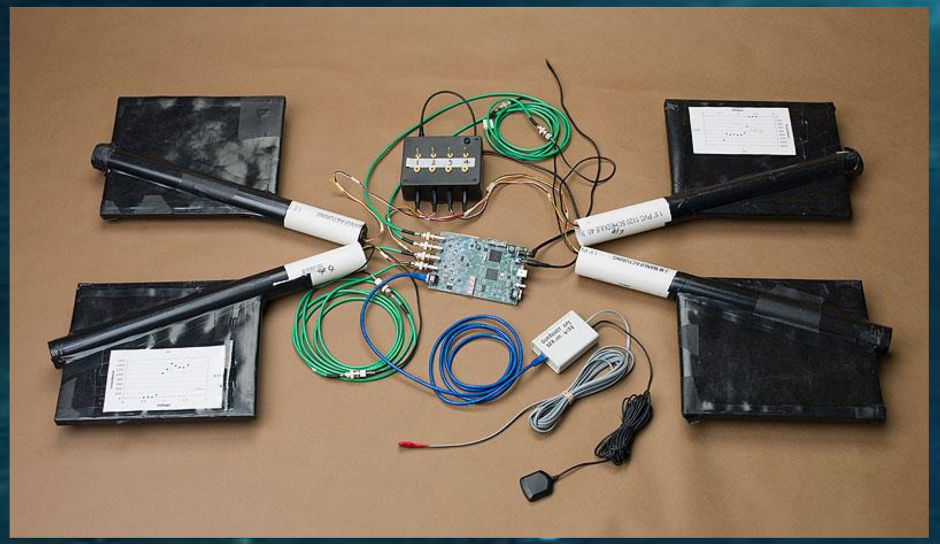
# Cosmic Rays and Shower Studies

Elizabeth McFarland, Damascus High School, 2015

## THE PROJECT

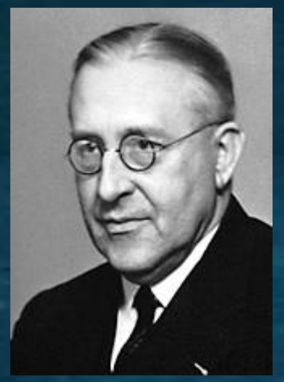
I used a set of four cosmic ray detectors and the Java Equip program to perform shower studies in order to determine the relationship between the area of the spread of the detectors and the number of hits registered on all four detectors simultaneously. By uploading the data onto the cosmic ray e-lab site, I was able to examine this relationship and form a basic pattern through the use of four different spread areas.

[1]



Cosmic Ray detectors and equipment for data collection.

[2]



Victor Hess (1883-1964)

