The Detection of Cosmic Rays at Chicago State University
Interim Report

Chicago State University SPS Chapter
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INTRODUCTION

The research of our SPS chapter is part of the experimental high energy nuclear physics program at CSU. Our work takes place in a detector lab dedicated to, among other things, the construction of a muon tracker detector to measure cosmic ray flow for several applications [1]. Under the direction of Dr. Garcia, physics professor and chapter advisor, we are using the SPS Research Award to construct a prototype of the muon tracker. The prototype will consist of an array of four scintillators and four photomultiplier tubes (the equipment needed to process and analyze the signal is part of Dr. Garcia's lab). The evaluation of the performance of the prototype detector will enable us to finalize the design of the muon tracker detector.

METHODOLOGY

THE SCINTILLATION DETECTOR

As muons, which are electrically charged, traverse the scintillating crystal they produce luminescence. This light travels to the phototube, where the signal is amplified via a series of dynodes and gives an electrical pulse proportional to the number of photons detected. The light then emerges from the optical fiber as an electrical pulse. The electrical pulse is stored in electronic equipment and then read into a computer for analysis.

The first phase of the project consisted of understanding the principles of the muon detection techniques and obtaining experimental benchmarks for the measurements that we will perform using the tracker prototype, which we will build this Fall. To this end, we used the detector array and electronics shown in Figure 1. The detectors consist of thick scintillators attached to phototubes, and we use several NIM (nuclear instrument modules) to process the signals from the phototubes and count the number of muons that hit the detectors in coincidence.

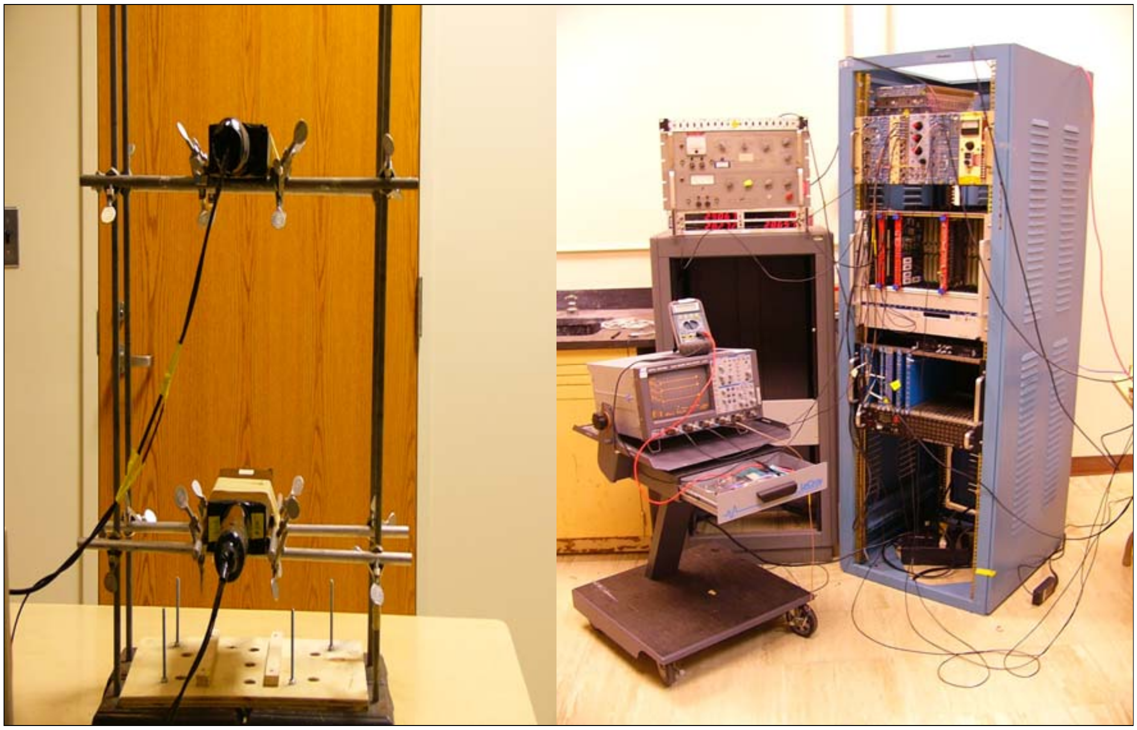


Figure 1*: Detectors (left) and instrumentation (right) used for bench mark measurements.*

VERTICAL FLUX MEASUREMENTS

In order to study the vertical flux, we used a coincidence between 2 detectors and varied the distance between them. By setting up a coincidence we were able to factor out noise and also limit the solid angle so that we get mostly vertical muons. We also connected the output to a discriminator in order to set an energy threshold for the incoming muons.

