Educational Cosmic Ray Arrays

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Abstract. In the last decade a great deal of interest has arisen in using sparse arrays of cosmic ray detectors located at schools as a means of doing both outreach and physics research. This approach has the unique advantage of involving grade school students in an actual ongoing experiment, rather then a simple teaching exercise, while at the same time providing researchers with the basic infrastructure for installation of cosmic ray detectors. A survey is made of projects in North America and Europe and in particular the ALTA experiment at the University of Alberta which was the first experiment operating under this paradigm.

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INTRODUCTION

As the first source of high energy subatomic particles cosmic rays played a major role in the early exploration of elementary particles. Now almost 100 years after their discovery by Victor Hess in 1912 they are again the focus of major research efforts because they allow one to probe particle energies not achievable by terrestrial accelerators. This current interest in cosmic rays combined with the relative ease of detecting high energy cosmic ray showers, the availability of surplus detectors from decommissioned particle physics experiments and advances in GPS technology have helped to spur on the large number of educational arrays that are appearing now around the world.

A typical educational array site consists of between two and four plastic scintillator detectors connected to photomultiplier tubes and read out by custom built electronics. The detectors are placed a few meters apart on the roof of a school, college or university building along with an antenna which uses the global positioning system to provide an absolute time reference. By requiring that two or more of the detectors register particles within a narrow time window one can distinguish between the relatively high flux of individual particles from low energy cosmics and the lower rate of extensive air showers caused by higher energy primaries. With a separation on the order of 10m between detectors a primary energy of roughly 10^{14}eV is required to produce a large enough shower to cause a coincidence. A number of these detector sites are deployed to form a sparse array with distances between sites ranging from a few kilometers to hundreds of kilometers.

If the inter-site spacing is small enough these arrays can look for showers from ultra high energy particles which can be several kilometers across at the Earth's

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surface. Otherwise the main physics target of these arrays is to search for a non-random component in the cosmic ray flux. Due to intergalactic magnetic fields it is expected that the arrival times and directions of cosmic ray primaries will be random. However there have been hints from experiments [1] that there may be a non-random component. Examples of possible sources for such correlated events are photodisintegration of high energy nuclei in the vicinity of the solar system or bursts of very high energy gamma rays. These can result in either changes to the average cosmic ray rate or separate but correlated showers hitting two or more sites.

From a research standpoint installing the detectors on schools has several advantages: teachers and students can be recruited to help test and maintain the equipment reducing the host institutions manpower requirements. Schools provide the infrastructure needed to maintain the site, such as power, a secure location and an internet connection thereby reducing the installation cost and complexity of the detectors. This kind of experiment also helps create publicity for physics and physics departments. From an educational standpoint enrolment in physics in most locations in North America and Europe has been decreasing during the last decade. This type of project allows students to have some exposure to a real physics experiment **before** they decide their university degree path. We've found that students can tell the difference between a real project and the usual teaching exercise and become more engaged when they realize that they are involved in actual research and have the opportunity to discover something new.

THE ALTA EXPERIMENT

The ALTA[2] experiment was the first educational cosmic ray array with its emphasis being more on research than outreach. This choice affects both the design and operation of the experiment. The roof top enclosures are installed as permanent parts of the school roofs with all cable runs in grounded metal conduit. To ensure that the direction of incoming cosmics can be related back to astronomical coordinates the detectors are fixed in position and a precision GPS compass is used to measure the alignment of the 3 detectors to north. An energy and relative timing calibration is periodically done on each site or when any component is changed. The electronics uses seven discrete crate mounted boards [2] with charge integration for energy determination, timing between detectors measured with 25ps binning and a GPS system designed specifically for precise timing [3][3]. It was decided to use a light guide to readout the scintillator since that gives the best timing and light collection uniformity. All of this ensures high quality data but increases the cost and the installation complexity of each site reducing their total number.

