electrons and recoil protons. After traversal of the vacuum tank the beam is monitored by a fission chamber located in the beam catcher.

The region of the neutron beam from which decay events are detected is surrounded by an electrostatic shield held at +7 kv. Protons from decay events occurring in a portion of the beam about one inch in length which recoil into a 10-degree cone about a line perpendicular to both the beam direction and the direction of polarization pass through a wire grid and, their direction established, are first accelerated through 1000 volts and then further accelerated and focussed by a 6000-volt cylindrical electrostatic lens onto the first dynode of an electron multiplier. The electrons are detected by two scintillation counters using 5-in. diameter by $\frac{1}{8}$-in. thick plastic phosphors. The resolution of the scintillation counters is about 30% and their outputs are passed through pulse-height analyzers to select those pulses corresponding to electrons of energy between 350 and 550 kev. The electron counters are located at 160° from the proton direction to maximize the product $(\vec{p}_e \times \vec{p}_\nu)$.

Coincidences between the proton counter and the two electron counters separately are recorded, and the asymmetry between the two coincidence rates is determined for both polarized and unpolarized neutrons. The latter condition is achieved by switching off the polarizing magnetic field with the guide magnetic field still on. Under this condition the magnetic field over the region of the electron trajectories resulting from the stray field of the guide system is always present. This stray field amounts to about 4 gauss and is unaffected by the polarizing field. The difference between the asymmetries with polarized neutrons and with unpolarized neutrons is used to obtain the time reversal coefficient D.

Most of the data has been accumulated using a one-half inch iron block as polarizer and with an arrangement which records coincidences for one hour with polarized neutrons followed by one hour with unpolarized neutrons in an automatic sequence. Under these conditions about 18 true events and 35 random events are recorded in each of the two coincidence channels for unpolarized neutrons and a similar number for polarized neutrons in 20 hours of operation. Data have also been taken without the quartz filter and also with a one inch block of iron as a polarizer. Checks have also been made on the asymmetry with no quartz or iron in the beam to provide a high-intensity source of unpolarized neutrons.

The polarization was measured without disturbing the magnetic fields in the region of the neutron beam by diffracting 2.8-A neutrons from the (100) planes of a cooled Haematite antiferromagnetic crystal located at the source volume of the neutron beam and then diffracting these neutrons again from the (111) planes of a magnetized face-centered cubic crystal of cobalt iron alloy. This showed that the direction of polarization was within five degrees of the vertical and with the aid of the method of Stanford *et al.*[2] indicated that the average polarization of the beam was about 40% with the one inch iron block as polarizer. By comparison of the single transmission effects the polarization was estimated to be 27% with the half-inch block and the quartz filter.

Combining the measurements under the various experimental conditions yields a present value of $D = -0.02 \pm 0.28$ where the error is primarily statistical but includes an allowance for the uncertainty in polarization and geometric corrections. This value has to be compared with expected values of $D = 0$ for time-reversal invariance not being violated and $|D| = 0.5$ for full violation with an equal mixture of axial vector and vector interactions each with $C_i' = C_i$. The present result is thus consistent with time-reversal invariance and suggests that full violation does not occur. The experiment is continuing but due to the current interest in this topic it is through that this preliminary result may be useful.

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[1] Jackson, Treiman, and Wyld, Phys. Rev. 106, 517 (1957).

[2] Stanford, Stephenson, Cochran, and Bernstein, Phys. Rev. 94 374 (1954).

EXPERIMENTAL LIMIT OF THE NEUTRINO REST MASS*

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As stated recently,[1] an empirical determination of the neutrino rest mass can be obtained from the H^3 - He^3 mass difference and the H^3 β

end-point energy. Sakurai[2] has noted that this is of course valid only if one has the true end-point energy but not for the extrapolated value. The spread in β end-point data reported in the literature, however, is large, i.e., 1.3 kev, when compared with the magnitude of extrapolation from the last experimental points in any one of the β spectra. Consequently the difference between the experimental lower limit for the true β end point and extrapolated end point is comparable with or less than experimental error and at present trivial. If one takes the experimental lower limit of the true end point, i.e., the last experimental point in the β spectrum, and subtracts this from the H^3 - He^3 mass difference, the result is an empirical upper limit for the neutrino rest mass. This upper limit is independent of any theory of β decay and requires only the assumption of conservation of mass and energy. This was the basis of the estimate of the order of 1 kev for the upper limit of the neutrino rest mass by Friedman and Smith.