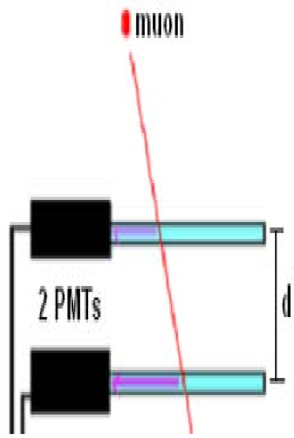


***Figure 2**: Principle of Vertical Flux*

For our flux calculations, we employed an approximation that is widely used for a setup involving 2 flat detectors:

$$F_{\mu} = \frac{(\text{count rate})\, d^2}{(\text{area of top panel})\,(\text{area of bottom panel})}$$

We compared our values to the PDG (Particle Data Group) theoretical value, which basically states that muons reach the Earth with a typically constant flux of 1 per square centimeter per minute.

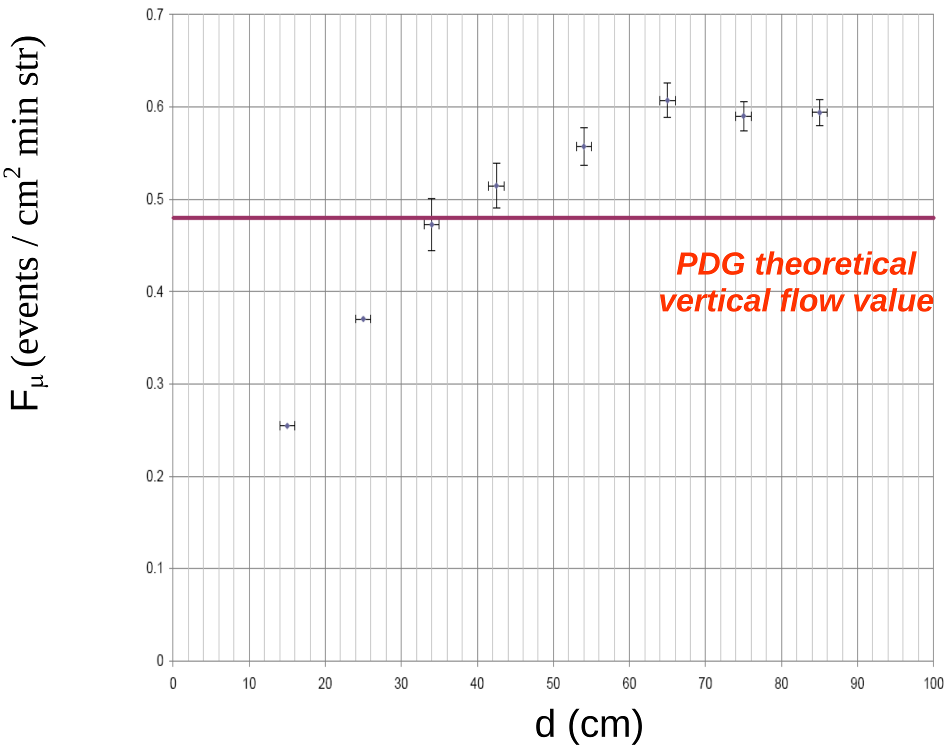


Figure 3*: Vertical Flux for specified distances*

We found that the vertical flux results are within 20% of the PDG value. The error may be due to the approximation used to calculate the flux, where we assume that we are using detectors that are very thin in comparison to the distance between them. To a lesser degree, the error may be also due to the lack of discrimination for completely vertical muons.