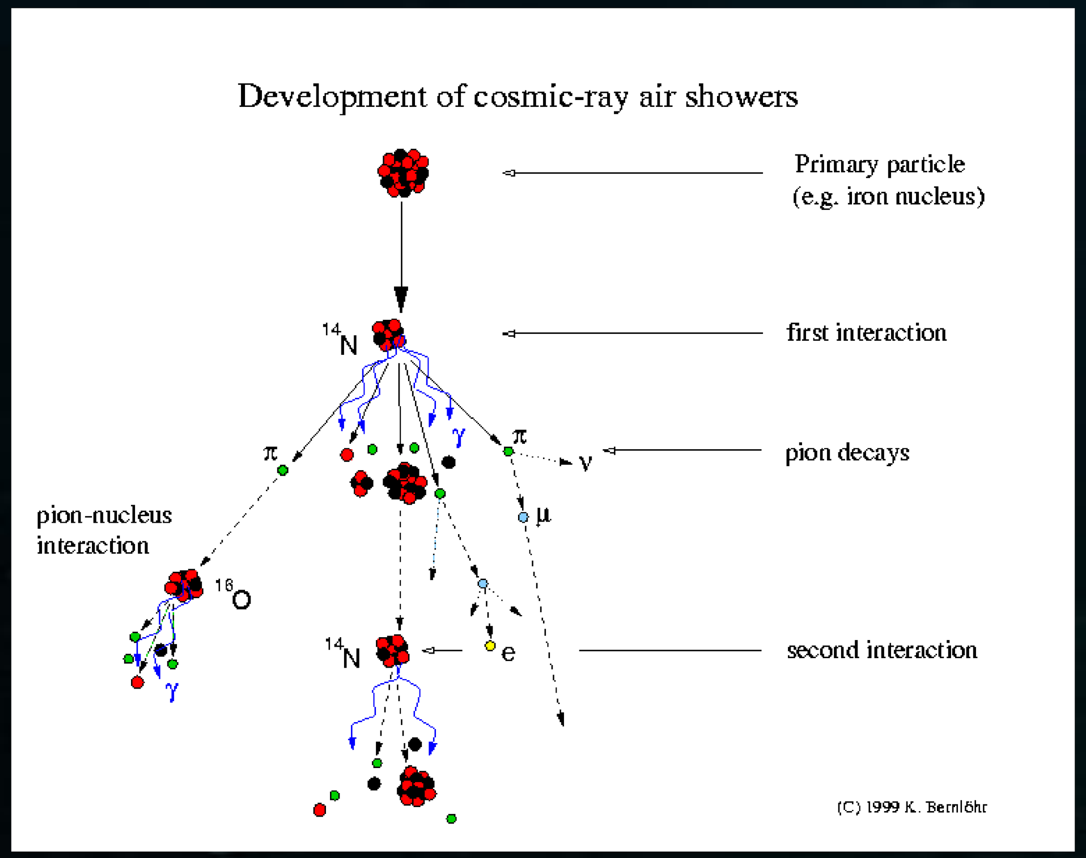
## INTRODUCTION

Defined as high-energy particles emanating from all directions in space, Cosmic Rays were first discovered in 1912 by Victor Hess. These rays travel at nearly the speed of light and are composed of 89% Hydrogen, 10% Helium, and roughly 1% heavier element nuclei, and also of subatomic particles such as the electron and positron.

## COSMIC RAY SHOWERS

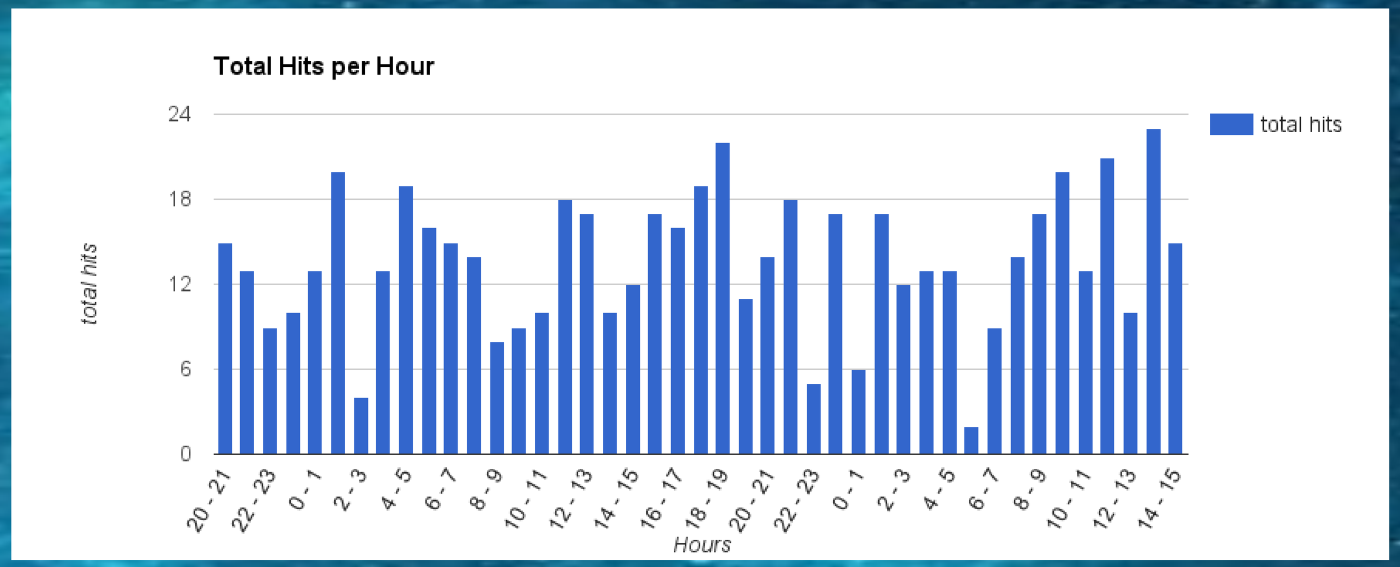
A cosmic ray shower is not a cosmic ray. Due to the abundance of particles in Earth's atmosphere, cosmic rays hardly ever make it all the way to the surface. Instead, we detect the shower of particles caused by the cosmic ray colliding with particles in the atmosphere. The primary particle of the cosmic ray collides with another particle, thereby creating new particles, usually pions, which will either collide again or decay. The shower gets wider and wider the closer it gets to the ground, as demonstrated in the image below.

