High Accuracy Mass Determination of Unstable Nuclei with the Penning Trap Mass Spectrometer ISOLTRAP at ISOLDE/CERN

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Mass measurements on short-lived isotopes delivered by the on-line mass separator ISOLDE are the task of the ISOLTRAP experiment at CERN. Accurate experimental mass values serve as a stringent test of nuclear models, help to improve them for predictions of nuclear properties far from nuclear stability and can reveal nuclear structure. The ISOLTRAP system [1] installed at the on-line mass separator ISOLDE/CERN is a triple trap mass spectrometer. It consists of a radio frequency quadrupole (RFQ) ion beam buncher, a Penning trap ion cooler and a Penning trap mass spectrometer. In the ion beam buncher the 60 keV ISOLDE ions are electrostatically retarded before they enter a linear Paul trap system where they are cooled by buffergas collisions and accumulated. After accumulation the ions are ejected as a short 2.5 keV ion bunch, which is transported to ground potential by passing through a pulsed drift tube. The low energy ion bunches are then captured with high efficiency in the first Penning trap of the ISOLTRAP system. This trap [2] acts as an ion cooler and isobar separator with a resolving power of $m/\delta m(FWHM) \approx 10^5$. In the second Penning trap the mass measurement is carried out via the measurement of the cyclotron frequency $\omega_c = q/m \cdot B$ of the stored ions. A resolving power of $m/\Delta m(FWHM) > 10^6$ enables separation of nuclei in their ground or isomeric states even for very low excitation energies. The accuracy delivered by ISOLTRAP for short-lived isotopes with a half-life of $T_{1/2} = 1\,\mathrm{s}$ and mass $m \approx 100\,\mathrm{u}$ is typically $\delta m/m = 1 \cdot 10^{-7}$. In 1999, a recently installed ion beam accumulator and buncher was taken into operation, a system which is based on a linear radiofrequency quadrupole (RFQ) ion trap. Three radioactive beam times were carried out with ISOLTRAP. In parallel, systematic tests were carried out of the RFQ ion beam buncher in order to investigate its properties and to optimize its parameters. Compared to the previously used beam buncher (based on a large Paul trap) it was possible to increase the efficiency for stopping and bunching of the ISOLDE beam by at least 2 orders of magnitude to reach a value of about 10 %. In the first beam time with a molten-lead target it was possible to extend the measurements on the mercury isotopic chain even further to the proton rich side reaching ^{182,183}Hg, both of which were not yet measured before. Furthermore, the isomeric states of ^{183,187,189}Hg were investigated. In the second beam time measurements were carried out on light isotopes in the mass region around A = 35. Using a CaO target with a cooled transfer line measurements on several Ar isotopes were performed. For ^{33,42,43}Ar the error for the measured mass could be improved by at least a factor 3. Figure 1 shows the cyclotron resonance curve for ^{33}Ar, which is an isotope of special interest because the ground state of ^{33}Ar is one endpoint of an isobaric mass multiplett. Using the ISOLTRAP data this mass multiplett is one of the best measured multipletts and can therefore serve as a stringent test of the isobaric multiplett mass equation (IMME). Further importance is due to the fact that ^{33}Ar is a test case for isospin violation corrections to superallowed mixed transitions. Furthermore, ^{33}Ar is the shortest-lived isotope ever measured with a Penning trap mass spectrometer ($T_{1/2} = 174\,\mathrm{ms}$). In a third beam time a LaO target with cooled transfer line was used for the production of xenon isotopes. Here, ISOLTRAP investigated the entire neutron-deficient part of the Xe isotopic chain from A = 114 to A = 123. For ^{114,115,116}Xe the mass table gives no experimental datum while for $^{117-122}$Xe the uncertainty is much larger than that achieved with ISOLTRAP. In the future, the extended applicability of ISOLTRAP will be employed for the accurate determination of masses in various regions of the nuclear chart. One example is the planned exploration of the neutron-rich side of ^{208}Pb. Despite the fact that this nucleus is the classical shell model nucleus, hardly any information exists about more neutron-rich isotopes. Such isotopes are particularly important for the adjustment of the parameters of models used for the prediction of the stability of 'super heavy' isotopes. Another example is the mass determination of very short-lived isotopes like ^{32}Ar and ^{74}Rb. The exact knowledge of the mass of ^{32}Ar makes it possible to improve the constraints on scalar weak interaction [3] while a good knowledge of the mass of ^{74}Rb helps to extend the charge dependent systematics of pure Fermi decays towards higher Z and can contribute to tests of the unitarity of the CKM matrix.

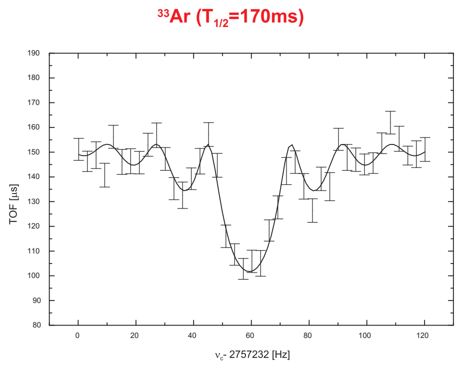

Fig. 1: Cyclotron resonance of ^{33}Ar ions. ^{33}Ar has a half-life of only $\approx 170\,\mathrm{ms}$ and is the shortest lived isotope ever studied in a Penning trap.

References

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