The considerations of Sakurai will become relevant only when the β end-point (true or extrapolated) can be measured with much higher accuracy than it is now known.

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2 J. J. Sakurai, Phys. Rev. Lett. 1, 40 (1958).

EXPERIMENTAL EVIDENCE FOR THE INFLUENCE OF ATOMIC BINDING ON THE DECAY RATE OF NEGATIVE MUONS*

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The entire body of observations on the rate of disappearance (Λ_{dis}) of negative muons in matter,[1] in particular the striking Z dependence of this rate, can be described by attributing the disappearance to a competition between nuclear capture (at a rate Λ_{cap}) and decay (at a rate Λ_{dec}), both taking place from the mesic K orbit. Λ_{cap} depends primarily on the probability of finding the muon inside the nucleus (Z, A) and thus strongly on Z (Wheeler's Z^4 law); on the other hand, one assumes customarily that Λ_{dec} is uninfluenced by the fact that the decay takes place from a bound orbit, i.e., one puts $\Lambda_{dec}(Z) = \Lambda_{dec}(0) \equiv \Lambda_{dec}(\mu^+)$. This assumption is in particular made when capture rates are calculated from the experimentally accessible disappearance rates.[2]

It is, however, clear that the ratio $R \equiv \Lambda_{dec}(Z)/\Lambda_{dec}(0)$ should differ from unity for several reasons: (a) reduction of the number of final states through the decrease in available energy; (b) Doppler effect and time dilatation caused by the motion in the K orbit; (c) distortion of the outgoing electron wave by the nuclear electric potential. Effects (a) and (b), which jointly lead to $R<1$, have been considered by various authors[3] for the case of point-like nuclei, while effect (c), which works in the opposite direction, has so far been consistently neglected.

In view of this situation and in order to enable one to make precise determinations of Λ_{cap} from Λ_{dis}, we are now measuring R directly for a variety of elements. Some preliminary results will be given here.

Our measurements are based on the following: Two quantities are, in principle, directly measurable: (1) $\Lambda_{dis}(Z, A)$, and (2) $N_e(Z)$, the number of electrons per N_μ muons stopping in a target (Z, A). As $N_e = N_\mu[\Lambda_{dec}(Z)/\Lambda_{dis}(Z, A)]$, an absolute measurement of these quantities would yield R directly. Such a measurement is however difficult as far as N_e is concerned. On the other hand, it is sufficient to count the N_e's from pairs of targets (Z_1, Z_2) with the same relative efficiency to determine the Z dependence of R. With the assumption that, say $\Lambda_{dec}(Z_1) = \Lambda_{dec}(0)$, R itself may be determined.

"Sandwich" targets were built up from alternating layers of elements Z_1 and Z_2. Each comprised about 5 sheets of either material and had a total thickness (6 - 8 g/cm^2) sufficient to stop most of the local high-purity μ^- beam.[4] The ratio $S \equiv N_\mu(Z_1)/N_\mu(Z_2)$ was determined directly with an anticoincidence range telescope that included, just behind the target, a thin (1/16 in.) scintillator. S could be obtained to an accuracy of $\pm$ 2%. The ratio $N_e(Z_1)/N_e(Z_2)$ was measured by observing the composite time distribution of decay electrons from the sandwich by means of the time-converter arrangement which had also served to measure $\Lambda_{dis}(Z)$ for pure targets.[2] A coincidence telescope consisting of three scintillators separated by two 1.8-g/cm^2 Al absorb-