UNVEILING THE SECRETS OF MUONS

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When cosmic rays collide with Earth's atmosphere they create secondary particles called pions and kaons that quickly decay into muons, which move at near light speed (so they have a warped perception of time) and have a lifespan of 2.2 microseconds.
These subatomic particles have many practical uses today, their ability to penetrate dense materials makes them a powerful tool to study the internal structure of objects and they are also used to calibrate particle detectors and investigate the nature of other subatomic particles.
Because of their great penetration power most of their interference can only be cancelled out by a thick layer of matter like that of the "Gran Sasso National Laboratories", which are located inside of a mountain to study neutrinos, dark matter and the interaction of high energy muons with matter.

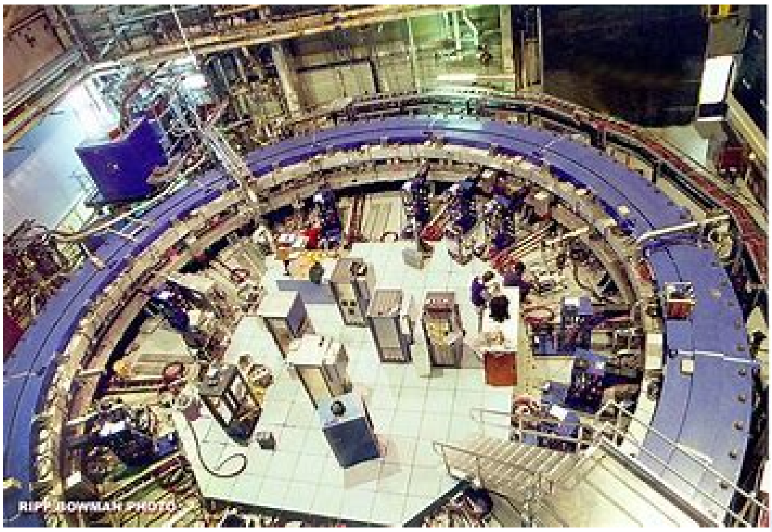
Despite sounding really complicated, they are part of our day to day life.

Introduction

Muons belong to the family of particles known as leptons, they are fundamental particles that have the charge and the spin of the electrons, but they have far more mass. They have a crucial role in particle physics and cosmic ray studies. This article talks about their discovery, properties, and how scientists detect them.

History of Muons

Muons were discovered in 1936 by Carl D. Anderson and Seth Neddermeyer while studying cosmic rays. Initially they were predicted by Hideki Yukawa for a mistake while he was studying the mesons. In the 1940s, Italian scientist Marcello Conversi, Ettore Pancini, and Oreste Piccioni conducted experiments on cosmic rays, recognized by the Nobel laureate Luis Alvarez as the beginning of modern particle physics. Over the years, muons have been the subject of numerous studies, including the Muon g-2 experiment, which precisely measured the anomalous magnetic moment of the muon. These studies have provided hints of possible new physics beyond the Standard Model.



(Brookhaven national laboratory, U.S dpt. of energy)

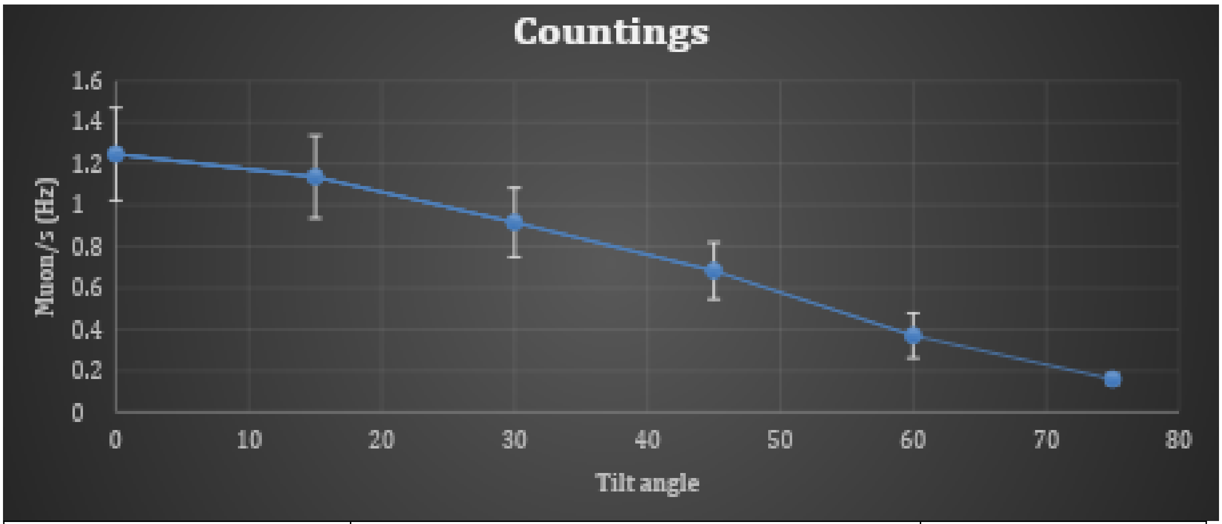
Properties of Muons

The Muons come in two types: negatively charged (μ^-) and positively charged (μ^+). They have a mass 207 times that of an electron (about 105 MeV/c^2).
Muons are unstable, with a lifetime of about 2.2 microseconds before decaying into electrons (or positrons) and neutrinos.
But, due to special relativity effects, such as time dilation, many muons produced in the upper atmosphere manage to reach the Earth's surface.
Muons are mainly produced in the Earth's atmosphere when cosmic rays collide with air molecules, generating pions that decay into muons.
The Muons also can penetrate deep into the Earth's surface, even passing through buildings and mountains.
The speed of these particles is so high (near light speed) that it causes a dilation of time compared to the passing of time on earth, this phenomena allows it to traverse 15km of earth's atmosphere in 2.2 microseconds defying the classic laws of physics.

