THE BUCKARRAY: DETECTING COSMIC RAYS WITH SMARTPHONES

THE OHIO STATE UNIVERSITY

Jorge Torres, Amy Connolly, Jordan Hanson.
Department of Physics, The Ohio State University

CCAPP

INTRODUCTION & PURPOSE

- Cosmic rays are high energy sub-atomic particles that strike the Earth form space. When falling upon the Earth's atmosphere, cosmic rays create a cascade of relativistic secondary particles which may reach the Earth's surface, and be detected.
- Detection of cosmic rays can be done measuring the particle flux on the ground, the fluorescence in the air, or the radio and acoustic signatures.
- One novel idea for detection is the observation of such particles by using an array of cellphones: detection by the CMOS sensors of smartphone cameras [4].
- A very large area (or very long run) is needed to accumulate a sufficient number of observed events. Having a large network of phones is relatively cheap, and sufficient to detect air showers from high-energy cosmic rays. This is the main advantage of this approach. This will serve as a 1) prototype for future arrays. and 2) as an educational outreach opportunity for local students.
- We propose a prototype array to be deployed at the OARDC in Wooster, OH, consisting of an array of phones and antennas to detect both RF radiation (due to particle oscillation about the geomagnetic field) and particles.
- The goals of this summer project are to assess the feasibility of the particle detector prototype by making an estimation of the number of particles the array would observe in a "realistic" amount of time.

Figure 1: The OARDC, in Wooster, OH.

METHOD

- Throughout this project, we used CORSIKA, a program for detailed Monte Carlo simulations of air showers initiated by high energy cosmic ray particles [2]. This program allows the user to modify the geomagnetic field and altitude, which were set to those of Wooster, Ohio, where Buckarray is planned to be set, in order to have a more realistic simulation.
- We simulated 100 cosmic showers of energies 10^{15} eV and 10^{16} eV, treating protons as primary particles, covering 360°azimuthally, but restricting the polar angle to be in the range 0°-30°normally distributed.
- The CORSIKA output is a datafile having information such as the type, position, and momentum components of the particles that reach an observation level. An observation level is defined as a user-chosen altitude at which data about particles will be stored in the datafile.
- Regarding the geometry of the array, after some testing we decided to use a 50×50 meters rectangular geometry with 143 phones distributed in a 13×11 rectangular array spaced by 2 meters.
- The final stage of the process consisted of counting how many photons, electrons, positrons, muons, and antimuons above certain energy hit, if any, a detector. We set the energy threshold to be 1MeV after estimating the energy loss for electrons and positrons passing through 1mm thick silicon [3].

