SEASA: The Stockholm Educational Air Shower Array

M. Pearce,[1] T. Burgess,[2] B. Lund-Jensen,[1] C. Nilsson,[3] S. Orsi,[1] S. Silverstein,[2] Y. Tayalati[1] and C. Wiedemann.[2]
(1) Dept. of Physics, The Royal Institute of Technology, Stockholm, Sweden.
(2) Dept. of Physics, Stockholm University, Stockholm, Sweden.
(3) The House of Science (Vetenskapens Hus), Stockholm, Sweden.

Abstract

An educational air shower array is under construction at the recently built AlbaNova University Center in Stockholm [1]. Each detector site consists of three plastic scintillator sheets in a triangular configuration, read-out by compact photomultiplier tubes (PMTs) through wavelength shifting bars. The PMT signals are received by a field programmable gate array (FPGA) based local data acquisition electronics system that is designed to be compact, low cost and scaleable. A commercial GPS timing module provides an accurate local clock to allow event synchronisation between the detector stations. Local control and readout are provided by a single-chip Linux system which sends data directly over the internet to a central server. Once commissioning is completed, the array will be significantly extended by the inclusion of local schools in the Stockholm region.

1. Introduction

Cosmic rays offer school and undergraduate students a relatively cheap and easy way to explore the world of subatomic physics 'hands-on'. Many universities operate experiments to study the muon components of cosmic rays, for example. More recently, there has been considerable interest in establishing large cosmic ray detector ground arrays for the study of air showers with local schools acting as detector nodes - an activity which was pioneered in Canada and USA [2]. This paper describes the design of a test-bed for the first schools-based air shower array in Sweden which will be located at the AlbaNova University Center in Stockholm. Two scintillator detector stations are placed on opposite ends of the roof of the main building and an additional station is placed on the roof of 'The House of Science'. The layout is shown in figure 1. Each station operates autonomously and sends data to central server where it is stored in a database. Timing information generated by a GPS-based system at each detector station is used to correlate events within the database.

pp. 1001–1004

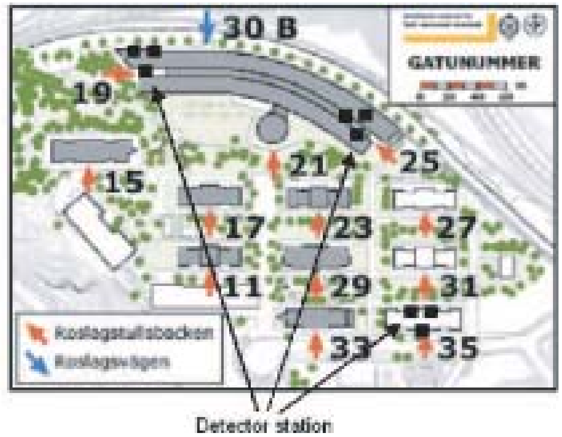

Fig. 1. The layout of the SEASA prototype array at AlbaNova University Center. The detector stations are separated by approximately 150 m.

2. Detector Stations

A detector station consists of three plastic scintillator detectors arranged in a triangular array. Each scintillator detector has an area of approximately 50×50 cm^2. The size is currently dictated by the availability of spare material. A wavelength shifting bar (Bicron BC-482A) is glued to two of the scintillator edges and connects to a photomultiplier tube (PMT), as shown in figure 2. The PMT signals are discriminated so a local coincidence trigger can be formed. The number of detector signals used to form the trigger and the length of the trigger window is programmable. This, together with the inter-detector spacing, will be optimised with simulations and measurements to define the energy threshold and manage the trigger rate. The raw PMT signals are integrated and the pulse heights measured to allow a crude estimate of the MIP multiplicity. Each detector is placed inside a weather-proof box and a heater system keeps the components at a stable temperature. A LED attached to each scintillator allows functionality checks to be carried out remotely. To reduce costs, all the front-end electronics is built using commercial off-the-shelf components. High voltage to the PMTs is provided by encapsulated DC/DC converters operating at 12 V which simplifies handling for students.

3. Data Acquisition System

The design of the data acquisition system has been inspired by the need to produce a compact, highly configurable, scaleable and low cost system. The system has three main components, a FPGA, a GPS receiver board and a single chip Linux system (an 'Etrax 100LX' based system from Axis Communications). The

