have one water Cherenkov detector of $10 m^2$ cross section, filled with 12000 l of purified water, covered with Tyvek, a PMT including the DAQ and power supply electronics [2]. The study was conducted using a photomultiplier tube (EMI-9530A) on the top looking downwards.

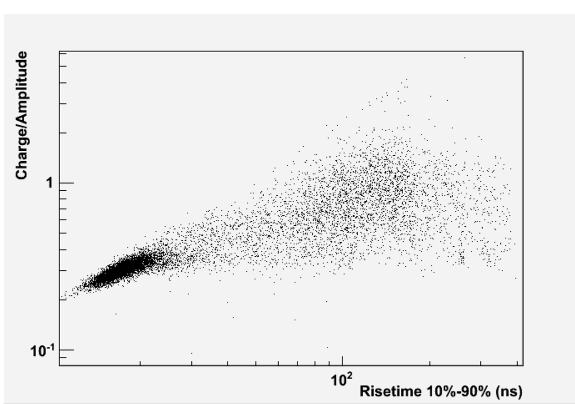
In this work we presents the results of calibration and temporal structure studies of two Water Cherenkov Detectors, one at 2200 m.a.s.l. (at laboratory) and another one at 4300 m.a.s.l. (at the CHARM site).

Figure 1. The CHARM observatory at 4300 m.a.s.l.

3 Results and discussion

A method based mainly on single-particle rates was used as a simple first estimator of the operation stability. The typical dispersion rms/mean was lower than 2% for the Water Cherenkov detectors at both sites. More complex monitoring can be done by using bi-dimensional correlation plots, Charge/Amplitude vs. risetime 10–90%, as shown in figure 2a for the Water Cherenkov Detector at the CHARM site and figure 2b for the Water Cherenkov Detector at the laboratory.

The plots 2a and 2b, can be used to separate many of the physical processes occurring inside WCD. By operating the WCD with a low threshold level was possible to detect single electrons and muons from the background as observe in the correlation plots of Charge/Amplitude vs. rise time 10–90%.



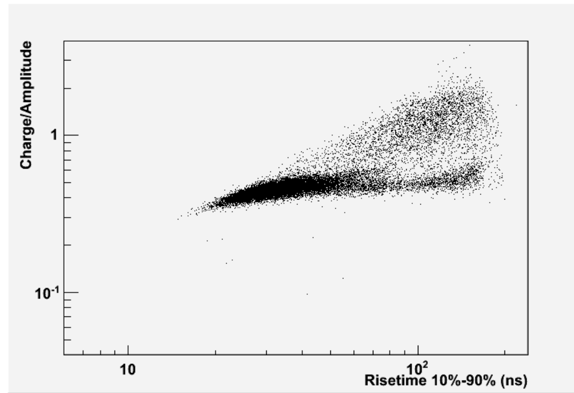
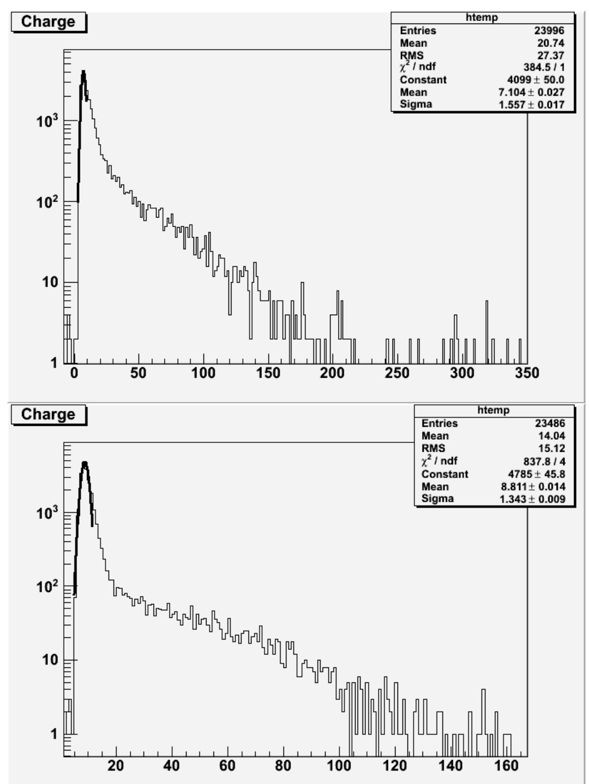


Figure 2. Correlation plot of Charge/Amplitude vs. rise-time 10–90% for the Cherenkov detectors; the figure 2a (first) is the response WCD detector at the CHARM site and fig 2b (second) is for WCD at laboratory.

