ΔE, then we obtain for the new ratio R, in units of $\hbar = c = 1$ and $e^2 \approx 1/137$,

$$R=(12.78\times10^{-5})\left[1-\frac{2e^2}{\pi}\left\{\frac{3}{4}\ln(m_\mu/m_e)+\ln(2\Delta E_e/m_e)-\ln(2\Delta E_\mu/m_e)+\left(\frac{m_\pi^2+m_e^2}{m_\pi^2-m_e^2}\right)\times\ln(m_\pi/m_e)\ln\left(\frac{m_\pi^2-m_e^2}{2\Delta E_e m_\pi}\right)-\left(\frac{m_\pi^2+m_\mu^2}{m_\pi^2-m_\mu^2}\right)\times\ln(m_\pi/m_\mu)\ln\left(\frac{m_\pi^2-m_\mu^2}{2\Delta E_\mu m_\pi}\right)-\frac{m_e^2}{m_\pi^2-m_e^2}\times\ln(m_\pi/m_e)+\frac{m_\mu^2}{m_\pi^2-m_\mu^2}\ln(m_\pi/m_\mu)-\ln\left(\frac{m_\pi^2-m_e^2}{m_\pi^2-m_\mu^2}\right)\right\}\right], \quad (2)$$

or

$$R=[11.00+0.27\ln(2\Delta E_e/m_e)]\times10^{-5}, \quad (3)$$

where ΔE_e and ΔE_μ are the energy intervals below the maximum energy over which electron or muon counts are being accepted[4]. We have omitted from Eq. (3) the term which depends on $\ln(\Delta E_\mu/m_e)$ since it is completely negligible. For $2\Delta E_e = m_e \approx 0.5$ Mev the radiative corrections amount to a surprisingly large decrease in the ratio of amount 14%.

We note that even though the rate for $\pi \to (\mu$ or $e) + \nu$ contains logarithms of the ultraviolet cutoff, the ratio of rates will not depend on the cutoff as long as we take it to be the same for each of the decay modes.[5] Furthermore, the contributions to Eq. (3) from virtual processes come almost entirely from very low photon momenta. If this were not true, but instead the contributions to R came from regions of large virtual photon momenta, then the radiative corrections might depend on the terms in f_1 dependent on $p\cdot k$ and k^2 and also on the other covariants.

The results given here do not agree with a recent "theorem" by Gatto and Ruderman.[6] However using a theorem due to Ruderman and Watson[7] a closely related statement can be made: Let Γ_P and Γ_A represent the rates for one of the pion decay channels with the leptons coupled with either P or A interaction. Then the ratio Γ_P/Γ_A including electromagnetic effects, expressed in terms of the bare masses, is equal to the ratio Γ_P/Γ_A without including electromagnetic effects. In particular for the electron decay mode $\Gamma_P/\Gamma_A = (m_\pi^{(b)}/m_e^{(b)})^{-1}$ with and without including radiative corrections. If we are interested in

$$\left(\frac{\Gamma_e}{\Gamma_\mu}\right)_A=\left[\frac{(\Gamma_e/\Gamma_\mu)_A}{(\Gamma_e/\Gamma_\mu)_P}\right]\left(\frac{\Gamma_e}{\Gamma_\mu}\right)_P,$$

then we note that the term in brackets is equal to the ratio of the square of the bare masses of the electron and muon with or without including conventional electrodynamics. However, one should also note that $(\Gamma_e/\Gamma_\mu)_P$ receives a large radiative correction which to first order in e^2 is around 11% decrease.

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$$\omega_{\max}=\left(\frac{2m_\pi^2}{m_\pi^2-m_e^2}\right)\left(\frac{\Delta E}{1+x}\right).$$

[5] If, for example, we take the cutoffs occurring in the virtual processes to be proportional to the respective masses of electron or muon, then R increases by about 1.5% over that given by Eq. (3).