[3]




## EXPERIMENT

The detectors were arranged in four different configurations, each of which ran a study for 19 hours. Because the cosmic rays almost never reach the ground, the detectors were calibrated to detect the muons that had decayed from the pions created in the collisions. The raw data were then run through the I2U2 Cosmic Ray e-Lab program to isolate the four-coincidence hits indicative of a cosmic ray shower. I then manually sorted the data into one-hour time blocks.

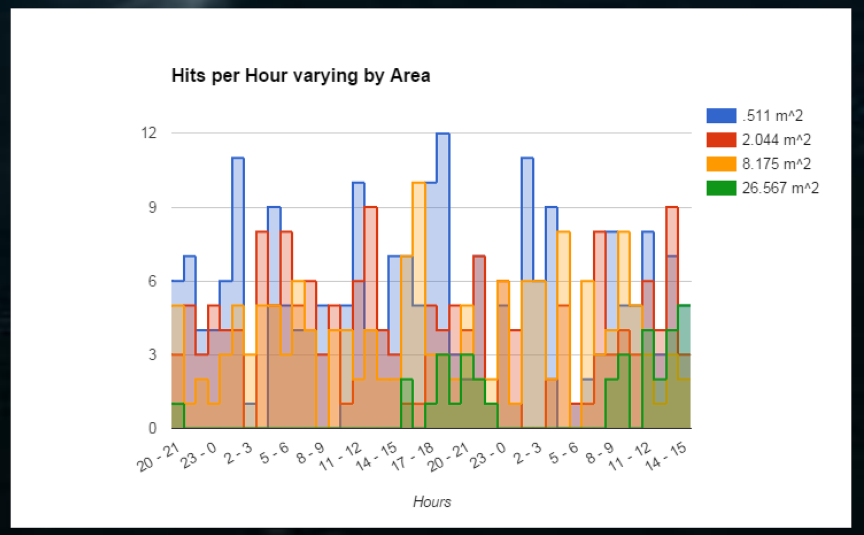



*First, I wanted to see if there was a correlation betwen number of hits and time of day, such as if the showers were more frequent in the sunlight. There does not seem to be a pattern. With more data it can be expected to either level out or show a pattern.*

## RELATIONSHIP BETWEEN AREA OF SPREAD AND NUMBER OF HITS


*I then separated the number of hits per hour into its corresponding area.*

It is fairly clear that the number of hits per hour decreases as the area of the spread increases.

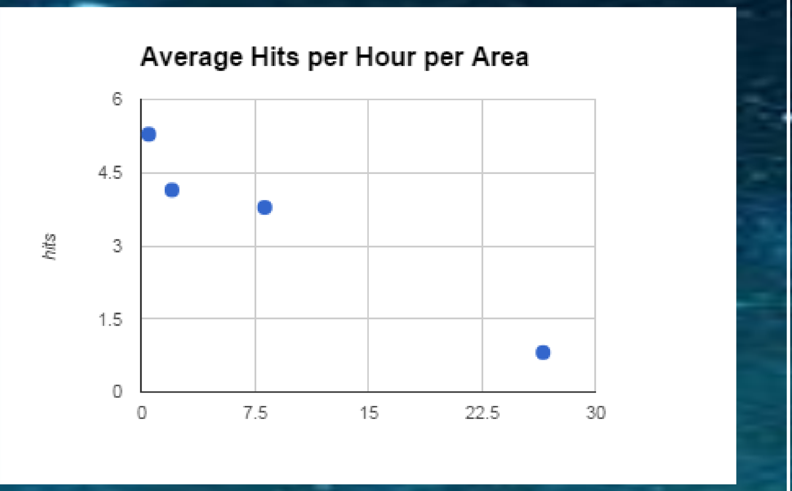



*This shows all the configurations' hit per hour overlaying each other to see more easily the differences between the areas.*

## MODELING THE RELATIONSHIP

Next, I averaged the number of hits per hour for each area of spread, and used that to model an equation that would demonstrate the relationship between them.

