then $G_{\pi N}=13.7$; $G_{\pi\ \mathrm{int}}=8.2$; $G_{NK\Lambda}=2.3$; $G_{NK\Sigma}=1.8$(γ_5 in K ints.), $G_{\pi N}=13.7$; $G_{\pi\ \mathrm{int}}=8.2$; $G_{NK\Lambda}=2.2$; $G_{NK\Sigma}=1.8$ (no γ_5 in K ints.).

If the calculated results for the relative sign of $G_{\pi N}$ to $G_{\pi\ \mathrm{int}}$ and $G_{NK\Lambda}$ to $G_{NK\Sigma}$ can be carried over to the g-coupling constants, the heavy-fermion mass degeneracy must be broken by the $\Xi K(\Lambda,\Sigma)$ interactions. Possible Lagrangians are

$$L=\tfrac{1}{2}g_\pi\{\phi_\pi\psi_{\frac{1}{2}}\beta\gamma_5\tau\nu\psi_{\frac{1}{2}}-\phi_\pi\psi_{(0,1)}\beta\gamma_5\tau\nu\psi_{(0,1)}\}$$
$$+g_K\{\phi_{\frac{1}{2}}\psi_0\beta[\gamma_5(1+\zeta_3\nu)/2+(1-\zeta_3\nu)/2]\psi_{\frac{1}{2}}$$
$$-\phi_{\frac{1}{2}}\,i\tau\psi_1\beta[\gamma_5(1+\zeta_3\nu)/2-(1-\zeta_3\nu)/2]\psi_{\frac{1}{2}}\}$$
$$(\gamma_5 \text{ in } K \text{ ints.}). \qquad (3)$$

The γ_5 multiplies $(1-\zeta_3\nu)/2$ instead of $(1+\zeta_3\nu)/2$ for the case of "no γ_5 in K ints." Another K interaction,

$$L_K=g_K\phi_{\frac{1}{2}}(\psi_0-i\tau\zeta_3\nu\psi_1)\beta(\gamma_5,1)\psi_{\frac{1}{2}},$$

with the π interaction of (3) also splits the masses.

It must be mentioned that lowest order perturbation theory is unable to account for any polarization of the Λ hyperon if the effective coupling constants are assumed real.[7, 8]

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ELECTRON DECAY OF THE PION

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It was predicted some years ago by Ruderman and Finkelstein[1] that if the decay of the pion into an electron and a neutrino goes through an axial vector interaction, then it should occur at a rate 1.3×10^{-4} of the normal decay into a muon and a neutrino. This conclusion has not been changed in the light of recent work on the nonconservation of parity in weak interactions.[2] However, experiments by Lokanathan and Steinberger[3] and by Anderson and Lattes[4] failed to show the existence of the electron mode of decay. Interest has been revived in a search for this decay by the evidence for the validity of a universal Fermi interaction, which, with the single exception of the π-e decay, is good.[5] Theoretical attempts to remove this discrepancy have been made by a number of authors.[6]

The experiment is made difficult by the presence of a large background of electrons from the π-μ-e chain of decay. However, these electrons can be distinguished in three ways. Firstly, they have a continuous spectrum with a maximum kinetic energy of 52.3 Mev, compared with the line spectrum of electrons from π-e decay of 69.3 Mev. Secondly, the π-e electrons should show a simple exponential decay with the mean life identical to that of the π-μ decay, while the π-μ-e electron time distribution would show a two-stage radioactive decay, with a fast rise (approx. π-μ mean life) and a slow fall (approx. μ-e mean life). Lastly, three charged particles can be seen in the π-μ-e chain, while only two are shown in the π-e decay.

We have used, like Lokanathan and Steinberger,[3] a range telescope to search for the high energy π-e electron. The apparatus is shown in Fig. 1. Pions from the CERN 600-Mev synchrocyclotron are incident upon the counter telescope $123\bar{4}$ and stopped in counter 3. The electron telescope is formed of counters 5-12 in fast coincidence,

