Cosmic rays in the classroom

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NIKHEF

Every second, millions of cosmic rays come crashing through the atmosphere, showering us with elementary particles!

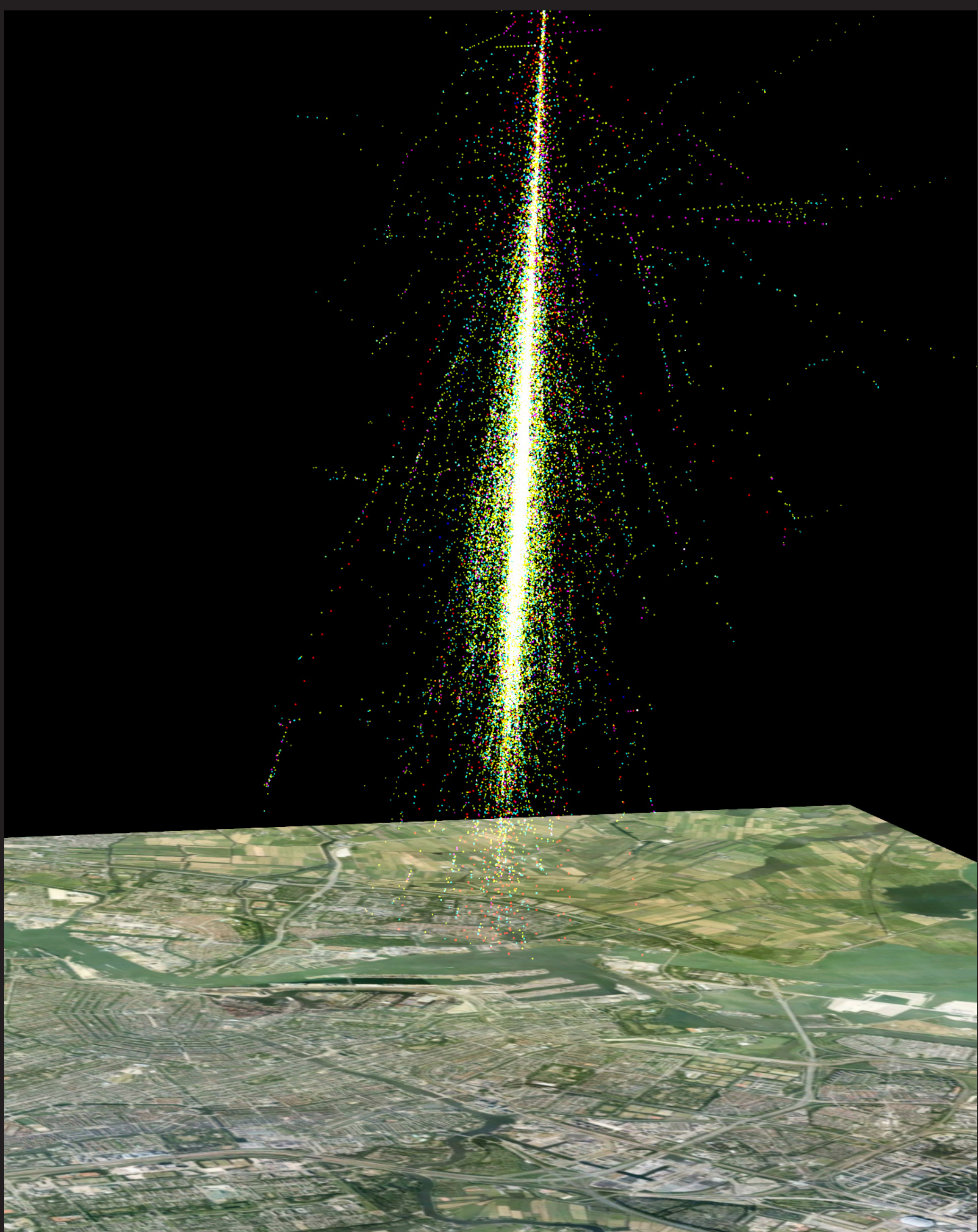
Introduction

We present a physics education experiment allowing (upper) high-school and starting bachelor students to measure an important constituent of cosmic rays, the muon, in the classroom! This two scintillator table-top setup is designed by Nikhef and produced on demand for schools and universities on a non-profit basis.

