Mass Spectrometry Division
Fachverband Massenspektrometrie (MS)

Michael Block
GSI Helmholtzzentrum für Schwerionenforschung GmbH
Planckstr. 1
64291 Darmstadt
M.Block@gsi.de

Overview of Invited Talks and Sessions

(Lecture room U A-Esch 2; Poster S Fobau Physik)

Invited Talks

MS 1.1	Mon	10:30–11:00	U A-Esch 2	**Shedding light on Isobars** — •Robin Golser
MS 2.1	Mon	14:00–14:30	U A-Esch 2	**Precision mass measurements of short-lived isotopes at TITAN** — •Jens Dilling
MS 6.1	Wed	14:00–14:30	U A-Esch 2	**Impact of the Coulomb barrier on the electronic and optical properties of polyanionic silver clusters** — Klara Raspe, Norman Iwe, Madlen Müller, Franklin Martinez, •Josef Tiggesbäumker, Lutz Schweikhard, Karl-Heinz MeiwesBroer
MS 6.2	Wed	14:30–15:00	U A-Esch 2	**Hitting proteins with a sledgehammer – mass spectrometry meets X-rays** — •Charlotte Uetrecht
MS 8.1	Thu	10:30–11:00	U A-Esch 2	**Penning-Trap Mass Spectrometry of the Heaviest Elements with SHIPTRAP** — •Oliver Kaleja, Brankica Andjelić, Olesya Bezrodnova, Klaus Blaum, Michael Block, Stanislav Chenmarev, Premaditya Chhetri, Christian Droese, Christoph E. Düllmann, Martin Eibach, Julia Even, Sergey Eliseev, Pavel Filianin, Francesca Giacoppo, Stefan Götz, Yuri Gusev, Manuel Gutiérrez, Frank Herfurth, Fritz-Peter Hessberger, Nasser Kalantar-Nayestanaki, Jadambaa Khuyagbaatar, Jacques J.W. van de Laar, Mustapha Laatiaoui, Steffen Lohse, Natalia Martynova, Enrique Minaya-Ramirez, Andrew Mistry, Tobias Murböck, Yuri Novikov, Sebastian Raeder, Daniel Rodriguez, Fabian Schneider, Lutz Schweikhard, Peter Thirolf, Alexander Yakushev
MS 8.4	Thu	11:30–12:00	U A-Esch 2	**Comissioning of and Preparations for First Experiments at CRYRING@ESR** — •Michael Lestinsky
MS 9.1	Thu	14:00–14:30	U A-Esch 2	**Precision Spectroscopy of Boron Atoms** — •Bernhard Maass, Jason Clark, Thomas Hüther, Phillip Imgram, Simon Kaufmann, Kristian König, Jörg Krämer, Jan Krause, Alessandro Lovato, Peter Müller, Krzysztof Pachucki, Mariusz Puchalski, Robert Roth, Rodolfo Sánchez, Guy Savard, Robert Wiringa, Wilfried Nörtershäuser

Invited talks of the joint symposium SYPS

See SYPS for the full program of the symposium.

SYPS 1.1	Mon	14:00–14:30	U Audimax	**Optimal control of many-body quantum systems** — •Simone Montangero
SYPS 1.2	Mon	14:30–15:00	U Audimax	**Light matter quantum interface based on single colour centres in diamond** — •Fedor Jelezko
SYPS 1.3	Mon	15:00–15:30	U Audimax	**Principles of Quantum Systems Theory and Control Engineering** — •Thomas Schulte-Herbrüggen

SYPS 1.4	Mon	15:30–16:00	U Audimax	**Quantum metrology with Rydberg atoms** — •Sebastien Gleyzes, Arthur Larrouy, Remi Richaud, Sabrina Patsch, Jean-Michel Raimond, Michel Brune, Christiane Koch

Invited talks of the joint symposium SYAD

See SYAD for the full program of the symposium.

SYAD 1.1	Tue	10:30–11:00	U Audimax	**Quantum States and their Marginals: from Multipartite Entanglement to Quantum Error-Correcting Codes** — •Felix Huber
SYAD 1.2	Tue	11:00–11:30	U Audimax	**The Uniform Electron Gas at Warm Dense Matter Conditions** — •Simon Groth
SYAD 1.3	Tue	11:30–12:00	U Audimax	**Relativistically intense laser-microplasma interactions (and potential applications)** — •Tobias Ostermayer
SYAD 1.4	Tue	12:00–12:30	U Audimax	**Motional quantum state engineering for quantum logic spectroscopy of molecular ions** — •Fabian Wolf

Invited talks of the joint symposium SYSI

See SYSI for the full program of the symposium.

SYSI 1.1	Wed	10:30–11:00	U Audimax	**The redefinition of the SI in November 2018** — •Terry Quinn
SYSI 1.2	Wed	11:00–11:30	U Audimax	**Quantum Hall effect and the new SI** — •Klaus von Klitzing
SYSI 1.3	Wed	11:30–12:00	U Audimax	**The electron charge for the definition and realisation of the ampere** — •Jan-Theodoor Janssen
SYSI 1.4	Wed	12:00–12:30	U Audimax	**The Planck constant and the realization of the kilogram** — •Stephan Schlamminger

Sessions

MS 1.1–1.7	Mon	10:30–12:30	U A-Esch 2	**Accelerator Mass Spectrometry and Applications**
MS 2.1–2.7	Mon	14:00–16:00	U A-Esch 2	**Precision Mass Spectrometry**
MS 3.1–3.15	Tue	16:30–18:15	S Fobau Physik	**Mass Spectrometry - Posters**
MS 4.1–4.7	Wed	10:30–12:15	U A-Esch 2	**Accelerator Mass Spectrometry and Applications**
MS 5	Wed	12:30–13:00	U A-Esch 2	**Annual General Meeting of the Mass Spectrometry Division**
MS 6.1–6.2	Wed	14:00–15:00	U A-Esch 2	**Clusters and Molecules**
MS 7.1–7.3	Wed	15:00–15:45	U A-Esch 2	**New Developments and Techniques**
MS 8.1–8.6	Thu	10:30–12:30	U A-Esch 2	**Precision Mass Spectrometry**
MS 9.1–9.7	Thu	14:00–16:00	U A-Esch 2	**Resonance Ionization Mass Spectrometry**

