A STUDY OF SINGLE-PARTICLE PARITY-NONCONSERVING NUCLEAR MATRIX ELEMENTS

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An IUCF-LANL-Princeton collaboration has been formed to measure the weak mixing between single-particle states in ^{207}Pb.[1,2] The experiment was originally motivated by recent measurements at the Los Alamos Neutron Scattering Center by the TRIPLE collaboration.[3,4] As discussed below, it is now understood that the experiment has the potential of measuring the isoscaler weak amplitude in nuclei,[5] in addition to any knowledge gained about the neutron-nucleus experiments.

The interpretation of the data from this experiment is straightforward. Indeed, one of the important features of ^{207}Pb is that it is a good shell-model nucleus. The states of ^{207}Pb can be well described as single-particle shell-model states.

A low-sensitivity (first-generation) version of the ^{207}Pb experiment is sensitive to large single-particle weak mixing matrix elements. Large single-particle weak matrix elements are an important requirement of several theoretical calculations of the TRIPLE experimental results.[6–11] An improved ^{207}Pb experiment, with sensitivity in the range of a few eV, is expected to see a non-zero parity non-conserving (PNC) effect.[5] An experiment with this sensitivity will be able to measure the isoscaler weak amplitude in nuclei.

The weak interaction of two nucleons in a nucleus is described by two dominant amplitudes, isoscalar and isovector, which correspond to rho-exchange and pion-exchange terms. The experimental limits on these amplitudes are shown in Fig. 1 (see Ref. 12).

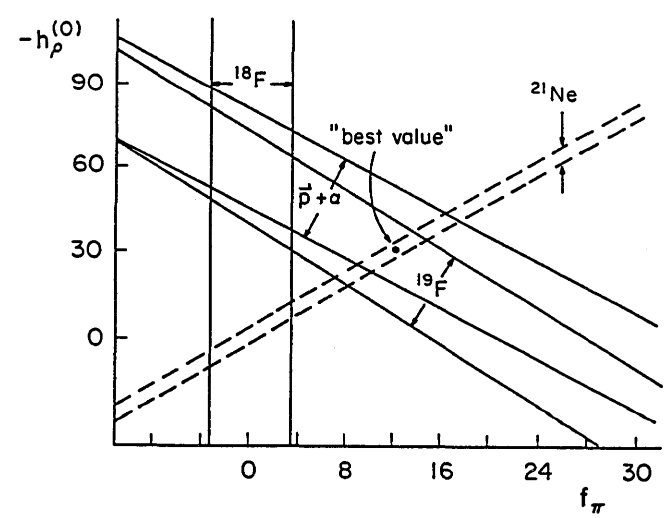

Figure 1. Plotted are the ranges in h_ρ^0 (isoscalar) – f_π (isovector) space allowed by various nuclear parity violation experiments (see Ref. 9).

