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First results from the Stockholm Educational Air Shower Array (SEASA)

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The 'Stockholm Educational Air Shower Array' (SEASA) project is establishing a network of time- synchronised scintillator detector stations at high-schools in the Stockholm region. High school students are contributing to the construction, installation, testing and running of the detector station placed on the roof of their school. This initiative aims to increase the students' interest in science and technology subjects by exposing them to modern research. Each station is equipped with three plastic scintillator detectors (each 0.3 m^2) arranged in a triangular formation. Signals from GPS satellites are used to time-synchronise signals from the widely separated detector stations, allowing cosmic ray air showers to be identified and studied. A low-cost and highly scalable data acquisition system has been produced using embedded Linux processors which communicate station trigger and monitoring data to a central database. Air shower data and the performance of each detector station can be visualised in real-time via a web browser. The status of the project is presented along with first results from the observation of air showers over Stockholm.

1. Introduction

The 'Stockholm Educational Air Shower Array' (SEASA) [1] project is establishing a network of cosmic ray detector stations over the Stockholm region. Each station consists of 3 large plastic scintillator detectors arranged in a triangular formation. Cosmic ray activity at stations separated by arbitrary distances is correlated using timing signals from GPS navigation satellites. A primary aim of the project is to give high-school students, aged between 16 and 18 years, the possibility to gain insight and work on a modern research project and so the detector stations are located at the high-schools (on roofs or in attics). The students themselves will participate in the construction, testing, installation, commissioning and running of their detector station. As well as these 'outreach' aims, scientific studies are also foreseen. A particularly interesting prospect is to study correlations between stations separated by large distances (e.g.: between towns) in order to identify cosmic rays sharing a common history. Such correlations could arise from the solar photo disintegration of heavy nuclei [2] or transient cosmic gamma-ray activity [3]. Another possible application is the forecasting of geomagnetic storms [4]. During the first phase of the project in 2005, the network will consist of 7 detector stations located in Stockholm at AlbaNova University Centre and four local high-schools. Additional stations are expected to be installed at other high-schools both within and outside of Stockholm in subsequent years.

2. System Design

Fig. 1 shows an overview of the SEASA system. A station comprises of three plastic scintillator detectors with photomultiplier read out, a data acquisition system based on a programmable logic array (PLA) and an embedded Linux processor, a programmable high voltage supply and a GPS receiver system.

The design of the scintillator detectors for the first two detector stations was motivated by the availability of materials left over from other research projects. The results presented in this paper are derived from these detector stations, which are located at the AlbaNova University Centre in Stockholm. A wavelength shifting bar (Bicron BC-482A) was used to transfer light from four rectangular pieces of plastic scintillators (Bicron

BC-408), approximately 150 cm x 13 cm x 1.2 cm, to a compact photomultiplier (Hamamatsu R5900U). The scintillators were placed either side of the wavelength shifting bar to maximise the light collection efficiency. One drawback with this setup is the large amount of expensive wavelength shifting bar which is needed. Future detectors will therefore use single pieces of scintillator, approximately 1.5 cm x 30 cm x 100 cm, read out by a large diameter (76 mm) photomultiplier (Photonis XP3314B) glued to the centre of the scintillator's largest surface. For both designs, the scintillator assemblies were wrapped in Dupont Tyvek and placed in a light-tight box. This was in turn put in a car roof box which prevents the scintillator assembly from being directly exposed to rain and snow.

The detectors have a typical separation of 10 m to 15 m and operate in a coincident mode, requiring all detectors to be hit within a predefined time window (up to 1 μs) for the station to trigger. Air showers with a primary particle energy above 10^{14}- 10^{15} eV are detectable by a station depending on the separation of the scintillator detectors [5].

An Altera Cyclone PLA is the key digital component. It processes data arriving from the detectors and environmental sensors (atmospheric, pressure, temperature), forming events which are sent to an embedded Linux system (Axis 82 Developer board [6]). The Linux system provides cold start configuration of the GPS receiver and PLA, as well as working as an interface to the central server. A GPS receiver card (Motorola M12+) and antenna (Motorola Timing 2000) [7] are used to provide a time tag for each coincidence event. The performance of the GPS time tagging is presented in detail elsewhere [8].

An important issue for the project is to visualize data interactively and in an interesting way, to engage students in the project. Therefore, a 'live' web-based viewer system has been developed. A server running a MySQL database under Linux constitutes the core of the system, where the information from the detector nodes is stored. Data from the server is sent in real-time to "viewer clients", on-line java-applet clients displaying live information about the detector nodes, as well as trigger statistics and housekeeping "on demand". Hardware parameters, for example high voltage levels and the coincidence window length, can also be set from the viewer. More details about the data acquisition and viewer system can be found elsewhere [8].

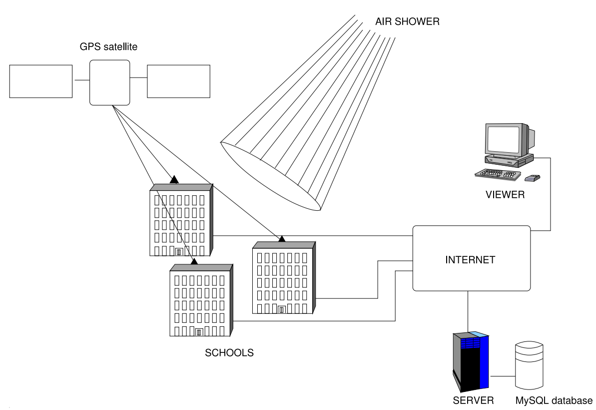

Figure 1. An overview of the SEASA system. The data flow is as follows: when an air shower triggers a station, a time stamp is provided by the GPS system and information about the event is sent over the internet to a central server. The server stores the data in a database and sends it to all active viewer clients.

