Study of temporal structure of signals in an Auger Water Cherenkov detector prototype.

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Abstract

Experimental data on the width of temporal signals from a Water Cherenkov Detector (WCD) prototype for the Pierre Auger Observatory are presented. In the domain of signals induced by single muons the width is dominated by the detector properties (”instrumental” width). The same follows for the width of signals of Extensive Air Showers (EAS) with small core distances. The small percentage of signals induced by the EASs with core distances large enough, has experimental width wider than instrumental. The experimental distribution of EAS signal widths is presented. This result is used to optimize the WCD local trigger that should reject rate of the low energy EASs at small core distances. Events with width $T_{50\%} > 25$ ns ($T_{50\%}$ is the interval at which the signals integral charge rises from 10% to 50%) were selected on event-by-event basis for further analysis of the signal temporal structure.

1 Introduction:

The Puebla University water Cherenkov detector (WCD)- the prototype of the Auger array particle detector- is being tested at the Puebla City elevation of 2.2 km. Along with measurements of the WCD energy deposition spectrum (see [1]) the temporal parameters of the signals were investigated with the aim of optimizing the Auger array trigger conditions, one of which is the threshold on the signal width. It is also interesting to check the possibility of getting additional information on the EAS parameters via the temporal width and the temporal structure of the WCD pulses. The Auger array will comprise an unprecedent large area of water Cherenkov detectors. The ”locally” recorded information in every WCD will in principle contain new data on EAS of energies lower than that of the EAS recorded by the Auger trigger (the Auger array energy threshold is expected to be of about 10 EeV).

2 Experimental results

The WCD signals (the sum of signals from three Hamamatsu PM tubes of type R5913) are recorded by a digital oscilloscope (Tektronix TC220) connected to a Pentium PC. The signals are selected by a given threshold peak amplitude. Based on a LabView [2] program we calculates on-line the integral signal charge Q as it encreases in time. Two signal widths are introduced: $\mathrm{T}_{50\%}$ ($\mathrm{T}_{90\%}$) is the time interval in which Q rises from 10% and 50% (90%) of its maximum value. Examples of signal width distributions are presented in Figure 1 for signal with integral charge Q$\geq$ 3 VEM (Q in units of vertical equivalent muons, VEM, see [1]). These distribution were obtained from the 14,052 signals that from a total of 200,000 satisfied the threshold condition. For this rather low threshold, Q$\geq$ 3 VEM, the ”instrumental” width dominates. The instrumental with, T_{inst}, is determined by the detector properties (water tank size, water transparency, reflection coefficient of the tank bottom and walls etc). For the Puebla prototype the instrumental width distribution $T_{50\%}$ ($\mathrm{T}_{90\%}$) is peaked around 18 (80) ns. The signal rise time is sharp (of about 10 ns) as it is determined by the fast first reflections of the Cherenkov light from the white tank sides and by the fast response of the R5912 tubes. The ”decay” part of the signal is longer as it is determined by the longer process of continuos light reflections. The important feature of the experimental width distribution is a rather sharp cut off of the instrumental part of the distribution: signals with width $\mathrm{T}_{50\%} > 25$ns ($\mathrm{T}_{90\%} > 100$ ns) have a flat width distribution.

This sector is the subject of our investigation. In Figure 2 the width distribution obtained in a 200 hour run is presented for the charge threshold $Q > 10$ VEM. Events with $Q > 10$ VEM are mostly EAS events (see [1]). The experimental distribution may be compared with the distribution expected for EAS signals selected by a given WCD energy deposition threshold. The expected distribution was derived from the EAS core distance distribution presented in [1] assuming that the WCD signal width depends on core distance R as approximated by Linsley,

