The Lifetime of the Muon

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Insert abstract here.

I. OBJECTIVE

To determine the lifetime of the muon.

II. INTRODUCTION

The muon was first discovered in 1936 by Carl D. Anderson and Seth Neddermeyer. They were studying cosmic radiation when Anderson noticed that certain particles curved differently from the known particles passing through a magnetic field. The negatively charged particles curved less sharply than electrons and more sharply than protons, but all carried the same velocity through the magnetic field. Originally, the charge of this particle was assumed to be of the same negative magnitude as electrons, and thus the difference in curvature was explained by giving this particle a mass greater than an electron and less than a proton. This particle was originally called a "mesotron", the "meso" prefix meaning "middle", as in having a mass between that of an electron or proton. Later in 1947, a particle with similar mass but dissimilar force properties was discovered. These two particles were grouped together as "mesons" instead of mesotrons (still meaning they have an intermediate mass to electrons and protons). The particle discovered in 1947 by Yukawa is now known as the π-meson. The previous meson mentioned is called the μ-meson, or the muon.

The decay of a muon is in accordance to the radioactive decay law, which states that the probability of decay for a small increment of time δt is stated in Equation 1. The constant λ is the decay rate, which results in a constant probability of decay. This means that the probability of decay does not change over the lifetime of the muon, as may contradict common sense of this probability increasing as the lifetime increases.

$$P(\delta t) = \lambda \delta t \tag{1}$$

When a muon decays, it splits into separate particles; the muon μ^- and the antimuon μ^+ decay into the particles given by Equation 2. The variables ν_e and ν_μ are neutrinos with small mass that only interact with the weak and gravitational forces; their respective antiparticles are $\bar{\nu}_e$ and $\bar{\nu}_\mu$.

$$\begin{aligned} \mu^- &\rightarrow e^- + \nu_e + \bar{\nu}_\mu \quad (100\%) \\ \mu^+ &\rightarrow e^+ + \bar{\nu}_e + \nu_\mu \quad (100\%) \end{aligned} \tag{2}$$

III. APPARATUS AND METHODS

In order to perform this experiment, a continuous source of muons is required. This supply of muons is available from the constant raining of cosmic rays on Earth's atmosphere. These high enery cosmic ray protons enter the upper atmosphere and collide with nuclei A, resulting in pion particles (Equation 3).

$$p + A \rightarrow \pi^{\pm}, \pi^0 \tag{3}$$

These pions decay

A. Calibration

IV. DATA ANALYSIS

V. CONCLUSION

[1] Tipler and Llewellyn, *Modern Physics* (Worth Publishers, 1978).
[2] Taylor, *An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements, 2nd Ed.* (University Science Books, 1996).
[3] *The Lifetime of the Muon*, Occidental College Physics Department (2018).
[4] *Model 77 Series IV Digital Multimeter Users Manual*, Fluke Corporation (2006).