3. First observations of air showers

Two cosmic ray detector stations have been installed on the roof of the main building at the AlbaNova University Center, approximately 200 m apart. As described above, each station has its own GPS system, and correlated events should be seen when large air showers hit both stations coincidently.

When both detector stations register triggers within a gate of 1 μs they are referred to as "super triggers", where it is assumed that a large air shower has hit both stations. The gate was chosen with the distance between the stations and the assumed shower front thickness taken into consideration. Fig. 2 shows the correlation in trigger time between station 1 and station 2, for all triggers that coincided within the second between the stations. Out of 78 triggers, 33 coincided within $1\mu s$ and 45 were uncorrelated. The normal trigger rate per station observed is about 35 triggers per hour. The probability of two air showers coinciding within the second is $(35/3600)^2$. For an acquisition time of 120 hours this gives $(35/3600)^2 * 120 * 3600 \sim 41$ triggers coinciding within the second, which is close to what is measured (45). This is a good indication that the GPS time tagging technique works, and that air showers can be correlated over arbitrary distances. More detailed studies are currently on-going.

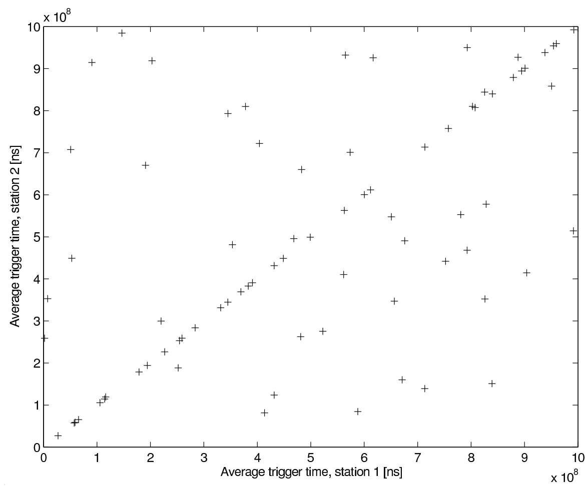

Figure 2. The trigger time for station 2 versus station 1 for events coinciding within the second. Out of 78 triggers, 33 coincided within 1 μs. The acquisition time was 120 hours.

4. Pulse length analysis

Super triggers originate, on average, from larger air showers than station triggers. Larger showers have a greater particle density and therefore deposit a larger amount of energy in the scintillator detectors. The energy deposited is not measured in a direct way, but an estimate can be made by recording the length of a discriminator signal which varies depending on he amplitude of the PMT pulse. Fig. 3 shows the pulse length distribution for ordinary triggers (top) and super triggers (bottom) for one of the detector stations. Similar behaviour was observed for the other station. A shift to higher pulse lengths can clearly be seen for super triggers, indicating that single large air showers have been observed.

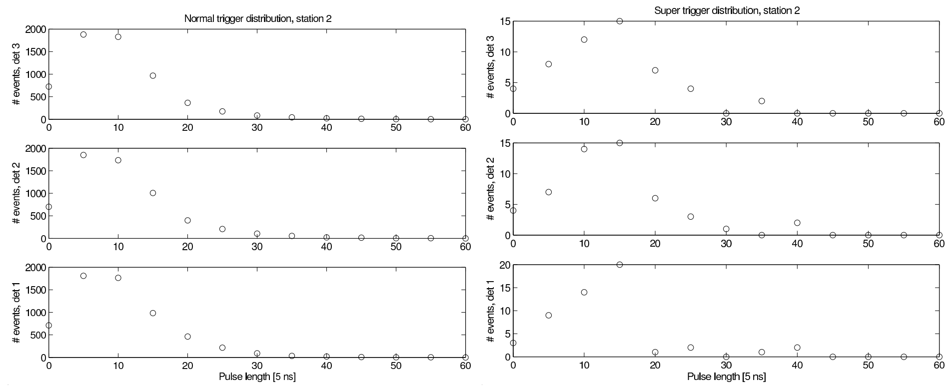

Figure 3. Pulse length distribution for ordinary triggers and super triggers in units of 5 ns for station triggers (left) and super triggers (right). A shift in pulse length is evident for the super triggers compared to the pulse length for the station triggers, indicating that super triggers originate from larger showers than station triggers.

5. Conclusions

The SEASA project is now at the end of the first phase: two stations have been deployed at the AlbaNova University Centre, and a proof-of-principle has successfully been made. Air showers have been detected, both by single stations, and coincidently by multiple stations, thereby proving the GPS time stamp technique. A third station is currently being installed at AlbaNova. An especially interesting feature with three stations is the possibility to make accurate determinations of the shower angle. This autumn, SEASA is brought to the next phase expanding the detector network to include four high-schools in the Stockholm area.

An interesting future possibility is to expand the SEASA network to towns outside Stockholm, making it possible to study long range correlations between air showers. This would allow studies which are complementary to professional arrays, such as searches for ultra-high energy bursts of γ-rays [3].

6. Acknowledgements

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