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Towards a precision Penning trap measurement of the 163Ho Electron Capture Q-value

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The results of solar, atmospheric, and reactor neutrino oscillation experiments have provided strong evidence for a non-zero neutrino mass. However, these measurements determine only the difference between the squared-masses of the neutrino mass eigenstates. The absolute neutrino mass scale is still unknown. Beta-decay experiments utilizing 3H and 187Re have obtained the most stringent upper limits on the (anti) electron neutrino mass of 2 eV. An emerging alternative method for a direct neutrino mass determination is based on calorimetric electron capture spectroscopy (ECS) of 163Ho. The ECHO collaboration in Europe, and the NUMECS collaboration in the USA aim for sub-eV sensitivity to the electron neutrino mass using this method. In both the beta-decay and EC experiments the neutrino mass is determined from a fit to data near the end-point of the decay energy spectrum. The end-point energy for zero neutrino mass, which corresponds to the Q-value for the decay, is a free parameter in the fit. Hence, an independent measurement of the Q-value is extremely important for interpreting experimental results and checking for possible systematic effects.
At CMU we are developing a high-precision double Penning trap mass spectrometer: the Central Michigan University HIgh Precision Penning trap (CHIP-TRAP), which will employ a simultaneous cyclotron frequency comparison technique using pairs of ions confined in two separate traps. This will reduce the effect of magnetic field fluctuations. The Q-value, defined as the mass difference between parent and daughter atoms, can be determined via
$Q = mp - md = (mp - me)(1 - R)$,
where $R = fc,p/fc,d$ is the cyclotron frequency ratio for ions of the parent and daughter species. CHIP-TRAP will utilize ions of 163Ho and the daughter 163Dy produced by a laser ablation ion source. This will minimize the amount of 163Ho, which must be synthesized, required for the measurement. A Q-value determination to ~1 eV is required for the 163Ho ECS experiments, corresponding to a fractional precision of ~5 parts-per-trillion in the cyclotron frequency ratio. In this presentation we will describe the current status of CHIP-TRAP, and of tests of ion production via laser ablation of the stable 165Ho isotope.

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