Annual General Meeting of the Mass Spectrometry Division

Wednesday 12:30–13:00 U A-Esch 2

MS 1: Accelerator Mass Spectrometry and Applications

Time: Monday 10:30–12:30 Location: U A-Esch 2

Invited Talk MS 1.1 Mon 10:30 U A-Esch 2

Shedding light on Isobars — •Robin Golser — University of Vienna, Faculty of Physics, Isotope Physics

Accelerator Mass Spectrometry (AMS) is an extremely sensitive method to measure minute amounts of radionuclides. An electrostatic accelerator of the Tandem type is utilized to break-up molecules and to provide sufficient energy to identify atoms by their nuclear charge. Abundance sensitivities can routinely be measured as low as 1E-15 if no isobar interferes. Isobars, i.e. atomic or molecular ions with almost the same mass as the ion of interest, are /the/ challenge in (A)MS. Exploiting electronic properties of the isobaric anions at sub-eV kinetic energies is becoming a breakthrough for isobar suppression. Key of a new method implemented at the Vienna Environmental Research Accelerator (VERA) is the (non-resonant) laser photo-detachment of the unwanted isobars in a linear, gas-filled radio-frequency quadrupole. The negative ions of interest remain unaffected by the laser light, when their electron affinity is greater than the photon energy. Although the technique has proven robust and reliable in all cases tried so far, we observe some unexpected phenomena. For example, certain molecules get significantly suppressed without laser, and a strong "chemical reaction" with oxygen occurs when, e.g. Hf-fluoride anions are used in order to measure Hf-182. We envision both new (A)MS isotopes and new (A)MS applications.

MS 1.2 Mon 11:00 U A-Esch 2

Cs isotope measurements by means of ILIAMS — •Johannes Lachner[1], Alexander Wieser[1], Dag Hanstorp[2], Maki Honda[1], Haimei Liang[2], Di Lu[2], Oscar Marchhart[1], Martin Martschini[1], Alfred Priller[1], Peter Steier[1], Julia Sundberg[2], Jakob Welander[2], and Robin Golser[1] — [1]Isotope Physics, Faculty of Physics, University of Vienna, Austria — [2]Department of Physics, University of Gothenburg, Sweden

The sensitive analysis of the trace isotopes ^{135,137}Cs in natural samples, which is of interest for environmental and radio-ecological studies, is one of the aims in the development of Ion Laser InterAction Mass Spectrometry (ILIAMS) at the Vienna Environmental Research Accelerator (VERA). Following the extraction of CsF_2^- and BaF_2^- from the sputter ion source, a suppression of the ^{135,137}Ba isobars can be accomplished using a combination of 1) collisional detachment in a He buffer gas filled radiofrequency quadrupole, 2) chemical reactions by admixing a small fraction of O_2 to the He buffer gas, and 3) photodetachment with 2.3 eV photons (λ=532 nm).

Experiments at the Göteborg University Negative Ion Laser LAboratory (GUNILLA) suggest that increasing the photon energy from 2.3 eV to 3.8 eV or 5.0 eV is not applicable since both CsF_2^- and BaF_2^- are detached at higher energies. On the other hand, the experiments revealed that the interfering isobar BaF_2^- is easier detached in collisions than CsF_2^-. First ILIAMS assisted AMS measurements at VERA resulted in the successful detection of ^{135}Cs and ^{137}Cs using in-house reference materials.

MS 1.3 Mon 11:15 U A-Esch 2

AMS of ^{90}Sr with ILIAMS — •Martin Martschini[1], Oscar Marchhart[1], Maki Honda[1], Dag Hanstorp[2], Johannes Lachner[1], Haimei Liang[2], Alfred Priller[1], Peter Steier[1], Alexander Wieser[1], and Robin Golser[1] — [1]Isotope Physics, University of Vienna - Faculty of Physics, Austria — [2]Department of Physics, University of Gothenburg, Sweden

The fission product ^{90}Sr ($T_{1/2}$ = 28.64 a) is of high environmental interest both for its radiotoxicity as well as its potential as a tracer. Present ^{90}Sr detection limits of mass spectrometric techniques like RIMS, ICP-MS or AMS are similar to the radiometric limit of 3 mBq.

The new Ion Laser InterAction Mass Spectrometry (ILIAMS) technique at the Vienna Environmental Research Accelerator (VERA) overcomes the limiting isobar problem in AMS. It provides near-complete suppression of isobar contaminants in negative ion beams via selective laser photodetachment in a gas-filled radio frequency quadrupole (RFQ). With 12 W of laser power from a 532 nm cw-laser and He-O_2 mixtures as buffer gas, ILIAMS provides a suppression of $^{90}ZrF_3^-$ and $^{89}YF_3^-$ vs $^{88}SrF_3^-$ of $>10^7$. Extraction of SrF_3^- from the ion source and elemental separation in the ionization chamber provide additional suppression of Zr. First measurements on a dilution series from IAEA-TEL-2016-03 reference solution and Zr- and Y-spiked targets were successfully conducted. One of the remaining challenges is the low sputter output from SrF_2 attributed to ionizer poisoning by Sr. In this contribution, we will detail these measurements including efficiency and the present sensitivity limit.

MS 1.4 Mon 11:30 U A-Esch 2

Tracing Nuclear Weapons Fallout Actinides and ^{99}Tc by AMS — •Karin Hain[1], Fadime Gülce[1], Michael Kern[1], Gunther Korschinek[2], Johannes Lachner[1], Martin Martschini[1], Peter Steier[1], Jan Welch[3], Masatoshi Yamada[4], and Robin Golser[1] — [1]Universität Wien, Austria — [2]Technische Universität München, Germany — [3]Technische Universität Wien, Austria — [4]Hirosaki University, Japan

Long-lived radionuclides emitted into the environment by nuclear weapons tests can be used to study their migration behaviour under different physio-chemical conditions. In order to allow a direct comparison, at VERA (Vienna Environmental Research Accelerator), we aim to analyse as many radionuclides as possible from the same sample. This requires a high overall detection efficiency including chemical sample preparation. The current procedure, which allows us to analyze ^{233,236}U, ^{239,240}Pu, ^{237}Np and ^{241}Am from the same 10 L ocean water sample, and depth profiles from the Pacific Ocean analysed accordingly will be discussed. In this context, experiments on the negative ion yield of Uranium from the ion source are being conducted from which the latest results will be presented. We recently started a project on the detection of nuclear weapons fallout ^{99}Tc in different environmental reservoirs. A chemical purification procedure adjustable to the respective sample matrix is currently being developed using a ^{99m}Tc tracer. Preliminary results on the chemical recovery of different approaches and test measurements at the Maier-Leibnitz-Laboratory will be discussed.