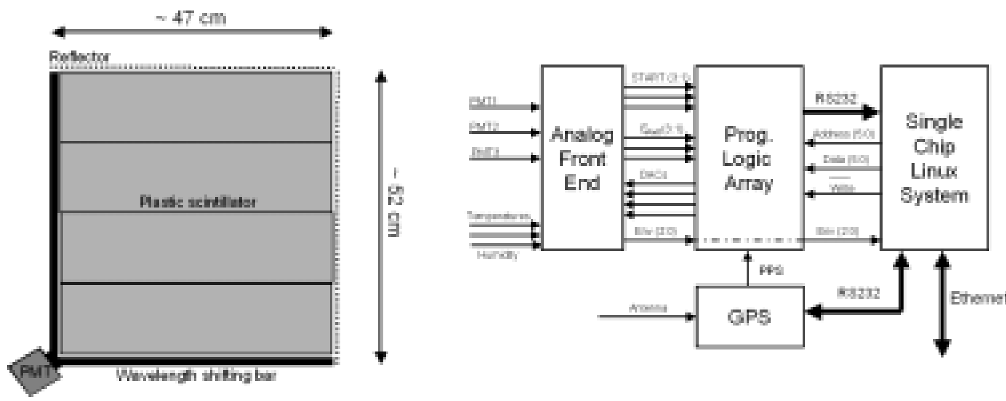

Fig. 2. Schematic overviews of the scintillator detectors (left) and data acquisition system (right).

FPGA generates a local trigger from the coincidence of the scintillator detector signals, provides control signals for the front-end electronics and environmental monitoring circuitry (temperature and humidity sensors). A Motorola UT+ Oncore GPS receiver card is used to provide timing information which allows triggers from widely separately detector stations to be synchronised. The Pulse Per Second (PPS) signal is used to reset a 100 MHz counter and increment a time-of-day clock (h, m, s) within the FPGA. The trigger signal produces a time-stamp from these counters, along with a fine increment from the counter. It is expected that this will allow the trigger time to be determined with an accuracy better than 50 ns. The single chip Linux system provides overall control of the FPGA and builds an event for each trigger. An in-built web server allows each detector node to communicate with a central server using TCP/IP protocols over the internet. The central server logs data from the entire array into a database. A web-based interface makes data available to students for further analysis. A secure web server running on the Linux chip provides a straight-forward way to configure and monitor each detector node remotely. Additional detector nodes can be trivially added to the system as the array is expanded.

4. Simulations

A combination of measurements and simulations will be used to optimise the performance of the array. Presented here are some preliminary results from simulations using the Aires program [3]. Figure 3 shows the probability of detecting a proton-induced air shower at a single detector station as a function of the particle density (muons and electrons) at ground level. A number of different

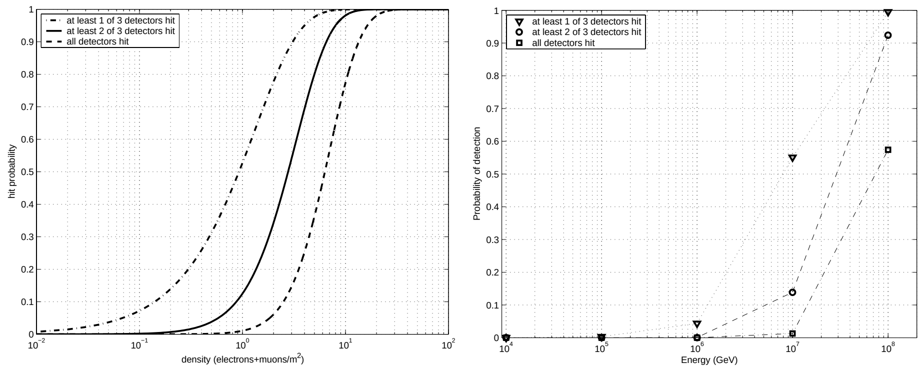

Fig. 3. The probability for detecting an air shower with a single detector station presented in terms of the ground multiplicity (left) and primary proton energy (right). A number of different trigger scenarios are shown in the figures, as explained in the legend.

trigger conditions are presented in the figure. This is also shown in terms of the energy of the primary proton. The conversion factor is estimated from the simulations assuming constant particle density in the proximity of the shower core (400 m $\times$ 400 m). Requiring activity in at least two out of three of the scintillators is a good compromise between the need to reject background but also minimise the energy threshold. These results indicate that SEASA will become sensitive in the energy range above 10^{16} eV.

5. Outreach Plans

Once the test array is commissioned, additional funding will be sought with the aim of inviting local schools to host detector nodes. This will be co-ordinated by 'The House of Science'. School students will help to build, test and commission their detector station as a part of their studies. As well as studying air showers, stand-alone data from the stations can be used to study correlations between cosmic ray counting rates and other variables such as the time of year and weather. It is noted that any type of sensor can be interfaced to the detector stations. For example, it is proposed to complement the temperature and humidity sensors with other environmental sensors (e.g. background radiation and aerosol detectors) which can be used by students following courses in environmental physics.

6. References

1. http://www.particle.kth.se/SEASA
2. http://csr.phys.ualberta.ca/nalta
3. http://www.fisica.unlp.edu.ar/auger/aires/eg_Aires.html