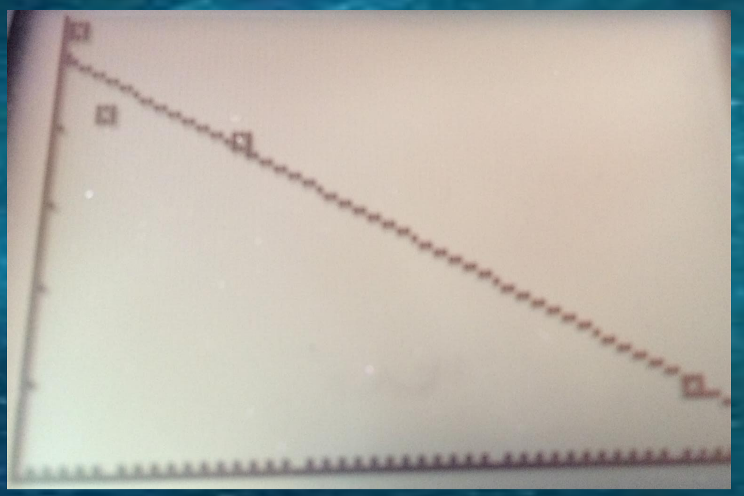
| Area (m^2) | Average Hits per Hour |
|---|---|
| 0.511 | 5.286 |
| 2.044 | 4.143 |
| 8.175 | 3.786 |
| 26.567 | 0.81 |




$$Y=-.1564X+4.9643$$

x= area in m^2
Y=average hits per hour

| Area (m^2) | Projected Value of Areas Average Hits based on Equation |
|---|---|
| 0.511 | 4.884 |
| 2.044 | 4.645 |
| 8.175 | 3.686 |
| 26.567 | .809 |



## ISSUES

The main issue with this study was that by uploading the data into the Cosmic Ray e-Lab site our geometries, the areas of the spreads, were erased. This caused a lot of backtracking while we tried to reconstruct the geometries and correctly match each with its corresponding data set. There were also issues with the computer shutting the data collection down after only a few hours, which prolonged the process by necessitating many re-runs of the program until it worked for the full 19 hours.

## UNFULFILLED ANALYSIS

Initially, we had also wanted to calculate the energy of the collision between the cosmic ray and the particle in the atmosphere for each spread, however, this turned out to be impossible to calculate accurately. We had no way to know whether our detectors were towards the middle of the spread, or along the outer border. We would either be calculating the minimum energy or the maximum energy. We also had no way to tell the angle at which the particles entered the detectors.

Given more time, we also would have run more studies with a greater variety of areas in order to test the accuracy of our model.

## ACKNOWLEDGMENTS

I would like to thank the Johns Hopkins University physics department, especially Dr. Swartz, for hosting us, along with the National Science Foundation, the United States Department of Energy, and Quarknet, along with Jeremy Smith and John Pisanic for providing us with this opportunity.

## REFERENCES

CERN: Accelerating Science. "Cosmic Rays: Particles from Outer Space." c2015. (accessed 28 July 2015) http://home.web.cern.ch/about/physics/cosmic-rays-particles-outer-space

Longair, Malcolm S. 1992 Particles, Photons, and Their Detection, Vol. 1 of High Energy Astrophysics, 2nd ed. , Cambridge, Cambridge University Press.

Gaisser. Thomas K., 1990, Cosmic Rays and Particle Physics, Cambridge, Cambridge University Press.

Simpson, J. A., 1983, "Elemental and Isotopic Composition of the Galactic Cosmic Rays, Annual Reviews of Nuclear and Particle Science, Vol. 33, 323-381.

Jokipii, J. R., and F. B. McDonald, 1994 "Quest for the Limits of the Heliosphere", Scientific American 272, 58-63.

Bernlohr, Konrad. "Cosmic Ray Air Showers." Max Plank Institute for Nuclear Physics. c1999. (accessed 28 July 2015) http://www.mpi-hd.mpg.de/hfm/CosmicRay/Showers.html

Photos from:

[1] www.fnal.gov "Femilab Today" and [2] http://nobelprize.org/nobel_prizes/physics/laureates/1936/hess-bio.html and [3] ASPERA Pictures for Press

Background provided by www.freeapplewallpapers.com