Array for measurement of the EAS pulse temporal structure at core distances R $>$ 500m.

Fernandez A.[1], **Garipov G.K.** [2], **Khrenov B.A.** [2], **Martinez O.** [1], **Salazar H.** [1], **Silaev A. A.** [2], **and Villasenor L.** [3]

[1] *Universidad de Puebla, Apdo. Postal 1364, Puebla,Mexico*
[2] *Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow, 119899, Russia*
[3] *IFM, Universidad de Michoacan, Apdo. Postal 2-82, 58040, Morelia, Michoacan, Mexico*

Abstract

Indications of the existence of temporal structure in the signals of Extensive Air Showers (EAS) of energies greater than 10^{17} eV at core distances of about 500 m (Atrashkevich et al ,1997, J.Phys.G, Nucl. Part. Phys., v.23,p. 237 and papers cited there) and the preliminary analysis of the Auger Water Cherenkov Detector (WCD) signal traces (Fernandez et al, this conference) stimulated us to intensify the temporal signal studies. For this aim we started to construct a hybrid array of one WCD plus an array of seven Air Cherenkov Detectors (ACD) one near the WCD and six in a regular hexagonal network centered on the WCD. Separation between ACDs is of about 750 m. The correlation in the temporal structure of the WCD signals and the position of the maximum obtained from the ACD array is studied. This hybrid array is located at the campus of the University of Puebla which is inside the city. Evidence that such an array can be successfully used to detect EASs with primary energies above 10^{16} eV in conditions of moderate to heavy light pollution environment such as the city of Puebla is presented.

1 Introduction:

The water Cherenkov detector (WCD)- the surface detector unit of the Pierre Auger Observatory array for the study of the extensive air showers (EAS) of extreme energies (primary energies E $>$ 10^{19} eV)- is capable to observe the temporal structure of the EAS signals [1]. The expected signals temporal profiles at very large EAS core distances R $>$1 km are structured due to wide spread in time of the arrival of the EAS particles (see calculations in [1]). At distances R $>$ 1 km the width of the arrival time distribution is more than 1 μs while the "instrumental" width of the particle signals (due to limited time of the Cherenkov light collection in WCD) is less than 0.1 μs. The EAS muons produce distinctly larger signals in WCD than EAS electrons or photons converting to electrons in the detector water. The detection of every photoelectron (p.e.) appearing in the cathodes of the PM tubes observing the detector water makes the temporal structure even finer- the width of 1 p.e. signal of the tubes used in our observations (Hamamatsu R5912) is of about 10 ns - and the "instrumental" width of the EAS electrons is also structured. From the WCD traces it is possible to obtain the information on the ratio of the muon to electron numbers and their arrival time distribution. It ha been shown in EAS model calculations that the ratio of muon to electron numbers and the arrival time distribution of muons, electrons and photons is sensitive to the primary mass [1] . In the Auger array the traces of the WCD signals will be recorded and by a further off-line analysis, the mass composition of the primary particles will be revealed. The litations in this approach arise from the fact that at comparatively small core distances R $<$ 1 km the number EAS particles arriving to a WCD is large and the signal becomes smooth (not structured) and more important,that muons are not separated in time from electrons (calculation results in [1] and also in the earlier work [2]). In contrast to those calculation results some experimental events observed in the Haverah Park WCDs had evident temporal structure [3]. In the scintillation detectors at core distances R=200-500 m in EAS of energies $10^{17} - 10^{18}$ eV the events with the unexpected temporal structure were detected (see [4] and works cited there). In the preliminary analysis of the profiles of signals in the WCD Puebla prototype [5], triggered by high EAS particle fluxes, structure in the pulses was also observed. In order to make a more extensive study of the structure of pulses in the WCD and in order to search for correlations of the parameters of the structured pulses with other EAS parameters we start to construct the EAS array around the WCD prototype of the Puebla University. For the location of the EAS core and for the measurements of the primery perticles energy an array of the air Cherenkov detectors (ACD) was selected. Additional information on the EAS development could be obtained if the air Cherenkov pulse profile would be measured and analyzed along with the WCD pulse profile. Below we present the description of the array, examples of the events registered simultaneously by the WCD and ACD and the status of the experiment.

