High Accuracy Mass Determination of Unstable Nuclei with the Penning Trap Mass Spectrometer ISOLTRAP

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The Penning trap mass spectrometer ISOLTRAP is installed at ISOLDE/CERN. It provides mass measurements of short-lived nuclides with very high accuracy. Accurate experimental mass values serve for testing nuclear models, help to increase their prediction power for nuclides far from stability and can reveal nuclear structure. Additionally, some mass values represent important input parameters for Standard model tests and astrophysical calculations.

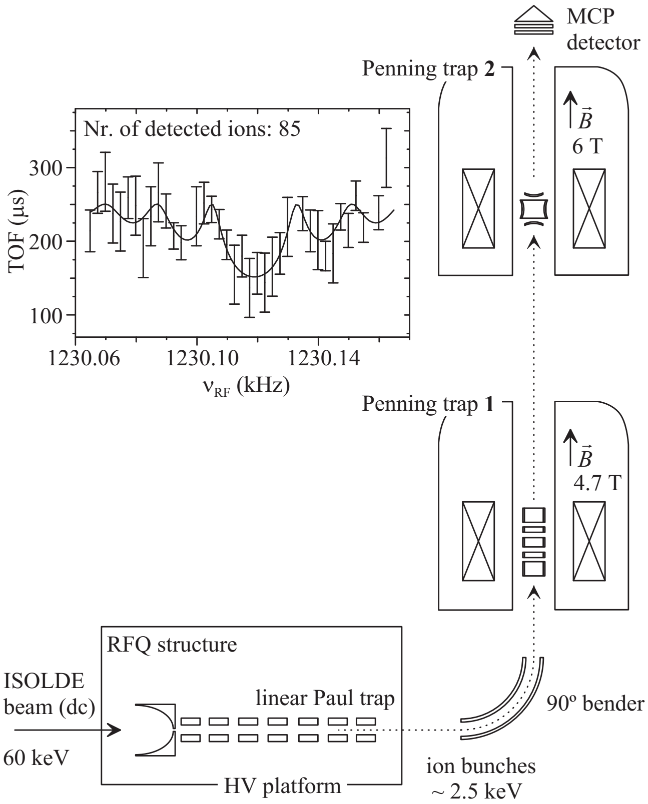

Fig. 1: Experimental setup of the ISOLTRAP spectrometer. The inset shows the cyclotron resonance curve for ^{74}Rb. Plotted is the time of flight (TOF) of the ions from the trap to the ion detector as a function of the applied radio frequency with the theoretical line shape fitted. This spectrum contains roughly one fourth of all ^{74}Rb data.

The ISOLTRAP Penning trap mass spectrometer (Fig. 1) consists of three main parts: a), a linear gas-filled radio-frequency quadrupole (RFQ) trap for retardation, accumulation, cooling and bunched ejection at low energy [1], b), a gas-filled cylindrical Penning trap for further cooling and isobaric separation [2], and c), an ultra-high vacuum hyperboloidal Penning trap for isomeric separation and the actual mass measurement [3]. The mass measurement is performed via the determination of the cyclotron frequency $\omega_c = q/m \cdot B$ of the ion with mass m and charge q revolving in the magnetic field of the strength B. The accuracy of the measured mass values is typically $\delta m/m = 1 \cdot 10^{-7}$.

Six radioactive beam times were carried out in 2000.

In the first beam time an uranium carbide target was used in conjunction with the resonant ionisation laser ion source (RILIS) to measure the mass of neutron rich tin isotopes. The isotopes ^{128,129,130,132}Sn were investigated. Particulary, the mass of the doubly magic ^{132}Sn is of interest for astrophysical calculations along the r-process path.

The second beam time was dedicated to neutron-deficient Sr isotopes. The mass of ^{76}Sr and ^{77}Sr could be measured by determining the mass of SrF_2 molecules. ^{76}Sr is a possible waiting point on the astrophysical rp-process path.

One major project in 2000 was the measurement of the Q-value of the superallowed β-decay of ^{74}Rb. Two beam times were performed to measure the mass of ^{74}Rb and its daugther nucleus ^{74}Kr. ^{74}Rb is the shortest lived nuclide ever investigated in a Penning trap ($T_{1/2} = 65\,\mathrm{ms}$). The accuracy of its mass value is governed by statistics and resolving power, that are limited by production rate and half-life, respectively. The relative accuracy reached for the mass of ^{74}Rb is about $3.4 \cdot 10^{-7}$ (i.e. $\approx 25\,\mathrm{keV}$). The measurement of ^{74}Kr was performed with an unprecedented relative accuracy of only $3 \cdot 10^{-8}$. Additionally, the masses of the krypton isotopes with $A = 73$ and 75 were measured.

One beam time was performed using a molten lead target to complete the picture of binding energies for the neutron-deficient mercury isotopes. The isotopes ^{179,180,181}Hg were measured for the first time closing the gap in the binding energy sytematics.

The last beam time in 2000 was used to measure the mass of ^{34}Ar produced in a CaO target. This value is needed with very high accuracy in the context of the FT-value systematics for superallowed fermi β decays. ISOLTRAP succeeded to measure this mass with an uncertainty below 1 keV.

Future mass measurements will be performed in astrophysically interesting regions like the neutron-rich Cd and Sn isotopes, the neutron-deficient Y isotopes and around the rp-process waiting points ^{68}Se and ^{72}Kr. Additionally, the measurements in the context of fundamental tests will be continued measuring ^{32}Ar. Future technical developments focus on the improvement of the overall efficiency by improving the detector setup as well as different parts of the ion transfer.

References

[1] F. Herfurth *et al.*, accepted for publication in Nucl. Instr. Meth. **A**, CERN preprint: CERN-EP/2000-062.

[2] H. Raimbault-Hartmann *et al.*, Nucl. Instr. Meth. **B126** (1997) 378

[3] G. Bollen *et al.*, Nucl. Instr. Meth. **A368** (1996) 675