However, when we compared our values to the correlation plot of:

$$Rate \propto \frac{1}{d^2}$$

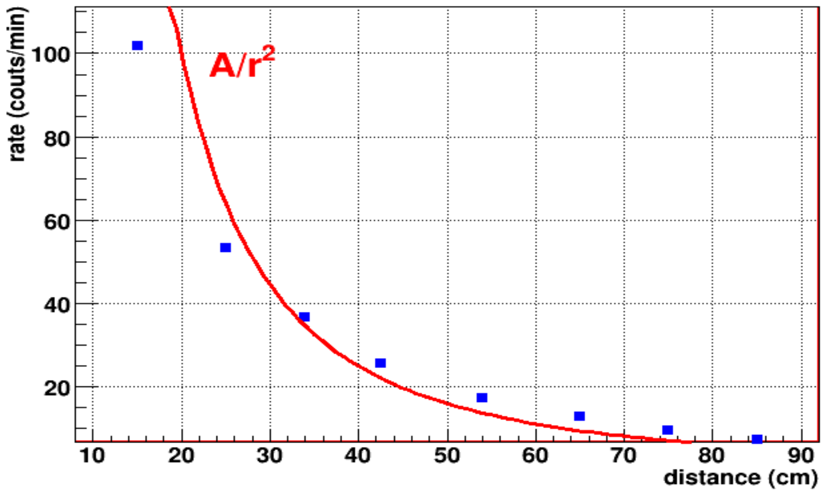


Figure 4*: Muon rate as a function of distance*

We found that the results are within estimates of the correlation plot. This led us to believe that the reason that our data did not agree with the PDG expected values was that the vertical flux has a geometrical dependence.

ZENITH ANGLE DEPENDENCE

In order to study the zenith angle dependence, we used a coincidence between 2 detectors placed a distance of 40 cm apart. We varied the zenith angle by varying the height of one side of the base, as shown in figure 5 below.

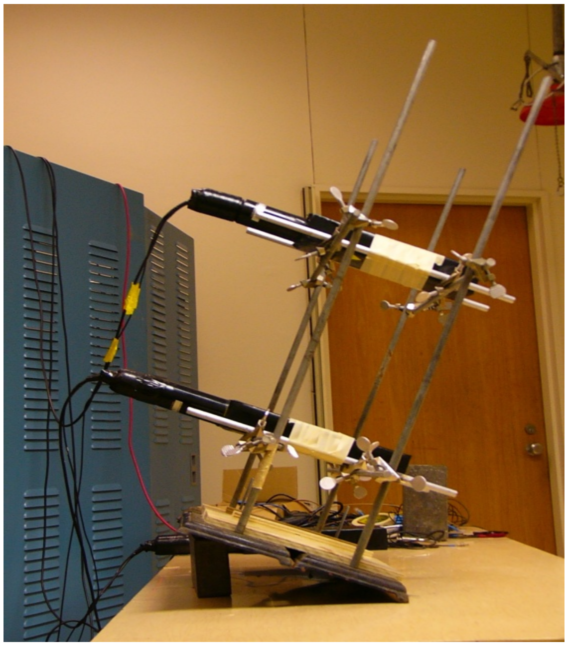


***Figure 5**: Principle of Zenith Angle Dependence*

We compared our values to the PDG theoretical value of proportionality, that the change in flux with changing azimuthal angle θ is proportional to COS ^{2} θ. We found that the dependence corresponds to the expected COS ^{2} θ and is off by about 2%.

