Quantities Relevant for Superallowed Fermi Transitions and the CKM Mixing Matrix

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The eigenstates of the quarks in weak interaction are not identical to the mass eigenstates. Therefore a unitary transformation is introduced, the CKM matrix. The most precise determination of the first element of the quark mixing matrix comes from nuclear beta-transitions between isobaric analogue states (IAS) with spin 0, where Gamow-Teller transitions are forbidden. Besides the main ingredients, partial half-life and decay energy, also detailed nuclear structure information is necessary for the small, but important corrections. Although nowadays Penning traps are powerful instruments to measure mass differences of beta-decays, precise measurements of reaction Q-values still are competitive. As one example of a precise measurement we have determined the Q-value for the ^{46}V decay to ^{46}Ti [1] using the superb energy resolution of the MLL Q3D magnetic spectrograph. We eliminated most systematic uncertainties by measuring the energy of the ^{46}Ti(^{3}He,t)^{46}V reaction relative to ^{47}Ti(^{3}He,t)^{47}V* where the final nucleus is also in the excited IAS. The difference in beta-decay Q-values is very small and measured to be 28.73±0.16 keV. A comparison of the recent measurements is shown in Fig. 1 as a function of the year of publication. The most recent value is from our Q-value measurements [1] combined with the most recent value for the ^{47}Ti-^{47}V mass difference [2]. Our work [1] obviously triggered an enormous effort to improve the Penning trap result [5].

We also measured the Q-values for the more exotic decays of emitters with N = Z-2: ^{20}Na, ^{24}Al, ^{28}P, and ^{32}Cl by (^{3}He,t) reactions [6], where the achievable precision is not quite as high. We reached about 1 keV uncertainty and improved the previous precision of 3 – 7 keV considerably.

To test the theoretical calculations of the “charge dependent” corrections, that take care of the violation of isospin symmetry, we investigated the ^{64}Zn(d_{pol},t)^{63}Zn reaction [7] using polarized deuterons available at the MLL Tandem accelerator. This is the closest reaction on a stable target to investigate pairing properties in the daughter nucleus of the ^{62}Ga-^{62}Zn decay. For a large number of states in the daughter nucleus the spectroscopic factors could be determined and compared with shell model calculations using the same residual interactions as in the calculations of the charge dependent corrections. Discrepancies can now be used to improve the calculations.

With the ^{64}Zn(p,t) reaction we searched for excited 0^+ states in ^{62}Zn, and found four such states below 5.4 MeV [8]. However the previous 0^+_2 assignment to a state at 2342keV had to be rejected. This knowledge again restricts the calculations of the charge dependent corrections.

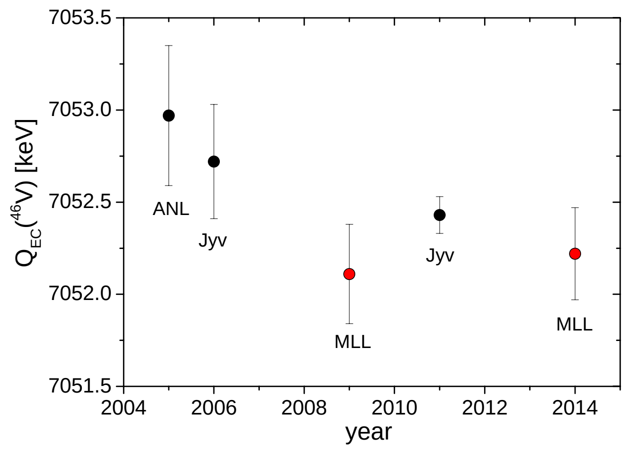

Figure 1: Penning trap (black) [3,4,5] and reaction Q-value (red) [1] measurements for the ^{46}V-^{46}Ti mass difference.

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