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High Precision Mass Spectrometry for Fundamental Tests of the Weak Interaction

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Nuclear decays are windows to test the validity of predictions of the Standard Model. In special, nuclear β-decay data of superallowed 0+⟶0+ transitions has provided crucial experimental input to tests of the unitarity of the Cabibbo-Kobayashi-Maskawa (CKM) quark-mixing matrix. These studies require precise understanding of properties of these special transitions, such as half-life, branching ratios and transition energies (or Q-values). For the latter, high-precision mass spectrometry plays an important role. The Q-values of these decays, which are essentially mass differences between the initial and final states, are key ingredients of the most precise evaluations of up-down element (Vud) of the CKM matrix. These measurements are challenging: they require relative mass uncertainties on the order of a few parts per billion. Nowadays, this level of precision can only be attained using Penning Trap Mass Spectrometry (PTMS).

Such studies are pursued at the TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN) facility in Vancouver. In this talk, I will address TITAN's most recent contributions to fundamental tests of the weak interaction, including the recent measurement of the Q-value of the 22Mg⟶22Na superallowed β+ decay. I will also cover our efforts to pursue the measurement of the Q-value of the 74Rb⟶74Kr superallowed decay. This case has the highest atomic number among all studied cases and is particularly challenging given its low half-life (˜65 ms). However, TITAN is uniquely situated to perform this measurement. It can perform PTMS of radioactive species using Highly Charged Ions (HCI), which permits a significant increase in precision comparing to conventional PTMS. On the other hand, employing HCI demands strict vacuum requirements in the mass spectrometer in order to prevent electron recombination. For that, a new cryogenic vacuum system is being integrated to the Penning trap.

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