MS 1.5 Mon 11:45 U A-Esch 2

Long-term Behavior of Actinides from Global Fallout and In-situ Tracer Tests — •Francesca Quinto[1], Horst Geckeis[1], Karin Hain[2], Markus Plaschke[1], Thorsten Schäfer[1], and Peter Steier[2] — [1]Institute for Nuclear Waste Disposal, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Isotope Research and Nuclear Physics, University of Vienna, Vienna, Austria

In order to evaluate the safety of nuclear waste disposal in deep geological formations, the long-term behavior of the actinides (An) in the environment must be studied. This is possible, e.g., with the investigation of chronologically defined nuclear contaminations like the global fallout and in situ radionuclide tracer tests. At the Grimsel Test Site (GTS) located in the granitic rock of the Aar Massif in Switzerland, we have analyzed the global fallout derived U-236, Np-237 and Pu-239 and the tracers U-233, Np-237, Pu-242, Pu-244, Am-241 and Am-243 employed in several in situ tests. Thanks to the sensitivity of accelerator mass spectrometry, we have determined An concentrations ranging from pg/g down to ag/g in groundwater samples sized 0.1 to 250 g. Such analytical capability has allowed gaining valuable experimental data on the retention and migration of An during more than a decade in the crystalline rock at the GTS.

MS 1.6 Mon 12:00 U A-Esch 2

Development of an analytical method for the determination of actinides in clay systems at ultra-trace levels with accelerator mass spectrometry (AMS) — •D. Glückman[1], F. Quinto[1], K. Hain[2], C. Joseph[1], V. Montoya[1], P. Steier[2], and H. Geckeis[1] — [1]Institute for Nuclear Waste Disposal, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Isotope Physics, Faculty of Physics, University of Vienna, Vienna, Austria

A potential host rock for the final disposal of high-level nuclear waste (HLW) is clay rock. In the case of the release of radionuclides from the repository, diffusion represents their main transport process in this formation. Under reducing conditions, which are expected in the repository, actinides are stabilized in low valence states (+III, +IV) normally resulting in low solubility and strong sorption in clay minerals which makes it difficult to study diffusion processes. For this reason, an analytical procedure capable of determining actinides at ultra-trace levels (fg/sample) was developed. For detection, accelerator mass spec-

trometry (AMS) was applied. The analytical procedure comprised the preparation of Opalinus Clay and Callovo-Oxfordian Clay / pore water samples spiked with U-233, Np-237, Pu-244, Am-243 and Cm-248, group extraction of these nuclides and their measurement with AMS. The analysis of these actinide nuclides at concentrations down to 1E+6 atoms/sample (ca. 0.4 fg/sample) from the same sample has been demonstrated by AMS. Such analytical capability will allow for the investigation of actinide diffusion under reducing conditions which will contribute to the safety assessment of HLW repositories.

MS 1.7 Mon 12:15 U A-Esch 2

Test of Projectile X-ray AMS for Nuclear Waste Management — •Markus Schiffer, Lena Bussmann, Claus Müller-Gatermann, Richard Spanier, Susan Herb, Alexander Stolz, Stefan Heinze, Gereon Hackenberg, and Alfred Dewald — University of Cologne, Institute of Nuclear Physics, Germany

Projectile X-ray AMS (PXAMS) is a well-known method for isobar separation by the measurement of characteristic X-rays. The discrimination of AMS nuclide and isobar suffers from low X-ray production yields and detection efficiencies, compared to the detection with particle detectors. New commercial Fast Silicon Drift Detectors (FSDD) with large active area of 50 mm^2 with high energy resolution, ΔE=123 eV at 5.9 keV, allow nowadays a high detection efficiency.

We investigate the projectile X-ray production yield at energies of 2 MeV/amu for medium mass isotopes on heavy stopper materials, like Au or U, to test its suitability as an alternative detection technique to liquid scintillator counting for the determination of isotopic concentrations of e.g. ^{90}Sr, which plays an important role for nuclear waste management.

In this kind of reaction we observed shifts in X-ray energies which are explained in literature by molecular-like electron states for heavy ion collisions. This may became important for the background by K_β, L_β and M_β lines.

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 de-excitation 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 ($\approx$ 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 Fun-

damental 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.

MS 3: Mass Spectrometry - Posters

Time: Tuesday 16:30–18:15 Location: S Fobau Physik

MS 3.1 Tue 16:30 S Fobau Physik

MOCCA: a 4k-pixel molecule camera for the position and energy resolved detection of neutral molecule fragments — •DENNIS SCHULZ[1], STEFFEN ALLGEIER[1], CHRISTIAN ENSS[1], ANDREAS FLEISCHMANN[1], LISA GAMER[1], LOREDANA GASTALDO[1], JULIA HAUER[1], SEBASTIAN KEMPF[1], SEBASTIAN SPANIOL[2], OLDŘICH NOVOTNÝ[2], and ANDREAS WOLF[2] — [1]Heidelberg University — [2]Max Planck Institute for Nuclear Physics, Heidelberg

The MOCCA detector is a 4k-pixel high-resolution molecule camera based on metallic magnetic calorimeters and read out with SQUIDs that is able to detect low-energy neutral molecule fragments. It will be deployed at the Cryogenic Storage Ring CSR at the Max Planck Institute for Nuclear Physics in Heidelberg, a storage ring built to prepare and store molecular ions in their rotational and vibrational ground states, enabling studies on electron-ion interactions. To reconstruct the reaction kinematics, MOCCA measures the energy and position of incident particles on the detector, even with multiple particles hitting the detector simultaneously. Using different read-out techniques, MOCCAs 4096 pixel can be read out by using only 32 SQUID channels in total.

We present the most recent data from measurements of the MOCCA detector at 10 mK with a 6 keV photon source, demonstrating low cross-talk between rows and columns of the detector, the read-out principle and the energy resolution measured to be below 200 eV.

