Performance of the Extensive Air Shower Array at the University of Puebla

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Abstract

We report on the performance of the EAS-UAP extensive air shower array after one year of operation. The array is located at 19N 90W, 800 g/cm^2; it was designed to measure the energy and arrival direction of primary cosmic rays with energies in the range of 10^{14} to 10^{16} eV. The array consists of 12 liquid scintillation detectors of $1m^2$ effective area distributed in a square grid of 20m that measure the lateral distribution function of the electromagnetic component and 3 large water Cherenkov detectors to help improve the measurement of the time profile of the signals.

1. Introduction

One of the main experimental problems in cosmic ray physics is the measurement of the primary composition at high energies and its possible variations around the knee. The EAS-UAP array was designed in order to contribute to the study of the lateral distribution of secondary particles of Extensive Air Showers in the region of $10^{14} - 10^{16}$ eV, and its dependence on arrival direction, primary energy and mass composition. The special location of this array (2200m above sea level and all the facilites coming from the Campus of the Puebla's University) could help to achieve a long time of operation, to have continuous improvement and to use it as an educational and training center. The EAS component to be measured is the electromagnetic one, obtaining the shower size N_e and the shower age s from the shape of the lateral electron distribution by fitting using the NKG function. Three Water Cherenkov Detector (WCD) to measure the signal profile and its relation with muons and electromagnetic particles in the EAS is operating as part of the detector array.

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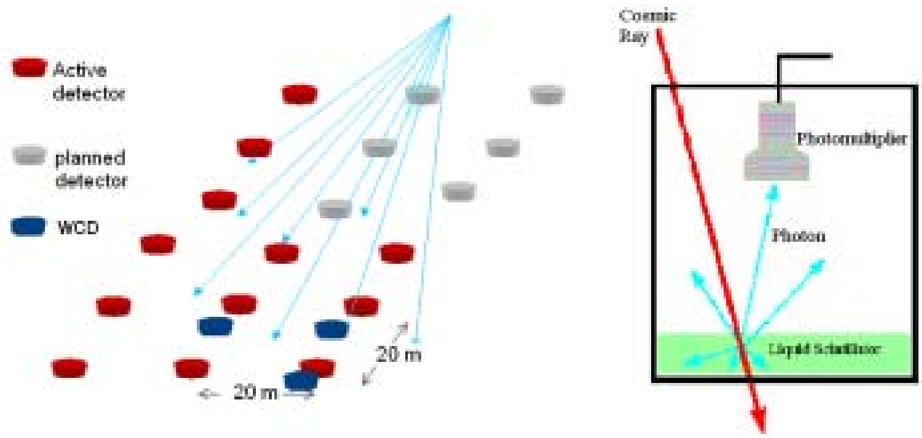

Fig. 1. EAS array layout (left) and description of a detector unit. (right)

2. Experimental setup

The array, located at the campus of the FCFM-UAP (19^o N, 89^o W, 800 g/cm^2), consists of 12 detectors distributed uniformly on a square grid with spacing of 20 m, as shown in figure 1. Each detector is composed of a light-tight cylindrical container with inner reflective walls filled with liquid scintillator up to a height of 13 cm; each container of 1 m^2 cross section equipped with one 5 inches photomultiplier (PMT) (EMI model 9030A) facing down 70 cm above the surface of the liquid, as shown in Figure 1. The trigger requires the coincidence of signals in the four central detectors, which form a rectangular sub-array with an area of 29 X 29 m^2 in order to assure that the shower core is located inside the array. The data acquisition (DAQ) system consists of a set of digital oscilloscopes that digitize the signals from the ten PMT's; the system is controlled by a PC running a custom- made acquisition program written in LabView.

The DAQ system makes on-line measurements of the integrated charge, arrival time, amplitude and width of the PMT signals of each triggered event. Individual rates are used to monitor the detectors. Left panel of the Figure 2 shows the measured single-particle rates of the running detectors.

Charge distribution of single-particle signals of one scintillator detector allows us to calibrate the array by means of the natural flow of single charged particles and henceforth allow us to convert the integrated charge generated by a given detector of a shower into the number of equivalent particles. In the case of the WCDs, the main component is a cilyndrical volume of clear water acting as a Cherenkov radiator viewed from above by three 20cm diameter fast photomultiplier tubes. A simple way to calibrate this detector is by using arbitrarily-crossing muons, as it turns out that their charge spectrum has a peak located at the same value as the correspondig to vertically-crossing muons (VEM) (F2, rigth panel).