Critical elements in the ALTA design are monitoring, automation and remote management. For this a custom GUI based DAQ program was written with built in graphs and simple statistical tools. All electronics settings are software controlled and any changes made to the software are logged with certain values, like high voltage settings, are recorded with every event. Data is automatically uploaded to a central

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[2] www.ualberta.ca/alta

[3] Relative timing between sites separated by hundreds of kilometers should be better then 16ns with the ALTA system.

computer and if a problem is detected at a site or its settings aren't correct for data taking that site is automatically reset to the correct values. If a student is conducting their own experiment they can prevent this automatic reset by simply checking a box on the screen and entering what time they will be done. In this way students are free to do what they like with the system while having the minimum impact on data collection.

Taking advantage of improvements in technology the newest electronics design reduces the number of boards from 7 to only 3 while decreasing their cost and increasing their performance. ALTA is directly working with the Silesian University in Opava and the Czech Technical University in Prague in the Czech Republic, King's college in London England and TRIUMF, the University of Victory and Saint Mary's University in Canada to create additional arrays and a more international project.

ARRAYS AROUND THE WORLD

While all of the educational cosmic ray arrays have the same general goals, research and education are to some extent in conflict with one another. For instance in research you want identical detectors with hardware settings always left at the optimum data taking values. While for education you want students to have as much hands-on experience as possible and freedom to change settings and hardware setup at will. Research demands more attention to things such as calibration and complete records of data taking conditions as well as more complex, and probably more expensive, electronics and installations. The various groups have placed different amounts of emphasis on physics and outreach which results in differences in their hardware and detector installations. Also most groups have invented their own hardware and detectors, often independently, so the same problem has been solved many times over. It should be noted that with 3 or more detectors it is possible to use the local relative timing between detectors to triangulate the incoming direction of the primary cosmic ray, whether or not this timing information is collected and used also impacts the complexity of each project's hardware. For software most groups have elected to use the commercially available Labview program.

Figure 2 shows the various projects currently operating, or under development, in North America. A brief summary of the major projects and their status follows[4]:

- ALTA (Alberta Large-area Time-coincidence Array) began detector work in 1993 with its first school sites operational in 1998. Crate mounted custom electronics is used along with a GPS system specifically designed for timing. Custom DAQ software is used to control the electronics. Each site uses 3 scintillators (60cmX60cm) in permanently installed enclosures. ALTA currently has 15 sites in Alberta and will be installing one in the Edmonton science centre this fall to create a site accessible to the general public rather then being restricted to high schools.
- CROP (Cosmic Ray Observatory Project) obtained a large number of detectors and power supplies from the decommissioned CASA array and

[4] These types of experiments are often not well publicized and it can be difficult to determine their current status. It is therefore possible that the list of projects given is not complete and some information could be out of date.

installed its first school sites in 2000 using 4 scintillators (60cmX60cm) per site in movable enclosures. They use a custom low-cost single board electronics system designed with QuarkNet and Fermilab that does rough GPS time stamping and energy measurements along with relative timing between detectors for up to 4 input channels. The board also has a built in barometric pressure sensor. CROP has 26 sites in Nebraska with a very good outreach program where students assemble their own detectors at summer workshops.

FIGURE 1. Educational cosmic ray arrays in North America

- CHICOS (California HIgh school Cosmic ray ObServatory) acquired pre-built outdoor detectors from the defunct CYGNUS array and began installing school sites in 2000. They use a simple custom built single board DAQ card with 2 scintillators ($\approx 1m^2$ each) per site. To obtain a tighter spacing and offer the possibility of observing ultra high energy showers CHICOS places detectors on colleges and middle schools as well as high schools. They now have 78 sites in the Los Angeles area making them the largest school array currently operating.
- WALTA (Washington Large area Time coincidence Array) installed its first school prototype in 1999 and currently has 16 sites using the QuarkNet DAQ card and a design similar to CROP.
- SALTA (Snowmass Area Large scale Time coincidence Array) began planning in 2001 and currently has 5 sites installed using CROP detectors.
- VICTA (VIctoria Cosmic ray Time coincidence Array) began in 2003 using the ALTA detector design and electronics. They currently have 1 test site installed with additional sites planned for this fall. In addition to schools a site will be installed at the Victoria science centre.
- TRIUMF (TRIUniversity Meson Facility) in Vancouver, BC has started an as yet unnamed project using the ALTA design and will be installing a site at the Vancouver science centre.

