PRECISE MEASUREMENTS OF THE MEAN LIVES OF μ^+ AND μ^- MESONS IN CARBON[*][†]

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The mean life of muons in vacuum calculated from the theory of weak interaction proposed by Feynman and Gell-Mann[1] is 2.26 ± 0.004 μsec. In this calculation a coupling constant $G = (1.41 \pm 0.01) \times 10^{-49}$ erg cm^3 obtained from the beta decay of O^{14} was used and no radiative corrections were made to the constant. In beta decay, however, a radiative correction to the coupling constant has to be made. Also another radiative correction pertaining to the muon decay process is necessary. Both of these corrections were made by Berman[2] and Kinoshita and Sirlin,[3] giving a value for the coupling constant $G = (1.40 \pm 0.01) \times 10^{-49}$ erg cm^3 and 2.31 ± 0.05 μsec for the muon mean life as compared to the experimental value of 2.22 ± 0.02 μsec.[4]

A more precise measurement of the muon mean life would give a value of the coupling constant to a better accuracy with the necessary radiative corrections amounting only to about 0.4%.

An experimental arrangement used in such a measurement is shown in Fig. 1.

The 70-Mev π^+ mesons from the Carnegie Tech cyclotron were stopped in a 1-in. thick carbon target and were detected by a coincidence arrangement $1+2+3+\bar{4}$. The electrons from muon decays were detected by counters $4+5+\bar{6}$. Muons from π^+ decays were randomly polarized, therefore eliminating a possible modulation of the decay curve caused by the muon precession in the stray magnetic field. Also Helmholtz bucking coils were used to reduce the magnetic field at the carbon target to about 0.2 gauss.

The high intensity of the π^+ beam allowed the operation of the cyclotron at a low level which reduced the general background in the experiment.

The time interval between a stopped π which gave rise to a muon (π mean life is ~0.02 μsec) and the electron from a muon decay was measured by counting the number of 10-Mc/sec pulses in that interval. The block diagram of the electronic circuitry is shown in Fig. 2.

A positive gate generated by a stopped π and an electron from muon decay was fed in coincidence with a continuous wave train from a 10.0016 ± 0.0002 Mc/sec oscillator. A Hewlett-Packard 520*A* fast scaler with a scaling range of 200 counted the pulses in the output train from the coincidence circuit. After the 10-Mc/sec pulses were counted, a 2-Mc/sec wave train originating in the memory circuit of the 256 *RCL* pulse-height analyzer complemented the Hewlett-Packard scaler and a count in an appropriate channel of the memory circuit was registered. In this fashion a muon decay curve was accumulated in the memory of the pulse-height analyzer. The electron pulses were delayed with respect to the π pulse by a fixed delay of 2.75 μsec. Such a delay allowed for the pulses to arrive well after the rise time of the fast gate,

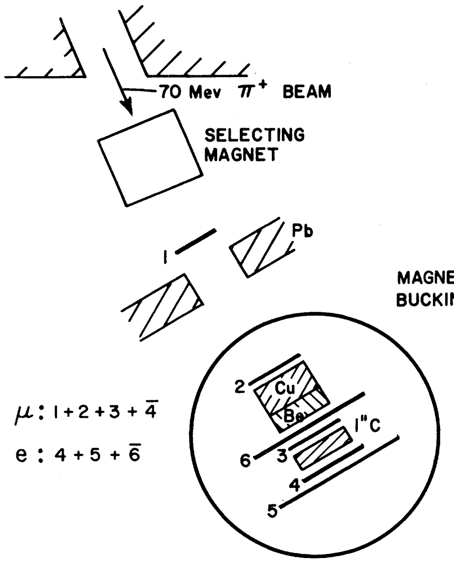

FIG. 1. Experimental arrangement.

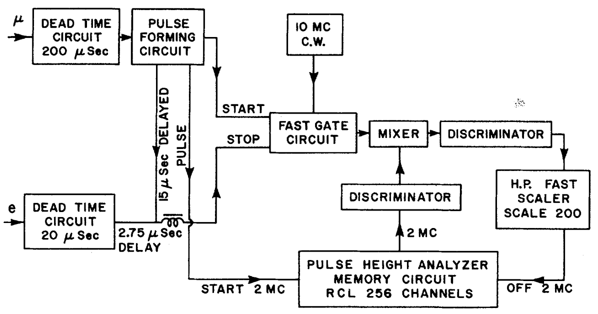

FIG. 2. Block diagram of the electronic circuitry.

therefore removing any electronic transient effects from the beginning of the decay curve. A stopped π generated a pulse which shut off the gate 15 μsec later if no electrons were detected. The electronic system was protected by circuits with appropriate dead times incorporated in the inputs to the fast gate.

In order to check the effects of the background on the value of the muon mean life, measurements were taken at several beam intensities. The ratio of the number of counts detected 10 μsec later varied from 450:1 to 30:1. Also measurements were made with and without an aluminum absorber placed in the detecting telescope between counters 4 and 5.

To check for the systematic errors originating in the electronic apparatus, muon decays were accumulated at various settings of discriminators and also a measurement was made with an altered shape of the fast gate. No systematic changes in the measurement were observed.

The linearity of the system was checked by means of two pulse generators triggering the fast gate on and off at random. In such a case the number of counts accumulated in each channel is proportional to its width, and if the system is linear the data should fall on a straight line with a zero slope. Repeated tests during the experiment with approximately 60 000 counts/channel produced straight lines with slopes less than their errors. A systematic check of the oscillator frequency was also performed.

A total of 14 runs were taken, each containing about 300 000 μ^+ decays. Data from each run were analyzed by a method of least squares with an IBM-650 computer. The weighted average of the results gave the mean life of 2.211 ± 0.003 μsec. The error is computed from the variance of the 14 runs.

This result is in good agreement with the value obtained by Fisher et al.[5] of 2.20 ± 0.015 μsec and with a recent measurement by Telegdi et al.[6] of 2.208 ± 0.005 μsec.

From the measured mean life and utilizing the latest value[7] for the muon mass, $(206.76 \pm 0.03)m_e$, the coupling constant calculated from the V-A theory is $G = (1.428 \pm 0.002) \times 10^{-49}$ erg cm^3. The radiative correction of Kinoshita and Sirlin applied to the mean life measurement gives the value $G = (1.431 \pm 0.002) \times 10^{-49}$ erg cm^3.

A measurement of the mean life of the negative muon in carbon was also made in this experiment. The necessary changes for the measurement were to reverse the direction of the magnetic fields used in the experiment and to add some absorber in the range telescope in order to stop the negative muons in the carbon target.

The mean life for the negative muons was found to be 2.043 ± 0.003 μsec. Assuming that the decay rates in carbon of the negative and positive muons are equal, the capture rate of negative muons in carbon obtained from this measurement is $(3.73 \times 0.11) \times 10^4$/sec.

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