

The Washington Large Area Time Coincidence Array

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Abstract

The number and density of schools in the Seattle area is convenient for the study of distributed particle showers produced at the top of the atmosphere by ultra-high energy ($> 10^{19}$ eV) cosmic rays. We are forming a collaboration for the development of a distributed detector network to study air showers from such ultra-high energy cosmic rays. We call the cosmic ray measurement component WALTA (WASHington Large-area Time-coincidence Array). WALTA aims to provide teachers and students the opportunity to become active participants in forefront scientific projects. A cornerstone of the program will be to install a measurement module at each participating school.

1 Introduction:

Ultra-high energy cosmic ray particles with energies greater than about 5×10^{19} eV cannot traverse great distances through the cosmos without losing energy to pion photoproduction in collisions with the cosmic microwave background. Such a particle will lose energy until it is below threshold for this reaction. This process, referred to as the GZK cutoff (Greisen, 1966, and Zatsepin & Kuzmin, 1966), happens in about 50-100 Mpc (Cronin, 1992 and Aharonian & Cronin, 1994). Hence for a 10^{20} eV particle to arrive at Earth, it must originate in the local neighborhood. The observed arrival direction of events with energies greater than 5×10^{19} eV provide no compelling evidence for a nearby source. However there is a possible indication of correlations in event arrival direction (Cronin 1999). Further, there are no known nearby astrophysical objects which are likely to accelerate particles to these energies (Hillas, 1984 and Biermann, 1997). This paradox is one of the major current mysteries in astrophysics.

2 NNODE and WALTA:

We are forming a collaboration for the development of a distributed detector network that will support measurements of air showers from ultra-high energy cosmic rays and can also support a broad class of other physical measurements. Other researchers have expressed interest in using the framework, for example, as a seismograph network for geophysics studies, a passive radar network for ionosphere studies, and air sampling for atmospheric studies. We call the overall network NNODE (Northwest Network for Operation of Distributed Experiments), and we call the cosmic ray measurement component WALTA (WASHington Large-area Time-coincidence Array). The focus of the efforts of our subgroup within NNODE is WALTA. The project is to be a direct physical science outreach program between faculty and students of the University of Washington and the science teachers and students of Washington-area schools (grades 7-12). The detection techniques and philosophy are similar to those of the ALTA project in Alberta, Canada (Pinfold). The groups in Washington and Alberta have a loose collaboration.

Technological advances of the past decade have made such distributed experiments practical. Powerful yet inexpensive desktop computers are available and each detection site can have its own unit. The Global Positioning System (GPS) can provide very good absolute timing and positioning between distributed sites. Finally the Internet provides convenient communication between each of the sites. Each WALTA/NNODE measurement module is envisioned to consist of a computer with an Internet connection, a GPS timing system, and measuring equipment. The measuring devices used will depend on the science investigation. For the WALTA investigation, modules will consist of scintillation paddles to detect distributed particle showers produced by ultra-high energy cosmic rays. We plan to ultimately locate the majority of the modules at public and private schools and to enlarge the network as additional schools participate.

An aspect of this program is that the teachers, and through them their students, will have the opportunity to directly contribute in cutting edge scientific research. We expect that this direct involvement will motivate and energize teachers and result in their learning science at a deeper level. It may also spark the imaginations of their students, encouraging their consideration of careers in the sciences. The teachers and their students will be able to learn about scientific techniques, mathematical tools, and the latest measurement technology and see them applied as new results emerge. Many elements of the project will provide a basis for classroom teaching units in science, mathematics, and technology. The classroom learning will be made more immediate by the ongoing measurements of the systems and the emergence of new results.

3 WALTA and Cosmic Ray Studies:

An ultra-high energy cosmic ray colliding with the upper atmosphere will produce a cascade of particles which at ground level contains several billion particles and covers tens of km². Sampling the particles from such a shower requires a distributed detector with sites separated on the order of a km.

To study the potential performance of WALTA, we chose 32 candidate sites in the Seattle area. (See Fig. 1) These locations are associated with the University of Washington, high schools, middle schools, and other local universities and community colleges. The list is neither exhaustive nor confirmed. At each site we anticipate placing three or four 1-inch thick scintillators of approximate area 1 m² each. These detectors would be separated by approximately 10-20 m. At this spacing, the individual sites will measure cosmic rays of energy near the knee ($\approx 10^{15}$ eV). This will provide students with high rate data similar in character to the low rate data from ultra high energy events.

Each site would trigger independently. We would require that some number of detectors at each site observe a signal corresponding to a minimum number of vertical equivalent muons. The data from each site would be transferred via the Internet to a central computing location to be analyzed off-line for inter-site coincidences.

The 32-site array covers a large area, approximately 200 km². However, the spacing is not uniform. The mean nearest-neighbor spacing between these sites is approximately 1.4 km but varies greatly. As a result, "holes" in the array reduce the trigger efficiency significantly. However, the autonomous nature of the individual sites makes the array very easy to expand. That is, holes can be filled and the array can easily be extended into the urban areas north, east, and south of Seattle. Thus the array can be made more efficient and larger.