- Some additional projects in the United States that are planned or have started are: TECOSE (TExas Cosmic Observations by School Experimenters), PARTICLE (Physicists and Rochester Teachers Inventing CLassroom Experiments), TECOP (TEnnessee Cosmic ray Observatory Project), CLASA (Chicago Large Air Shower Array), FTASA (Florida Tech Air Shower Array) and SCROD (School Cosmic Ray Outreach Detector). Most are using the QuarkNet DAQ card.

The major groups in Canada and the United States have formed a loose collaboration known as NALTA[5] (North American Large area Time coincidence Arrays) who's goal is to share education resources and information between groups. It is also planned to have one central access point where students and researchers can make use of data from all of the NALTA sites creating in effect a single giant array.

In the past few years activity on a number of educational arrays has begun in Europe as well as can be seen in figure 3.

- HiSPARC (High School Project on Astro physics Research with Cosmics) started around 2002 and has placed pairs of detectors housed in rooftop car carrier boxes on schools in 5 cities in the Netherlands. They use their own custom electronics system and are currently up to 30 sites.

FIGURE 2. Educational cosmic ray arrays in Europe

- An unnamed project started in Finland in 2002 involving 3 universities and 3 polytechnic institutes. They have no sites operational at this time but are developing their own custom electronics using 4 detectors per site.
- SEASA (Stockholm Educational Air Shower Array) is installing 3 (30cmX100cm) detectors per site also housed in rooftop car carrier boxes. They have a custom made single board DAQ card but unlike all of the projects described so far they are not using a standard PC to connect to their data acquisition system but instead are using an embedded processor (a so called linux on a chip system) on an additional board. This processor board

[5] www.ualberta.ca/nalta

has its own network connection but no display or keyboard, instead a custom java applet is used to control the system and readout the data using TCP/IP. SEASA has two sites at AlbaNova University and plan to install their first school site this year.

- CZELTA (CZEch Large-area Time-coincidence Array) was started in 2004 by the Institute of Experimental and Applied Physics at the Czech Technical University in Prague. They currently have 2 sites using triplets of ALTA detectors and ALTA electronics installed in Prague and Opava with a third site to be installed in Pardubice later this year. Their goal is to create clusters of arrays in various cities in the Czech Republic.
- ROLAND MAZE PROJECT in Poland obtained funding in 2004 for 10 sites in the Lodz area. They plan to use a custom made PCI readout board and 4 scintillators per site ($\approx 1 m^2$ each) readout using wavelength shifting fibres.
- An unnamed project in Belgium has begun using 5 scintillators (40cmX200cm) per site. They are currently developing their own custom electronics system and like SEASA will also be using a microprocessor instead of a standard PC for their readout and control computer.
- EEE (Extreme Energy Events) is a project which is now in development in Italy with an initial goal of installing 3 school sites per city in each of 7 Italian cities. This is the only array which will not be using plastic scintillator as a detector. Instead they will be using a telescope of 3 multigap resistive plate chambers (160cmX82cm) filled with a freon/sulfur hexafluoride gas mixture. Approximately 20 of these chambers have been built now at CERN.
- King's College in London is currently building detectors and will be installing 3 sites using ALTA electronics in the next few months.
- Other experiments include: RELYC in France will be using Belgium electronics with 4 detectors/site (40cmX50cm), a group in Portugal wants to start an array with a goal of 10 schools using 3 detectors/site with a custom PCI DAQ card, a project has begun in Dusseldorf Germany with one test site installed in a school, and groups in Denmark and Liverpool England are in the early stages of planning their own experiments.

Having helped found NALTA we hope that a similar collaboration can be set up between Europe and North America to share ideas, reduce the duplication of efforts and ultimately share data to allow students or researchers to treat the current collection of educational arrays as one massive global array of detectors. This would significantly extend the reach of any single local array.

REFERENCES

1. D.J. Fegan, B McBreen and C. O'Sullivan, *Phys. Rev. Lett.*, **51** (1983) 2341
   G. R. Smith, M. Ogmen, E. Buller and S. Standil, *Phys. Rev. Lett.*, **50** (1983) 2110
2. W. Brouwer, et. al., *Nucl. Instr. and Meth.* A **539** (2005) 595.
3. W. Brouwer, et. al., *Nucl. Instr. and Meth.* A **493** (2002) 79.