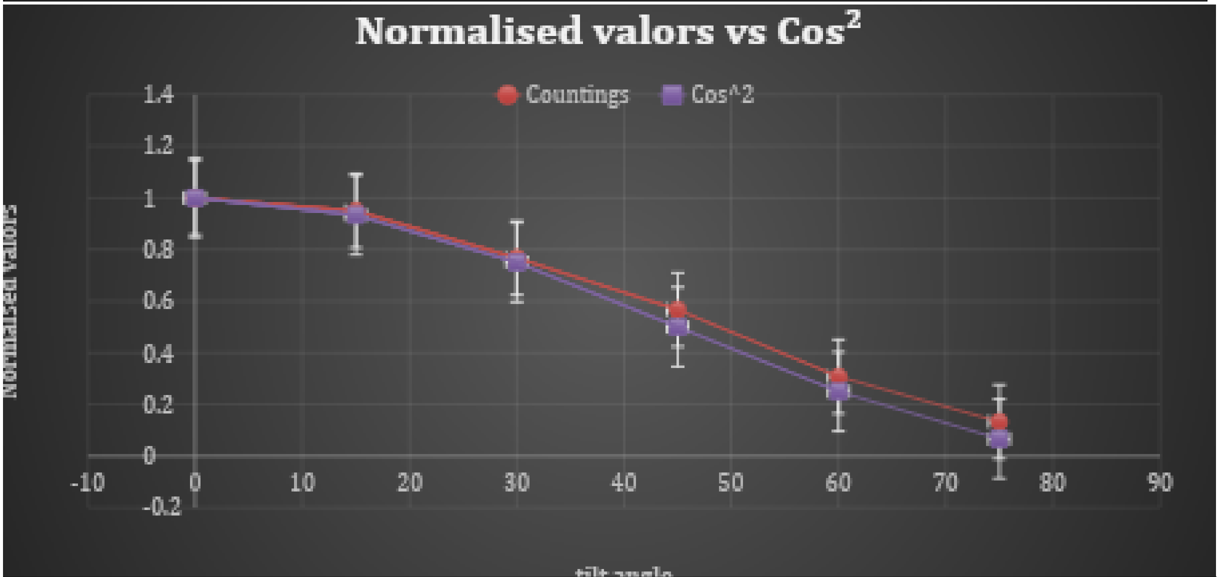
How we can detect them

During the international cosmic day lesson we were shown how telescopes measure muons by using scintillators made to emit a light signal when traversed by a high energy particle and then the light gets amplified by PMT's (photomultiplier tubes).
To select which analog pulses have to be transformed to digital ones (binary or hexadecimal), circuits called discriminators are used, the most common are threshold discriminators.

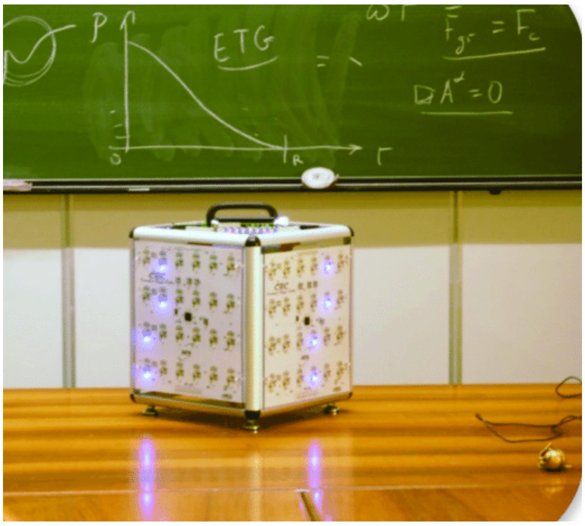
We were then given the opportunity to count the number of muons that set off the sensors on the cosmicrayslive app with the telescope getting tilted by 15° everyday about a week until it reached 75°.
Everyday we counted the number of muons detected in one minute five times and also the error.
It's important to note that the number of muons steadily decreased during this time since the shortest route to earth's surface is a straight line and thus it gives less muons the time to decay.
We also compared the chart of our measurements with the trend of cos^2 from the tilt angle of the telescope.



Tilt angle	muon/s (Hz)	uncertainity
0°	1,247	0,225
15°	1,137	0,2
30°	0,917	0,167
45°	0,683	0,137
60°	0,37	0,108
75°	0,16	0,025



Tilt angle	Normalised values	uncertainity	cos^2
0°	1	0,18	1
15°	0,95	0,16	0,933
30°	0,767	0,134	0,75
45°	0,567	0,11	0,5
60°	0,308	0,087	0,25
75°	0,133	0,02	0,067



Bibliography: For cosmic ray cube photo credits to researchgate.net and also credits to Wikipedia for some extra information.
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