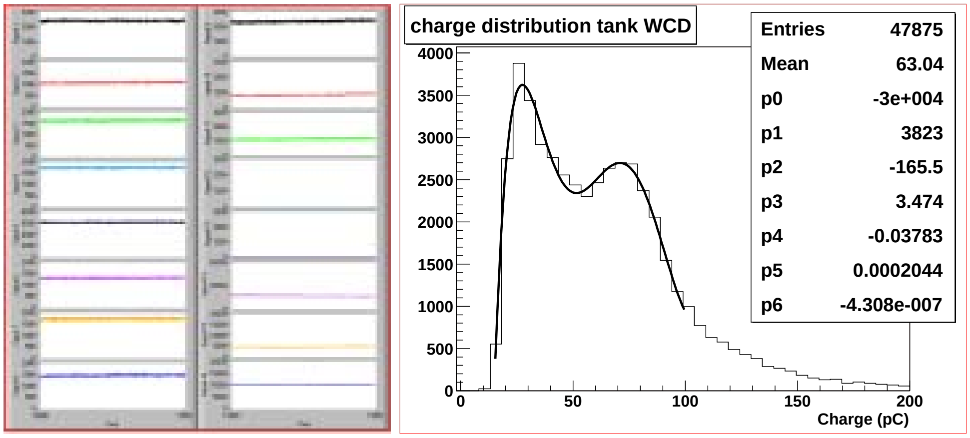

Fig. 2. Front panel of the monitoring system of the rate of ten operating detectors (left) and Single-muon spectrum of the WCD, used for calibration in VEM. (right)

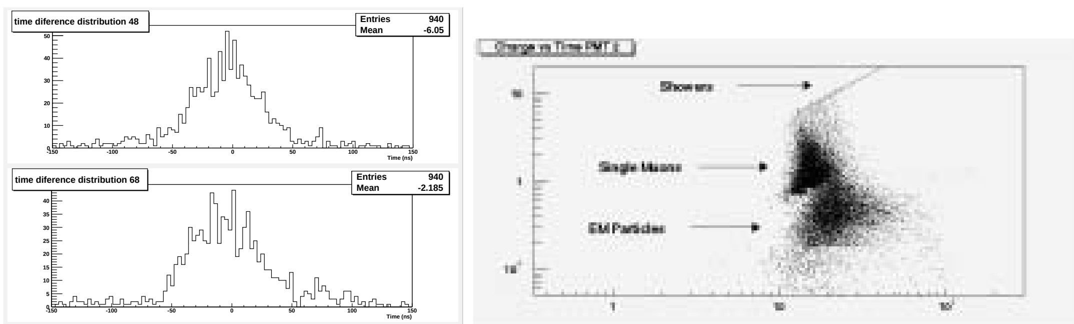

Fig. 3. Distribution of arrival times of the detectors triggering(Left)and Charge vs Rise Time of the WCD (right).

Angular accuracy. In order to estimate the angular resolution of the array, we assume the front of the EAS as a flat disk, approximately perpendicular to the direction of the primary cosmic ray. So, if the time of arrival of the first shower particles detected in two adjacent tanks of the array, separated by a distance d are s_1 and s_2, neglecting the curvature of the shower front, the direction of the incident particles n, is obtained by the relation $\sin\theta\sin\varphi = c/d(s_2 - s_1)$. Assuming that the errors in θ and φ are equal, we can therefore write the error in θ as,

$$\Delta\theta = \sqrt{2}[2(c/d\Delta s)^2 + \frac{1}{2}(\Delta d/d)^2 \sin^2\theta]^{1/2} \qquad (1)$$

Specifically, for $1m^2$ detectors separated by 20 m and a zenith angle of 20^o, a typical shower may have a particle density of $50/m^2$ at the core, and thus we obtain $\Delta\theta = 5.1^o$. Our results shows that the angular accuracy is less than 5.5^o

in the range from 20^o to 60^o degrees. Figure 3(left) shows the distribution of the time differences for two of the detectors triggering.

3. Discussion and results

During the first year of operation, we have mainly measured the arrival direction of showers and monitored the stability of the detectors. The single-particle rate of the detectors varies slightly during day time, due to temperature variations. The direction of the primary cosmic ray is inferred directly from the relative arrival times of shower fronts at the different detectors. The experimental zenithal distribution fits to the function $Acos^{6.6}\theta sin\theta$ [1].

We determine the number of particles in each detector using the single-particle charge spectrum discussed above. The core position, lateral distribution function and total number of shower particles (N_e) are reconstructed from the fit of the particles densities recorded by the different detectors. As electron lateral function we use the NKG expression. Finally, the shower energy is obtained by means of the relation $N_e(E_0) = 177.8 * E_0^{1.107}$ [2]. After one year of operation, the fitted slope for the differential particle spectrum was found to be 2.48, in agreement with the literature. Regarding the operation of the WCD, Figure 3 (right) shows clearly the separation of the muon events, the electromagnetic events and shower events, when the trigger correspond to a fixed low threshold for the signal in the WCD. Similar results have been reported at this conference(L. Villaseñor). Because the large volume of the detector, the width of the signal for electromagnetic and muon component are very similar.

4. Conclusion

An analysis of the EAS-BUAP data collected in the first year of operation, allows us to conclude that the detector array shows good stability and the data acquisition system is working well, while the analysis method we use provides results in good agreement with the literature. On the other hand continuos educationl and training work is doing with students. The authors are very grateful to FERMILAB for sharing equipment. This work was done with partial support of the CONACyT-G32739-E.

References

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