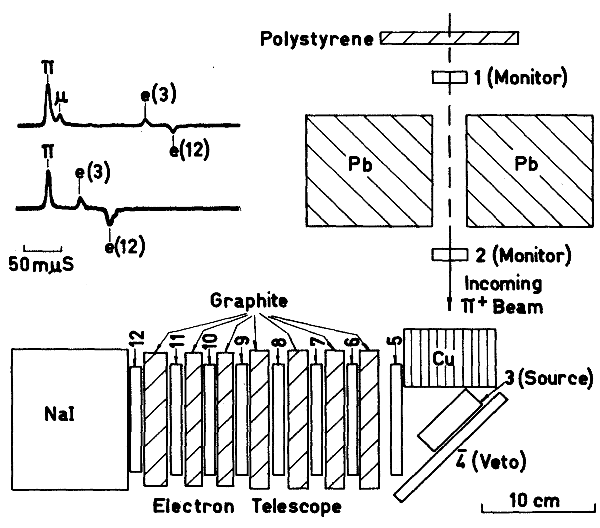

FIG. 1. Experimental layout, and (inset) typical π-μ-e and π-e pulse.

with various amounts of high-density graphite inserted between the counters. These two telescopes are in coincidence so that all 5-12 coincidences which occur between 60 mμsec before and 160 mμsec after a stopped pion in the $123\bar{4}$ telescope are counted. If such a coincidence occurs, the pulses appearing in counter 3 and in counter 12 are photographed with a fast (~2000 Mc/sec) travelling-wave oscilloscope. Figure 1 (inset) shows two typical events corresponding to a π-μ-e and a π-e decay. There is a fixed delay between the $e(3)$ pulse and the $e(12)$ pulse. In this way all the time information associated with the decaying pion is recorded. At the same time we recorded on a slow oscilloscope the pulses from a large sodium iodide crystal backing the range telescope.

The events which we saw on the fast oscilloscope could be classified into various categories:

(1) π-μ-e (see Fig. 1).

(2) π-e (see Fig. 1). Included in this category will be false "π-e" events, where we could not resolve the muon pulse.

(3) Prompt coincidences between the two fast telescopes. π-e events where the electron appeared very close to the pion are included here.

(4) Randoms, i.e., events which have an improper time distribution; among them, for example, events where $e(3)$ comes before the pion pulse.

The fraction of π-μ-e events where we could not resolve the muon was obtained from runs with no absorber in the electron telescope, where the number of genuine π-e events was negligible, and was about 0.23 of the total detected π-μ-e events. Figure 2 shows the electron range curves we obtained with different thicknesses of absorber. The π-μ-e and π-e events were selected directly from the film, and both curves are normalized to the same number of stopped pions. The π-μ-e curve shown does not, of course, represent the background in the experiment, because only the false "π-e" events provide a background there. It can be seen from the π-e range curve that within the errors the number of π-e events does not fall with increasing absorber thickness. The end-point of the μ-electron spectrum shown in Fig. 2 has been calculated using the (dE/dx) for positrons given by Rossi,[7] corrected according to Sternheimer's calculation of the density effect.[8]

From the runs with absorber thicknesses of 30, 31, 32, and 34 g/cm² we obtained 40 π-e events in which the pion decayed later than 8.3 mμsec, from a total of 124 photographs. The rest of the events were made up of 16 π-μ-e, 27 prompt and 41 accidentals. At the maximum absorber thickness we had a total of 17 events; of these 8 were π-e, 7 prompt, 2 accidentals, and we observed no π-μ-e event. In the 40 π-e events there were $16 \times 0.23 \cong 4$ false π-e events.

An integral decay curve of the 40 π-e events is shown in Fig. 3(a). The straight line corresponds to the π-μ mean life given by Crowe.[9] The mean life calculated from these events, after subtraction of background, is

$$\tau_{\pi\text{-}e} = 22 \pm 4 \text{ m}\mu\text{sec}.$$

From the runs with no absorber we selected the false π-e events and an integral decay curve for these events is also shown in Fig. 3(a). It can be seen that this distribution is linear in time and is quite different from the exponential distribution of the true π-e events. A further check on these results is an integral decay curve for the π-μ decay from the π-μ-e events corrected for the resolution time between the two telescopes. This is shown in Fig. 3(b).

