DIY PARTICLE DETECTOR

S'Cool LAB

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Our research group of the S'Cool LAB Summer Camp 2017 built detectors which in principle work similar to a Geiger counter but use semiconductors in order to detect ionizing particles. An oscilloscope was used to distinguish the amount of voltage recorded over time. These output signals were then interpreted using a microcontroller and the counts of muons detected were visualised. It was all about applied physics and building several detectors from scratch. We have used one of the most fundamental electronic components, semiconducting diodes made of silicon (Vishay BPW34), to detect particles like muons.

Project Overview

The goal of the project was to be able to detect particles and then distinguish which of them were muons. Muons are constantly bombarding the Earth's surface. That being said, the flux of muons at sea level is higher than expected based upon their half life of 2.2 us. This difference is explained using time dilation which deciphers the increased particle range for particles moving close to the speed of light such as muons.

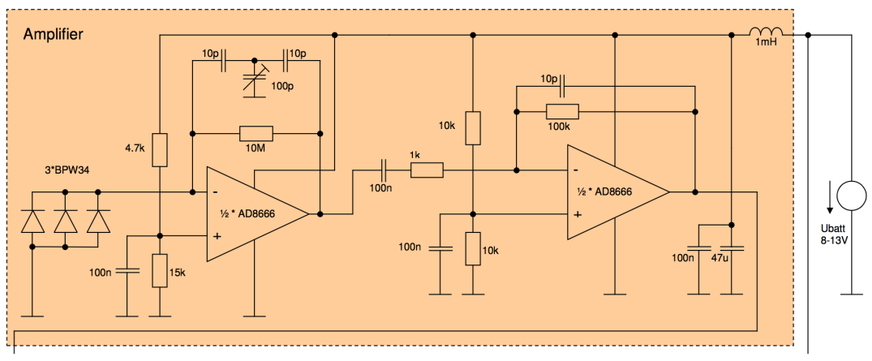

Fig.1 - Schematic of the detector circuit using several silicon photodiodes as sensors in reverse bias mode [1]

Fig. 2 - The picture shows one setup to detect cosmic particles. The lead plates trigger an electromagnetic cascade which has to be registered by at least two detectors at the same time (coincidence method).

