Measurement of Decay Rate of Cosmic Ray Muons in Various Materials

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In this article, we are reporting cosmic ray muon decay rate using two and three coincidence method and using plastic scintillation detectors. We obtained that the decay rate of muons is higher for the materials having high density or having large atomic number.

Introduction

Cosmic rays with energies ranging from 10^8 to 10^{20} eV continually bombard the Earth's upper atmosphere where they interact with different particles to produce secondary particles including pions and Kaons, which subsequently decay to muons. At sea level about 80% are muons, the rest are electrons and protons. The flux is on the order of 10^{-2} /cm^2 -sec-sr. Since Muons are unstable particles with rest particle life time 2.19 μs, they decay into electrons, anti-neutrino and neutrino. However, being relativistic particles, they travel a very large distance with a speed equivalent to speed of light in different materials. The muons can also be captured by the nucleus. The probability of capture depends on the atomic number (Z) of the absorbing material and goes like Z^4 for smaller Z values.

Experimental Details

The main part of the apparatus is three plastic scintillators kept parallel to one another at a certain separation with their faces horizontally. The scintillator material emits a light when an Ionizing particle deposits energy in it. The light pulses are converted into electrical pulses by the photomultiplier tubes (PMT). The signals from the three PMTs are detected by the discriminators, which generate logic pulses when they receive signals larger than a predetermined threshold. Coincidence units and a gate generator form the trigger logic that defines when the events should be captured by the digital storage oscilloscope. Since the muons are nuclear particles which interact weakly with the matter, so they pass through different materials without any decay or capture. However, if they pass through a sufficiently high denser or high Z value material they can decay into electrons and neutrinos. In the present work I used three coincidence method using three Plastic Scintillators at a certain separation and take two coincidence & three coincidence count rates by placing various materials with varying their thickness regularly.

Results and Discussions

The Fig. 1 represents the variation of decay of muons at ground level per square meter per min. with the thickness of Aluminum.

The Fig. 2 represents the variation of decay of muons at ground level per square meter per min. with the thickness of other materials such as Clay, Glass, and Lead etc. The Table 1, Table 2, Table 3 and Table 4 represent the essential fit parameters for Al, Clay, Marble and granite respectively. From the Figures we can conclude that the decay rate of cosmic ray muons is greater in the materials having larger the density or Z value.

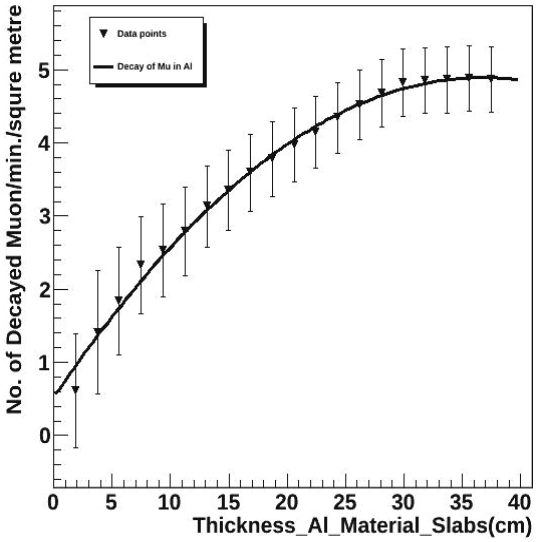

Fig.1 Shows the decay rate (Y-axis) of muons with thickness (X-axis) for Aluminum. Here the data points are fitted by 2nd order polynomial.

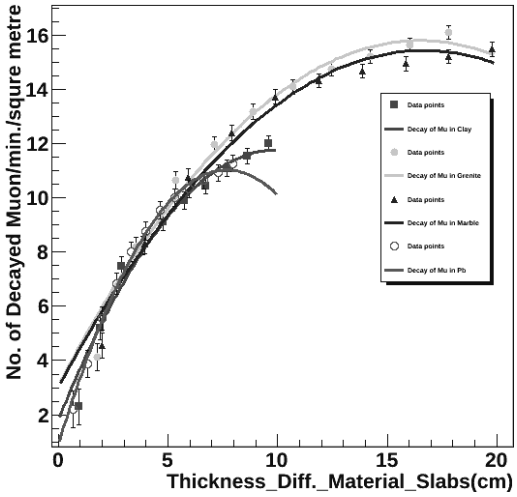

Fig.2 Shows the decay rate (Y-axix) of muons with thickness (X-axis) of different materials such as clay (in square block), granite (closed circle), marble (up triangle) and lead (open circle) . Here all the data points are fitted by 2nd order polynomial.

EXT. NO.	NAME	VALUE	ERROR
1	P0	5.15794e-01	5.20907e-01
2	P1	2.37685e-01	5.31297e-02
3	P2	-3.22656e-03	1.21651e-03

Table 1: Shows the fitting parameters for Al.

EXT. NO.	NAME	VALUE	ERROR
1	P0	1.80128e+00	5.72811e-01
2	P1	2.00966e+00	2.15270e-01
3	P2	-1.01391e-01	1.81987e-02

Table 2: Shows the fitting parameters for Clay.

EXT. NO.	NAME	VALUE	ERROR
1	P0	3.02945e+00	4.43929e-01
2	P1	1.48840e+00	8.28355e-02
3	P2	-4.46361e-02	3.45776e-03

Table 3: Shows the fitting parameters for Marble.

EXT. NO.	NAME	VALUE	ERROR
1	P0	3.07902e+00	4.53300e-01
2	P1	1.54084e+00	9.37268e-02
3	P2	-4.66481e-02	4.33259e-03

Table 4: Shows the fitting parameters for Granite.

Results and Discussions

We have made a systematic study of decay of muons in different materials using three coincidence methods of plastic scintillators. It is observed that the decay rate of muons is higher for the materials having high density or having large atomic number.

Reference

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