Escaramujo: An Education Outreach Project

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Purpose

The Escaramujo Project is a high-energy physics educational outreach program that aims to work with highly motivated professors and students to start a hardware effort in instrumentation, form an international community, and collaborate on future high-energy physics experiments.

Advanced undergraduate and graduate classes in 10 countries across Latin America will partake in a five-day workshop that focuses on cosmic rays, elementary particle physics, and instrumentation. After the workshop, each university will keep the detector that they construct, and professors and students will be able to expand upon the experiments they started.

Stages of the Workshop

The workshop will be conducted in three stages: a conceptual stage (concepts), a hands-on stage (hardware), and an analysis stage (software).

CONCEPTS

Students will learn the background technology and concepts necessary to understand how the device works; they will focus on researching the instrumentation, as well as learning how ionization and scintillation play a role in the functionality of the cosmic ray detector.

HARDWARE

Emphasis on the instrumentation hardware: Students will assemble the detector with materials provided by the program, as well as understand the care necessary to construct and maintain the device. Students will start up the detector, troubleshoot as necessary, and begin taking data.

SOFTWARE

Students will analyze the data using C++ and ROOT; they will apply concepts from the technology background and experimental setup to interpret the time and location data to determine various characteristics of muons, such as their lifetime or flux.

Detecting Cosmic Rays

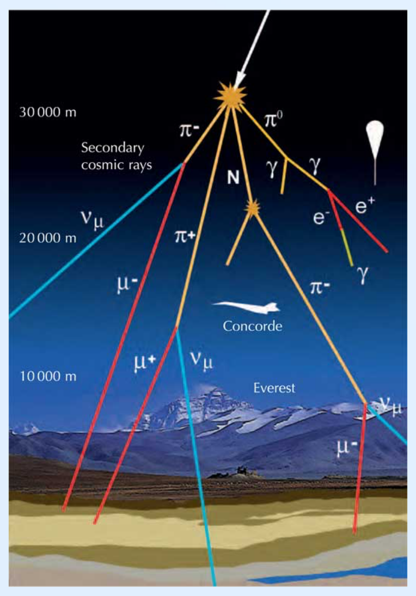


Figure 1: A cosmic ray decaying into pions and then muons as it approaches the Earth's surface.

Cosmic rays are a form of **high-energy radiation** that originate from outer space, and mostly consist of protons. As the rays approach Earth, they collide with air molecules in the atmosphere and break up into showers of **secondary particles** including pions and kaons (Figure 1). Before many of these secondary particles even reach the Earth's surface, they decay even further, primarily into muons**. Approximately 70% of the secondary particles that reach the Earth's surface are muons,** making them the most common secondary particles detected at sea level, and the easiest cosmic ray particles to detect.

Because muons are so massive, they are unstable and decay into an electron (or positron) and two neutrinos:

$$\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e$$

$$\mu^- \rightarrow e^- + \nu_\mu + \bar{\nu}_e$$

Muons can be detected by **scintillation counters**, which involve the use of scintillators, silicon photomultipliers (SiPMs), data acquisition boards (DAQs), and a computer (in our case, a Raspberry Pi)**.** The scintillator detects charged particles by generating photons when excited by the ionization energy of the incident radiation (Figure 2). Total internal reflection directs the photon to the SiPM, which converts the light signal into an electrical pulse via the photoelectric effect. This electrical pulse can then be read by a DAQ, which sends the counter data to the Raspberry Pi for storage and analysis. Using this method, muons can be detected and their characteristics analyzed.

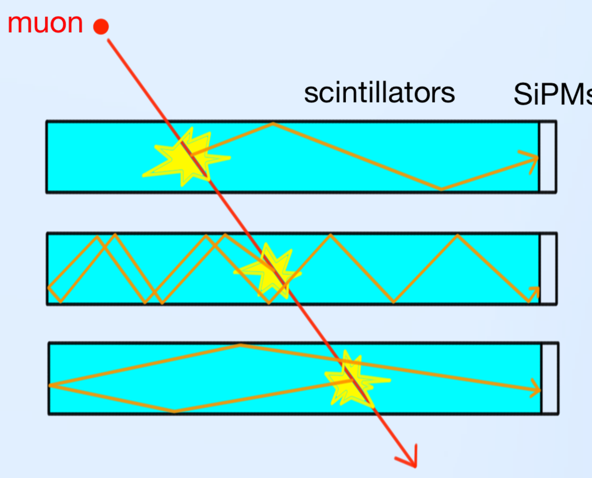


Figure 2: A muon strikes a stack of scintillating plates and releases a photon. Total internal reflection allows the photon to be detected by the SiPM.

