Design, construction, characterization and use of a detector to measure time of flight of cosmic rays

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Abstract. In the study of cosmic rays, measurements of time of flight and momentum have been used to identify incident particles from its physical properties, like mass. In this poster we present the design, construction, characterization, and operation of a detector to measure time of flight of cosmic rays. The device is comprised of three plates of plastic scintillator arranged in vertical straight line, they are coupled to one photomultiplier tube. The analogical output has been connected to a data acquisition system to obtain the number of digital pulses per millisecond. We present preliminary results.

1. Introduction
Cosmic rays at the top of the terrestrial atmosphere include all stable charged particles and nuclei with lifetimes of order $10^6$ years or longer, when they collide with atmospheric atoms produce secondary particles [1]. Scintillation is a method for detecting this cosmic radiation. It uses photomultiplier tubes (PMT) coupled to scintillators that produce flash light when struck by radiation. These flashes are detected by the PMT, hence the output pulses of it contain information on the energy of the incident particle. Scintillation is applied in Time of Flight detectors (TOF) that are made to measure the velocity of the particles from the time difference between the pulses obtained from the scintillator counters [2]. Velocity can be combined with a measure of the momentum of particles to determine its mass, and therefore its identity [3].

2. Hypothesis
Particles can be identified by measuring its time of flight and momentum.

3. Objectives
3.1. General Objectives
Design, construct, operate, and characterize a detector to measure time of flight of cosmic rays.

3.2. Specific Objectives
• To detect particles from the flash light produced in plates of plastic scintillator in a particular range of time.
• Determine the velocity of particles that go through the detector.
• Calculate the mass of particles to identify them.
4. **Design of the experimental prototype**

The main parts of the detector are three plates of plastic scintillator produced by Sumitomo Chemical, arranged in a vertical straight line, separated by one meter with extensor aluminium plates, as is shown in Figure 1.

They are connected with optical fibers of 3.15 m long, and a guide of light to a photomultiplier tube from Hamamatsu (H10493-012), whose effective area is a circle of 25 mm of diameter [4]. The dimensions of the plastic scintillators are 5 cm length, 0.6 cm width, and 5 cm height. They are covered with aluminium plates to block out external light. The inside walls of the aluminium plates are polished to mirror level to reflect photons inside the box, and ensure that most of them are guided toward the PMT. Three pieces with a set square form were designed to set the plastic scintillators. The base for the photomultiplier tube is in the middle part of the detector, which is inside of an aluminium tube.

5. **Construction**

We cut, polished, and fixed with screws all the pieces. Finally, the detector was fixed to a cabinet using aluminium tape. This process is presented in Figure 2.

![Figure 1. Designed parts of the detector.](image1)

![Figure 2. Construction and assembling.](image2)

6. **Tests**

Tests were done at Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois. The block diagram for the connection of the detector is shown in Figure 3. The operation voltages for the PMT applied were: Low Voltage Input (Red) +14.01 V, Low Voltage Input (Green) -14.04 V, and Vcont Input (White) +1.135 V.

The discriminator board was powered applying +5 V and -5 V to its terminals, the input signal was produced for the detector, and digital signal was connected with a BNC coaxial cable to a data acquisition system of 32 channels, that is the CompactRIO from National Instruments that was programmed to obtain the number of counts per millisecond.
7. Results
The analogical and digital outputs are shown in Figure 4. The configuration parameters for the oscilloscope were: Channel 1 (Digital) 2.00 V, Channel 2 (Analogical) 200 mV, and Time 1.00 µs. The chart Counts vs Time, and the histogram for the frequency distribution are shown in Figures 5, and 6.

Figure 3. Block Diagram for the connection of the system.

Figure 4. Oscilloscope display for the detector outputs. Digital output is channel 1 at the top. Analogical output is channel 2 at the bottom.

Figure 5. Counts per millisecond vs time in a recording of 30 minutes

8. Conclusion
Analogical signals of 400mV of amplitude in a time scale of 1 µs were obtained with the photomultiplier tube. A faster data acquisition system is required to see the difference of time in the three pulses produced by the plastic scintillators, since they should be in the range of nanoseconds. That would be necessary for measuring the time of flight of particle that come from cosmic rays.
Figure 6. Frequency distribution of digital pulses per millisecond in a recording of 30 minutes.

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