The discovery of cosmic rays dates back to 1910 when Theodor Wulf took his hand-crafted electrometer from Maastricht to the Eiffel tower in Paris, which led him to conjecture that the ionizing radiation, responsible for the electrometer's discharge, does not come out of the Earth itself, but out of the sky! Ever since, people have climbed mountains, gone up in hot air balloons or sent experiments up in space craft to study these 'space invaders'.

Today, we do know that cosmic rays are high-energy particles (like Hydrogen, Helium and Iron nuclei), originating in outer space, that travel at nearly the speed of light. When these high-energy particles impinge on our atmosphere, they collide with air molecules producing a cascade of secondary particles that shower down through the atmosphere (see figure). The majority of the secondary particles reaching the surface of the Earth are muons (heavier siblings of electrons), with an average intensity of about 100 muons per m^2/sec.

Today, almost 100 years after their discovery, we still have not identified the mysterious sources in our universe responsible for the cosmic rays. Several huge experiments (e.g. the Pierre Auger Observatory in Argentina, the Ice Cube neutrino telescope deep in the Antarctic ice and the ANTARES neutrino telescope at the bottom of the Mediterranean Sea) frantically try to resolve this mystery! In several countries, high-school projects (such as HiSPARC in the Netherlands) have also joined the race to register the highest energy cosmic ray.

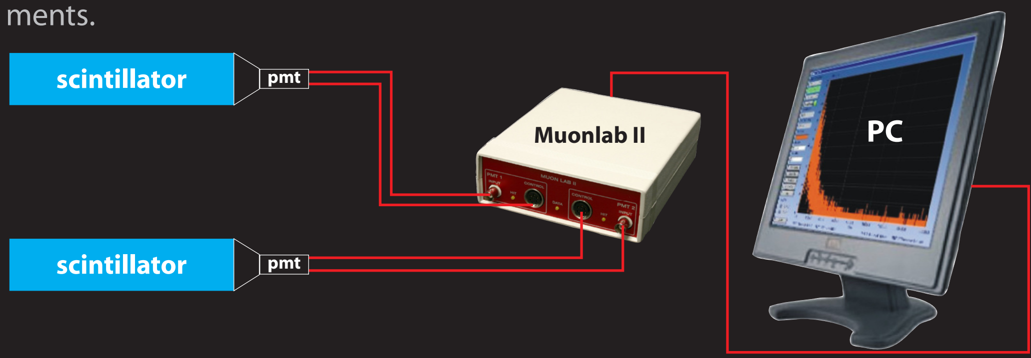


Setup

The setup consists of one or two scintillator detectors connected to the Muonlab II that interfaces to a PC (see figure). The device has a time resolution of one nanosecond, enabling a muon *lifetime* measurement for which only *one* scintillator detector is needed. In a configuration with *two* scintillator detectors, vertically separated by a few meters, the setup measures the *velocity* of muons.

A detector comprises the scintillator material that is connected to a photo-multiplier tube (PMT) and is completely enclosed by a protective cover. When a muon traverses the scintillator, a short light flash is generated, which is amplified and converted into an electrical signal by the PMT. The PMT is controlled and read-out by the Muonlab II, which itself is controlled via a USB interface.
A two scintillator setup costs € 2500, PC not included.

The Muonlab II comes with a LabWindows-based control and analysis software package. A graphical user interface allows the students to set the parameters for a particular run and to graphically display, analyze and store the measurements.



Experimenting with space invaders

Cosmic rays, notably the muons, can be made visible at high schools with relatively simple devices such as a Wilson cloud chamber or a spark chamber. We present a muon detector setup which in addition allows high-school students to actually measure phenomena outside the scope of classical Newtonian physics: the mean lifetime and velocity of muons.

This way students get a chance to not only enter the world of quantum mechanics but also to ponder how a particle with such a short lifetime manages to reach the surface of the Earth while being created at a height of many kilometers. Does it travel faster than the speed of light? To really convince the students that faster-than-light muons do not excist, they can do a direct measurement of muon velocities and use Einstein's theory of special relativity to find the solution for this apparent paradox.

Creative students can also use the setup to measure the muon flux in different locations (duplicating e.g. Wulf's original experiment) or to study the angular dependence of the muon flux.