Measurement of branching-ratios in the β decay of ^{38}Ca

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A major upgrade to our data-acquisition electronics was completed in 2012 based on the lessons we had learned [1, 2] from our two previous branching-ratio measurements of ^{38}Ca and our off-line tests with a ^{22}Na source. One key improvement was to reduce the number of events that triggered as β-γ coincidences but were recorded as incomplete, from 3.5% to 0.3%, by minimizing the chance of overlap between successive β-γ coincidence pulses. Another improvement we implemented was to independently measure electronic dead-times on a cycle-by-cycle basis by inserting pulser signals from a constant frequency pulse generator in coincidence with gating signals from β-singles events, γ-singles events, and β-γ coincidence events. These improvements allowed our third measurement of the ^{38}Ca branching ratios in the fall of 2012 to be fully successful.

Once again, the ^{1}H(^{39}K, 2n)^{38}Ca reaction in inverse kinematics was used to produce pure ^{38}Ca nuclei at a ^{39}K beam energy of 30A MeV, and our fast tape-transport system was used to repetitively move collected samples to a well-shielded counting location where they were stopped between a 1-mm-thick plastic scintillator for β particles and our well-calibrated 70% HPGe detector for the γ rays. Time-tagged β-γ coincidences were recorded event by event.

At the beginning of this experiment, we thoroughly examined the response of our system immediately after the counting began as the sample arrived at the counting location. In the analysis of our last experiment we could find no β-γ coincidence events recorded for the first 45 ms of the 1.6-s count time and we were concerned that our system might have been effectively blocked for that period as a result of a high counting rate, possibly linked to the primary beam that had only just been interrupted. Our investigation concluded instead that the blank period in our data stream was caused by a delay in the operation of our tape-brakes, which meant that the tape came to rest 45 ms after the electronic stop signal had been issued to them. To accommodate this fact, we delayed the beginning of the count period by 60 ms, thus ensuring that the implanted ^{38}Ca nuclei were precisely positioned between the detectors before the counting period began. We also set a 0.5-s interval between the end of one cycle and the beginning of the next in order to leave sufficient time for the data from that cycle to be transferred to the computer.

Our time base for the measurement thus became 1.6-s collect, 0.229-s move, 1.54-s count, and 0.5-s delay for each cycle. During 7 days of beam time, approximately 9 million β-γ coincidence events were collected from over 370 million β singles in 60,847 cycles separated into 61 separate runs. A measurement of β-γ coincidences with a ^{22}Na source followed at the end of the branching-ratio experiment for ^{38}Ca. Since the branching ratio for ^{22}Na β^{+} decay is precisely known and is essentially 100%, this measurement served the purpose of independently checking the response of our system to positrons and high-energy γ rays comparable to those from ^{38}Ca.

The analysis of this experiment is nearly complete and will lead to our final result for the superallowed branching ratio of ^{38}Ca, with its associated uncertainty budget. We expect that we will be able to quote the branching ratio for the Gamow-Teller branches from ^{38}Ca to a relative precision of about

0.3%. Since these branches represent ~23% of the decays from ^{38}Ca, the relative precision on the superallowed Fermi branch, which is determined by subtraction from 100%, will be at or below 0.1%. It thus would be the first measurement of a $T_Z = -1$ emitter with significant non-superallowed branches to be measured with a precision of 0.1%, and will complete all the data required for a precise *ft*-value result for ^{38}Ca.

To our knowledge, this promises to be the most precise branching-ratio measurement ever made for short-lived beta emitter. It will also provide the first mirror pair of $0^+ \rightarrow 0^+$ superallowed emitters (^{38}Ca and ^{38}K^m) and will make possible a more demanding test of the isospin symmetry-breaking correction, δ_C, used to extract V_{ud} from the measured *ft* values. By improving our ability to discriminate among the different calculations of δ_C, measurements of $T_Z = -1$ emitters like ^{26}Si, ^{34}Ar and ^{38}Ca, can potentially lead to reduced uncertainties on δ_C and ultimately to reduced uncertainties on V_{ud} as well as the unitary sum for the Cabibbo-Kobayashi-Maskawa matrix.

[1] H.I. Park, J.C. Hardy, V.E. Iacob, M. Bencomo, L. Chen, J.R. Goodwin, V. Horvat, N. Nica, B.T. Roeder, L. Trache and R.E. Tribble, *Progress in Research*, Cyclotron Institute, Texas A&M University (2011-2012), p. I-7.
[2] V.E. Iacob, J.C. Hardy, and H.I. Park, *Progress in Research*, Cyclotron Institute, Texas A&M University (2011-2012), p. V-21.