JYFLTRAP : Q_{EC}-values of the superallowed decays of ^{50}Mn and ^{54}Co

J. C. Hardy

We have now completed our second successful measurement of superallowed Q_{EC} values in collaboration with the group at JYFLTRAP, an on-line Penning trap mass spectrometer at the University of Jyväskylä cyclotron facility. The Q_{EC} values of ^{50}Mn and ^{54}Co [1] have now been added to our first results on ^{26}Al^{m}, ^{42}Sc and ^{46}V [2]. Penning-trap measurements of superallowed Q_{EC} values have become particularly interesting since our earlier discovery with the CPT trap [3] that the Q_{EC} value for ^{46}V was significantly different from a previous reaction measurement. This was the first Penning-trap measurement of any of the "well known" superallowed transitions. Until then, all these Q_{EC} values had been determined entirely from reaction measurements, so there arose considerable concern that there might be some undiscovered systematic problem with that type of measurement.

Our repeat measurement [2] of the ^{46}V Q_{EC} value confirmed the first Penning-trap result [3] but also confirmed earlier reaction results for the ^{26}Al^{m} and ^{42}Sc Q_{EC} values. This effectively eliminated any concerns about systematic problems with all reaction measurements. However it left doubts about the 30-year-old (^{3}He,t) Q-value measurement by Vonach *et al.*[4] of seven superallowed transitions, which included the now-discredited value for the ^{46}V. Perhaps other results in that publication were wrong as well; in particular, the accepted Q_{EC} values for ^{50}Mn and ^{54}Co depended strongly on the Vonach result and their measurement by Penning trap became a priority.

As we did in our earlier experiment at Jyvaskyla, we produced ^{50}Mn and ^{54}Co via (p,n)-reactions. A powerful advantage of this approach is that, not only were the superallowed emitters of interest produced in the primary reactions but ions from the target material itself – the beta-decay daughters of these emitters – were also released by elastic scattering of the cyclotron beam. As explained in Refs. [1, 2], with the JYFLTRAP system we can isolate a specific nuclide from the reaction products and measure the cyclotron frequency of its ions in the Penning trap. For the first time, in this measurement we also employed a fast cleaning procedure to prepare isomerically pure ion samples, and measured part of the data employing the so-called Ramsey excitation scheme [1]. For each determination of a Q_{EC} value, the cyclotron frequency measurements were interleaved: first we recorded a frequency scan for the daughter, then for the mother, then for the daughter and so on. This way, most possible systematic effects could be reduced to a minimum or eliminated. For each measurement, data were collected in several sets, each comprising ~10 pairs of parent-daughter frequency scans taken under the same conditions.

Our Q_{EC}-value results are 7634.48(7) keV and 8244.54(10) keV for ^{50}Mn and ^{54}Co respectively. Both results differ from the values published by Vonach *et al.*[4] by more than 2.5 keV (5 or more of the latter's standard deviations). Evidently, whatever problem Vonach *et al.* had with their measurement of the ^{46}V Q_{EC} value extended to ^{50}Mn and ^{54}Co as well: all three of these values are lower than the modern more-precise values by approximately the same amount.

The new result for ^{46}V led to its corrected $\mathscr{F}t$ value becoming significantly higher than that for any other well known superallowed transition. The most obvious explanation of its unusual value was that the correction for isospin symmetry-breaking, which depends upon the nuclear structure of the parent and daughter nuclei, was missing some important components. We re-examined these calculated corrections and discovered that by including the *sd*-shell with the *fp*-shell in our configuration space, we could remove the shift in the ^{46}V result but, at the same time, we introduced shifts in the $\mathcal{F}t$ values for ^{50}Mn and ^{54}Co as well [5]. With the previously accepted Q_{EC} values for those nuclei, their $\mathcal{F}t$ values became anomalous. Our new measured Q_{EC} values for ^{50}Mn and ^{54}Co completely resolve this discrepancy and provide strong confirmation of the new calculated correction terms.

[1] T. Eronen, V. -V Elomaa, U. Hager, J. Hakala, J. C. Hardy, A. Jokinen, A. Kankainen, I. D. Moore, H. Penttilä, S. Rahaman, S. Rinta-Antila, J. Rissanen, A. Saastamoinen, T. Sonoda, C. Weber and J. Äystő, Phys. Rev. Lett. **100**, 132502 (2008).

[2] T. Eronen, V. -V Elomaa, U. Hager, J. Hakala, A. Jokinen, A. Kankainen, I. D. Moore, H. Penttilä, S. Rahaman, A. Saastamoinen, T. Sonoda, J. Äystő, J. C. Hardy and V. Kolhinen, Phys. Rev. Lett. **97**, 232501 (2006).

[3] G. Savard, F. Buchinger, J. A. Clark, J. E. Crawford, S. Gulick, J. C. Hardy, A. A. Hecht, J. K. P. Lee, A. F. Levand, N. D. Scielzo. H. Sharma, K. S. Sharma, I. Tanihata, A. C. C. Villari and Y. Wang, Phys. Rev. Lett. **95**, 102501 (2005).

[4] H. Vonach *et al.*, Nucl. Phys. **A278**, 189 (1977).

[5] I. S. Towner and J. C. Hardy, Phys. Rev. C **77**, 025501 (2008).