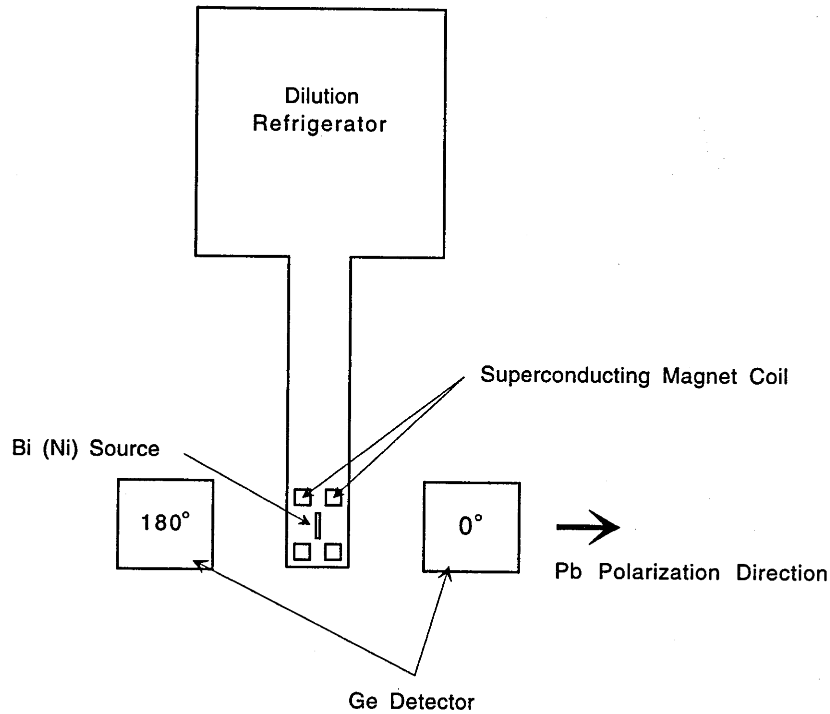

Figure 2. Experimental setup for the forward-backward asymmetry measurement.

A strong limit on the isovector amplitude is given by the measurements of the polarization of the 1081-keV gamma line in ^{18}F. Other measurements are sensitive to different linear combinations of the isoscalar and isovector amplitudes. The extraction of the isoscalar amplitude necessarily involves a nuclear structure calculation, which will be different for ^{207}Pb than in other cases. The fact that ^{207}Pb is one nucleon removed from a doubly-magic nucleus leads us to believe that modern shell model calculations will be able to predict the relevant nuclear structure reliably. In many previous measurements of the isoscalar amplitude, nuclear structure uncertainties dominate the error in the extraction of the amplitude.

The weak mixing of single-particle states is measured by detecting either a circular polarization or a forward-backward asymmetry of the 1.063 MeV gamma ray emitted from the decay of ^{207}Bi down through states of ^{207}Pb. The circular polarization of the gamma rays is measured for unpolarized ^{207}Pb and the forward-backward asymmetry requires polarized ^{207}Pb nuclei. Either PNC effect is proportional to the single-particle weak matrix element and is a consequence of transitions between parity-mixed states of ^{207}Pb.

The experimental setup for the circular polarization experiment consists of a ^{207}Bi source, gamma polarimeter, intrinsic CsI gamma detectors and a fast data-acquisition system. The setup details were described in a previous annual report, and will not be repeated here. The setup for the asymmetry measurement is considerably different and is shown in Fig. 2. The major components of this setup are a dilution refrigerator, a source consisting of ^{207}Bi diffused into a Ni lattice, and two intrinsic Ge detectors. A holding field is set up inside the dilution refrigerator by a superconducting coil; the direction of this field is flipped by 180° every 10 min during data taking. The ^{207}Bi nuclei are polarized

