Electronics for the Extensive Air Shower Detector Array at the University of Puebla

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Abstract. In this paper we describe in detail the electronics cards that were designed to be the basis of the data acquisition system (DAS) of the extensive air shower detector array built in the Campus of the University of Puebla. The purpose of this observatory is to measure the energy and arrival direction of primary cosmic rays with energies around \(10^{15}\) eV. The array consists of 18 liquid scintillator detectors (12 in the first stage) and 6 water Cherenkov detectors (one of \(10\) m\(^2\) cross section and five smaller ones of \(1.86\) m\(^2\) cross section), distributed in a square grid with a detector spacing of \(20\) m over an area of \(4000\) m\(^2\). The electronics described here uses analog to digital converters of 10 bits working at a sampling speed of \(40\) MS/s and field-programmable gate array (FPGA).

Keywords: Cosmic rays; ADC; FPGA.

INTRODUCTION

The extensive air shower detector array at University of Puebla (EAS-UAP) was designed to measure the lateral distribution and arrival direction of secondary particles for EAS in the energy region of \(10^{14} - 10^{16}\) eV. The special location of the EAS-UAP array; 2200 m above sea level; and all the facilities coming from the Campus of the University of Puebla make it a valuable apparatus for the long term study of cosmic rays and at the same time an important training center for new physics students interested in getting a first class education in the field of cosmic rays in Mexico.

The energy spectrum of primary cosmic rays is well described by a power law, i.e., \(dE/dx \sim E^{-\gamma}\), over many decades of energy with the spectral index \(\gamma\) approximately equal to 2.7, and steepening to \(\gamma = 3\) at \(E = 3 \times 10^{15}\) eV. This structural feature is known as the "knee" of the cosmic ray spectrum.

The nature of the knee is still a puzzle despite the fact that it was discovered more than 46 years ago. The best handle to study the composition of primary cosmic rays by using ground detector arrays is the measurement of the ratio of the muonic to the electromagnetic component of EAS; Monte Carlo simulations show that heavier primaries give rise to a bigger muon/EM ratio compared to lighter primaries of the same energy.

The EAS-UAP array is expected to contribute to unveiling the mystery of the origin of the knee by detecting thousands of cosmic rays with energies around \(10^{14} - 10^{16}\) eV. In this paper we describe in detail the electronics cards that were designed to be the basis
of the data acquisition system of the EAS-UAP detector array.

EXPERIMENTAL SETUP

The EAS-UAP array has been described in detail elsewhere [1, 2, 3], it is located in the campus of the University of Puebla in Mexico (UAP) at 19° N, 89° W and 800 $gcm^{-2}$; it consists of 18 liquid scintillator detectors distributed uniformly on a square grid with spacing of 20 m, and six water Cherenkov detectors (one of 10 $m^2$ cross section and five smaller ones of 1.86 $m^2$). It uses both Cherenkov and liquid scintillator detectors to attempt a measurement of the muonic component of EAS [4, 5].

Data Acquisition System

At the moment the EAS-UAP array is using a temporary DAS based on a set of digital oscilloscopes that digitize the signals from the PMTs of the liquid scintillator and water Cherenkov detectors. All the digital oscilloscopes are connected to the GPIB port of a PC in a daisy chain configuration.

The system is controlled by the PC running a custom-made acquisition program written in a graphical language called LabView. We used commercial NIM modules to discriminate the PMT signals at a threshold of -30 mV and to generate the coincidence trigger signal Fig. 1. The DAS acquires all the PMT traces for each triggered event. The acquired traces are used by the PC to perform on-line measurements of the integrated charges, arrival times, amplitudes and widths of all signals the PMTs, these data are saved into a hard-disk file for further off-line analysis.
Description of the Electronics

The new electronics is meant to replace the digital oscilloscopes and the commercial NIM and CAMAC modules that we are using at the moment. Fig. 2 shows a photograph of the new electronics card and Fig. 3 shows its corresponding block diagram.

The analog signal from the PMTs is inverted by using a fast operational amplifier configured to have a gain of -1. This inverted signal is sent to an analog to digital converter (ADC) with a 10 bit resolution and a sampling speed of 40 MHz. This ADC can accept signals with amplitudes from 0 to 2 V. The 10-bit ADC output is connected to a field-programmable gate array (FPGA), Virtex XCV50 from Xilinx. This FPGA was programmed to behave like the block diagram shown inside the rectangle shown in Fig. 3.
The FPGA counts the number of events which have amplitudes above a pre-established threshold. This threshold is programmed by the PC into the comparator module. All events above threshold are recorded into the FIFO memory and this number is updated in the threshold module. Since the parallel port is not fast enough to process the output of the ADC, the 10-bit data from the ADC is saved temporarily into the FIFO memory. The data from the latter is downloaded into the PC in synchronous mode. The control module takes charge of doing this synchronization between the master clock, the ADC and the FIFO memory during the process of writing into the FIFO and also between the parallel port and the FIFO during the process of reading the FIFO memory by the PC. The control module also keeps track of the empty and full flags used to determine if the FIFO memory is empty of full. The mux module is used to pass the 10-bit data into the PC through the parallel port. This is done in two steps: in the first one the least significative 8 bits are read out by the data bus of the parallel port (connectors 2-9), and in the second step the remaining two bits are acquired by the parallel port through the state register pins (connectors 10 and 11).

CONCLUSIONS

We have described in detail the electronics cards that were designed to be the basis of the data acquisition system (DAS) of the extensive air shower detector array built in the Campus of the University of Puebla (located at 19°N, 90°W, 800 gcm$^{-2}$). The purpose of this observatory is to measure the energy and arrival direction of primary cosmic rays with energies around $10^{15}$ eV. The electronics described here uses analog to digital converters of 10 bits working at a sampling speed of 40 MS/s and a field-programmable gate array to replace the set of digital oscilloscopes, NIM and CAMAC modules presently used as the basis of the EAS-UAP data acquisition system.

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REFERENCES