A cost-effective DAQ for EE cosmic ray research

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1. Introduction

Extreme energy cosmic rays (EECR) ($E > 10^{19}$ eV) could allow for the exploration of physics beyond what is possible with accelerators[1]. The flux of cosmic rays at these energies is small and require large area detectors. AGASA[2] and HIRES[3] are the two largest experiments covering areas of the order of 100 km^2 and have detected the largest energy cosmic rays. The Pierre Auger observatory [4] now under construction will cover an area of 3000 km^2.

A common characteristic of shower detectors is the need to synchronize detection sites at large distances. Today this can be done with the use of GPS clocks, for example as described in ref. [6]. While relative timing is often accurate the absolute time requires careful corrections to the measurements. In addition to time stamping it is also required that signals from different detectors are digitized for future processing. We present in this paper an alternative low cost DAQ with relative good timing accuracy that can be used with scintillator arrays. The DAQ uses commodity off the shelf (COT) equipment and could help physics teachers to interest students in software development, signal processing and physics research.

2. Experimental Setup

Our experimental setup, shown in Fig. 1, includes four scintillator paddles to detect particles from a shower produced by the EECR. The scintillating light is detected by the photomultipliers. The geometry and number of coincidences required can be used to select different energy thresholds.

The signals from the photomultipliers is acquired directly by the high sampling rate 8 channels Delta 1010LT sound card[7]. This card has the virtue that it can be daisy-chained for a large number of detectors and sampling frequency can also be controlled externally. The coincidence is software defined because all inputs are digitized concurrently. The sampling is limited to $\sim 100 ksamples/s$. In order to assure that no sample is lost, a combination of programming techniques (using large circular buffers and multithreaded code) and a suitable choice of operating system (RTLinux [8]) was used.

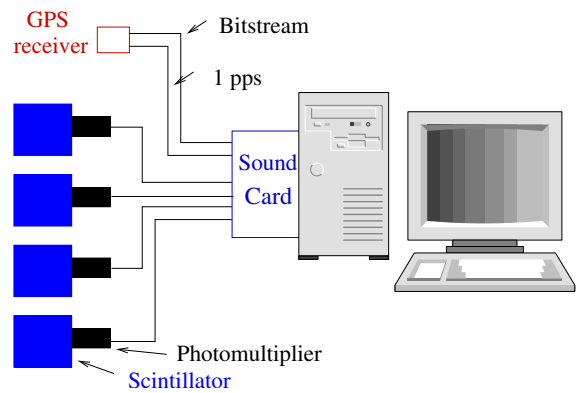

Figure 1. Experimental setup with the Delta 1010LT sound card and the deluo GPS receiver for time stamping.

The GPS signal is fundamental to time stamp the signal. The time stamped signal can be used to synchronize detection sites[9]. For this work we used a NMEA compliant GPS receiver sold by Deluo [11]. This receiver [11] outputs the precision 1 pulse per second (pps) signal and a bitstream with the NMEA code. This bitstream (at 4800 baud) has a complete description of the position, time and quality evaluation of the signal received by each one of the satellites in view (upto 12 satellites) [12]. Usually these signals are acquired through the computer serial port. In order to facilitate the offline time reconstruction assuring the synchronism between data channels and GPS stamping the bitstream is also recorded.

3. Results

To verify the correct operation of the system, data from photomultipliers were acquired and compared against a coincidence time measured by an accurate GPS/HP 53132A counter combination. The coincidence was established by traditional NIM electronics. The CNS GPS and software was used to time stamp the coincidences. The intrinsic accuracy of the system is about 150 ps and the vendor estimated time accuracy to UTC is 50ns, both well

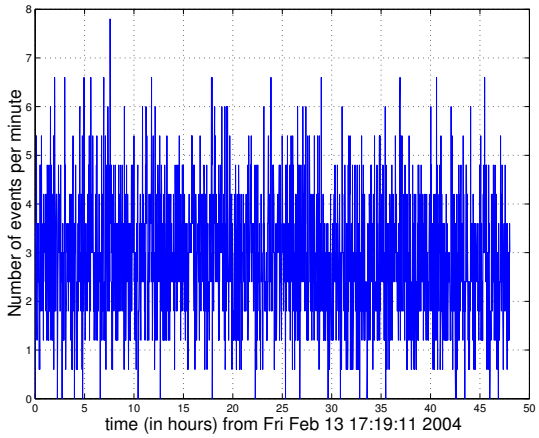

Figure 2. Coincidence between to channels of the experiment.

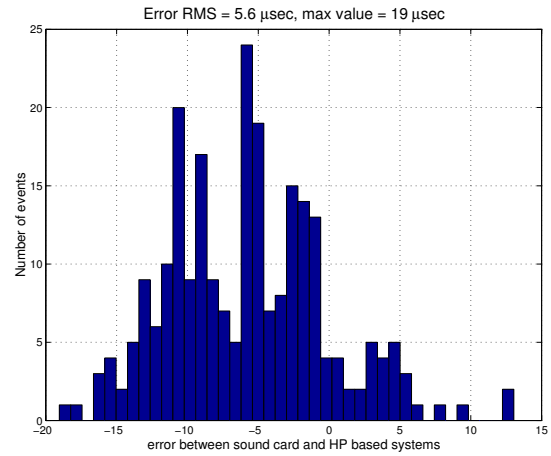

Figure 3. Deluo GPS timing information measured against the CNS clock.

beyond the present needs. The pmt signal is short. Because of the low pass filter at the input of the sound card the signal is attenuated but still large enough for detection. Shaping the signal would improve the performance. Figure 2 show the number of two fold coincidences per minute determined by the DAQ.

The Deluo GPS produces a precise 1 pps signal. If all sites would be receiving signals from the same satellite constellation a relative timing between sites could be achieved to $\sim 1\ \mu s$. It is well known however, that a "sawtooth" correction need to be applied to this information if the absolute time information is desired. We have performed such a correction benchmarking against the CNS timing information. Because the "sawtooth" is not perfectly linear a quadratic fit was used and solves the problem for most of the cases whilst providing quality measurement.

Figure 3 shows the present accuracy in timing determination. An RMS of 5.6 μs is obtained. Because the sampling is done every $10\mu s$ we don't expect and rms better than $\sim 2\mu s$. The Deluo receiver has few problems that still need to be understood. The most severe cases are when the time varies quickly and outside the "sawtooth" behavior. This is under investigation but represents less than 1% of the acquisition time.

4. Conclusions

We present a very economical alternative to detect and time stamp cosmic ray showers using a simple system which includes a high performance sound card and a NMEA compliant GPS receiver. The inclusion of the GPS bit stream together with data allows for precise timing of the event. At the moment this can be done a the level of 5.6 μs, but improvements are being worked out. We are also considering shaping the PMT signal and apply optimal filtering techniques to obtain precise event timing. This system provides a cost effective way to spread a large number of detectors in a reasonable amount of time.

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