that the photoelectrons from the metastables are also polarized, and in principle could be collected to form polarized electron beams. Further experiments on the production of metastables, photoionization, and acceleration are now in progress in cooperation with N. Heydenburg, G. Temmer, and J. Weinman at the Department of Terrestrial Magnetism.

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SEARCH FOR THE DECAY $\mu^+ \to e^+ + \gamma$*

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It has been pointed out recently that the existence of a heavy charged boson with the properties required to give couplings consistent with the universal V-A Fermi interaction will lead to the occurrence of the decay $\mu^+ \to e^+ + \gamma$.[1,2] The branching ratio $\rho = R(\mu \to e + \gamma)/R(\mu \to e + \nu + \bar{\nu})$, when calculated by assuming such an intermediate meson coupling, is of order 10^{-4}. Previous experiments have given a value of $\rho \leq 2 \times 10^{-5}$.[3] This note is to report the results of an experiment in progress at the University of Rochester synchrocyclotron, designed to obtain a more precise value of ρ.

The arrangement of the detection apparatus is shown in Fig. 1. A 32-Mev π^+-meson beam is stopped in the carbon target. The μ^+-mesons arising from π^+ decay also stop and decay in the target. The stopped π^+ beam had an intensity of 5×10^5 mesons/minute. Two counter telescopes are placed so as to observe coincident positrons and gamma radiations emitted in opposite directions from the target.

The positron telescope consists of two scintillation counters e_1 and e_2 followed by a water Čerenkov detector, e_3 (see Fig. 1). Only positrons with energy $E \geq 35$ Mev were counted by this telescope. The solid angle subtended by this counter array at the source was 5% of 4π.
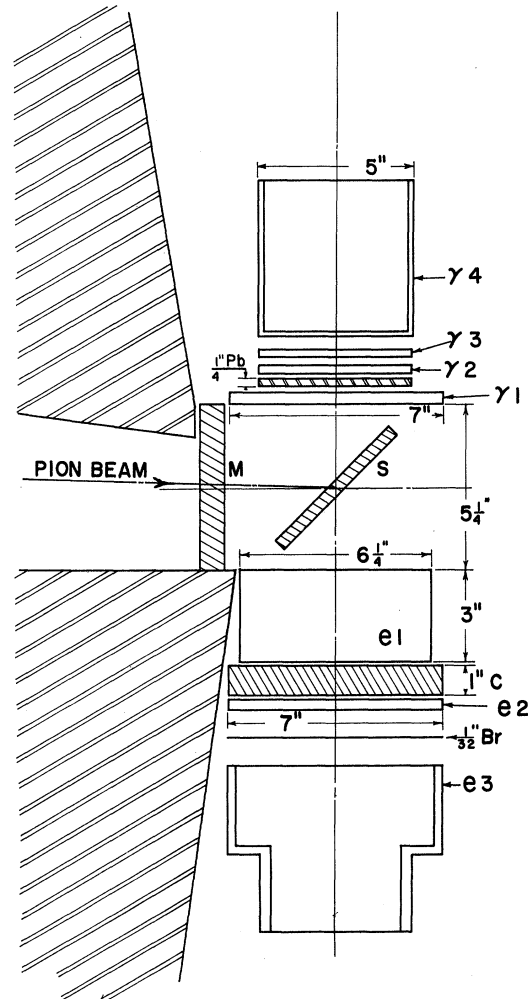

FIG. 1. Arrangement of detection apparatus with respect to the 32-Mev pion beam. M is the meson moderator and S is the target in which the pion beam stops. One inch of carbon absorber is placed between e_1 and e_2, 1/32 in. of brass between e_2 and e_3, and 1/16 in. brass between γ_2 and γ_3 (not shown).

For calibrating purposes, the positron telescope was first placed in a 95-Mev/c electron beam, and the delay and gain of each of the counters adjusted to form coincidences. Checks of these settings were made by observing coincidences in the electron beam moderated to 50 Mev/c, and also by observing μ^+-decay positrons with $E > 35$ Mev/c. The counting rate observed for μ^+-decay positrons is consistent with that expected from the solid angle and approximate estimates of scattering and radiation losses. The intrinsic efficiency of the positron telescope was estimated to be 75% for 55-Mev positrons.