MS 3.2 Tue 16:30 S Fobau Physik

Recent developments at the Greifswald MR-ToF device — •PAUL FISCHER, GERRIT MARX, and LUTZ SCHWEIKHARD — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

The multi-reflection time-of-flight mass spectrometer (MR-ToF MS) at the University of Greifswald is further employed to develop and refine related techniques. In particular, metal cluster ions are produced in a laser ablation source and stored between electrostatic mirrors for several hundreds of milliseconds, leading to high mass resolving powers and the possibility to study ion properties as well as the storage characteristics of the trap itself.

Recently, the behavior of short-term ToF fluctuations between measurements have been studied with respect to comparability when the ion species of interest and the species used for a subsequent offline correction exhibit large mass differences [1]. Furthermore, the system's capabilities for the capture and selection of ions with large mass differences has been refined by employing multiple in-trap lift capture pulses and an in-trap deflection scheme allowing the retention of multiple ion species [2].

[1] P. Fischer et al., Int. J. Mass Spectrom. 432:44-51(2018)
[2] P. Fischer et al., Int. J. Mass Spectrom. (in print)

MS 3.3 Tue 16:30 S Fobau Physik

Photoexcitation of size-selected ions in an electrostatic storage device — •PAUL FISCHER, GERRIT MARX, and LUTZ SCHWEIKHARD — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

An electrostatic ion beam trap (EIBT) [1] (or multi-reflection time-of-flight mass spectrometer (MR-ToF MS) [2]) has been utilized for systematic investigations of molecular photofragmentation. To this end, bismuth clusters have been produced by a laser ablation source and subsequently stored and mass-selected [3] in the trap. A pulsed laser beam ($\lambda = 532$nm) is guided through the trap axially, the pulse timing of which is chosen to interact with the stored ion bunch at its turn-around point in the trap's mirror potential. Simultaneously, the trap is opened to release the clusters towards an ion detector. Thus, the fragment ions leave the EIBT as individual bunches and their masses can be determined via ToF mass spectrometry. In cases where higher resolving power is needed, the opening of the mirror can be delayed to allow MR-ToF operation. This marks a novel form of use for an MR-ToF MS in the sense that the device is used both to preselect an ion species of interest and investigate its reaction products in a single measurement cycle.

[1] H. Wollnik et al., J. Mass Spectrom. Ion Processes 96(3):267-274(1990)
[2] D. Zajfman et al., Phys. Rev. A 55:R1577-R1580(1997)
[3] P. Fischer et al., Rev. Sci. Instrum. 89:015114(2018)

MS 3.4 Tue 16:30 S Fobau Physik

High-Precision Mass Measurements with PENTATRAP — •Rima X. Schüssler[1], José R. Crespo López-Urrutia[1], Menno Door[1], Pavel Filianin[1], Wenjia Huang[1], Charlotte König[1,2], Kathrin Kromer[1,2], Yuri. N. Novikov[1,3], Alexander Rischka[1], Christoph Schweiger[1], Sven Sturm[1], Stefan Ulmer[4], Sergey Eliseev[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Ruprecht-Karls-Universität Heidelberg — [3]Petersburg Nuclear Physics Institute, Gatchina, Russia — [4]RIKEN, Ulmer Fundamental Symmetries Laboratory, Saitama, Japan

The high-precision Penning-trap mass spectrometer PENTATRAP, situated at the Max-Planck-Institut für Kernphysik, Heidelberg has recently demonstrated a relative mass precision of 10^{-11} using highly-charged xenon ions. Mass-ratio measurements of single stable and long lived highly charged ions are performed by determining their respective cyclotron frequencies in the strong magnetic field of a Penning trap. A unique feature of the experimental setup is the use of five cylindrical Penning traps, making simultaneous storage and measurement of several ion species possible. At this precision level, PENTATRAP will, for example, contribute to electron-neutrino mass related measurements within the ECHo collaboration, which determines the de-excitation spectrum following the electron capture in ^{163}Ho.

The current status as well as the first measurements with PENTATRAP will be shown on the poster.

MS 3.5 Tue 16:30 S Fobau Physik

Development of an efficient high-current ion source for Accelerator Mass Spectrometry — •Dimitar Yordanov[1], Hans Hofsäss[1], Georg Rugel[2], Shavkat Akhmadaliev[2], Johannes von Borany[2], and Jenny Feige[3] — [1]Georg-August-Universität Göttingen — [2]Helmholtz-Zentrum Dresden-Rossendorf — [3]TechnischeUniversität Berlin

A new concept for Caesium sputtering ion source is studied experimentally and theoretically regarding a development of a new high-efficient and high-current ion source for Accelerator Mass Spectrometry (AMS) to quantify the ratios of long-lived cosmogenic radionuclides in micrometeorites. The source design is modular providing ease of access and simplifying maintenance while having better mechanical stability at the same time. The results show: the geometry of the cathode and the ionizer, as well as the distance between them and the radius of the extraction hole, are factors influencing the ion-optics, the focus of the Cs beam on the sample, the sputtering of the sample and the extracted current of the ions. Moreover, for an additional increase of the sputtering process on the sample, the cathode bias is higher than usual – up to 20 kV. The experimental results at different configurations of the source are supported by 3D model of the source for the ion-optics and the particle trajectories, as well as Child Langmuir Law is included. The authors would like to thank the Federal Ministry of Education and Research of Germany for its financial support (project 05K2016), and the HZDR's Ion Beam Center for its essential contribution to the realization of this project.

MS 3.6 Tue 16:30 S Fobau Physik

Interaction of size-selected stored anionic tin clusters with electrons — •Markus Wolfram, Steffi Bandelow, Alexander Jankowski, Stephan König, Gerrit Marx, and Lutz Schweikhard — Felix-Hausdorff-Straße 6, Institut für Physik, Greifswald, Deutschland

At the ClusterTrap-setup [1] size-selected mono-anionic tin clusters Sn_n^{1-}, n = 7 - 75, are stored simultaneously with electrons in a Penning trap to produce poly-anionic clusters by electron attachment [2].

In addition to doubly and triply charged clusters with the size of the precursors, fragments such as Sn_{n-7}^{1-}, Sn_{n-10}^{1-} or Sn_{n-15}^{1-} are observed [3]. The latter come along with the clusters Sn_{10}^{1-} and Sn_{15}^{1-}, probably due to fission as in the case of the group-14 neighbor element lead [4].