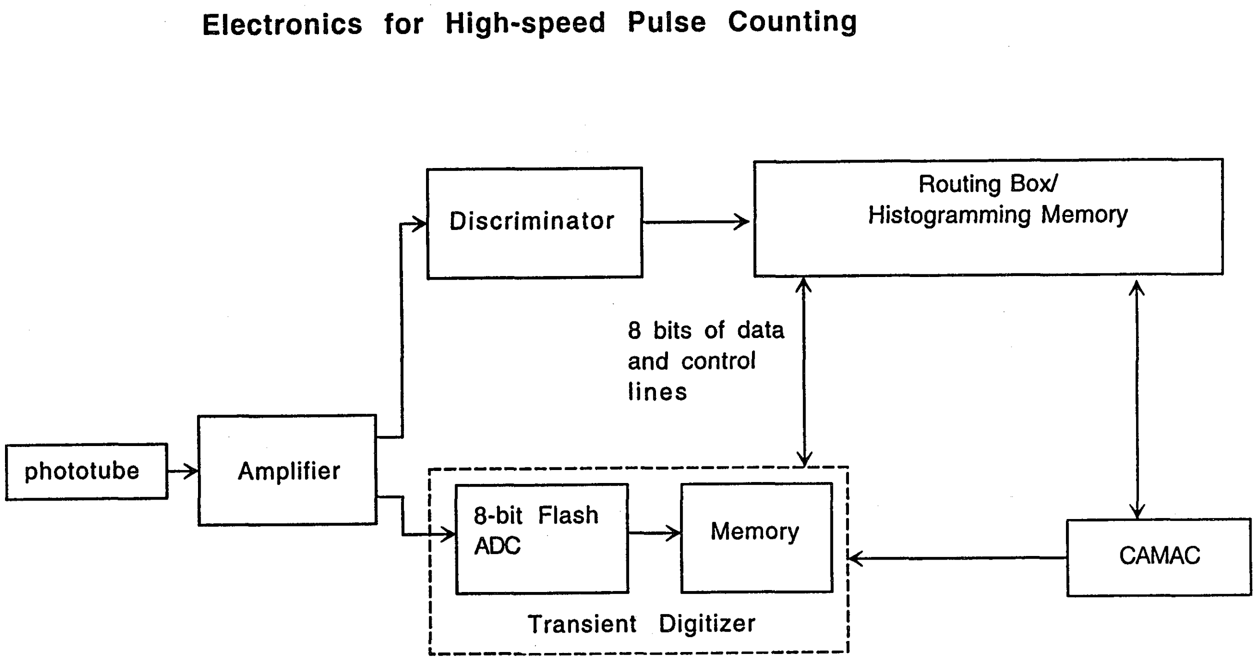

Figure 3. The modified data acquisition system.

by the large internal field of the Ni lattice and by the low (7-10 mK) temperature of the dilution refrigerator. We are using the dilution refrigerator located at Princeton University to measure the forward-backward asymmetry of the 1.063-MeV line.

The progress made during the last year on each experiment follows.

One of the major technical hurdles of the circular polarization experiment is the high counting rates needed to get sufficient sensitivity. The analyzing power of the polarimeter is ~ 1 %, so the expected experimental asymmetry is small. Thus, the experiment must be capable of high data rates in the detectors and data-acquisition system. The gamma detectors use intrinsic CsI, which has a decay lifetime of 30 ns and can be used for gamma rates of ~ 1 MHz. The data-acquisition system is very fast and is discussed below. The expected sensitivity of the experiment is ~ 50 eV for a 1-2 month run.

The main components of the data acquisition system are shown in Fig. 3. The transient digitizer (TD) (DSP model 2030S) samples, holds and converts the output of the photomultiplier tube. The routing box is a device built at IUCF and is used to interface the TD with a histogramming memory. Originally, we used a commercially-available histogramming memory module (Ortec model HM413), but we have later found that the HM413 induces false asymmetries in the data. Thus, we have redesigned the routing box to include memory and a CAMAC interface. The data-acquisition system now contains just the TD and the routing box, with the routing box doing the task of the histogramming memory in addition to controlling the TD and routing the detector signals. An energy spectrum taken with our CsI crystals and the data-acquisition system is shown in Fig. 4. This spectrum was taken with a ^{137}Cs source at a counting rate of 100 kHz.

Since the last annual report, we have run the polarimeter, and done systematic error studies. We have particularly worked on systematic errors arising from electronics effects