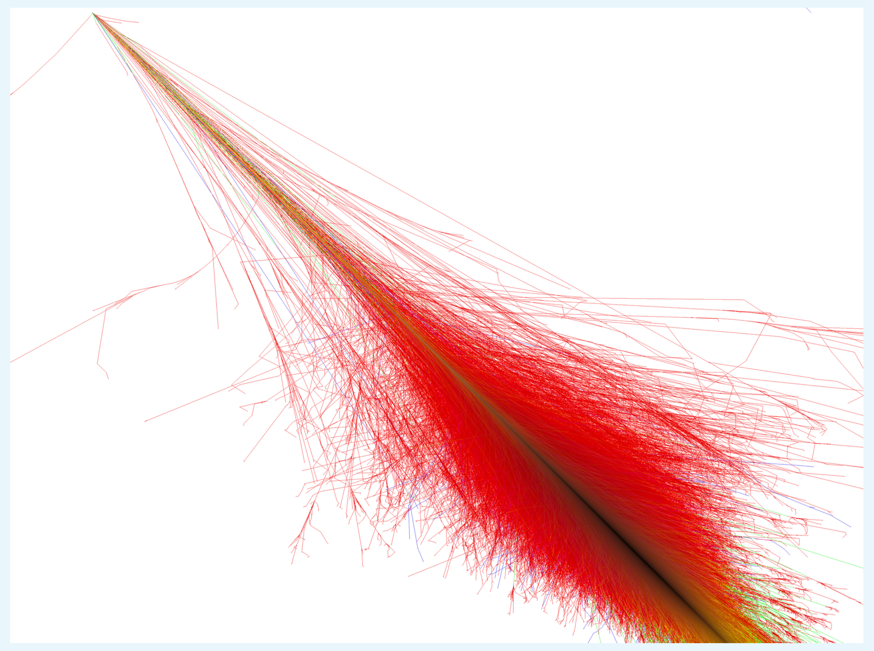

Figure 5: xz-projection of a 10^{15} eV proton shower, zenith angle: 45°. Made with CORSIKA.

RESULTS

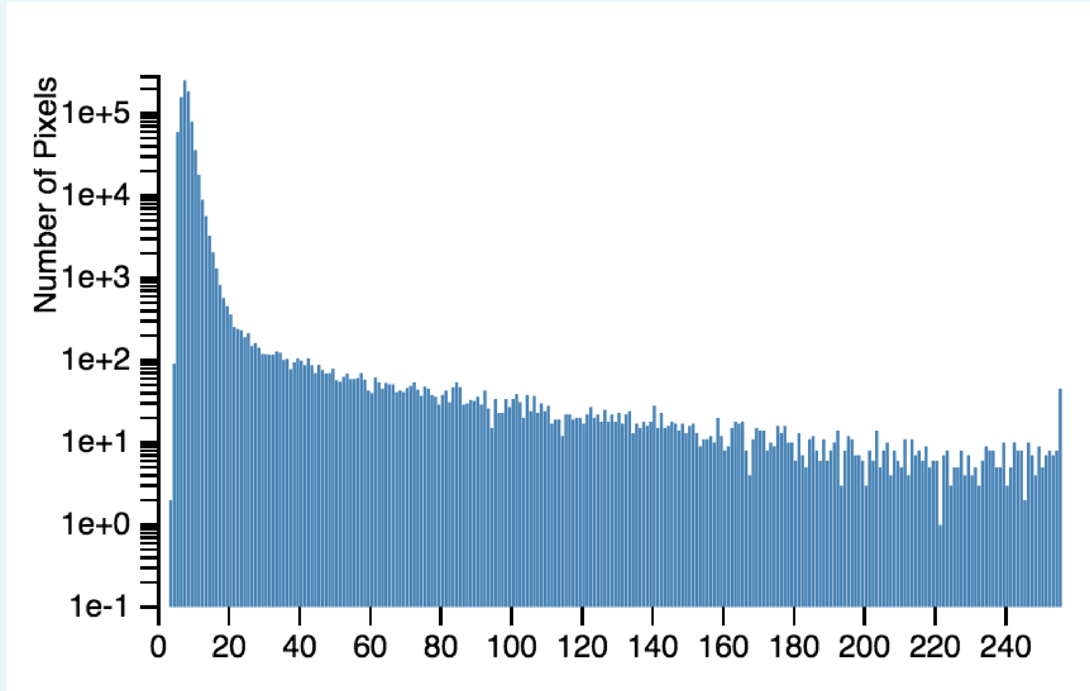

Figure 3: The distribution of pixel intensity values in candidate muon events.