[1] F. Martinez et al., Int. J. Mass Spectrom. 365-366, 266 (2014)
[2]A. Herlert et al., Phys. Scripta T80, 200 (1999)
[3] S. König et al., Eur. Phys. J. D 72, 153 (2018)
[4] S. König et al.,Phys. Rev. Lett. 120, 163001 (2018)

MS 3.7 Tue 16:30 S Fobau Physik

The Heidelberg compact EBIT as a source for highly charged holmium ions for high-precision mass spectrometry at Pentatrap — •Ch. König[1,2], J. R. Crespo López-Urrutia[1], M. Door[1], Ch. E. Düllmann[3], P. Filianin[1], W. Huang[1], K. Kromer[1,2], D. Renisch[3], A. Rischka[1], R. X. Schüssler[1], Ch. Schweiger[1], S. Eliseev[1], and K. Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg — [3]Johannes Gutenberg-Universität Mainz, 55128 Mainz

The electron capture decay of ^{163}Ho to ^{163}Dy is a promising candidate for the determination of m_{ν_e} in the sub-eV range. For this purpose the ECHo collaboration [1] aims to perform a calorimetric measurement of the ^{163}Dy* de-excitation spectrum. With its Penning-trap setup the Pentatrap [2] experiment will contribute an independent Q-value as a consistency check acquired by a high-percision mass measurement of the mother and daughter nuclide with a relative mass ratio uncertainty of 10^{-11}. In order to achieve such an accuracy highly charged ions are necessary which can be produced in electron beam ion traps. Ions of various masses (40-165 amu) have been successfully produced, in particular charge states of up to 45+ have been achieved for ^{165}Ho using a sample size of about 10^{12} atoms. The injection of the atoms into a Heidelberg compact EBIT [3] is done via in-trap laser ablation.
[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 3.8 Tue 16:30 S Fobau Physik

Environmental influences on the high-precision mass measurements at PENTATRAP — •K. Kromer[1,2], M. Door[1], A. Rischka[1], R.X. Schüssler[1], C. König[1,2], Ch. Schweiger[1], W. Huang[1], P. Filianin[1], S. Eliseev[1], and K. Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Ruprecht-Karls-Universität Heidelberg, 69120 Heidelberg

PENTATRAP [1] is a Penning-trap experiment consisting of five traps used to measure mass-ratios currently reaching a relative uncertainty of close to 10^{-11}. This allows for mass-ratio measurements of stable and long-lived highly charged ions with numerous applications, among others in neutrino physics [2] and tests of special relativity [3]. The systematic uncertainties stemming from environmental influences including the magnetic field, pressure and temperature fluctuations are being measured in order to find possible correlations to fluctuations in the cyclotron frequency of the trapped highly charged ions. This will determine if further stabilization, e.g. an active stabilization of the magnetic field with Helmholtz coils centered around the traps, will be necessary and to what extend.
[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 3.9 Tue 16:30 S Fobau Physik

Activity determination of reference nuclides in the nuclear waste management — •C. Müller-Gatermann[1], S. Heinze[1], M. Schiffer[1], A. Stolz[1], G. Hackenberg[1], S. Herb[1], L. Bussmann[1], R. Spanier[1], A. Dewald[1], R. Magreiter[2], E. Strub[2], M. Michel[2], K. Eberhardt[3], M. Dewald[4], and B. Dittmann[4] — [1]Institut für Kernphysik, Köln, Deutschland — [2]Abteilung Nuklearchemie, Köln, Deutschland — [3]Institut für Kernchemie, Mainz, Deutschland — [4]Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) GmbH

In the field of nuclear waste management liquid scintillation technique (LS) plays an important role among others, but complex chemistry is needed to reach low detection limits. We explored the possibility to replace LS by AMS techniques for specific isotopes. For the test we used reactor concrete material originating from KNK and MZFR research reactors from Karlsruhe, in addition we irradiated concrete samples with thermal as well as with epithermal neutrons with different doses at the Mainz TRIGA reactor. In order to verify the AMS results we measured the concentration of γ-emitters also activated in the sample material. This data can be used for consistency check. In this contribution we describe the experimental setups and discuss the results obtained so far.

MS 3.10 Tue 16:30 S Fobau Physik

Investigation of formate and halide adducts on coinage metal phosphine complexes in isolation — •Björn Kwasigroch, Sebastian V. Kruppa, Michael Borchers, Christoph Riehn, and Gereon Niedner-Schatteburg — Fachbereich Chemie

und Forschungszentrum OPTIMAS, TU Kaiserslautern, Erwin-Schrödinger-Str. 52, 67633 Kaiserslautern, Germany

Coinage metal complexes are of interest for potential application, e.g. in photocatalysis [1]. Here, we use the phosphine complexes $[M_1M_2(L^{Cy})_2]^{2+}$(M=Cu, Ag, Au, L^{Cy}=bis(dicyclohexylphosphino)methane) and his anionic adducts as a model system in order to investigate metallic d^{10}-d^{10} interactions [2,3]. To this end, we utilized quadrupole ion trap tandem mass spectrometry. Formate adducts $[M_1M_2(L^{Cy})_2(CHOO)]^+$ were investigated via collision-induced dissociation (CID) and infrared multiphoton dissociation (IRMPD) spectroscopy in the C-O- and C-H-stretching region, supported by density functional theory (DFT) calculations. We observed branching ratios of CO_2/ CHOOH fragmentation in CID and a shift in the antisymmetric C-O- and C-H-stretching modes by IRMPD which depend on the coinage metal, respectively. The influence of halide anions X (Cl, Br, I) in $[M_1M_2(L^{Cy})_2X]^+$ complexes are explored systematically with respect to their CID fragmentation. We found metal/ halide dependent fragmentation pathways.

References: [1]V. W.-W. Yam et al., Chem. Rev. 2015, 115, 7589-7728; [2]S. V. Kruppa et al., Phys. Chem. Chem. Phys. 2017, 19, 22785-22800; [3]S. V. Kruppa et al, J. Phys. Chem. Lett. 2018, 9, 804-810.

