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Production, Purification, and Analysis of a Ho-163 Sample for the Neutrino Mass Determination

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The ECHo collaboration investigates the electron capture decay (EC) of Ho-163 for determining the mass of the electron neutrino. The spectrum of the EC is recorded by metallic magnetic calorimeters (MMC) and the neutrino mass is deduced from the analysis of the endpoint region of the spectrum. The required Ho-163 samples are produced by reactor activation of enriched Er-162. Co-produced long-lived radio isotopes producing unacceptable levels of background need to be removed. By ion exchange chromatography both prior to and after the irradiation a pure Ho fraction can be obtained, leaving Ho-166m as the only remaining long-lived contamination.

Resonance ionization at a mass separator offers a suitable method to further purify the sample and to implant Ho-163 into the calorimeters in a single step. This combines additional element-selectivity and high ionization efficiency, in particular regarding lanthanides, with precise control and monitoring of the implantation. The RISIKO mass separator of the LARISSA working group is an ideal tool with its existing resonance ionization laser ion source and the associated high-performance pulsed Ti:sapphire laser system. This highly element-selective method and a sector field mass separation result in no radioactive co-implants beyond a fraction of 1 ppb with respect to Ho-163. To increase the implantation yield, a new focusing and scanning stage is currently being designed which matches the beam characteristics to the miniature geometry of the MMC.

In addition to the calorimetric spectrum, an independent measurement of the EC Q-value, i.e., the mass difference between parent and daughter nuclide, is necessary as a consistency check and to quantify systematics such as solid state effects. The ideal way for a model independent Q-value measurement is by high-precision Penning-trap mass spectrometry. For this purpose the chemically purified Ho-163 sample is sufficient as the only isobar, Dy-163, is suppressed by the chemical separation. Ion production from samples with only 10^16 atoms was studied at TRIGA TRAP using an improved laser ablation ion source. Determination of the Q-value was demonstrated and the uncertainty of the atomic masses of Ho-163 and Dy-163 improved by a factor of two compared to literature. This combination of sample and ion production can now be used at SHIPTRAP to perform the measurements on a 30 eV uncertainty level, thus providing the very important input for the ECHo project.

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