Exploratory measurement of the ^{42}Ti half-life

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In our program to study superallowed beta decay, we are currently focused on completing the four mirror pairs with A ≤ 42 because they have the potential to distinguish clearly between competing calculations of the isospin-symmetry-breaking corrections required to extract V_{ud} from the experimental *ft* values [1,2]. What is required is precise measurements of the superallowed decays from the T_Z = -1 parent nuclei, ^{26}Si, ^{34}Ar, ^{38}Ca and ^{42}Ti. (The corresponding decays of ^{26}Al^m, ^{34}Cl, ^{38}K^m and ^{42}Sc are all well known.) We have recently published branching-ratio results for ^{38}Ca [3], are well advanced on ^{34}Ar [4] and plan a measurement on ^{26}Si in the summer of 2014. We report here our first exploratory measurement on ^{42}Ti ($t_{1/2}$ = 199 ms). To date, its branching ratio is known to ±2% and its half-life to ±0.2% [5], both being of insufficient precision to contribute meaningfully to the determination of V_{ud}.

For our study, we used our 4π proportional gas counter and digitizer-based data-acquisition system [6] to measure the half-life of ^{42}Ti. The advantages of this experimental set-up are that it has nearly 100% overall efficiency for the detection of decay positrons and it allows us to record the maximum information, including waveforms from the detector, for later off-line analysis.

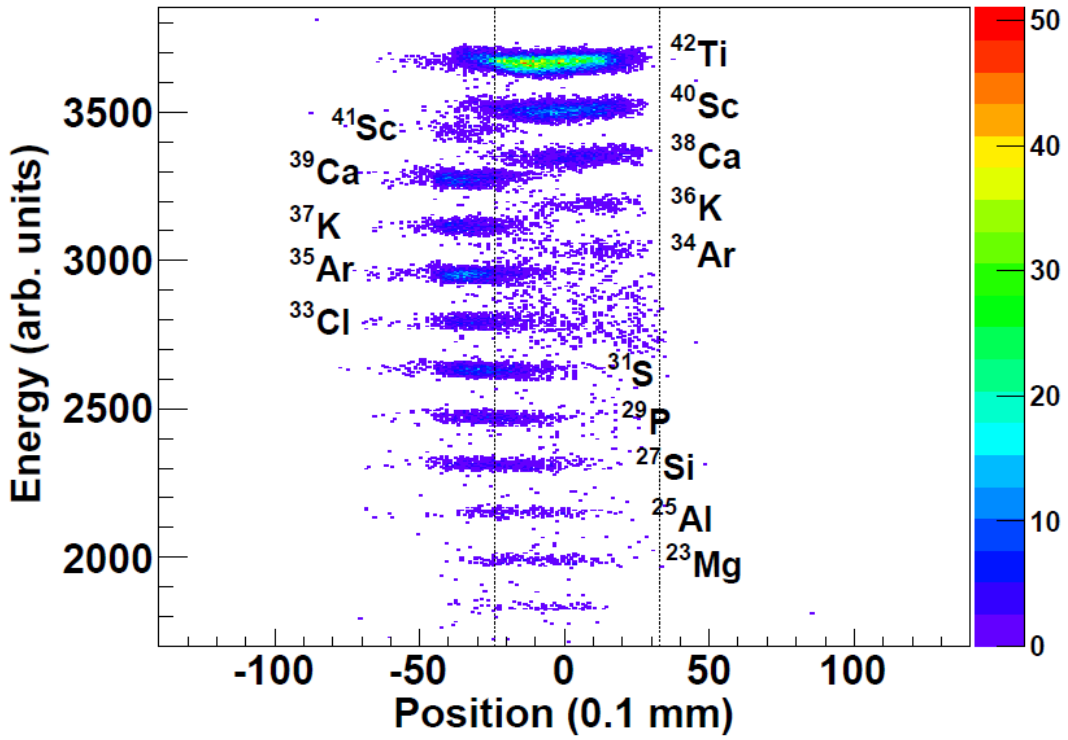

FIG. 1. The deposited energy versus position as obtained with the PSSD in the MARS focal plane when the reaction was ^{4}He(^{40}Ca, 2n)^{42}Ti. The spectrometer had already been optimized for ^{42}Ti production. Dashed lines show the position of the extraction slits in MARS, which we used during these measurements. Impurities are all identified.

