Time Reversal Invariance Violation in Polarized Neutron Beta Decay

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The existence of CP violation is established in neutral kaon decay. Recently, the implied consequence of CP violation: T violation, has also been observed in neutral kaon decay. Although there have been many searches for T violation in other systems, it has yet to be observed. The emiT collaboration has just completed the first run of an experiment to the search for T violation in free neutron beta decay, using cold, polarized neutrons at the National Institute of Standards and Technology's Cold Neutron Research Facility (CNRF). This experiment, which ran at CNRF during the first half of 1997, utilizes an octagonal array of detectors to observe neutron-decay electron and recoil proton in coincidence. The experiment is designed to detect a correlation of the form,

$$\hat{\sigma}_n \cdot (\boldsymbol{p}_e \times \boldsymbol{p}_\nu)$$

which is odd under time reversal. The coefficient of this term in the neutron-decay correlation has been previously shown to be less than 1.1×10^{-3}. The present apparatus is designed for greater sensitivity. The neutrons in the cold (T=40 Kelvin) beam are polarized to 96% with a supermirror polarizer. Electrons are detected with four 50 cm long plastic scintillators. The recoil protons, whose maximum energy is less than 750 eV, are accelerated by a 36 kV potential onto thin window PIN diodes. The characteristic delay time between the decay proton and electron is used to distinguish signal from background. The proton drift time is greater than 0.5 μs and most backgrounds are prompt. Figure 1 shows detected proton energy versus time, illustrating the separation of the proton signal from the large prompt background. Anticipated sources of systematic uncertainty were reduced in the detector design and measurements were made to assess the effect of certain crucial factors. As a test of the analysis, tilting the polarization guide field to be perpendicular to the beam and blocking off half of the beam to destroy its cylindrical symmetry temporarily created one type of spurious T-violating signal. The presence of the large parity-violating asymmetries (characterized by the A and B coefficient), makes a spin-dependent count rate in the coincidence detector pairs, which mimics the D-coefficient. We were able to see a positive effect at the level of 5×10^{-2}. In the normal configuration the contribution from this effect is below our sensitivity. The data analysis is in its final stages and slight improvement on the limit on the T violating D coefficient is expected.

Footnotes and References

†The participating institutions of the emiT collaboration are: Lawrence Berkeley National Laboratory, University of California at Berkeley, University of Michigan, National Institute of Standards and Technology, Notre Dame University, Los Alamos National Laboratory, and University of Washington.

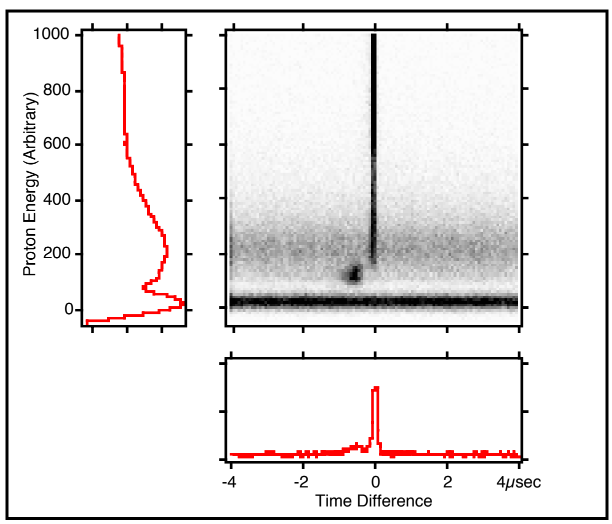

Fig. 1. A plot of proton detector energy versus coincidence time shows clearly the large prompt events, mostly from background gamma rays. Delayed coincidences, from neutron decay protons, show up to the left of the prompt events in this figure.