MS 3.11 Tue 16:30 S Fobau Physik

Temperature dependent magnetic studies of an isolated Fe - spin crossover complex by X-ray Magnetic Circular Dichroism (XMCD) spectroscopy — •Michael Lembach[1], Matthias P. Klein[1], Joachim Hewer[1], Vicente Zamudio-Bayer[2], Martin Timm[2], Christine Bülow[2], Julius A. Wolny[1], Tobias J. Lau[2], Volker Schünemann[1], and Gereon Niedner-Schatteburg[1] — [1]Fachbereich Chemie, Biophysik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Helmholtz-Zentrum für Materialien und Energie BESSY II, 14109 Berlin, Germany

Magnetic properties of isolated molecular ions have become an interesting research field since the last decade. One field of interest are so called spin crossover complexes. They are able to reversibly change their spin multiplicity from its electronic ground state to a energetically higher electronic state by change of temperature or pressure[1]. We explore the difference between bulk and gas phase spin crossover temperatures. Here, the monometallic complex $[Fe(btpa)]^{2+}$ (btpa = N,N,N',N'-tetrakis(2-pyridylmethyl)-6,6'-bis-(aminomethyl)-2,2'-bipyridine)[2] was investigated with regard to the temperature dependent spinmagnetic behavior by X-ray Magnetic Circular Dichroism (XMCD) spectroscopy. We found a decreasing dichroic effect with an increase of the temperature from 4.5 K to 25.0 K. We successfully fit the obtained temperature dependent magnetization data of the $[Fe(btpa)]^{2+}$ complex to a Brillouin function.

MS 3.12 Tue 16:30 S Fobau Physik

A graphene-based neutral particle detector — •Jessica Warbinek[1], David Leimbach[1], Di Lu[2], Dag Hanstorp[2], David Pegg[3], Jakob Welander[2], Avgust Yurgens[4], and Klaus Wendt[1] — [1]Johannes Gutenberg-Universität Mainz — [2]University of Gothenburg — [3]University of Tennessee — [4]Chalmers University of Technology Gothenburg

A transparent neutral particle detector for applications in the fields of atomic and molecular physics as well as mass spectrometry is presented, which is operational for particle energies in the range of few hundreds eV to a maximum of some tens of keV. The traditionally used target material for the initial conversion electrode, indium tin oxide (ITO), which has to combine good optical transparency with reasonable electric conductivity, has been replaced by a graphene layer. This substitution leads to a transmission of signicantly shorter wavelengths of light down to 230 nm compared to ITO-based detectors, which are limited at about 335 nm. In this way collinear laser - ion beam interactions on atoms, molecules and clusters of ions, used e.g. for photodetachment measurements, are enabled throughout the whole visible spectral range down to the far UV. Moreover, the background signal from the photoelectric effect is drastically reduced when using graphene. The application of this new detector type will enable studies on electron affinities of rare radioisotopes and was already successfully used for the first ever determination of this quantity in astatine at ISOLDE/CERN.

MS 3.13 Tue 16:30 S Fobau Physik

Towards parts per trillion mass measurements on light nuclei at 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

The precise knowledge of the atomic masses of various light nuclei, e.g. of the proton, deuteron, helion and triton, is of great importance for several tests of fundamental physics. For example, the mass of the proton is an important input parameter for hydrogen spectroscopy. Furthermore, an essential consistency check of the KATRIN experiment will require an ultra-precise measurement of the mass difference of triton and helion on a so far unrivalled level of precision of 6 meV/c^2. However, five sigma discrepancies between high-precision measurements of these light nuclear masses question their current literature values [1] and give strong motivation for a new and independent experiment, the LIONTRAP (Light ION TRAP) apparatus, aiming for relative uncertainties of a few parts per trillion. The results of the first measurement campaign on the proton mass [2] and the complete setup will be presented, which includes several new developments, e.g. a doubly compensated Penning trap, an in-situ B2 shim coil, various precisely tuned detection systems and a simultaneous phase-sensitive measurement technique with two neighbouring ion traps.

[1] J. A. Smith et al., Phys. Rev. Lett. 120, 143002 (2018)
[2] F. Heiße et al., Phys. Rev. Lett. 119, 033001 (2017)

MS 3.14 Tue 16:30 S Fobau Physik

Metastable states of the silicon anion observed in a cryogenic storage ring — •D. Müll[1], F. Grussie[1], E. A. Guerin[1], A. Becker[1], K. Blaum[1], C. Breitenfeldt[1,2], S. George[1,2], J. Göck[1], M. Grieser[1], R. von Hahn[1], P. Herwig[1], J. Hörl[1], Á. Kálosi[3], J. Karthein[1], C. Krantz[1], H. Kreckel[1], S. Lohmann[1], C. Meyer[1], P. M. Mishra[1], O. Novotný[1], A. P. O'Connor[1], D. Paul[1], R. Repnow[1], S. Saurabh[1], K. Spruck[1], S. Sunil Kumar[1], X. Urbain[4], S. Vogel[1], P. Wilhelm[1], and A. Wolf[1] — [1]Max-Planck Institut für Kernphysik, Heidelberg, Germany — [2]Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald, Germany — [3]visitor from Charles University Prague, Czech Republic — [4]Institute of Condensed Matter and Nanosciences, Université Catholique de Louvain, Louvain-la-Neuve B-1348, Belgium

We have used the Cryogenic Storage Ring (CSR) at the Max Planck Institute for Nuclear Physics to study the metastable states of the silicon anion. To this end we have stored a fast (58 keV) Si^- beam in the near-perfect cryogenic vacuum of the CSR, using only electrostatic deflection elements. We used several continuous laser systems at 633 nm, 980 nm, 1064 nm and 1390 nm, as well as a tunable pulsed optical parametric oscillator, in order to obtain information about the decay of the metastable anionic states by selective photodetachment. As a result, we show evidence for the existence of an extremely long-lived metastable state with a lifetime of several hours. We also found indication of another metastable state with a lifetime on the order of 20 s, in agreement with theoretical predictions.

MS 3.15 Tue 16:30 S Fobau Physik

Construction of a new electrospray ionization time of flight mass spectrometer (ESI-TOF-MS) for femtosecond laser experiments — •Peter Krüger and Karl-Michael Weitzel — Philipps-Universität Marburg, Germany

Femtosecond laser mass spectrometry (fs-LMS) is a versatile method with many different applications [1]. It not only offers great temporal and mass resolution, but also allows non-resonant excitation schemes due to high laser peak intensities.