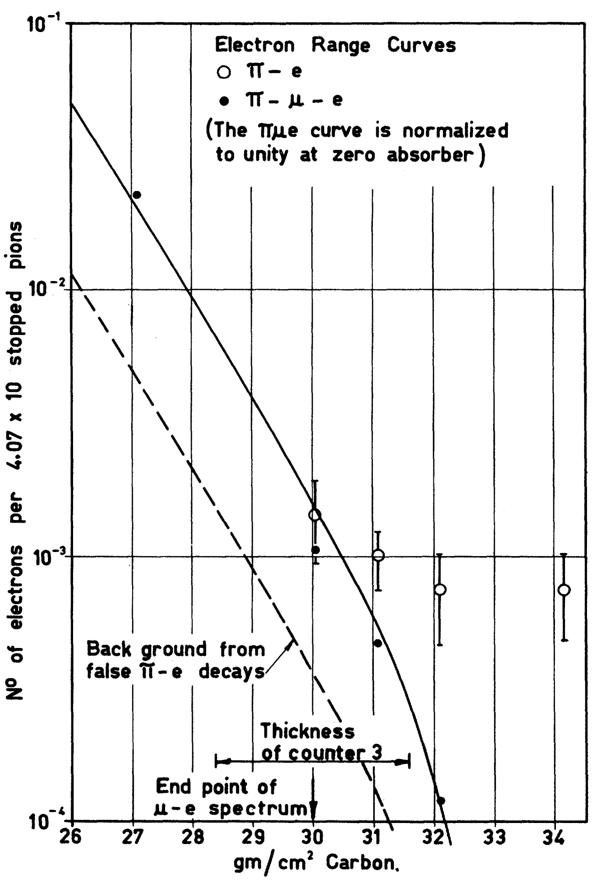

FIG. 2. Range curves for the π-μ-e and π-e events.

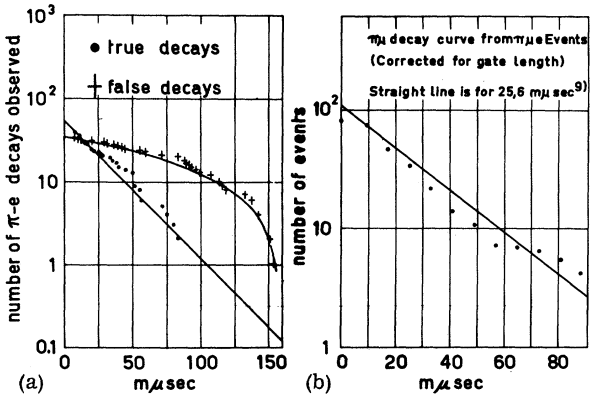

FIG. 3. (a) Integral decay curves for the π-e events, and false "π-e". (b) Integral decay curve for the π-μ decay. The straight lines shown correspond to the π-μ mean life given by Crowe.[9]

We also observed that in the sodium iodide crystal there was in general no pulse, or at most a very small pulse, associated with each π-μ-e event. On the other hand, most of the pulses associated with π-e events were large. We did not make any systematic use of this information, as the number of π-e events seen in each absorber run was too small.

The above results seem good evidence for the existence of the electron decay mode of the pion. We have not so far determined experimentally the efficiency and effective solid angle of the electron telescope. If we assume the merely geometric solid angle of 0.8% of 4π and an efficiency of 100% we get as a lower limit for the branching ratio

$$\frac{\pi \rightarrow e + \nu}{\pi \rightarrow \mu + \nu} > 4 \times 10^{-5}.$$

This number has been calculated from our 40 events, from which we have subtracted 4 events for the false "π-e" events which must be there, and we have added 37% for the early π-e decays occurring in the first 8.3 mμsec. The correction for accidentals was evaluated from the number of events which show on the fast scope as time inverted π-e decays (e-π events). This correction turned out to be zero.

This value for the branching ratio must be considered as a lower limit because we know that a large correction must be made for the efficiency of the telescope. To give an idea of the order of magnitude of this correction, we recall that Lokanathan and Steinberger[3] calculated an efficiency of 50% for their telescope which was similar to ours. As a conclusion we can say that the value we obtain for the branching ratio is not in disagreement with that predicted by Ruderman and Finkelstein.[1] The experiment is still in progress and we hope soon to have a more accurate numerical result.

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β DECAY OF THE PION*

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The electron-neutrino decay mode of the pion has been the object of several unsuccessful searches.[1-3] The latest and most sensitive of these[3] puts an upper limit of about 10^{-5} for the relative frequency of this process.

On the other hand, there has recently been