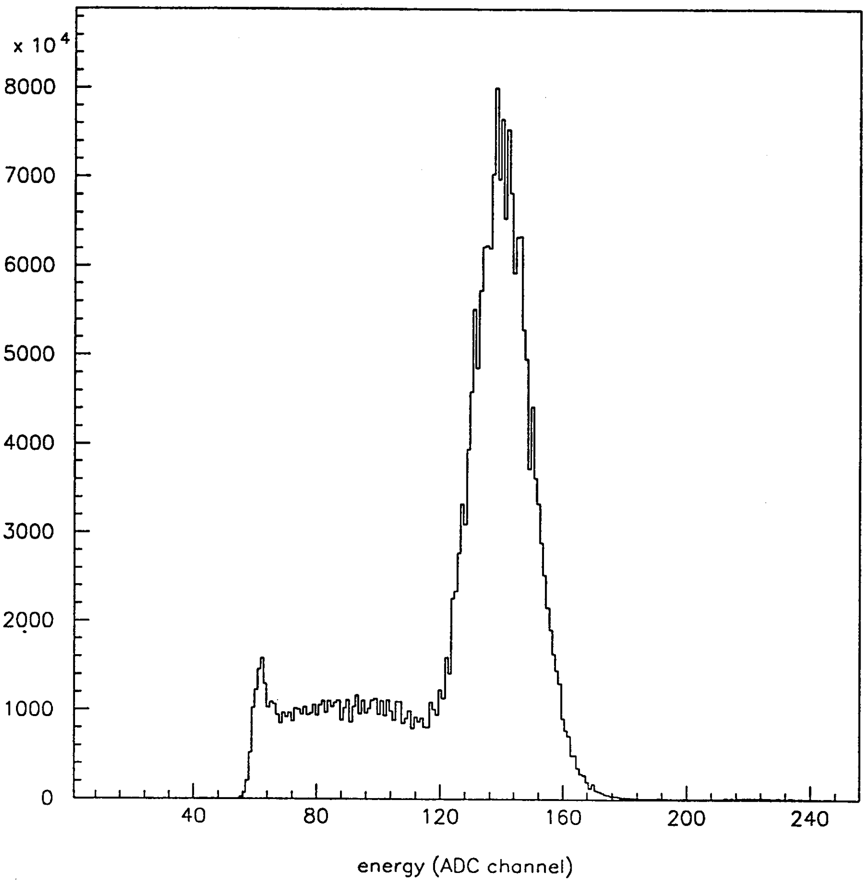

Figure 4. Energy spectrum taken at 100 kHz rate with the fast data-acquisition system and CsI crystals. The deadtime at 100 kHz rate is 1.7

and from magnetic field effects on the photomultiplier tubes. A 4.2-mCi ^{207}Bi source was ordered. Unfortunately, the company (Isotope Products Laboratory) was only able to deliver a 0.8 mCi source. The smaller source activity has forced us to redesign the polarimeter to allow for more source volume.

So far, we have had three test runs on the dilution refrigerator for the asymmetry experiment. Presently, the data show no PNC effects on the 1.063 MeV gamma ray line. The other prominent lines, at 560 keV and 1.720 MeV, will not show a PNC asymmetry and are thus good measures of false asymmetries produced by systematic errors. These lines show no asymmetry, indicating systematic errors are smaller than the statistical errors. The present sensitivity of the data is $\sim$ 20 eV.

As previously noted, systematic effects have so far not been a problem in the forward-backward asymmetry measurement. Nevertheless, we have added a precision timing measurement to the data stream, reduced the temperature variation in the data-acquisition area, lowered the time spent in each field orientation, and added an eight-spin field direction sequence, which eliminates the effects of linear and quadratic drifts in the system. All of these measures were taken to reduce systematic error.

The improvements we want to make to the forward-backward asymmetry measurement are to increase statistics and to increase the polarization of the Bi (and, hence Pb) nuclei.

The polarization in our last run was only 13%, and work is continuing to improve the polarization. In particular, new sources have been fabricated and measurements using an X-ray fluoresence spectrometer and an electron microscope have been made to determine the crystal properties of the sources.

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A MEASUREMENT OF PARITY-VIOLATING NEUTRON TRANSMISSION IN XENON

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A series of measurements of parity violating neutron transmission asymmetries in heavy nuclei carried out by the TRIPLE collaboration have demonstrated a number of cases of large amplifications of parity violating effects.[1] We are preparing an experiment to measure the parity violating asymmetry in polarized neutron transmission through xenon. There are two separate motivations for carrying out such a measurement. First, such a measurement would be a useful addition to understanding the A-dependence of the effect.