WALTA school-network cosmic ray detectors

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Abstract—The Washington Area Large-scale Time coincidence Array (WALTA) is placing particle detector arrays in secondary schools in the Seattle area to build up a large-scale ultra-high energy cosmic ray detector network, one of several such projects around the world. Scintillation counters salvaged from the CASA experiment in cooperation with the CROP group at the University of Nebraska at Lincoln are refurbished by teachers and students, tested, calibrated, and installed in four-fold arrays at high school sites. To identify time coincidences, a GPS time synchronization system is employed. Data are acquired using a custom low-cost data acquisition card. Here we will describe the logistics of WALTA and show samples of data taken with a prototype array at the University of Washington.

Index Terms—Cosmic Rays, Air Showers, Secondary Schools.

I. INTRODUCTION

ParticIe physics groups around the world are starting outreach programs to place cosmic ray detectors at secondary schools in order to study extensive air showers. In the Seattle area, secondary schools are spaced nearly optimally to detect ultra-high energy air showers which extend for kilometers. The schools are also spread over a large area and might detect separate, correlated pairs of air showers that are tens of kilometers apart. With this method, the schools provide the infrastructure to power the detectors and transfer data to a central location, as well as enthusiastic volunteers to set up and monitor the detectors. In addition to air shower studies, the equipment is also used by students and teachers for a variety of elementary experiments and classroom activities.

In development at the University of Washington since 2000, the WALTA project[1][2][3] now has twenty participating schools in the Seattle area. Testing of all the pieces of the experimental apparatus is complete. We will begin taking multisite coincidence data during the upcoming school year with the new GPS-based data acquisition card.

II. ELEMENTS OF THE EXPERIMENT

Each school is provided with the same set of equipment: four pieces of scintillator, four photo-multiplier tubes, a high voltage supply, and a data acquisition (DAQ) card with a GPS unit. The school is responsible for providing boxes to protect the counters from the weather, space for counters on the rooftop of their school or another appropriate location, a computer to collect the data from the card, and internet access to send the data to the university so it can be searched for coincidences.

The participants may also retrieve data from other sites for analysis.

The scintillator, photomultiplier tube (PMT), and high voltage module were recovered from the CASA experiment[5] in the Utah desert by members of WALTA and CROP[4]. Our teachers and students refurbish the equipment, polish the edges of the scintillator, and with our help remount the PMT. They re-wrap each unit and test it for light leaks.

Students characterize the counters by looking at the singles rate as a function of high voltage and threshold settings and choose appropriate values.

Students and teachers at the schools work either as part of their regular classroom curriculum or as after-school clubs. In addition to preparing the apparatus for measurements of air showers, they perform experiments on other sources of radiation, electrical interference, and tests of muon event rates. We invite students and teachers to attend three conferences per year where they can hear about other physics projects and share their own measurements with their peers.

A. The scintillator counters

Each piece of scintillator has an area of 0.36 m² and is 1.27 cm thick. The best choices of high voltage and threshold typically yield a singles rate near 100 Hz, including both muons and the background radioactivity. Because our high voltage modules allow only a single setting, the same for all four counters at one school, the usual case is that the counter with the lowest rate operates at 100 Hz and the others are several times higher.

B. The DAQ card

The counters are read out by an inexpensive DAQ card[6], shown in Fig. I developed with the support of QuarkNet[7] and in collaboration with engineers at Fermilab and the University of Nebraska. The user can select none, 2, 3, or 4-fold coincidence and also select the effective gate width from 48 ns to 50 μs, based on the fundamental clock cycle of 24 ns.

When there is a coincidence, the card reports the rising and falling edges of a discriminator, so it records when the input pulse goes above and then falls below a threshold voltage. The time to digital converter chip and its readout circuitry allow for multi-hit events and we record all edges up to our gate window – with one limitation – for each coincidence. Each edge is recorded with five-bit resolution within this clock cycle for an actual resolution of 0.75 nanoseconds. The limitation mentioned above is that this chip can store only the first rising and the first falling edge for each 24 nanosecond clock cycle. Multiple, closely spaced edges will be lost.
This design allows us to measure the relative arrival times of the particles in the air shower to within 0.75 nanoseconds, which is sufficient to estimate the arrival direction of air showers. We also plan to use the time over threshold to estimate the particle density, and use the multihit capability to record the width of the shower front for each coincidence. With this precision on the card, we are actually limited by the speed of the PMT’s.