The γ-ray telescope consists of three scintillation counters γ_1, γ_2, γ_3, and a water Čerenkov counter γ_4; γ_1 is an anticoincidence counter. A $\frac{1}{4}$-in. Pb radiator is placed between γ_1 and γ_2.

The γ-ray telescope was also calibrated in the 95-Mev/c electron beam; the gains and delays were adjusted first for $\gamma_2\gamma_3\gamma_4$ coincidences and then for $\bar{\gamma_1}\gamma_2\gamma_3\gamma_4$ events. The anticoincidence efficiency was about 99%.

A further calibration was carried out with high-energy photons from π^- capture in a liquid hydrogen target. The effective solid angle and intrinsic efficiency of the γ-telescope were measured by observing the fraction of π^- mesons absorbed in hydrogen that gave γ counts at several distances of the telescope from the hydrogen target. The measured solid angle in the final experimental arrangement is about 4.5% of 4π. The efficiency for 55-Mev γ-rays is estimated to be 19%, by taking it as 75% of the measured efficiency for the somewhat higher average energy gamma-ray spectrum from π^--capture. The

minimum electron energy for detection was about 12 Mev.

A block diagram of the electronics is given in Fig. 2. To reduce the random e-γ coincidence rate, a "fast-slow" coincidence circuit was used that took advantage of the speed of the 6655A multipliers to reduce the effective resolving time for e-γ coincidences.

The relative delay of the two telescopes was adjusted by aligning both telescopes in the 95-Mev electron beam, which has enough range to penetrate both.

Two runs have been completed to date. The first run, on 3-4×10^8 stopped mesons taken with a relatively high background random rate, gave 208 total counts (real plus random), 170 random counts, or

$$\rho = (1.7 \pm 0.9) \times 10^{-5}.$$

The second run, at a lower background rate, gave for 5.3×10^8 mesons 240 total, 237 random counts, or

$$\rho = (0.9 \pm 7) \times 10^{-6}.$$

The quoted errors are statistical standard deviations.

The possible systematic errors of the experiment are such as to permit absolute estimates to be in error as much as 25 to 50%. Accordingly, we feel that the present experiments indicate that the probability that the branching ratio exceeds 1.0×10^{-5} is not over 0.5. Further work is in progress.

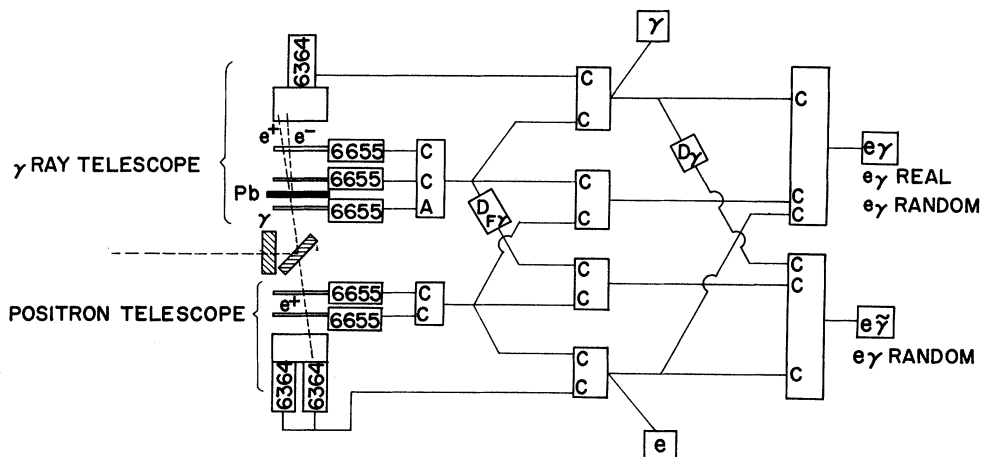The authors would like to acknowledge the generous loan of the liquid hydrogen target by Dr.