2 Experimental array

One ACD is an open photomultiplier (PM) tube (in a real construction 3 tubes are operating in parallel) having a wide field of view for the registration of EAS air Cherenkov radiation.

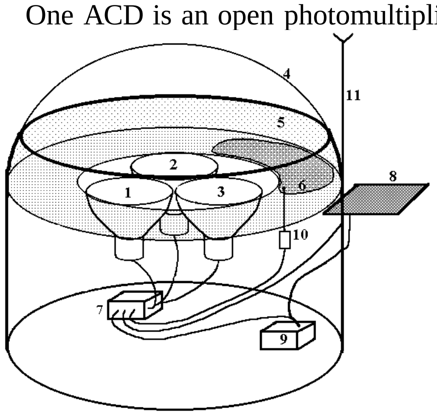

Figure 1: Air Cherenkov detector design. 1,2,3- PM tubes, 4- glass cover, 5- hard dark container, 6-shutter (only one shutter petal is shown), 7- electronics, 8- solar panel, 9- battery, 10- shutter motor, 11- transmitter antenna.

The ACD array is composed of six detectors placed around the Puebla University WCD prototype in a triangular network with separation L $\cong 750m$ between them.A seventh ACD is placed near the WCD. With this geometry the rate of showers producing large signals in the WCD (10-20 VEM) at core distances R=200-700 m (primary energies E $>$ 10^{17} eV) is high- 1 event per night. Cloudless nights in the Puebla city are frequent ($\cong 70\%$ of all nights) but the light pollution environment of the big city puts severe limitations on the open PM tube operation. For operation in conditions of high background light the tubes with the multialcali cathodes (FEU-110) were chosen. Operation of the FEU-110 tubes was proved to be stable at anode current up to 10 mA. The area of the FEU-110 tube is comparatively small (the operation cathode diameter is 70 mm) and for the efficient EAS registration 3 tubes are needed in every ACD. The detector sensitive area is 115 cm^2 and the aperture of view is equal to 1.5 *sr*.

In the range of wavelengths effectively registered by the FEU-110 tube the Puebla city background light intensity ν was measured by the method described in [6] at the roof of the Physics Department building. It was found that in good weather conditions (clear cloudless nights) the scattered city light has an intensity $\nu = 0.4$ photons/$cm^2.ns.sr$. With this background light the ACD noise σ in a time interval of 50 ns is equal to $\sigma = 20$ photo electrons (p.e.). In the first measurements of the EAS signals with the ACD prototype the signals selected above the level of 5σ =100 p.e. coincided in 95 % of events with the signals in WCD positioned 20 m below. The temporal profiles of the ACD signals recorded with the Tektronix TC 220 oscilloscope were regular with a width of 30-50 ns. After testing the ACD prototype the following ACD design was chosen. (Figure 1): three FEU-110 tubes are enclosed in a cylindrical container with a glass cover. The container shields the PMTs from the backgroud city lights. During the day the tube cathodes are protected from the direct sun light by the shutter. The ACD aperture is opened by an automatic shutter device when the background light is below a given threshold. During the day the solar panels charges the battery. At night the battery is the ADC power supply. The use of a preamplifier (with the gain of about 50) and the use of only 9 dinodes (the 10th is used as anode) allows to operate the PM tubes at low voltage and keeps the anode current of the 3 tubes below 1 mA in the presence of city lights. The electronics power consumption is about $3\,W$.

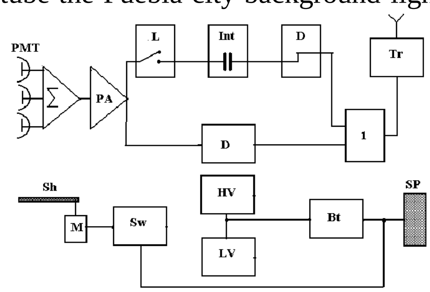

Figure 2: Block diagram of the detector electronics. PA- preamplifier, L- latch, Int- integrator, D - discriminators, Tr- transmitter, Sh- shutter, M- shutter motor, Sw- shutter switch, HV- high voltage supply, LV- low voltage supply, Bt -battery, Sp - solar panel.

