Cosmic Ray Detector

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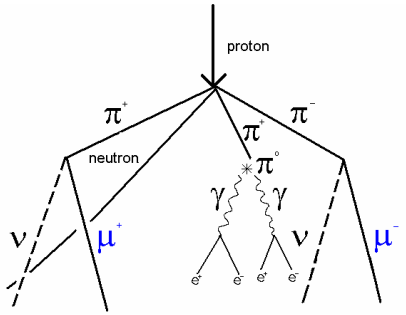
Cosmic Rays

What are Cosmic Rays?

Cosmic rays are high-energy charged particles travelling at nearly the speed of light that constantly bombard the earth from all directions. Any subatomic charged particle originating from outside earth's atmosphere can be considered a cosmic ray. When cosmic rays strike the earth's atmosphere they collide with the nuclei of atoms such as nitrogen and oxygen, which creates a cascade of other subatomic particles such as *muons* and *pions* in what is known as a cosmic ray shower as shown below.



Muons (shown above in blue) are of particular interest in the detection of cosmic rays as they decay much slower (micro-second order) than the other high energy particles and they don't strongly interact with matter so they can pass through bulk material quite easily. These aforementioned characteristics make muons the best means of detecting when a cosmic ray has hit the atmosphere.

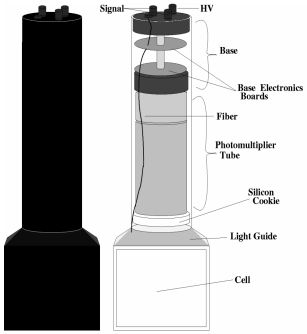
Why Detect Cosmic Rays?

Cosmic rays are responsible for many natural phenomenon here on earth. For example the northern lights are due to low energy cosmic rays interacting with earth's magnetic field. Also the ionisation of molecules in the lower atmosphere due to cosmic rays has an impact on the formation of clouds and electrical storms. On a less local scale, most cosmic rays have been travelling for a very long time, affording us an indication of the state of the early universe. Therefore, a continued study of cosmic rays will help us better understand the world and the universe around us.

Method of Detection

Detectors

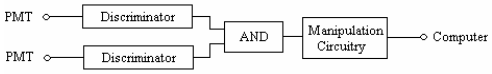
To detect the muons caused by cosmic rays, scintillator-photomultiplier tube (PMT) detectors were used in conjunction with coincidence detection circuitry. The scintillators, which are made of a special type of plastic, emit light when an incoming particle excites atoms that then decay back down to a stable state, emitting light (photons) in the process. These photons when propagate down a light guide that funnels them to the PMT. There they strike a photocathode that, through the photoelectric effect, produces electrons. These electrons then strike a number of metal plates that are at increasing potentials (called dynodes) creating a cascade effect (imagine rolling a small rock down a hill full of loose rocks), that finally terminates at the anode where the electric signal is sent through to the circuitry. A typical scintillator-PMT detector is shown below.



Outside of Detector Inside of Detector

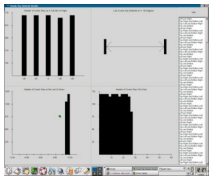
Detection Circuitry

Muons are the only particles with enough energy to trigger and pass through a detector and also trigger and pass through the detector opposite it. Since these particles are moving at nearly the speed of light, both detectors would trigger at approximately the same time (called a *coincidence*), so a circuit was designed to detect these coincidences. An integrated circuit called a *discriminator* outputs a "true" logic voltage when the magnitude of the PMT output crosses a certain threshold voltage. Each detector outputs to a discriminator, and the discriminators attached to detectors opposite to each other output to an AND gate which outputs a "true" logic voltage when both discriminators trigger. The AND gate output is then manipulated to make it compatible with the attached computer's data acquisition software.



Software

The software designed for the cosmic ray detector served three purposes: to acquire data from the detection circuitry, saving the data to a file for future reference, and displaying the data in a window while it's being obtained. Whenever a coincidence is detected the circuit sends a signal to the data acquisition software that then determines which pair of detectors fired. The data acquisition software then saves this information to a file and messages a Graphical User Interface (GUI) with the data. The GUI will then plot the data to a series of histograms displayed in a window open on the screen as shown below.



Results

At the end of the summer all of the aforementioned components of the cosmic ray detector were assembled together and working properly. A stand to support the detectors was constructed as well as a circuit box to house the circuitry. The detector array is intended to be put on display in the physics building's foyer for the general public

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