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MUON K-CAPTURE COMPARED TO β DECAY FOR $C^{12} \to B^{12}$

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Recent refinements of the theory of the V-A universal Fermi interaction[1] have made it desirable to attempt a more precise experimental comparison of the coupling strengths of electrons and muons to nuclei. For this purpose we have measured the rate ratio $(C^{12}+\mu^- \to B^{12}+\nu)/$ $C^{12}+e^- \to B^{12}+\nu)$. The experiment was originally suggested by Tiomno, and measurements with cosmic-ray muons have been reported by Godfrey.[2]

We used the mixed π^-, μ^-, and e^- beam of 220 Mev/c momentum from the CERN Synchrocyclotron in the arrangement shown in Fig. 1. The beam was pulsed either 54.2 or 13.5 times per sec. Three experimental arrangements were used in which (1) the beam was stopped in C^{12} and decay electrons from muons and B^{12} were viewed with a scintillation telescope, (2) the beam was stopped in a $10\times10\times10$ cm^3 scintillation crystal and the decay electrons were detected with the same crystal, (3) the same as (2) but with a 6-cm thick crystal. In (1) the uncertainties in estimating the counting efficiencies were large; (2) and (3) gave similar results, but (3) was much more comprehensive and will be reported.

Figure 1 shows the delayed activity recorded in the $6\times10\times10$ cm^3 scintillator as a function of Cu absorber in front of the counter. A $1\times30\times30$ cm^3 scintillation counter above suppressed a large fraction of the cosmic-ray background. The data were obtained by triggering a time-to-pulse-height converter (20 channels) by each beam pulse from the cyclotron, and feeding the pulses from the stopping counter to a time-to-amplitude channel. In Fig. 1 we have collected the counts arriving in the time interval from 3.6 msec (beginning of 5th channel) to 14 msec (end of 17th channel). When both π^- and μ^- stop in the crystal a delayed activity is formed. The decays of these activities are shown in Fig. 2. The yield of the 80-msec activity at the π^- peak indicates that somewhat less than 1% of the π^- captures lead to this activity.[3] The half-life at the μ^- absorption peak is 20.7 ± 0.3 msec, in agreement with the presently accepted value[4] of 20.6 msec for B^{12}. The B^{12} activity, extracted as indicated in Fig. 1, was constant when the voltage on the photomultiplier (RCA C7170) was varied from 2400 to 3200 volts. The total B^{12} counting rate amounted to about 100 per min at the μ^- peak, or 860 ± 30 for 10^6 monitor counts 1-2. The error is estimated from uncertainties in the extrapolations.

The number of muons stopping in the scintillator was obtained by counting delayed "self-coincidences." A pulse from the counter started a 10-μsec sweep on the time-to-pulse-height converter, and the pulses from the same counter were displayed in the 20 channels. Absorption and photomultiplier voltage curves were also taken for this activity. For 10^6 monitor counts we obtained in this way $41\,800\pm1000$ muons when corrected for the 10% capture probability in C. The error is also in this case estimated from uncertainties in extrapolations.

Both muon and B^{12} counts were found to vary strictly proportional to the intensity of the beam. When a μ^- slows down and stops in the scintillator the probability that it will form B^{12} is thus found to be (2.06 ± 0.10)%.

A short run was made to look for γ rays from possible captures to excited bound states of B^{12}.

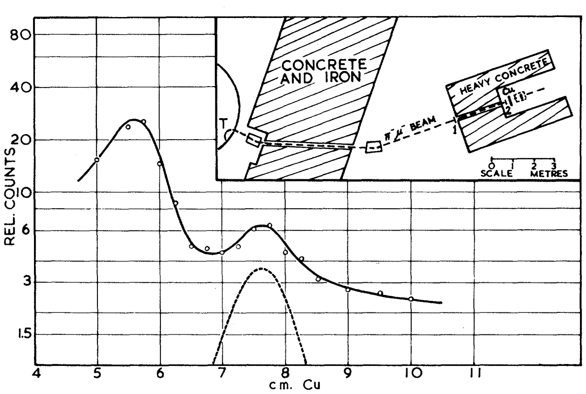

FIG. 1. Experimental arrangement, and absorption curve of activity in the scintillator between the beam pulses of the cyclotron. The dotted curve represents the B^{12} activity after subtraction of background and π-capture activities.