Experimental Setup

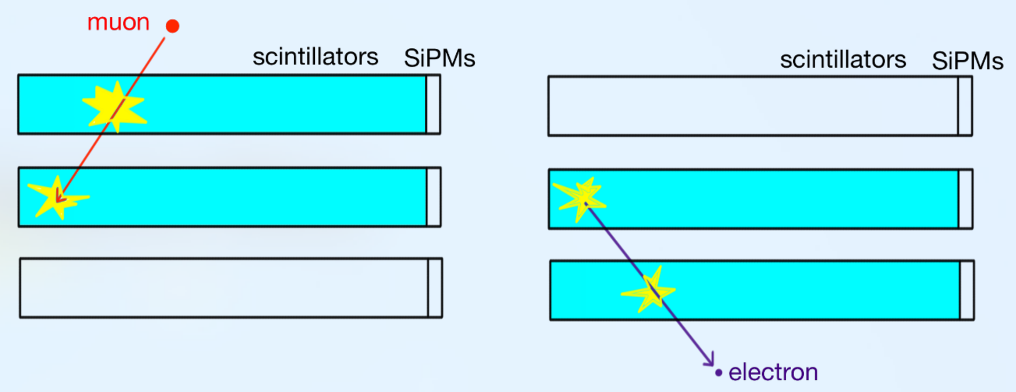


Figure 3: A muon is stopped in the middle scintillating plate and decays into an electron. The particles cause the plates to scintillate as they pass through.

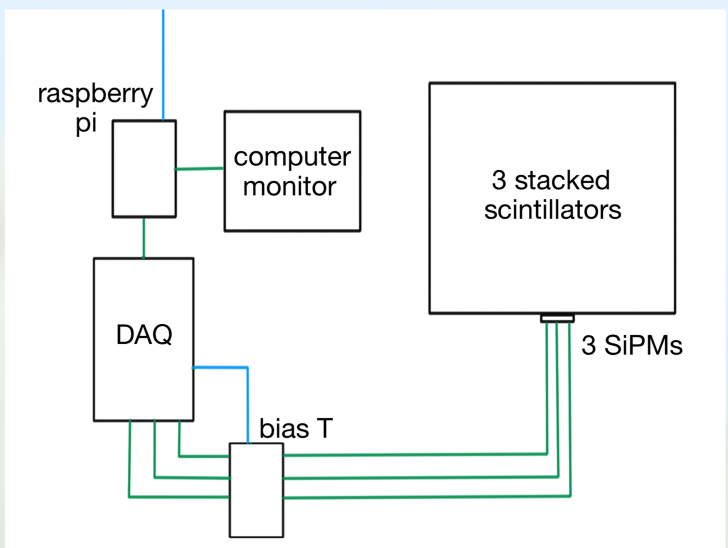


Figure 4: The signal travels from the scintillation counter through a bias T. If the signal meets the trigger criteria, the DAQ records the data and stores it in the Raspberry Pi. This data can then be read and analyzed using the Raspberry Pi, computer monitor, mouse and keyboard.

Approximately 10 muons pass through the detector every second; however, only a fraction of that data is actually useful. In order to look at characteristics of muons, the detector depends on the **delayed coincidence method**. The detector is triggered by incidences of muon decay. If we get simultaneous signals, or a **coincidence,** in the top and middle plates, one of two options may have occurred: a muon passed through the detector at such an angle that it missed the third plate, or a muon was stopped in the middle plate and it decayed. If we receive a second signal in the middle plate directly after such an observation, we know that the resultant pulse is from the electron produced by the decay.

