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INVESTIGATION OF TIME-REVERSAL INVARIANCE IN THE BETA DECAY OF THE NEUTRON

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It has been pointed out by Jackson *et al.*[1] that a violation of time-reversal invariance in the beta decay of the neutron would give rise to a term of the form $D\vec{J}\cdot(\vec{p}_e\times\vec{p}_\nu)/JE_eE_\nu$ in the angular distribution of the decay products. In this expression J is the spin of the neutron; p_e, E_e, and p_ν, E_ν are the momenta and energies of the electron and neutrino, respectively. The coefficient D of this term is related to the beta-decay coupling constants by the expression

$$D=\frac{2\,\mathrm{Im}(C_SC_T^*-C_VC_A^*+C_S'C_T'^*-C_V'C_A'^*)}{|C_S|^2+|C_V|^2+|C_S'|^2+|C_V'|^2+3(|C_T|^2+|C_A|^2+|C_T'|^2+|C_A'|^2)}$$

We are measuring the magnitude of this coefficient D using a beam of neutrons from the NRX reactor as a source.

Figure 1 shows a plan view of the apparatus mounted adjacent to the shield of the reactor.

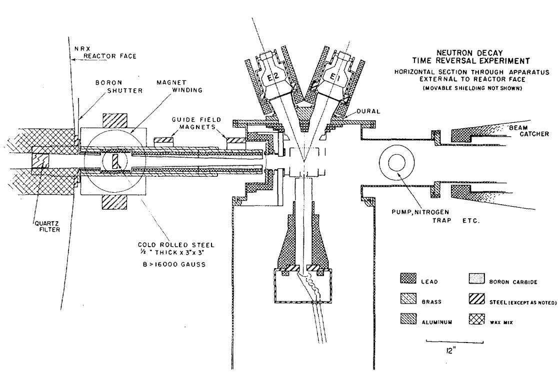

FIG. 1. Plan view of the apparatus located at the face of the NRX reactor.

The collimated beam passes through a 3.5-inch thick filter of crystalline quartz where the unwanted epithermal neutrons are preferentially scattered out prior to polarization of the thermal neutrons. The quartz, held at room temperature, causes a reduction in the epithermal neutrons of a factor of 3.2 and a reduction in the thermal neutrons of a factor of 1.9. The filtered beam then passes through a block of cold rolled steel, one-half inch thick, magnetized in a vertical direction to a flux density greater than 16 000 gauss. The preferential scattering by the iron of those neutrons whose spin direction is parallel to the direction of the magnetic field results in the transmitted beam being partially polarized. After further collimation and in the presence of a magnetic guiding field of about 150 gauss, the polarized neutrons enter a vacuum tank in which decays are observed by the simultaneous detection of decay 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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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