The battery of 12 V should have a capacity of about 3 A/hrs to maintain the ACD operation during one night. The block diagram of the ACD electronics is shown in Figure 2. The signals from the 3 tubes are summed and amplified (in the bandwidth of expected frequencies) before coming to the registration circuit. The discriminator selects the EAS signals higher than a given threshold.
At the next step the discriminator pulse opens the linear latch and the tube signal goes to the integrator-comparator system which produces the output signal with the width proportional to the tube signal charge. The block diagram of the ACD electronics is shown in Figure 2. Signals from 3 tubes are summed and amplified (in frequency bandwidth of expected signals) before coming to the registration circuit. The starting time of the output signal is a measure of the arrival time of the EAS Cherenkov signal.

Every output signal is sent to the registration unit located in the central ACD. In the registration unit the coincidences of at least 3 ACDs in time interval 10 μs are selected and all 7 ACDs signals are recorded. In the central ACD not only the standard information (the arrival time and the charge) of the signal is recorded but also the temporal profile of the pulse is registered on one of two traces of the Tektronix oscilloscope. On the second trace the standard signals of all 7 ACD are recorded. The ACD address of the signal is coded by the amplitude of the signal. The computer connected to the Tektronix oscilloscope decodes the information from the 7 ACDs and analyses the profile of the central ACD pulse.

Two kinds of the communication lines are in progress now. a) The FM low power transmitter-receiver line on the frequency of about 1000 MHz and the band width of about 1-2 MHz and b)The light diode transmitter-PM tube receiver line (in the mode of the direct view line). The whole design of the ACD array is aimed for a fully automatic and autonomous long time operation. At the moment of preparation of the present paper three ACDs has been installed and tested. Examples of recorded events with signals in ACDs and WCD are shown in Figure 3.

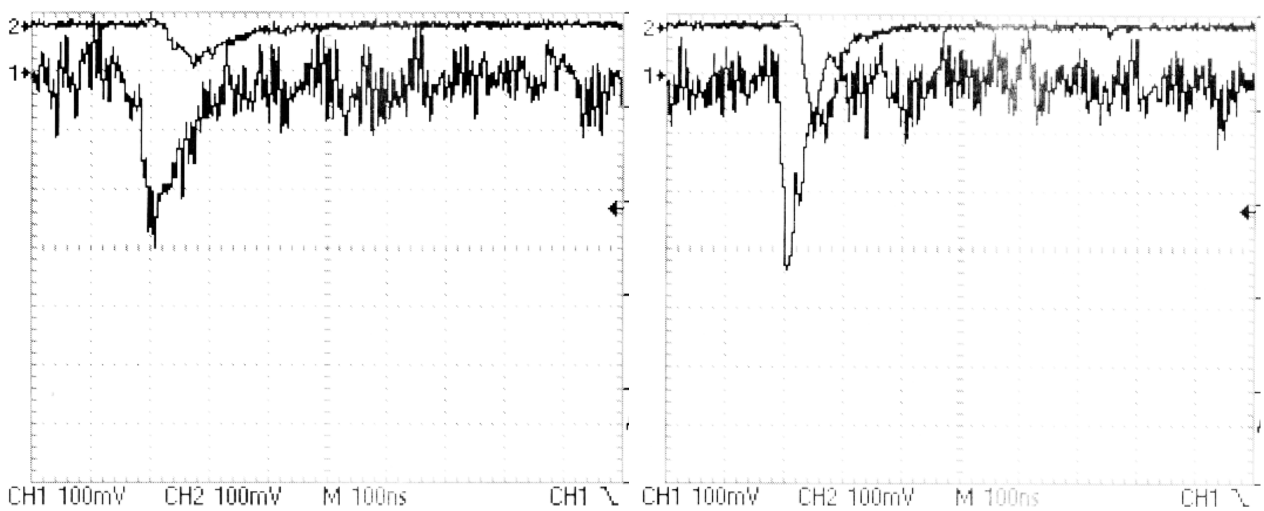

Figure 3: Two examples of recorded events with signals in ACD (channel 1) and WCD (channel 2) are presented. Left picture: signals without structure; right: an event with structured signals.

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