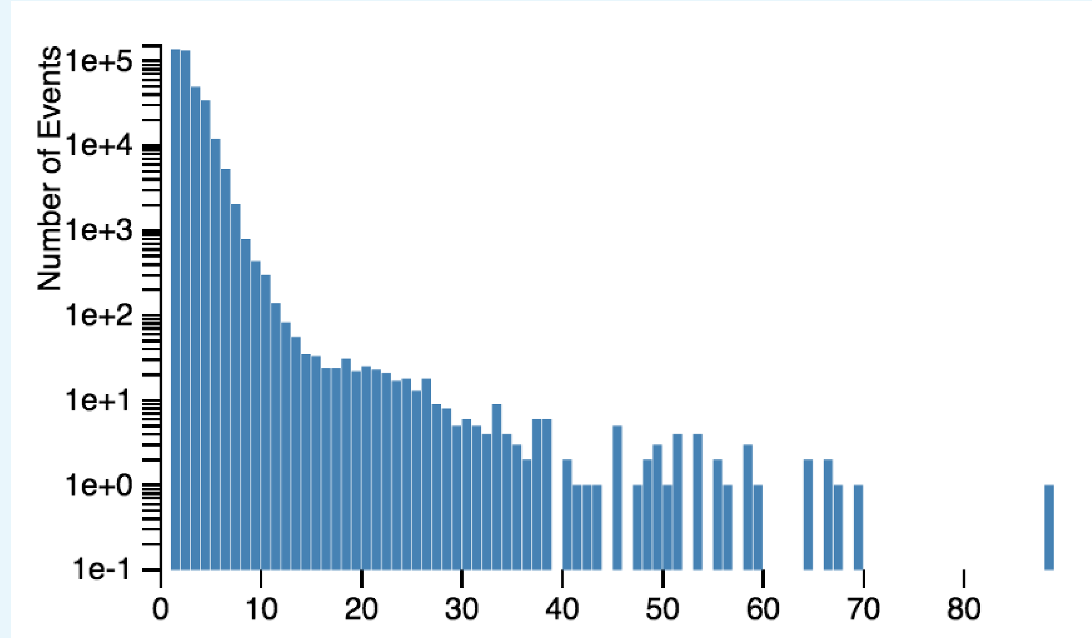

Figure 4: The number of above-threshold pixels in candidate events.

Thus far we have no results to show, regarding the simulations.
On the other hand, we have been using two cellphones with CRAYFIS running on them, and recording events. Figures 3 and 4 show the data that one of the phones has obtained up to now. This information can be retrieved by every user from the CRAYFIS webpage.

DISCUSSION & CONCLUSIONS

We studied the feasibility of The BuckArray - A Symbiotic Radio-Frequency/Particle Detector for Cosmic Ray Air Showers, a prototype array that can serve as a prototype for future detectors.

- The results we obtained do not allow us to determine the feasibility of the Buckarray. However, they give us a coarse idea of the order of magnitude of the amount of particles we can expect, but further research needs to be done in this aspect.
- In order to evaluate feasibility, we need to incorporate time in our study, i.e. how many particles we expect to hit the detector as a whole per unit of time. This is to be done by extracting information from the cosmic-ray flux.

ACKNOWLEDGMENTS

I would like to thank Prof. Connolly and Jordan Hanson for advising me in this research. We would also like to thank Prof. John Beacom for useful comments, and to the Ohio Supercomputer Center for the computing resources, and guidance.

FUTURE RESEARCH

We need to study the following aspects to have a decisive argument on the feasibility of the project:

- Accounting for the background noise, and how we can filter it from actual data, as well as the incorporation of the limitations of CRAYFIS and the sensor itself (e.g. low efficiency) into our study.
- Compare our results with real data, obtained by getting more cellphones to run the app.
- Optimization of the simulations.

REFERENCES

[1] O. S. Center. Ohio supercomputer center. `http://osc.edu/ark:/19495/f5s1ph73`, 1987.

[2] D. Heck, J. Knapp, J. N. Capdevielle, G. Schatz, and T. Thouw. *CORSIKA: a Monte Carlo code to simulate extensive air showers.* Feb. 1998.

[3] K. A. Olive et al. Review of Particle Physics. *Chin. Phys.*, C38:090001, 2014.

[4] D. Whiteson, M. Mulhearn, C. Shimmin, K. Cranmer, K. Brodie, and D. Burns. Searching for ultra-high energy cosmic rays with smartphones. *Astropart Phys*, 79:1–9, 2016.