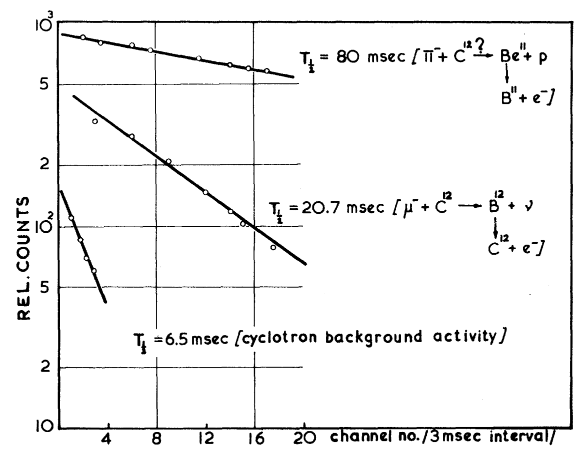

FIG. 2. Decay of the delayed activity at the π^- peak, μ^- peak, and with a large absorber.

The 10-μsec time-to-pulse-height converter was again used with pulses from the plastic (counter 3) commencing the sweeps, and pulses from an 8-cm diameter, 10-cm long NaI(Tl) crystal (No. 4) in anticoincidence with coincidences 3-4 entering the sampling channel. Only accidentals were observed. The limited solid angle of the NaI(Tl) and the shortness of the run did not make it possible to conclude other than that less than 25% of the captures led to excited states.

With the mean life of μ^- in vacuum and in C as 2.21 and 2.02 μsec, respectively,[5] and the mean life of B^{12} as 29.8 msec with a 3% correction[6] for decays to excited states of C^{12}, we get 312 ±18 for the ratio of the μ^- capture rate giving B^{12} to the decay rate of B^{12} to the ground state of C^{12}. The theoretical value given by Godfrey[2] is 228, assuming equal coupling constants for μ^- capture and β^- decay. Our experiment therefore yields a ratio $R=[C_{\mathrm{GT}}(\mu^- \text{ capture})/C_{\mathrm{GT}}(\beta^- \text{ decay})]^2=1.37\pm0.08$. The gap between experiment and the primitive theory may possibly be bridged by effects as discussed in reference 1. Judging from theoretical estimates,[2] contributions from μ^- captures to excited bound states of B^{12} are not capable of explaining the difference.

Except for possible influences of effects already mentioned,[1] Tolhoek[7] has tentatively interpreted some data on the absolute values of the capture rates and their ratios for a number of nuclei in the neighborhood of Ca^{40} in terms of a universal Fermi interaction with a value for the Gamow-Teller coupling constant which is higher for μ capture than for β decay, but with the same coupling constant for the Fermi part in both cases (use is made of shell model calculations[8]). This interpretation provides roughly a range of 1.4 to 2.2 for the value of R.

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MEASUREMENT OF THE ASYMMETRY PARAMETER IN μ-e DECAY*

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The angular distribution of the positron from the decay of the positive muon has the form $1-(\xi/3)\cos\theta$, where θ is the angle between the muon spin and the positron direction. The V-A theory predicts that the parameter ξ should be -1.[1] Experimental measurements of the decay asymmetry obtain the quantity $a = P(\xi/3)$ where P is the polarization of the muons at the time of decay. So far all published measurements of $-a$, using muon beams of unknown polarization, have been well below 1/3. For example, the Nevis[2] and Chicago[3] results for μ^+ in graphite are $-a = 0.25\pm0.02$ and 0.229 ± 0.008, respectively. This experiment is an attempt to make a measurement of a in a situation in which P is very nearly equal to unity by making use of the fact that a strong magnetic field applied along the muon spin direction can eliminate most of the depolarization on muons before they decay in nuclear emulsion.[4-6]

The muons used in this experiment came from pions which were produced at the Nevis cyclotron. These pions came to rest in 600-micron-thick Ilford $G5$ nuclear emulsion on which was imposed a magnetic field of 25 000 gauss in the plane of the pellicles. Then the decay distribution is of the form $1+a\cos\beta\cos\phi$, where β and ϕ are the angles which the initial directions of the muon and positron make with the magnetic field direction.

The plates were area scanned for muon endings. Only those events were recorded for which