Accuracy studies and first mass measurements at TRIGA-TRAP*

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Introduction: At present atomic masses are obtained with the highest precision by measuring the cyclotron frequency of a stored ion in a Penning trap [1]. TRIGA-TRAP at the research reactor TRIGA-Mainz is so far the only Penning trap mass spectrometer installed at a nuclear reactor, which provides short-lived neutron-rich radionuclides in the mass region 80 < A < 140 by thermal-neutron induced fission. The goal of TRIGA-TRAP is to perform mass measurements on these nuclides in order to contribute to improvements of nuclear structure studies, nucleosynthesis calculations and the predictive power of nuclear mass formulas [2].

Results: At TRIGA-TRAP the time-of-flight ion cyclotron resonance (TOF-ICR) method is routinely used to determine cyclotron frequencies of ions produced by offline ion sources. A laser ablation ion source [4] provides carbon clusters $^{12}C_n^+$ as reference ions for mass calibration and to study systematic uncertainties of the mass spectrometer. One systematic uncertainty due to non-linear magnetic field fluctuations depends on the time elapsed between two measurements Δt. The magnitude of this effect was determined in a long-term measurement of the cyclotron frequency of C_{20}^+ to be

$$\frac{\Delta\omega_{ref}}{\omega_{ref}} = 4\cdot 10^{-11}/\min\cdot\Delta t.$$

A trap misalignment leads to a systematic uncertainty in the mass calibration which increases with the mass difference of the ion of interest to the reference ion ($m - m_{ref}$). This so-called mass-dependent systematic effect was investigated by the determination of well-defined frequency ratios r of carbon cluster ions over a broad mass-range. About 70 frequency ratio measurements yield

$$\frac{\Delta r_m}{r} = -1.8(1)\cdot 10^{-9}\ (m - m_{ref})/u$$

as the result for the mass-dependent systematic effect at TRIGA-TRAP. After correction of these two systematic effects the residual relative systematic uncertainty of the measurements was found to be $2.5\cdot 10^{-8}$. A detailed description of these tests is given in [4].

Ions for a mass measurement of ^{197}Au have also been produced with the laser ablation ion source using a gold foil as target. The literature value of the mass of ^{197}Au listed in the atomic-mass evaluation (AME) 2003 [5] was confirmed with the TRIGA-TRAP mass spectrometer. The frequency ratio to C_{16}^+ was determined with a precision of 6.9 keV ($\delta m/m = 3.7\cdot 10^{-8}$). A cross-check with C_{15}^+ has been performed at the same time to ensure the accuracy of the measurement. The results of the measurements are shown in Fig. 1.

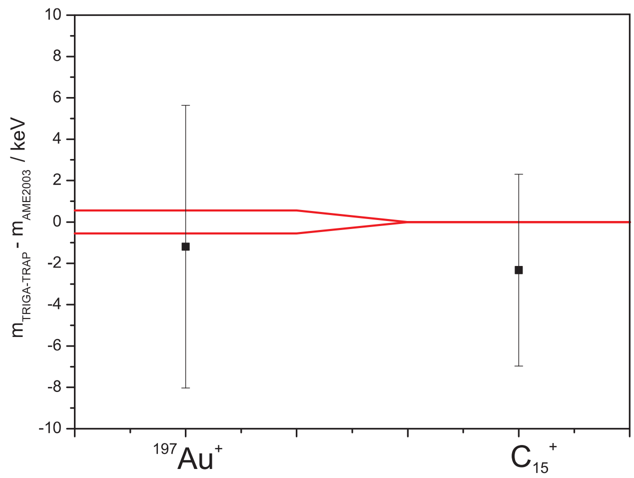

Figure 1: Results of the mass measurement of $^{197}Au^+$. The red lines represent the uncertainty of the literature values in [5], and the data points the results of TRIGA-TRAP.

Outlook: Further offline mass measurements on lanthanoids and actinoids will be performed in 2010. Concerning the online coupling to the TRIGA reactor, a gas-jet system is being connected to an ECR ion source to transport and ionize the radionuclides. An RFQ buncher is being installed to provide cooled ion bunches for high-precision mass measurements on neutron-rich fission products.

References

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