C. The GPS unit

An add-on commercially available GPS unit provides time-stamps for each coincidence. This is used to match events seen at one school with particles recorded at other schools. Based on tests with air shower data and with pulse generators, two sites can be matched to within 24 nanoseconds in the best case and 350 nanoseconds in the worst case, depending on the GPS satellites in view. The GPS unit is modified slightly for our use by the manufacturer to provide timing information that is not normally available in a GPS navigation device. We also designed a custom connector that allows us to use much longer cables than we would otherwise. The method is described in another paper in these proceedings[8].

III. THE PROTOTYPE ARRAYS

We have run a prototype site on the rooftop of the physics department at the University of Washington to test the equipment, make adjustments to the DAQ card, and to the experimental design. We have configured the card to report coincidences that are two-fold or greater with an effective gate width of 1.2 microseconds. Each of the four channels had a singles rate between 100 and 500 Hz and the coincidence rate we observed was around 1 Hz, though this varied with the spatial configuration of the units. We expect a range of configurations for each of our participating schools because they will be limited by the size and shape of their rooftops; typical spacing of modules in our tests was 6 meters.

The card was operated with a variety of software: a basic serial port terminal, a LabView interface for Windows, and a command-line interface on Linux. We have also developed the essential software to unpack the encoded data from the card, test the data for correctness and for proper operation of the card, and search the data for cosmic ray air shower events and multi-site coincidences.

IV. PERFORMANCE

The distribution of the difference in rising edge times for pairs of channels for two-fold coincidences is shown in Fig. 2. Other pairs of channels look similar. The coincidences from air showers are clearly visible, as is the level of the random background.

A similar demonstration can be done with three-fold coincidences; because there is less random background, the air showers with hundred nanosecond structure are apparent. We scan through the same data set for these events during offline analysis and order the leading edge times of the pulses. There are two time differences for each event, one on each axis in the scatter plot in Fig. 3. As in the previous figure, 90% of the data are within 50 ns and are in the lower left corner of the plot. The backgrounds in this case are symmetric with respect to a diagonal of slope one, so the excess most clearly seen along the horizontal axis is due to air showers.

These data confirm our ability to discriminate both the short and the long time structure of air showers. These structures are useful for the correlation of ordinary air showers and for ultra-high energy cosmic rays, respectively.

We received our first shipment of cards from the production run and distributed them during our summer workshop for teachers in August 2003. At that time we tested the multi-site coincidence capabilities of the GPS timestamp. We set four

Fig. 1

Fig. 2

QUARKNET DAQ CARD

TIME BETWEEN RISING EDGES OF TWO-FOLD COINCIDENCES

Number observed in dataset

0

100

200

300

400

500

600

700

-600

-400

-200

0

200

400

600

nanoseconds

0

100

200

300

400

500

600

700

-600

-400

-200

0

200

400

600

nanoseconds
tests with pulse generators, confirmed the operation of the GPS time-matching system.

V. CHALLENGES

Nearly twenty schools have participated in the WALTA program since it began, shown in Fig. 4. They have prepared their scintillator modules and have been working with NIM electronics for the past couple years. Nine schools now have DAQ cards and are preparing to operate their counters, first in their classroom, and then shortly afterward put their counters on the rooftops. The array at the University of Washington has been operating this summer and the first school arrays should be operating by the end of winter. We expect several multi-site coincidences from ultra-high energy air showers each month from groups of closely spaced schools. We will also look for coincidences on city-wide scales and in coordination with other school-based arrays around the world.

In addition to preparing and maintaining the detectors for large-area coincidence array, our participants have performed many small scale experiments on their own as part of their curriculum. We expect they will want to continue to do this, and we will be challenged to make the data acquisition software used to operate the DAQ card flexible enough to allow them to do other interesting projects.

After these first sites are operating well we hope to expand to other schools in the Seattle and King County area. The area directly south of the University of Washington site is where
the highest density of schools are, with a spacing of about one kilometer. Expanding to the rest of King County retains a reasonable density of schools while extending the total area covered by this experiment.

The design and testing of the many pieces of the WALTA experiment are complete. The apparatus meets all specifications and has been demonstrated to detect cosmic ray air showers with very precise particle timing and also provide accurate two-site event time matching. The software tools are available for us and for the students, and they are now being used at the schools.

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