We tried two reactions, ^{4}He(^{40}Ca, 2n)^{42}Ti and ^{3}He(^{40}Ca, n)^{42}Ti, in inverse kinematics at different primary ^{40}Ca beam energies to test the production of ^{42}Ti with MARS. A position-sensitive silicon detector (PSSD) was inserted at the MARS focal plane to identify the nearby reaction products and to optimize the separation of ^{42}Ti. From the results obtained with this detector, we concluded that the ^{4}He(^{40}Ca,2n)^{42}Ti reaction produces fewer strong impurities and is thus more suitable for future measurements of ^{42}Ti. This reaction can provide approximately 2000 particles/s of ^{42}Ti with 300 nA of ^{40}Ca at 32*A*-MeV. More details about the production of ^{42}Ti are described elsewhere in this report [7].

With this beam, the spectrum of products shown in Fig. 1 was recorded in the MARS focal plane once the spectrometer had been tuned for ^{42}Ti. With the extraction slits set as indicated in the figure, our primary concerns among the remaining impurities were ^{40}Sc ($t_{1/2}$ = 182 ms), ^{41}Sc ($t_{1/2}$ = 596 ms), ^{38}Ca ($t_{1/2}$ = 444 ms) and ^{39}Ca ($t_{1/2}$ = 860 ms). To investigate the effect of impurities on the decay of ^{42}Ti, we varied the thickness of the aluminum degrader in front of our collection tape from 1.00 to 4.00 mils in six steps, and measured the decay spectra at each.

Fig. 2 presents the calculated implantation profiles of ^{42}Ti and the identified impurities in and beyond the collection tape under two conditions, 1.00 mil of Al degrader (see Figure 2(a)) and 2.75 mils of Al degrader (see Figure 2(b)). It is evident that the former is expected to be nearly free of impurities while the latter should be overwhelmed by impurities. Decay data were analyzed for the three thinnest degrader settings – 1.00, 1.25 and 1.50 mils – and processed in the manner described in Ref [5]. Then a least-squares fit was performed for each case with a fit function that included, in addition to ^{42}Ti and its daughter ^{42}Sc, contributions from impurities as determined from the calculated implantation profiles. The ^{42}Ti half-life results from these three measurements were consistent with the result in Ref. [5], which was obtained with a trap system. This gives us confidence that by using a 1.00-mil degrader and running the left extraction slit at -1.5 mm instead of -2.5 mm (see Fig. 1) we should have a very nearly pure ^{42}Ti beam. The prospects for high-precision measurements of the half-life and branching ratio of ^{42}Ti appear very promising.

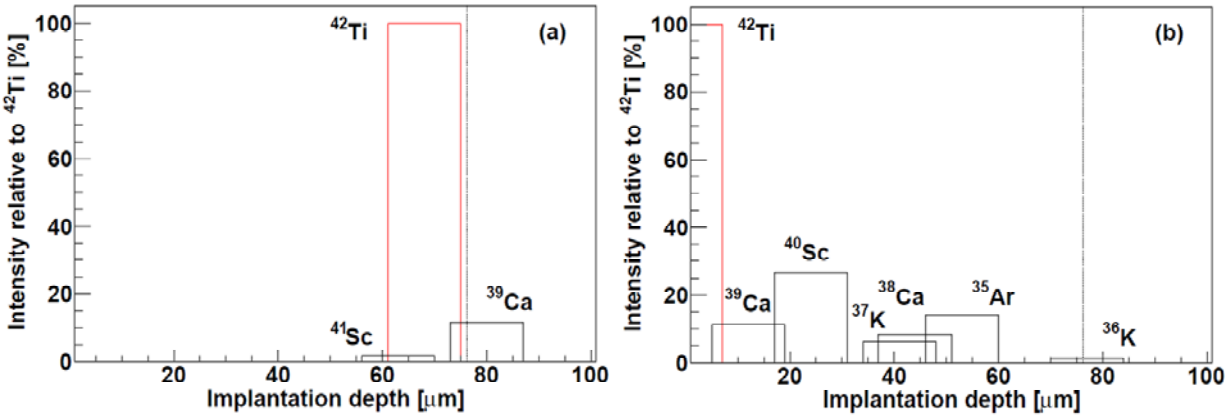

FIG. 2. The calculated implantation profiles of ^{42}Ti (red) and identified impurities (black) in and beyond the collection tape, under two different conditions: (a) 1.00 mil of Al degrader and (b) 2.75 mils of Al degrader. The calculations incorporate the measured momentum spread of MARS. In both cases the beams enter from the left, with the dashed line indicating the back of our 76-μm-thick collection tape. All ions left of the dashed line are collected in our sample; all others are not.

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