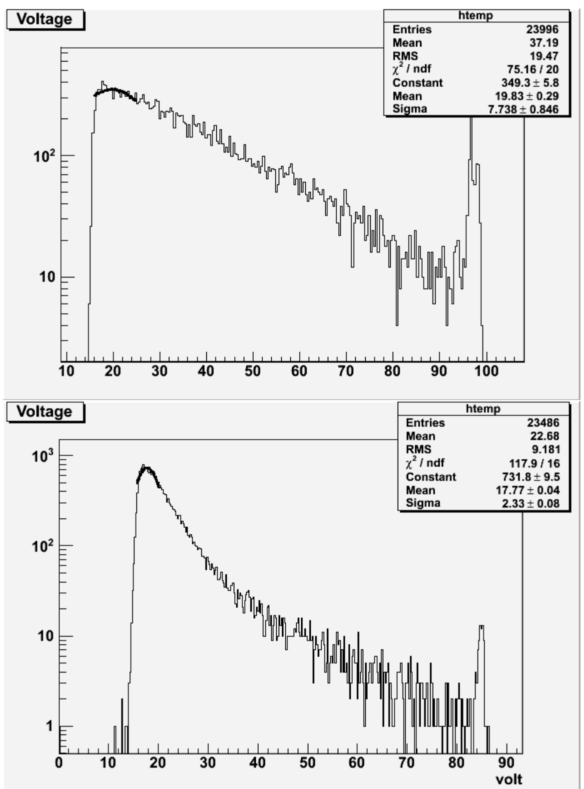
In the fig. 2a, is visible an accumulation of events in the region 0.2 < charge/amplitude < 0.4 and rise times<30ns that corresponding to isolated electrons, and at region charge/amplitude around 1 and rise time around 100 ns corresponding to single muons. In the figure 2b that corresponding to WCD at the laboratory, is clearly visible the increase in the number of electrons in the region charge/amplitude around 0.4 and 20 < rise times<60 ns, not so, the number of single muons is practically the same as it was registered by the WCD located at CHARM site.



The charge distribution. The figure 3a is the response detector at the CHARM site and the figure 3b for detector at laboratory

Calibration of the detectors allows us to convert the electronic signals measured in each detector into the number of particles in the Extensive Air Showers reaching the detector. We consistently use the natural flux of background muons and electrons to calibrate our detectors. We used dedicated calibration runs to obtain the spectra of charge depositions for secondary cosmic ray events triggered by a simple amplitude threshold, as shown in figure 3a and 3b.

The second curve in the histogram of each plot on the figures 3a and 3b corresponds to the mean charge deposited by particles crossing the detector in arbitrary directions, while the first peak corresponds to corner-clipping muons and also EM particles that produce smaller signals. The events at the end of the drawing correspond to small showers registered by the WCD



The amplitude of signals. The figure 4a is the response detector at the CHARM site and the figure 4b for detector at laboratory.

The amplitude of the signals produced into the WCD can be seen in the histogram of voltage generated in the figures 4a for the detector located at the CHARM site and the figure 4b for detector at laboratory.

The signals of crossing muons of the water Cherenkov detectors are proportional to their geometric path lengths. The first peak corresponds to amplitudes of signals of corner-clipping muons and EM particles, clearly visible in the figure 4b, and not in the figure 4a. It is possible to note one second curve in the histogram of the figure 4b as corresponds to the mean amplitude by particles crossing the detector in arbitrary directions. The event's distributions in the figures 4a and 4b at the end of the drawing correspond to small showers registered by the WCD that produce large signals.

4 Conclusions

In this work we report the results of the temporal structure studies of two Water Cherenkov Detectors, one at 2200 m (at laboratory) and another one at 4300 m (at the CHARM site). We study the rise time parameter, peak amplitude and integrated charge of the signals obtained from the detector WCD. As seen in the graphs, it is possible to differentiate the work cycle in both detectors.

5 References

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