$$T_{50\%} = 2(1 + R/30)^{1.6} \tag{1}$$

where R is in m and T is ns. T values in this formula are normalized to Watson and Wilson data [3] on the width of WCD signals in EAS of zenith angles $\theta < 40^o$ at R=300-600 m. The experimental percentage of signals with width $T_{50\%} > 25$ ns among all signals with $Q \geq 10$ VEM is of about 1% -close to what is expected for EAS events. The shape of the experimental width distribution presented in Fig. 2 agrees with the expected one (within the statistical errors of the experiment). For near vertical EAS ($\theta < 40^o$) the final selection criterion in the Auger array is: the width threshold for signal coincidences in neighboring WCDs separated by distance 1.5 km (core distances R>0.5-1 km)is $T_{50\%} \simeq 100$ ns. With this width selection criterion and energy deposition threshold Q=1-3 VEM the event rejection factor by the local WCD trigger in the Auger array is larger than 10^3. If near horizontal showers ($\theta > 60^o$) have to be also searched and effectively selected then the criterion on the signal width should be as loose as possible (remark of A. Watson at the Morelia Auger meeting, February 1999). From the present experiment it follows that the threshold $T_{50\%}$ = 25 ns is the optimal value. This value is below the widths expected for WCD's triggered by EAS of zenith angles $\theta = 60 - 70^o$ and the WCD trigger rejection factor of useless events is still high enough (10^2). Summarizing the data of the present work and the data [1] on the energy deposition distribution in WCD we suggest the following criteria for the Auger array event selection in every WCD: $Q > 1$ VEM and $T_{50\%} > 25$ ns. The local rate of events selected by those criteria is less than 20 Hz- low enough for use in the Auger array data acquisition system.

Events with width $T_{50\%} > 25$ns and $Q \geq 20$ VEM were selected for further analysis on the event-by-event basis. The high energy deposition threshold was chosen to minimize the statistical fluctuations in arrival time of the detected particles. Every selected oscilloscope trace was checked by eye in search for the pulses with more than one peak (structure pulses).

The second peak should be separated from the main one by a "valley" wider than 10 ns (the digital oscilloscope has the time bin equal to 2 ns). The structure pulses were grouped in two classes: in events of the 1-st class the secondary peak arrives in the vicinity of the "rise" time of the main peak (in an interval of 20 ns from the beginning (Q=10%) of the pulse); in events of the second class the second peak arrives after the main peak. Examples of structured pulses are presented in Figure 3. The secondary pulses are narrow ($T \cong T_{inst}$), their peak values are much higher than 1 VEM: after substraction of the continuous pulse amplitude the average peak value is equal to 4 VEM. The probability to observe the structured pulse is of about 20%. The relation between events of the first and the second classes is 2:1. Taking into account the difference in time between the rise part and the decay part of the main pulse the probability to observe the secondary peak at the rise part is much higher ($\cong 8$ times higher) than at the decay part. This fact could be related to fluctuations in arrival time of EAS muons which arrive in average earlier than the EAS electrons and photons [4]. The present data are not statistically sufficient for final conclusions. For a better understanding of the structured pulse phenomenon the WCD operation in an EAS array capable to to fix the EAS core position and its arrival direction is very important. The detection and analysis of the structured pulses were started in the Haverah Park array [5] but no final conclusions were derived. The modern technology of digital oscilloscopy gives more precise data on the pulse structure and this direction of the experimental study is interesting.

References

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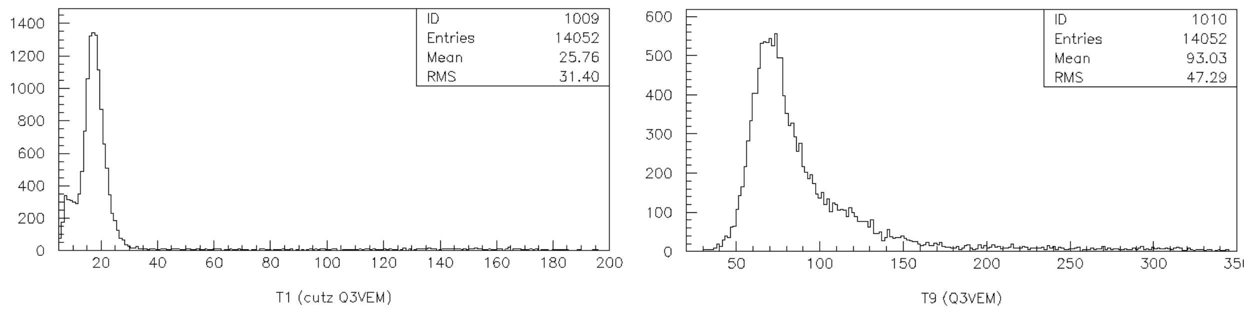

