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Exotic superallowed (and mirror) beta-decay studies with the TAS technique

Abstract:
Nuclear physics provides one of the most precise probes to test the electroweak interaction [Har20]. The procedure is based on the study of super-allowed Fermi beta decays, and requires high-precision determination of the half-life of the decay, the Q value and the branching ratio of the 0+ to 0+ transition (in the case of T=1 analog decays). The method relays on the validity of the Conserved Vector Current (CVC) hypothesis, and actually it provides a way to test it. If the hypothesis holds, it is expected that the corrected Ft values of the super-allowed transitions do not depend on the decay and can be directly related to the fundamental vector coupling constant (Gv).
From the mean value of the corrected Ft values, it is possible to determine Gv, and from the ratio of Gv/GF the Vud matrix element can be determined. In the equation, ft stands for the conventional ft value definition, δ_(R)^',δ_NS,δ_C,Δ_R^V are small corrections, and GF is the weak interaction constant of the muon decay. Vud is the largest matrix element of the upper row of the Cabibbo-Kobayashi-Maskawa (CKM) matrix. This provides a way to test the unitarity of the CKM matrix, which is a fundamental requirement for the validity of the Electroweak Standard Model.

Through careful filtering, several decays are accepted as known with sufficient precision to be included in the calculation (see Hardy et al. [Har20]), but there is limited knowledge of several heavier decays that could also be considered. The interest in these studies arises mainly because adding heavier systems to the compilation can provide a more stringent test of the theoretical corrections employed in the calculations of the Ft values. With this letter of intent, we propose to study some cases with A ≥ 70, that can be of interest in this realm.

The study will profit from the use of the total absorption spectroscopy technique (TAS), that can provide gamma-cascade efficiencies of almost 100%, of interest for detecting weak gamma decay branches. These decay branches de-excite populated 1+ and non-analog 0+ states in the daughter nucleus that compete with the ground state (gs) to ground state transition. The technique will allow us to determine more precise branching ratios in combination with the high-resolution technique. In our measurements, it is also foreseen to apply a new method to determine the gs to gs feedings [Gua20], which is based on a revised method introduced originally by Greenwood et al. [Gre96]. The procedure (see Guadilla et al. [Gua20]) has been already successfully applied to the 100Tc decay study [Gua17,Gua20], which is a decay that has a similar beta decay pattern (large gs to gs branch), providing a precision of the order of 0.5%.

The study we propose represents a first effort to obtain information on heavier systems, which could allow for more rigorous evaluation of the theory used to determine the corrections needed to achieve the corrected Ft values. Similar studies can also be performed in mirror T=1/2 nuclei [Nav09].
The measurement will be carried out using the upgraded hybrid TAS array, which has been developed within the [(NA)2STARS] project and will be installed at DESIR. This new hybrid TAS will consist of either DTAS [Tai15,Gua18] or Rocinante [Val17], which was refurbished recently [Orr25], together with new LaBr3(Ce) modules arranged in a star-shaped configuration.

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