MS 2: Precision Mass Spectrometry

Time: Monday 14:00–16:00 Location: U A-Esch 2

Invited Talk MS 2.1 Mon 14:00 U A-Esch 2

Precision mass measurements of short-lived isotopes at TITAN — •Jens Dilling — TRIUMF, Vancouver, Canada — University of British Columbia, Vancouver, Canada

The atomic mass is a fundamental property and acts as a fingerprint of the individual atom or isotope. The atomic mass also plays a vital role in our understanding of nature, ranging for example from the chemical element nucleosynthesis in the Universe to testing the nuclear strong force on a fundamental level. The most precise way to measure atomic masses is via ion traps and here in particular with so-called Penning traps. At the TRIUMF laboratory in Vancouver, we have developed very sensitive and fast methods using ion trap techniques at TITAN (TRIUMF's Ion Trap of Atomic and Nuclear science). The system is suited and optimized for accelerator-produced isotopes, capable of measurements of isotopes with 5ms half-lives and includes features for fast separation of contamination using a multi-reflection device. In this talk I will give an overview of ion trap mass measurement programs and provide an overview of the TRIUMF activities. I will also report on recent measurements with TITAN, as well as current developments.

MS 2.2 Mon 14:30 U A-Esch 2

Status report of the TRIGA-TRAP experiment — •Jacques J. W. van de Laar[1,2], Klaus Blaum[3], Michael Block[1,2,4], Stanislav Chenamrev[1,2,5], Christoph E. Düllmann[1,2,4,6], Steffen Lohse[1,2], Szilard Nagy[3], and Fabian Schneider[1,2] — [1]Institut für Kernchemie, Johannes Gutenberg-Universität Mainz, DE — [2]Helmholtz-Institut Mainz, DE — [3]Max-Plank-Institut für Kernphysik, Heidelberg, DE — [4]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, DE — [5]Petersburg Nuclear Physics Institute, Gatchina, RU — [6]PRISMA Cluster of Excellence, Johannes Gutenberg-Universität Mainz, DE

High-precision experimental data of ground-state properties of exotic nuclei allow testing the reliability of nuclear mass models. The TRIGA-TRAP experiment is a double Penning-trap mass spectrometer used to perform high-precision mass measurements of long-lived transuranium isotopes and short-lived fission-products at the research reactor TRIGA Mainz. Promted by a recent recharge of the superconducting magnet, the magnetic field has been mapped in detail, a new drift electrode section has been installed, and the whole setup was aligned and optimized with the help of a position-sensitive ion detector. First measurements with $^{197}Au^{+}$ and carbon clusters were performed to investigate the performance and the magnitude of systematic effects. The current status and the latest results will be presented.

MS 2.3 Mon 14:45 U A-Esch 2

Recent Developments at the FRS Ion Catcher — •Christine Hornung[1], Daler Amanbayev[1], Samuel Ayet[1,2], Sönke Beck[1], Julian Bergmann[1], Timo Dickel[1,2], Hans Geissel[1,2], Florian Greiner[1], Lizzy Gröf[1], Gabriella Kripko-Koncz[1], Ivan Miskun[1], Wolfgang Plass[1,2], Christoph Scheidenberger[1,2], and the FRS Ion Catcher Collaboration[1] — [1]II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Gießen, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

At the FRS Ion Catcher at GSI/FAIR, projectile and fission fragments are produced at relativistic energies at the FRS, separated in-flight, range-focused, slowed-down and thermalized in a cryogenic stopping cell (CSC) and transmitted to a multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS). With the MR-TOF-MS direct mass measurements of more than 30 exotic nuclei were performed, achieving mass accuracies down to 6E-8. These precision measurements show the need to improve current mass models for nuclei in the vicinity of the doubly magic nucleus ^{208}Pb.

The FRS Ion Catcher was also used to measure half-lives and branching ratios with a novel technique. This has been tested with the short-lived α-emitting nuclide ^{216}Po and for the second excited state of ^{119}Sb. These results and recent technical upgrades of the RFQ beamline, connecting the CSC with the MR-TOF-MS, (an RFQ switch yard, a calibration source and a dedicated RFQ mass filter) will be presented.

MS 2.4 Mon 15:00 U A-Esch 2

In-trap laser ablation in a Heidelberg compact EBIT for the production of highly charged ions of rare species — •Ch. Schweiger[1], J. R. Crespo López-Urrutia[1], M. Door[1], Ch. E. Düllmann[2], S. Eliseev[1], P. Filianin[1], W. Huang[1], C. König[1,3], K. Kromer[1,3], D. Renisch[2], A. Rischka[1], R. X. Schüssler[1], and K. Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Johannes Gutenberg-Universität Mainz, 55099 Mainz — [3]Ruprecht-Karls-Universität Heidelberg, 69117 Heidelberg

The ECHo experiment [1] aims to determine the electron neutrino mass on the sub-eV level by a calorimetric measurement of the deexcitation spectrum of ^{163}Dy following the electron capture process in ^{163}Ho. As an independent consistency check the Q-value of this process will be measured as the mass difference of ^{163}Ho and ^{163}Dy with the high-precision Penning-trap mass spectrometer Pentatrap [2] with a relative mass uncertainty of 10^{-11}. At this level of precision highly charged ions have to be used. These can be efficiently produced in electron beam ion traps (EBITs). Given an available ^{163}Ho sample size of about 10^{14} atoms (≈ 27 ng), in-trap laser ablation is used for an efficient injection of ^{163}Ho into the trapping volume of a Heidelberg compact EBIT [3]. In the talk the current status concerning setup and characterization as well as measurements of the target lifetime are presented.

