MEASUREMENT OF μ^+ LIFETIME

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The conservation of the weak-coupling vector current in the presence of strong interactions[1] is a hypothesis which still lacks convincing positive experimental verification. As a consequence of this hypothesis a lepton-pion coupling arises which is large when the available energy is large as in muon capture or short-lived β decay. In μ^- capture the effect amounts to 20-30% of the rate, but it seems unfortunately to be quenched by an equally large pseudoscalar coupling induced by virtual π-meson emission.[2] Recent experiments on muon capture between the ground states of C^{12} and B^{12} support, but do not prove, these conclusions.[3] In β decay, relativistic effects and radiative corrections tend to eclipse the effect of the mentioned lepton-meson coupling.

The remarkable agreement of the experimental with the "theoretical" value for the lifetime of the muon (as stressed by Feynman and Gell-Mann[1]) is therefore the strongest indication that the vector current is conserved and the strengths of axial and polar vector currents are equal when strong interactions are not present. In view of this, we decided, in the spirit of experiments involving weak interactions, to attempt to bring the experimental value of the μ^+ lifetime (2.22 $\pm$ 0.02 μsec)[4] even closer to the "theoretical" value (2.31 $\pm$ 0.05 μsec).[5] Meanwhile, Swanson et al.[6] have reported a measurement where they succeeded in this, their new value being $\tau(\mu^+) = 2.261 \pm 0.007$ μsec.

The philosophy of our experiment was to elaborate on the detection equipment for muons and their decay electrons, and to read their time difference in a simple manner from pulses on an oscilloscope film. We used 30 hours running time of the CERN cyclotron to set up the experiment and expose the films, while it took us about 300 hours to read and analyze 10^5 traces.

The experimental arrangement is shown in Fig. 1. A 180-Mev/c meson beam is momentum-analyzed by two successive bending magnets after leaving the fringing magnetic field of the cyclotron. The velocity-selecting Čerenkov counter 1 in coincidence with the scintillation counters 2 and 3 registered the passage of a μ^+. Counter 1 consisted of a 10-cm thick cylinder subdivided along the beam direction into 5 cells which were filled with different mixtures of water and ethylene glycol.[7] The decrease in the velocity of the particles by slowing down is thus compensated for by an increase in the index of refraction (from 1.33 to 1.37) so as to keep the angle of the Čerenkov light refracted out of the radiator constant. A ring image, corrected for spherical, astigmatic, and some of the chromatic aberrations, was formed on four 56 AVP photomultipliers by reflecting the light in a nearly spherical mirror and passing it through a ring-shaped Lucite lens. The detection efficiency of the Čerenkov counter for muons was 98%, while for π mesons and electrons of the same momentum it was less than 10^{-5}.

The muons were on the average stopped in the middle of counter 4, which was a Plexiglas cylinder 5 cm thick and 10 cm in diameter. But for the side facing the photomultiplier (RCA C7071) the radiator had a reflective coating of evaporated aluminium, thus making it 4π-sensitive. The counter was surrounded by two layers of 1-mm thick mu-metal, which reduced the

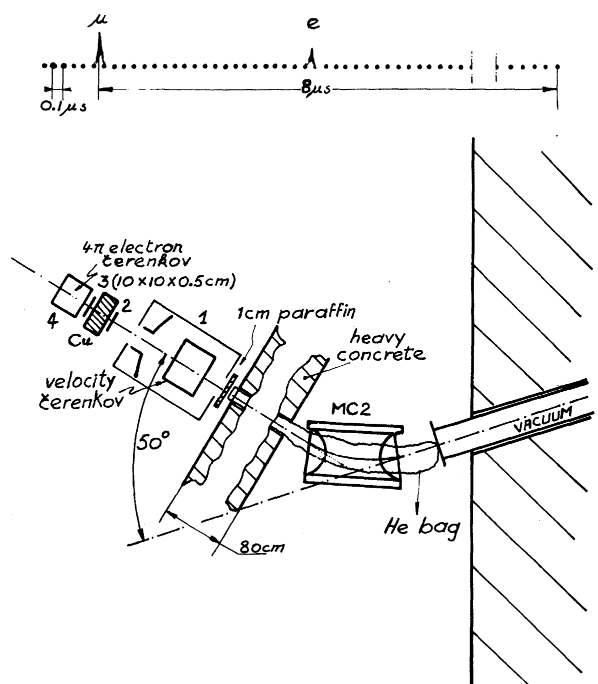

FIG. 1. Experimental arrangement and a facsimile of a typical oscilloscope trace.

magnetic field in the interior to of the order of 10^{-2} gauss.

A coincidence between counters 1, 2, and 3 with 4 in anticoincidence (1-2-3-4) started the sweep on a 445 Tektronix oscilloscope. The intensity of the oscilloscope beam was modulated with a 10-Mc temperature-controlled crystal oscillator. Thus a picture as shown in Fig. 1 appears on the screen of the oscillograph. The pulse from the electron counter 4 in anticoincidence with 2 (4-$\bar{2}$) is shown as a later pulse. The accidental counting rate is obtained from the frequency of pulses appearing at times earlier than the μ pulse, and from the "doubles" rate. The latter consists of pulses from a muon, its decay electron, and an accidental. We had a total of 581 such doubles, and by analyzing their time variation along the sweep the corresponding variation in the accidental coincidence rate could be determined. We considered such an analysis necessary since the intensity pattern of the beam pulses from a cyclotron can be very asymmetrical, but we found a flat distribution over the measured time interval.

Every third trace on the film had an electron pulse. The accidental rate was 0.8% of the counting rate in the first channel. The film was scanned with the help of a microfilm reader which made it possible to locate the position of the pulses to about 0.02 μsec. The scanning was performed and controlled by five physicists and four technicians, and we have not been able to discover any systematic errors. The least-squares treatment of the data was done with the CERN Mercury computer. The results of our measurements are shown in Fig. 2. Our value for the mean life (2.20 ± 0.015 μsec) disagrees with the recent result of Swanson et al.,[6] and agrees with the classical value of Bell and Hincks.[4] The error has arbitrarily been increased from the statistical error ($\frac{1}{2}$%). Previous experiences with similar measurements of lifetimes seem to indicate that errors of less than 1% require the convergence of results of different experimental methods.

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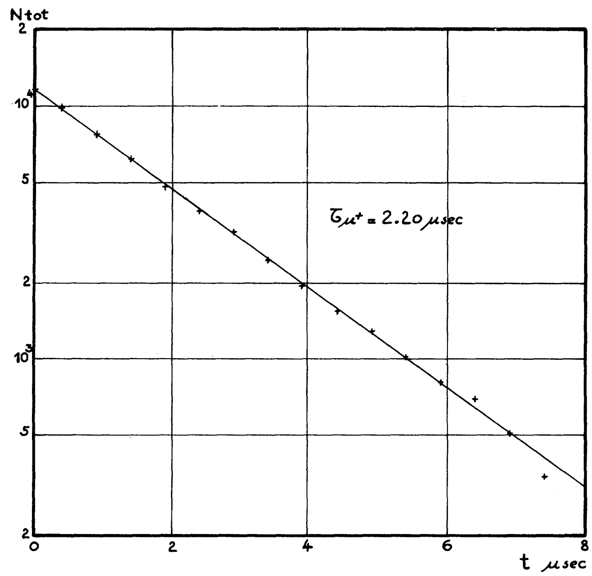

FIG. 2. Decay curve of the muon (background subtracted).

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