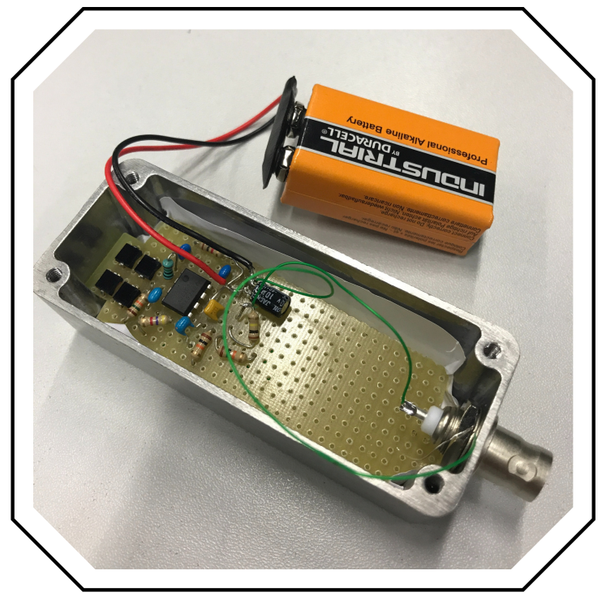

Fig.3a - Top view of the assembled circuit

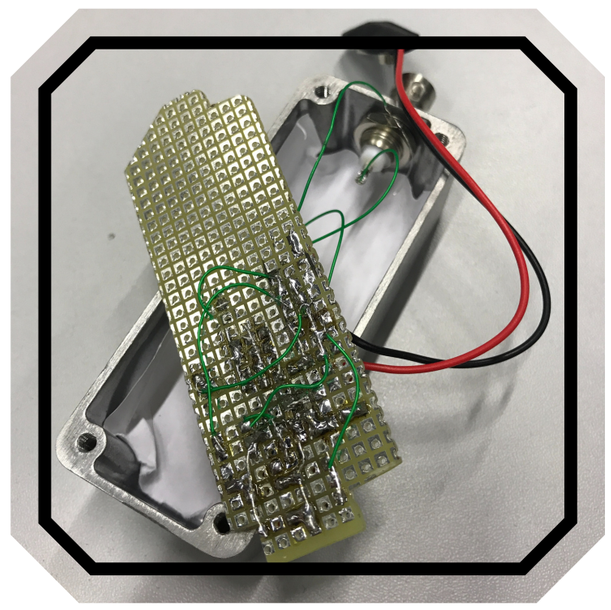

Fig.3b - Bottom view of the assembled circuit

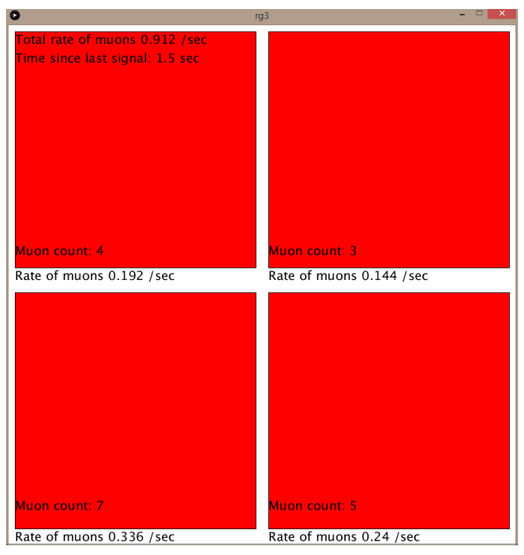

Fig.4 - Event display programmed using Processing.org

Detector Setup

The semiconductors surface is the area of detection. When radiation strikes the semiconductors, it generates a current impulse which is then amplified twice and outputed as voltage. This process is known as transimpedance amplification. These voltages are detected by an oscilloscope and the signal is interpreted. In order to get a simple visualisation of muon counts, also known as an event display, a program was written in Python using Processing.org.
The program reads an Arduino Due board through a USB connection, using the coincidence detection method to construct a graphical visualization of the activity in the sensors. Additionally averaging algorithms are used to calculate the rate of muons, number of muons, and the time since last trigger.

Figure 1 shows the schematic illustration of the electronic circuit. It was used in order to build four separate detectors which were then separately shielded in metal containers. Signals from each of the detectors were displayed individually. According to Figure 5, the acceptance angle theta is equal to 57 degrees, which is equivalent to 0.76 steradians. According to the equation for muon flux at sea level, $I=0.82*10^{-2}cm^{-2}s^{-1}str^{-1}$ [2], the expected rate would be $1.87*10^{-3}$ counts/s or 6.7 muons per hour.

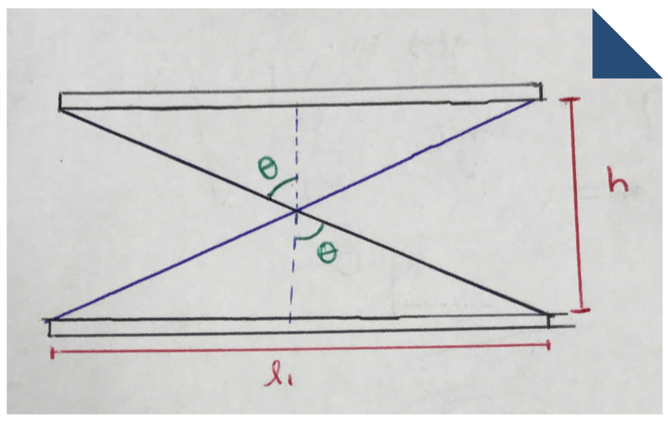

Fig.5 - Illustration of the acceptance angle of two stacked detectors with length l and distance h

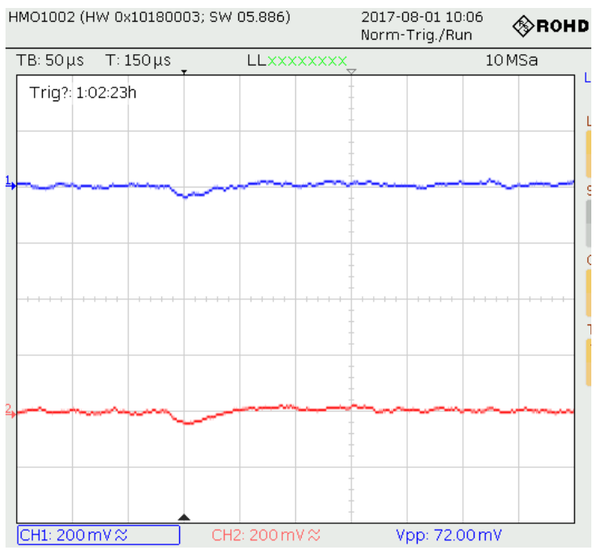

Fig.6 - Two simultaneous signals representing a detected muon in a stacked detector setup, the previous trigger was 1 hour earlier.

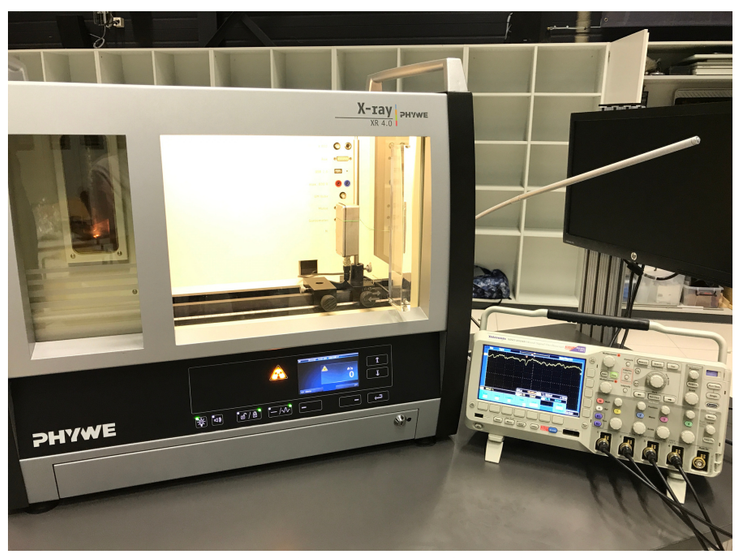

Fig. 7 - A setup in the X-ray machine showing that muons deposit enough energy to be detected. (Cathode voltage: 20 kV, current: 0.01 mA)

CERN

References:

[1] http://www.opengeiger.de (Bernd Laquai)

[2] http://courses.washington.edu/phys433/muon_counting/counting_telescope.pdf