[1] Gastaldo, L. et al., Eur. Phys. J. Special Topics 226, 1623 (2017)
[2] Repp, J. et al., Appl. Phys. B 107, 983 (2012)
[3] Micke, P. et al., Rev. Sci. Instrum. 89, 063109 (2018)

MS 2.5 Mon 15:15 U A-Esch 2

Current status of the high-precision Penning-trap mass spectrometer Pentatrap — •M. Door[1], J. R. Crespo López-Urrutia[1], P. Filianin[1], C. König[1], K. Kromer[1], Y. Novikov[2], A. Rischka[1], R. X. Schüssler[1], Ch. Schweiger[1], S. Sturm[1], S. Ulmer[3], S. Eliseev[1], and K. Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Peterburg Nuclear Physics Institute, 188300 Gatchina, Russia — [3]RIKEN, Ulmer Fundamental Symmetries Laboratory, Wako, Saitama 351-0198, Japan

The high-precision Penning-trap mass spectrometer Pentatrap [1] located at the Max-Planck-Institut für Kernphysik in Heidelberg is aiming at mass ratio measurements of stable and long-lived highly charged ions with relative uncertainties of 10^{-11}, or better. This allows, among others, contributions to neutrino physics research, e.g. by the mass difference measurement of the mother and daughter nuclide of the electron capture decay of ^{163}Ho to ^{163}Dy [2] or a direct test of special relativity [3], e.g. via the mass difference of the mother and daughter nuclide of the neutron capture in ^{35}Cl to ^{36}Cl. With its first proof-of-principle measurements Pentatrap has recently demonstrated a relative mass precision of $3 \cdot 10^{-11}$ to determine absolute masses and electron binding energies of highly charged ions of different xenon isotopes in different charge states. The talk will present the experimental setup and current to near future measurements at Pentatrap.

[1] Repp, J. et al., Appl. Phys. B 107, 983 (2012)
[2] Gastaldo, L. et al., Eur. Phys. J. ST 226, 1623 (2017)
[3] Rainville, S. et al., Nature 438, 1096 (2005)

MS 2.6 Mon 15:30 U A-Esch 2

Towards parts per trillion mass measurements with LIONTRAP — •Sascha Rau[1], Fabian Heisse[1,2], Florian Köhler-Langes[1], Wolfgang Quint[2], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]GSI-Helmholtzzentrum für Schwerionenforschung Darmstadt, Germany

A new ion trap setup termed as LIONTRAP (Light ION TRAP), dedicated to high-precision mass measurements of light ions, has been constructed at the University of Mainz. We recently measured the proton's atomic mass by comparing the cyclotron frequencies of a single proton and a bare carbon nucleus [1], achieving a relative mass uncertainty of 3.2×10^{-11}, a factor of three more precise than the CODATA value, and revealing a 3-sigma deviation with respect to this value. This, however, is not enough to explain recently discussed discrepancies in light ion mass measurements [2], the so-called "light ion mass puzzle" , which is of special interest since some of these mass values (^{3}T and ^{3}He) are used as important consistency check for the determination of the mass of the electron-antineutrino $\bar{\nu}_e$ at KATRIN. The status of the current measurement campaign striving for a precision of better than 1×10^{-11} for the atomic mass of the deuteron together with previous results of LIONTRAP will be presented. In addition, a method to reduce the leading order magnetic field inhomogeneity, which was limiting the precision of the last measurement campaign, by more than 2 orders of magnitude, will be discussed.

[1] F. Heiße et al., Phys. Rev. Lett. 119, 033001 (2017)
[2] S. Hamzeloui et al., Phys. Rev. A 96, 060501 (2017)

MS 2.7 Mon 15:45 U A-Esch 2

The Revision of the SI: Mass spectrometry and the XRCD method used for a redefinition of the mole — •Axel Pramann, Olaf Rienitz, and Bernd Güttler — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

The General Conference on Weights and Measures (CGPM) has voted for the revision of the SI on November 16, 2018. The SI base units will be realized and defined via fundamental constants. In case of the amount of substance, the SI unit mole will be defined via the Avogadro constant NA best accessible by applying the X-ray-crystal-density XRCD method by counting silicon atoms in single-crystalline silicon spheres [1]. In this approach, high-resolution MC-ICP-MS is a central experiment (determination of the molar mass M of the Si spheres). During the last decade the unceratinties u(M) were reduced by three orders of magnitude and the contribution of u(M) to u(NA) was reduced from 60% to 6%. The uncertainty obtained for urel(M) < 1 x 10-9 is unique in chemistry so far. The changes in chemistry and physics when using the amount of substance prior and after the revision are discussed using practical examples. Moreover, the dissemination of the amount of substance (mol) in the future is decribed [2].

[1] K. Fujii et al., Metrologia, 53, A19 (2016). [2] B. Güttler, O. Rienitz, A. Pramann, Annalen der Physik, accepted.