High Precision Q Value Measurements of Superallowed Beta Emitters

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INTRODUCTION

The nuclear beta decays between isobaric analog states of spin-parity 0+ and isospin T=1 provide valuable information for testing the Standard Model of particle physics. These so-called superallowed beta decays are of pure Fermi type rendering the decay matrix element to be very simple [1]. The most precise V_{ud} matrix element of the Cabibbo-Kobayshi-Maskawa (CKM) quark-mixing matrix is obtained from the superallowed beta decays.

There are about 20 nuclei that decay via superallowed beta decay that are possible to produce at present radioactive ion beam facilities. To be able to use these nuclei for extraction of V_{ud} of the CKM matrix, three experimental quantities are needed: the half-life, the branching ratio and the decay energy. From these, an ft value is obtained. Additionally a few theoretical corrections are needed to correct for instance isospin mixing and nuclear structure [2]. Together the theoretical corrections and experimental information provide an Ft value for each superallowed decay. According the conserved vector current hypothesis these values should be the same for all. Currently, data for 13 such emitters are known to comparable precision and contribute to the world average Ft value.

The decay energies (Q-values) determine the f value, which is proportional to Qυ requiring the Q value to be determined about 5 times more precisely than half-life and branching ratio to obtain *ft* value. The decay energy is perhaps the most easiest quantity to measure and presently precision in Ft is most often not limited by the Q value but other factors like the branching ratio or theoretical corrections. In this contribution Q-value measurements with JYFLTRAP Penning trap setup are presented.

EXPERIMENTAL SETUP

The JYFLTRAP Penning trap installation [3] at the University of Jyväskylä, Finland, has been extensively used for superallowed Q-value measurements. Coupled to the IGISOL [4] radioactive ion beam production facility, any element is available and so far Q-values ranging from 10-C to 62-Ga have been determined. Using mass doublet technique in which the Q-value can be directly determined, precision down to

$\Delta Q/M = 10^{-9}$ have been reached. This roughly corresponds to 50-eV level for the studied nuclei. The Q-values are determined with time-of-flight ion-cyclotron resonance (TOF-ICR) technique [5]. The most precisely determined Q-values are measured employing the Ramsey's method of time-separated oscillatory fields [6]. Since the probing time of ions is limited due to short half-lives, these studies significantly benefit from the Ramsey method since it provides same precision in about three times shorter time.

RESULTS

Until June 2010, when IGISOL and JYFLTRAP were shut down for relocation, Q values of 14 different superallowed beta emitters have been determined. These are shown in Figure 1 with values measured with other Penning trap facilities.

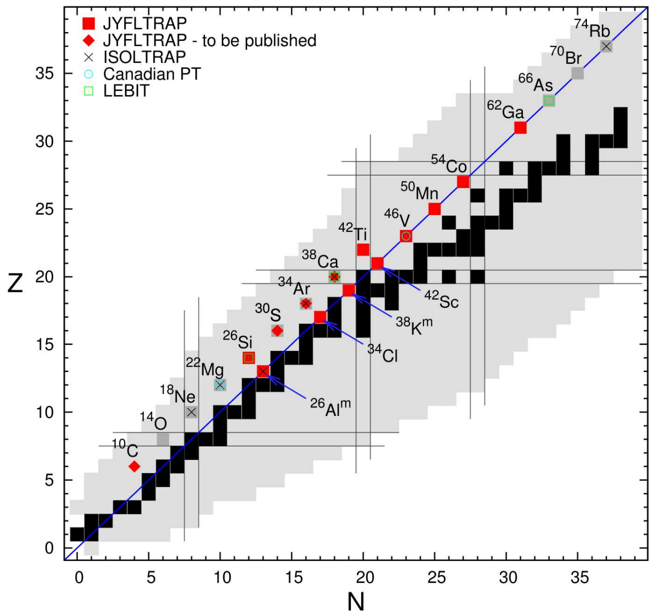

FIGURE 1. Chart of the nuclei where superallowed beta emitters have been indicated. The Q values of nuclei marked with red color have been measured with JYFLTRAP, with cross at ISOLTRAP (ISOLDE, CERN), with circle at Canadian PT (Argonne) and with squares at LEBIT (MSU).

All of the Q values have been measured with mass doublet technique in which the Q value is directly determined by measuring the frequency ratio of superallowed parent and daughter ions. Thus, the daughter ion mass is needed only with moderate (1 keV) precision in order to be able to determine the Q value to 10-eV level. Also mass dependent systematic shifts are negligible.

Ten Q values of superallowed beta emitters that belong to the set of "best 13" contributing to the world average Ft value have been determined with JYFLTRAP. In cases of ^{42}Sc, ^{46}V, ^{50}Mn and ^{54}Co a significant deviation to old (3He,t) reaction Q value measurements were found [7] and in later compilation [1] results reported in this reference were removed. Q values of other emitters ^{10}C, ^{26m}Al, ^{34}Cl and ^{38m}K were found to be consistent with old reaction based measurement results. The result for Q-value of ^{62}Ga enabled it to be included to the set of best known emitters. Also the Q value of ^{34}Ar was measured.

Additionally several Q values have been determined. These include ^{26}Si, ^{30}S, ^{38}Ca and ^{42}Ti that can contribute to the world average Ft value once the half-lives and branching ratios have been determined precisely.

SCOPE FOR EURISOL

Several superallowed emitters that are not yet experimentally accessible or have very poor production yield with current on-line facilities exists. These are N=Z (T_z=0) nuclei heavier than ^{62}Ga and Tz=-1 nuclei heavier ^{42}Ti. High-precision Q-value, half-live and branching ratio measurements would not perhaps contribute to the CVC tests since strongest influence there clearly originates from lighter, already precisely measured, nuclei. Instead, these heavy nuclei would provide valuable data for evaluating isospin symmetry breaking corrections δ_C.

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