Measurement of Weak Coupling Constant blahblah

1 Introduction

The muon, a fundamental particle produced in the upper atmosphere as a secondary product of cosmic ray collisions, was originally discovered in 1936 []. It decays via the weak interaction with a mean decay lifetime of $2.2\mu s$, longer than every known particle other than the neutron []. With muons comprising 80% of cosmic ray flux at sea level, the muon is a good candidate for the study of the weak force [].

Our experiment consists of two main components: the muon lifetime measurement and the muon mass measurement. We describe the experimental setup which consist of a system of three scintillators and Photomultiplier Tubes (PMTs). Using this system, the cosmic ray muons and their decay products are detected along with their enegy. The muon lifetime and mass results are presented with the relevant statistical analysis of data, and compared to previous experimentally established values. Finally, the muon mass and lifetime values are used to calculate the weak force coupling constant, G_F.

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2 Background

2.1

Muons (μ^-) and antimuons(μ^+) are the most numerous charged particles at sea level [**?**], most of them produced at a height of about 15 km from decays of charged kaons and pions that are formed from the interaction of cosmic ray particles with the Earth's upper atmosphere [**?**]. The muon is produced in a weak decays as shown for example in Figure and at sea level forms 80% of cosmic ray flux.

In free space, negatively charged muons decay weakly into an electron, muon neutrino, and electron antineutrino [**?**] (Figure):

$$\mu^- \rightarrow e^- \nu_\mu \overline{\nu_e} \tag{1}$$

with a corresponding antimatter process of

$$\mu^+ \rightarrow e^+ \overline{\nu_\mu} \nu_e \tag{2}$$

The muon lifetime is approximately 2.2μs [?], second only to the lifetime of the neutron. In matter, another decay is possible for μ^- via nucleus capture:

$$\mu^- p^+ \rightarrow n \nu_\mu \tag{3}$$

The lifetime asssociated with nuclear capture is typically shorter than the free muon lifetime. However, the products released in process pcap are neutral, and therefore not detected in our apparatus (????). Thus, the lifetime measurement desribed in this report is only relevant to muon decays mudecay and antimudecay.

Due to relativistic time dilation, the flux of muons at sealevel remains large at 10^{-2} cm^{-}2s^{-}1sr^{-}1.

The decay of the muon is desribed by an exponential function

$$N(t) = N_0 e^{-\Gamma_\mu t} \tag{4}$$

here Γ_μ is the decay rate, which gives the decay lifetime $\tau_\mu = 1/\Gamma_\mu$.

The decay rate Γ_μ is proportional to the square of the amplitude of the decay diagram (Figure **??**, which depends on the product of the couplings at each vertex. In this case, the coupling at each of the two vertices is proportional to $\sqrt{G_F}$, so we have

$$\Gamma_\mu \propto G_F^2 \tag{5}$$

A more involved calulation gives that the lifetime of the muon is

$$\tau_\mu = 192\pi^3\hbar^7 G_F^2 m_\mu^5 c^4 \tag{6}$$

where c is the speed of light, $\hbar$ is Planck's constant, and m_μ is the rest mass of the muon.

The weak decay of the muon is the clearest of all weak interaction phenomena in both its experimental and theoretical aspects. Thus, the muon decay is an effective means of studying the weak force, and specifically finding the weak coupling constant g_w.

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