Figure 1: Signal width distributions for signals with integral charge $Q > 3VEM$. Left (rigth) plot correspond to $t_{50\%}$ ($t_{90\%}$) distribution

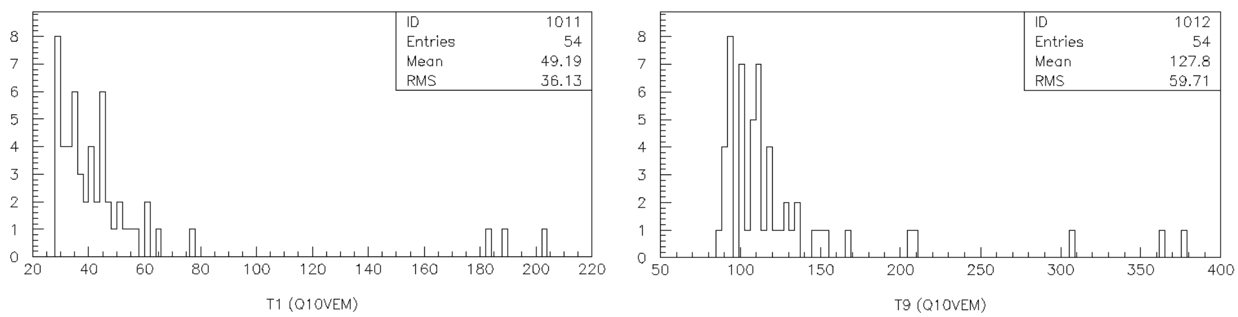

Figure 2: Same as Figure 1 but selecting events with T $t_{50\%} > 25$ns and integrated charge $Q > 10VEM$.

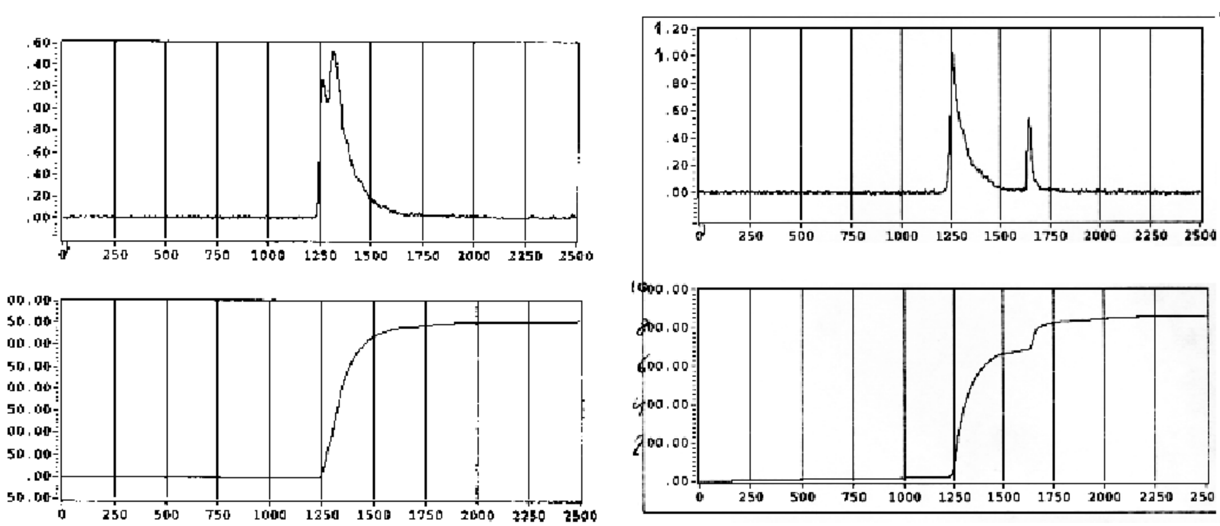

Figure 3: Two examples of recorded events with WCD structured signals. Left (rigth) picture shows signals with integral charge Q= 84 VEM (40 VEM), $t_{50\%} = 27.47$ ns. (25.32 ns.) and $t_{90\%} = 94.05ns.(161..41ns.)$