However, the technique relies on the sample of interest being in the gas phase, which poses a challenge regarding high molecular masses. This limitation can be overcome by employing an electrospray ionization (ESI) source, which allows intact vaporization and soft ionization of heavy molecules, e.g. biopolymers or pharmaceuticals [2].

In the current work we present a new apparatus specifically designed to combine the advantages of ESI and fs-LMS. The experimental setup consists of an ESI source, an ion guide, and an interaction region where the ion beam and a fs-laser beam overlap. This interaction region constitutes the source of an ion time-of-flight mass spectrometer (ion TOF-MS) and an electron TOF-MS with spatially resolved detector. The setup is described and first experiments aimed at the photoionization/-dissociation of cations and photodetachment/-dissociation of anions by the femtosecond laser pulses will be discussed.

[1] K.W.D. Ledingham, R.P. Singhal, Int. J. Mass Spectrom. Ion Proc., 163, 149, (1997) [2] J.B. Fenn, Angew. Chemie, 42, 3871, (2003)

MS 4: Accelerator Mass Spectrometry and Applications

Time: Wednesday 10:30–12:15 Location: U A-Esch 2

MS 4.1 Wed 10:30 U A-Esch 2

Proof of suitability of ^{41}Ca as a reference isotope for the characterization of reactor concrete — •R. Spanier[1], S. Heinze[1], M. Schiffer[1], A. Stolz[1], G. Hackenberg[1], S. Herb[1], L. Bussmann[1], C. Müller-Gatermann[1], A. Dewald[1], R. Magreiter[2], E. Strub[2], M. Michel[2], K. Eberhardt[3], M. Dewald[4], and B. Dittmann[4] — [1]Institut für Kernphysik, Köln, Deutschland — [2]Abteilung Nuklearchemie, Köln, Deutschland — [3]Institut für Kernchemie, Mainz, Deutschland — [4]Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) GmbH

In the field of nuclear waste management reference isotopes are important for the radiological characterization of the radioactive material. Often ^{60}Co or ^{152}Eu are used for this purpose as they are relatively easy to measure by means of gamma ray spectroscopy. The disadvantages are the relatively short half-lives and in the case of reactor concrete these seed materials ^{59}Co or ^{151}Eu are contained only as trace elements and homogeneity of the seed material in a large amount of material is not guaranteed. Thus, these reference nuclides are not very well suited if longer storage and control is needed. Therefore, we investigated the suitability of ^{41}Ca as a reference isotope for reactor concrete e.g. originating from the bio-shield of a nuclear power station. We measured ^{41}Ca concentration of irradiated samples at the 6MV TANDETRON AMS set-up of the University of Cologne. The ^{41}Ca was chemically extracted as CaF to produce a sputter target for the AMS measurement . We will report on the results with respect to sensitivity and precision obtained so far.

MS 4.2 Wed 10:45 U A-Esch 2

AMS measurement of ^{14}C concentration in reactor concrete — •A. Stolz[1], S. Heinze[1], M. Schiffer[1], C. Müller-Gatermann[1], G. Hackenberg[1], S. Herb[1], L. Bussmann[1], R. Spanier[1], A. Dewald[1], R. Magreiter[2], E. Strub[2], M. Michel[2], K. Eberhardt[3], M. Dewald[4], and B. Dittmann[4] — [1]Institut für Kernphysik, Köln, Deutschland — [2]Abteilung Nuklearchemie, Köln, Deutschland — [3]Institut für Kernchemie, Mainz, Deutschland — [4]Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) GmbH

In the field of nuclear waste management ^{14}C plays an important role. So far ^{14}C is measured with the liquid scintillation technique (LS) for which chemical treatment of the sample material is needed. The detection limit for ^{14}C reached with the LS technique is limited to 1Bq/g when almost no background from other beta decaying isotopes is present. The AMS technique offers here a much higher sensitivity which becomes crucial in the future since the activity of the clearance levels for the release of material from regulatory control has been reduced from 1Bq/g to 0.1Bq/g. It appears that also the effort for a ^{14}C measurement is much reduced with AMS since no pre-treatment is needed. Especially in the case of reactor concrete origination e.g. from the bio-shield of a nuclear power plant the sample material can be directly burned in an Elemental Analyzer (EA) and the extracted CO_2 gas can be delivered to the AMS system. In this way automated measuring procedures became feasible with a high throughput and a cost reduction compared to the so far established measuring technique. We will report on first measurements and discuss the results .

MS 4.3 Wed 11:00 U A-Esch 2

Accelerator mass spectrometry of ^{93}Zr at the Australian National University — •Stefan Pavetich[1], L.Keith Fifield[1], Michaela B.Froehlich[1], Shlomi Halfon[2], Yanan Huang[1], Dominik Koll[1], Martin Martschini[3], Michael Paul[4], Asher Shor[2], Johannes H.Sterba[5], Moshe Tessler[4], Stephen G.Tims[1], Leonid Weissman[2], and Anton Wallner[1] — [1]Australian National University, Australia — [2]Soreq Nuclear Research Center, Israel — [3]University of Vienna, Austria — [4]Hebrew University, Israel — [5]Technische Universität Wien, Austria

Neutron capture cross sections at keV energies in the Zr mass region are important for nuclear astrophysics as this is the matching point for two components of the slow neutron capture process. Zirconium is used in cladding of nuclear fuel rods and is a high yield fission product, hence production rates of ^{93}Zr ($t_{1/2}$ ∼1.6 Ma), are important for nuclear technology and waste management. Despite their significance, neutron capture cross sections for production of ^{93}Zr are poorly known. The long half-life and decay characteristics, make decay counting of ^{93}Zr difficult. We have used accelerator mass spectrometry to measure ^{93}Zr produced by neutron activation of ^{92}Zr with thermal and keV neutrons, yielding independent values for the respective cross section. The main challenge here is the separation of ^{93}Zr from its stable isobar ^{93}Nb. The high particle energies available with the 14UD accelerator at ANU, combined with an 8-anode ionization chamber are ideal to tackle this challenge. The achieved detection limits of ^{93}Zr/Zr∼10^{-12} could lead to new applications of ^{93}Zr as environmental tracer.