Many of the site and array parameters must be optimized. This optimization is being studied through simulation using the CORSIKA code, version 5.624 (Heck, 1998). Figure 1 shows the site layout with a simulated vertical 10^{19} eV event to provide some indication of the array response. In the figure, the squares are centered on sites which have no response to the event. The 5 sites responding to the event are indicated by circles. The area of each circle is proportional to the number of particles detected at the site. The number of detectors and their geometry, the detector spacing, and the trigger requirements are all parameters which are currently under study. Furthermore, site locations required to eliminate holes in the effective detector sensitive area are being identified. Subsequently, we will search for new candidate sites to fill such holes.

One very dangerous possibility is that of high-energy tails on the resolution function. The observation of the highest energy cosmic rays is the critical feature of the experiment. If low energy events below the GZK cutoff can be falsely identified as having a high energy, it will seriously compromise the conclusions one can draw from the measurements. Simulations to study this possibility are also underway.

Finally efforts are underway to finalize the hardware design. To ensure the ease of expansion, the cost of each site must be minimized. Prototypes of a site system are being assembled and characterized.

4 Conclusion:

The scientific activity of the WALTA project has a number of aspects which can feed into teacher and student research experience. The technological examples provided by the network of computer systems, the display of data as it is acquired, the use of GPS circuits for timing, and the electronics of the detection system will serve as challenging examples for the technologically inclined students and the teachers of technology-

based classes. The analysis and interpretation of the results from many of the measurements will provide case studies for the application of statistics and mathematics that can be linked to mathematics classes. The physics that underlies the research activity also has many potential connections that can enrich high school physics classes.

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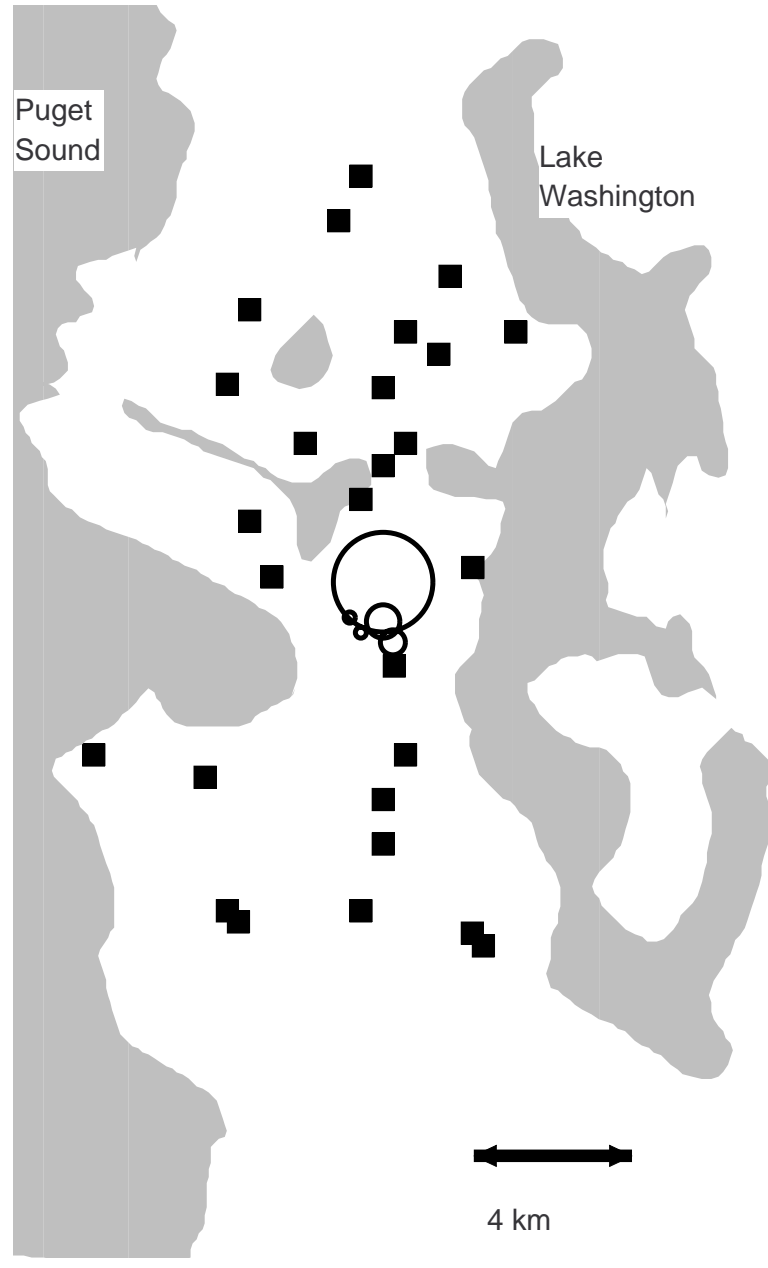


Figure 1: The Seattle area indicating a number of suggested sites.