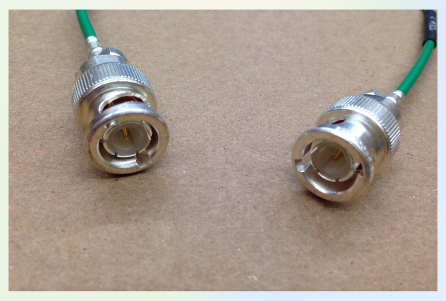
Quality Assurance

Quality assurance for the project involved the acquisition, fabrication, testing, and repair or replacement of parts.

First, three types of cables were adapted, including:

- **40-cable set of 5 nsec RG-174 cables** (One end converted to a pair of pins and sockets by soldering; one end used a lemo-to-BNC adapter.)
- **40-cable set of 2 nsec RG-174 cables** (Two ends converted to BNC connectors by crimping, Figure 5.)
- **2-cable set of 2 nsec RG-174 cables** (One end converted to power and one end converted to 3.5 mm audio jack by soldering.)

Figure 5: New BNC connectors on a 2 nsec RG-174 cable.



A multimeter was used to test cables, ensure that each conductor showed ~0 Ω of resistance, and that the cables were not shorted. The SiPMs were attached to a wrapped scintillator and hooked up to the oscilloscope to determine if pulses appeared when the bias voltage was set to 29.0 V (Figure 6). Noise was eliminated by setting the threshold voltage to -10.0 mV. The bias T boards were hooked up to 5 V power, and each adjustable bias mod was set to 30.0 mV.

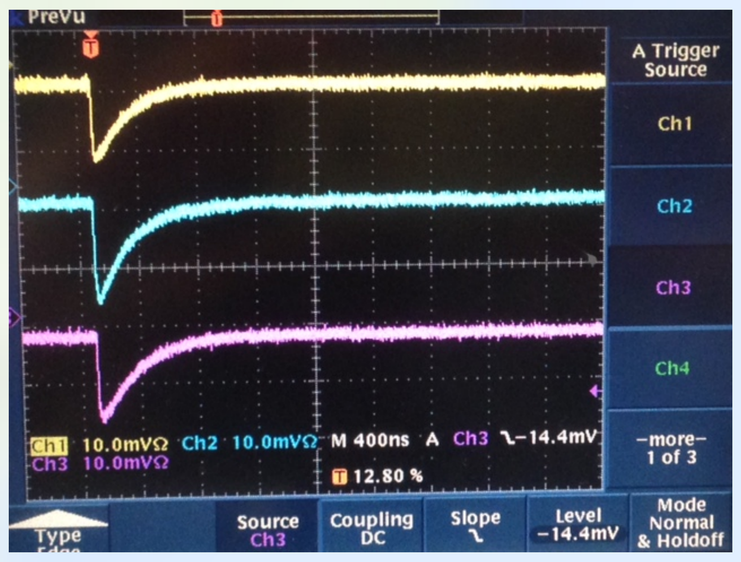
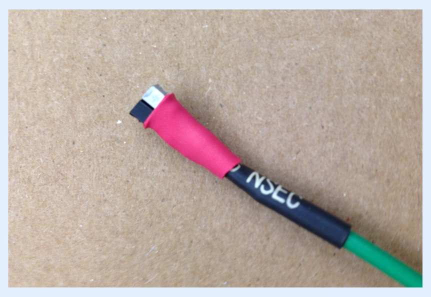


Figure 6: Typical oscilloscope pulse shape for a muon passing through three scintillating plates.

The signal side of each cable's pin and socket was marked silver so that it could easily be lined up with the corresponding connectors on the SiPM (Figure 7), and all hardware was marked with a number (1, 2, 3, . . .) so it could be tracked.

Figure 7: Color-coded pins and sockets on a 5 nsec RG-174 cable.



Future Work

The future of the project depends on the initial run. We intend to facilitate 10 workshops to get the project started, but afterward, it is up to the professors and students at each university to determine how to proceed. They will be given all of the tools necessary to collect and analyze muon data. However, many of the universities have expressed interest in further expanding the project to develop detectors for medical applications or to study volcano tomography by looking at different rock densities with muons.

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