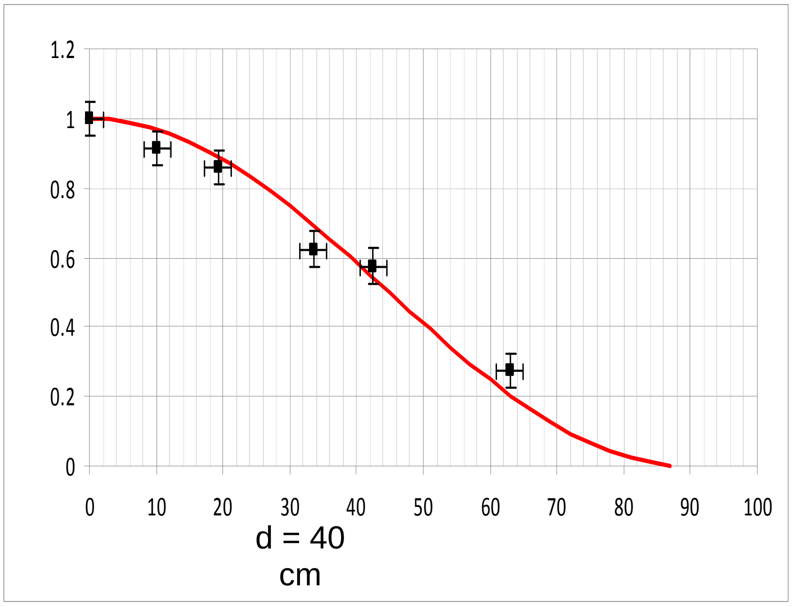


***Figure 6**: Flux as a function of azimuthal angle, at a separation distance of 40 cm*

DISCUSSION

Our initial work with the vertical flux gave us results that did not agree with the PDG value, but did agree with the correlation plot. This led us to believe that the vertical flux has a geometrical dependence and the error is due to the fact that in using flux approximation we assume that the thickness of the scintillator is very small in comparison to the distance between the two scintillators. That is not the case in our experiment, where our scintillators are 5 cm thick in comparison to a maximum separation distance of about 70 cm. Based on our data we can conclude that smaller active area detectors will better fit the vertical flux expected values. The rate dependence on the detector separation and the azimuthal flow distribution are consistent with standard flow measurements.

CURRENT WORK AND TIMELINE

Our work to date has been presented at The Women in Physics Conference at UIUC on 01/18/09 and I-LSAMP Conference for Undergraduate Research on 02/28/09. We plan to continue our research, using what we have learned so far and expanding upon it.

In order to better fit the vertical flux calculation, we plan to reduce the active area of the detectors. To this end, two plastic slats and optical fibers with different dimensions (purchased with the award and listed in the budget that follows), will be used to test different configurations. We will measure the number of photons produced by the muons when they cross the material and compare the results.

We are currently writing a program, using LabVIEW, which will allow us to control different electronic devices in order to produce benchmarks for our testing needs. One of these devices is an ADC (analog to digital converter). The ADC digitizes the pulse coming from the phototubes, allowing us to improve the calibration and to discriminate between the energies of the incoming muons. We will also include a TDC (time to digital converter) and will expand our benchmark measurements to include the measurement of life-time of the muon.

Upon completion of the muon life-time measurements, we will build the tracker prototype. For this, we will use different combinations of fibers and scintillators. For each arrangement fibers and slats we will measure the number of photons produced by the muons when they cross the material. Our objective is to find the configuration that optimizes the amount of light that is detected. We hope to accomplish this by the Spring 2010 semester so that we may apply what we learn from our data to build a tracker that will enable us to measure the muon flow for different applications, such as to search for cavities inside of Mesoamerican pyramids.

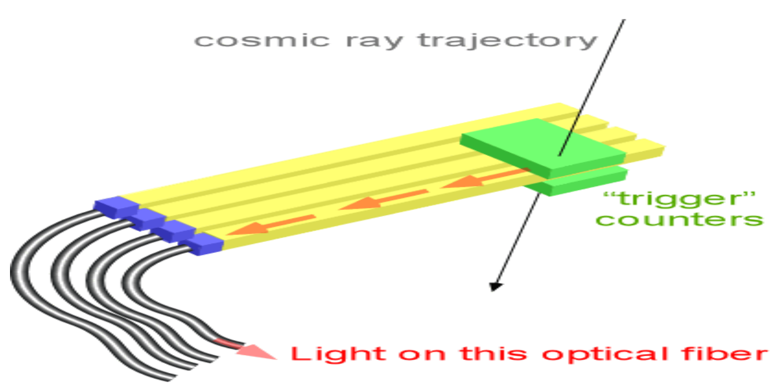


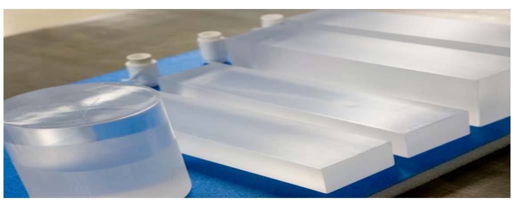
Figure 7: Muon tracker prototype

BIBLIOGRAPHY

1. E. Garcia, Measurement of Cosmic Ray Absorption To Search For Chambers in Mesoamerican pyramids, Productive Affinities Symposium: Successful Collaborations Between Museums and Academia. Evanston, IL (Oct. 2008)

BUDGET

The funds requested covered two modules each consisting of a phototube and a scintillator. We already have the equipment needed to process and digitize the signal from the phototubes at Chicago State University. The purchase of these materials completed the experimental set-up.

Qty.	Materials	Unit Price	Price
2	**Scintillators** BC408 from **Saint-Gobain Crystals** 	$450.00	$900.00
2	Phototubes Hamamatsu H5211A 	$550.00	$1100
		Total Price:	$2000