FIG. 2. Block diagram of coincidence circuitry used in this experiment. C = coincidence and A = anticoincidence.

Sidney W. Barnes, and the helpful assistance of Mr. Lawrence Ota.

PRECISE DETERMINATION OF THE MUON MAGNETIC MOMENT*

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When the existence of polarized meson beams and the anisotropic electron emission in decay was first detected,[1] it became possible to measure accurately the magnetic moment of the μ meson. This was first accomplished by a precession technique[1,2] to an accuracy of 0.7%, and to 0.06% by the resonance method,[3] which uses a radio-frequency magnetic field to induce transitions of the muon spin from a state of alignment to one of antialignment (or vice versa). The latter technique does not lend itself to use for experiments of improved accuracy at higher frequencies because of the large rf field required. A stroboscopic method was adopted,[4] in which the muon is brought to rest with its spin perpendicular to a magnetic field, H. The counting rate of the decay electrons in a particular direction varies in time as $\exp(-t/\tau)(1 + a\cos\omega_H t)$, where a is the usual experimental electron asymmetry, τ the muon mean life, and ω_H, the rate of muon precession, is equal to $geH/2mc$, where m is the muon mass, e the electronic charge, c the speed of light, and g the muon g-factor. By use of a higher precession frequency and by a different method of utilizing time information of the muon decay, the experiment described in this Letter achieved a muon moment accuracy of 0.007%.

Early experiments[2-5] displayed directly on a pulse-height analyzer (using a time-to-pulse-height converter) the electron counting rate vs time. More accuracy (which means higher fields

since the frequency uncertainty is fixed by the muon mean life) requires some method of folding the sinusoidally modulated decay curve into the memory of a pulse-height analyzer and of achieving better linearity than is possible with an analog time-to-pulse-height converter. The natural approach is to use a reference oscillator as in the resonance method, or as one input to a coincidence circuit whose other input is the electron count.[4] In the latter case a resonance curve is generated by the coincidence rate as the field or reference oscillator frequency is varied, although serious attention must be paid to reduce the systematic errors below the possible accuracy of this technique.

In this experiment a cw oscillator was used to measure both the muon and decay-electron times, modulo the period of the reference oscillator (86.200 Mc/sec). That is, one measures both the muon and electron phase with respect to this cw stable oscillator. The phase difference is generated electronically and stored in one of 10 channels of the pulse-height analyzer. If the reference frequency, ω, were exactly equal to the muon spin precession frequency, then the distribution-in-phase $[n(\phi)]$ for electrons emitted during a single period (of the 86.2-Mc/sec oscillator) occurring at delay time T, is independent of T. For $\omega_H \neq \omega$, $n(\phi)$ becomes $n(\phi + \alpha)$, i.e., retains its functional form but is shifted along the ϕ axis by an amount $\alpha = (\omega_H - \omega)T$. Thus a measurement of α vs T gives $\omega_H - \omega$ and thus ω_H itself.

The electrons are grouped into two time intervals. Those immediately following the stopping of the muon are referred to as the early electrons. The remainder are referred to as the late electrons. The average $n(\phi)$ for these two groups are displayed separately, and α determined for each. The quantity $(\alpha_{early} - \alpha_{late})$ is then a direct measure of $\omega_H - \omega$. This subtraction procedure has the important advantage of canceling out systematic errors due to uncertainties in the starting phases.

Figure 1 shows the counter, absorber, and target arrangement. An incoming μ meson is defined by a $123\bar{4}$ coincidence which serves to open a 2×10^{-7}-sec gate for the fast counter pulse in the μ timing channel and a 6-μsec gate that permits a 2×10^{-7}-sec gate to be opened by a decay electron in the electron channel. A forward emitted electron is defined by a $\bar{1}345$ coincidence, a backward one by a $23\bar{1}\bar{4}$ coincidence. Either of