Update on the progress of the ^{37}K β asymmetry experiment

R. S. Behling, B. Fenker, M. Mehlman, D. Melconian and P. D. Shidling

The standard model of particle physics makes predictions for the spin polarized observables of a nucleus that undergoes beta decay. The TRINAT collaboration made up of members from the Texas A&M University Cyclotron Institute and the TRIUMF laboratory in Vancouver BC have a well-established program of measuring these spin polarized observables in the beta decay of alkali atoms confined in a magneto optical trap. For a number of years an experiment has been preparing to measure for the first time the beta asymmetry of ^{37}K.

The beam for this experiment was taken in December 2012 at the TRIUMF laboratory. This experiment was an upgrade to a previous experiment carried out by the TRINAT collaboration in 2002 that did not publish a result for the beta asymmetry because of an uncontrolled systematic in the background. The upgrade to the experiment was extensive and the goal of the December run was not only to show physics improvement by publishing a meaningful value for the beta asymmetry but to also to demonstrate engineering improvements and characterize the system that the collaboration will now use to produce more precise measurements in the future. The experiment was successful in that we were able to have the whole system operate and run in most ways according to the design specification and according to preliminary analysis will have a measurement that will be statistics limited to the 1.5% level of precision. The new parts of the experiment that were successfully demonstrated were a new larger vacuum chamber to house the experiment, detection of shake-off electron, a new method of trapping the atoms, a new scheme for optically pumping the atoms, new detectors to measure the radioactive decay of the trapped ^{37}K, new VME modules to record the data, and finally new software to control the data acquisition.

The large vacuum chamber was designed so that a more uniform electric field could be achieved in the region between the atom cloud and the MCP detectors. The original design specification for the apparatus was that a 1 kV/cm electric field would be applied to this region allowing for total separation of charge states +1 and +2 in the ion time of flight spectrum. This goal was achieved but on the eve of the commencement of the experiment a spark shorted two of our electrostatic hoops together and we decided to run at a more modest 350 V/cm field to avoid further damaging the apparatus. Even at this lower voltage we had 100% collection of the shake-off electrons coming from the beta decay. The addition of this shake-off electron detector was one of the largest improvements over the previous experiment. Its value has already been shown in the data analysis by greatly reducing background from decays not originating in the trap.

In this experiment we used a new scheme for trapping the atoms know as an AC-MOT. We originally decided to implement this scheme because it would allow eddy currents in the wall of the chamber to die away faster than the traditional DC-MOT. This decrease in eddy currents would translate into more counting time. The AC-MOT delivered on this point. As a trade-off, the increased dispersion of the eddy fields heated the experimental apparatus more than the previous trap setup. This increased heating lead to a spike in the partial pressure of hydrogen in the system. The hydrogen pumping efficiency of the system had already been compromised by the failure of a non-evaporable getter pump.

The increased hydrogen load together with the decreased pumping efficiency meant that the measured trap lifetime of 0.6 s, about half of the radioactive lifetime of ^{37}K, was limited by collisions with stray hydrogen. These losses were a major contributor to the low count rates that we observed. These problems have all been subsequently addressed and should not be a problem in future experiments.

From previous TRINAT experiments we tried to improve on our ability to polarize the atoms since the quantity that we observe is really the asymmetry multiplied by the polarization. To improve the polarization of the atoms we would need to improve the circular polarization of the laser light and would also need to be increase the power in the beams. We successfully accomplished both of these goals. With stable ^{41}K we are able to demonstrate >99% polarization. During the experiment the number of ^{37}K that were in the trap was much lower than in previous experiments and the reasons for this decrease were simply that the TiC target did not produce as much ^{37}K as it previously had as well as the aforementioned vacuum problems. This decrease in the number of atoms meant that the same technique that we previously used to measure the polarization by counting photoions was not available to us. In this case we will have to use the polarization that we determine from the recoil asymmetry in conjunction with the lower limits that we can place on the asymmetry from our test with stable potassium in our final physics result.

Lastly the data acquisition worked according to specification. Before the experiment we made the decision to digitize all of the waveforms from the silicon strip detectors. We have subsequently built up a lot of knowledge about how the detector behaves and have developed strategies for working with the ~6 billion waveforms. As a result of our experiences we are seeking to digitize the waveforms from the ion MCP which will greatly simplify the trigger logic for the experiment and to write a peak finding algorithm for the silicon detectors that will run on FPGAs of the data acquisition boards alleviating the need to store all of the waveforms on disk. The analysis of the data is ongoing and we expect to publish the results by the end of this year.