MS 4.4 Wed 11:15 U A-Esch 2

Detection of Extraterrestrial ^{60}Fe in Antarctica with AMS — •Dominik Koll[1,2], Thomas Faestermann[1], Gunther Korschinek[1], Silke Merchel[3], Jan M. Welch[4], and Sepp Kipfstuhl[5] — [1]Technische Universität München, Germany — [2]The Australian National University, Australia — [3]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [4]TU Wien, Austria — [5]Alfred Wegener Institute, Germany

The long-lived radioactive isotope ^{60}Fe with a half-life of 2.6 Myr is mainly produced by stellar nucleosynthesis and ejected into space by core-collapse supernovae. Former investigations by Accelerator Mass Spectrometry (AMS) showed a supernova signal on Earth 1.7-3.2 Myr ago.

Considering an enrichment of the solar neighborhood in long-lived radionuclides by previous supernovae, deposition of ^{60}Fe on Earth could be currently ongoing. To investigate this case, 500 kg of Antarctic snow were analyzed by Accelerator Mass Spectrometry with the 14 MV tandem accelerator and the Gas-filled Analyzing Magnet System (GAMS) at the Maier-Leibnitz-Laboratorium in Garching, Germany.

Indeed, ^{60}Fe was discovered in Antarctic snow and by the measurement of ^{53}Mn, which is dominantly produced by cosmic ray interactions with solar system objects, the origin of these ^{60}Fe atoms could be deduced.

MS 4.5 Wed 11:30 U A-Esch 2

First tests of the new 135° gas-filled magnet at the Cologne 10 MV AMS-System — •Susan Herb, Richard Spanier, Markus Schiffer, Heinze Stefan, Claus Müller-Gatermann, Gereon Hackenberg, Lena Bussmann, Alexander Stolz, and Alfred Dewald — Institut für Kernphysik, Universität zu Köln

The AMS setup at the Cologne 10 MV Tandem Accelerator is dedicated to measure isotopic ratios of medium mass nuclei. After the first measurements of ^{53}Mn, measurements of ^{60}Fe and ^{63}Ni are possible with the new 135° gas-filled magnet. The isotope ^{60}Fe is of great importance for nuclear astrophysics and ^{63}Ni for nuclear waste management. Test measurements of the new gas-filled magnet were performed with stable Fe and Ni beams. In order to avoid high energy loss in the entrance window of the magnet, the mylar-foil was replaced by a Si_3N_4 window. In addition a new 5-anode gas-detector was positioned after the magnet. A large 2cmx2cm Si_3N_4 foil is used at the entrance and x-slits allow to reduce scattered particles. We will present the first results on the isotope separation and transmission of the system.

MS 4.6 Wed 11:45 U A-Esch 2

Super-SIMS at HZDR - first steps with halogens — •G. Rugel[1], A.D. Renno[1], S. Akhmadaliev[1], G. Belokonov[1], R. Böttger[1], J. von Borany[1], J. Gutzmer[1], P. Kaever[1], M. Meyer[1], P. Noga[2], C. J. Tiessen[1,3], J. Voigtländer[1], N. Wagner[1], M. Wiedenbeck[4], A. Winter[1], and R. Ziegenrücker[1] — [1]HZDR, Dresden — [2]STU MTF, Bratislava — [3]A.E. Lalonde AMS, Ottawa — [4]GFZ Potsdam

The integration of an ion source with very high spatial resolution with a tandem accelerator is a long-standing concept for improving analytical selectivity and sensitivity by orders of magnitude [1-3]. Translating this design concept to reality has its challenges [e.g. 4-6]. Supporting a strong focus on natural, metallic and mineral resources the Helmholtz Institute Freiberg for Resource Technology installed such a system at the Ion Beam Centre at HZDR. This so-called Super-SIMS is the combination of a CAMECA IMS 7f-auto with the 6 MV Dresden Accelerator Mass Spectrometry facility [7,8], which quantitatively eliminates isobaric molecular species. We will present measurements of the performance parameters of the instrument as well as first results of halogen

(F, Cl, Br, and I) determinations in galena and sphalerite. Ref.: [1] Purser et al. Surface and Interface Analysis 1(1), 1979, 12. [2] J. M. Anthony, D. J. Donahue, A. J. T. Jull, MRS Proceedings 69(1986)311-316. [3] S. Matteson, Mass Spectrom. Rev., 27(2008)470. [4] Ender et al. NIMB 123(1997)575. [5] Maden, PhD thesis, ETH Zurich 2003. [6] Fahey et al. Analytical Chemistry 88(14), 2016, 7145. [7] Akhmadaliev et al., NIMB 294 (2013) 5. [8] Rugel et al. NIMB 370 (2016) 94.

MS 4.7 Wed 12:00 U A-Esch 2

Nuclear Forensics on the 135Cs/137Cs ratio by ICP-QQQ-MS — •Dorian Zok, Rebecca Querfeld, Lena Grüger, and Georg Steinhauser — Leibniz Universität Hannover - Institute of Radioecology and Radiation Protection

The atmospheric fallout and the Chernobyl disaster have released a lot of radioactive material, which has contaminated Germany. The most famous element is the cesium with his directly produced radioactive fission isotope 137Cs (T1/2 = 30 a). Just with the 137Cs it is not possible to say something about the origin. The remedy is the ratio 135Cs/137Cs with the long-living isotope 135Cs (T1/2 = 2.3 Ma). Additionally, the formation of the daughter 135Cs from the mother 135Xe depends on the currently occurring neutron flux. The analyse is done by a Triple-Quadrupole-Mass spectrometer (ICP-QQQ-MS). This allows a further suppression of isobaric interference by the use of a reaction gas after a previous element-specific separation. In the case of cesium the nitrous oxide N2O reacts with the isobaric Barium (Ba) to barium oxide (BaO+). The radioecological questions of the wild boar paradox with the not decreasing amounts of radiocesium and the general analyse of environmental and food samples are in the focus of the research. Another point is the origin analyse of radioactive, amorphous glass beads out of the destroyed reactors in Fukushima, with should be achieved with a spatially resolved laser ablation unit coupled to the mass spectrometer.

MS 5: Annual General Meeting of the Mass Spectrometry Division

Time: Wednesday 12:30–13:00 Location: U A-Esch 2

General Meeting

MS 6: Clusters and Molecules

Time: Wednesday 14:00–15:00 Location: U A-Esch 2

Invited Talk MS 6.1 Wed 14:00 U A-Esch 2

Impact of the Coulomb barrier on the electronic and optical properties of polyanionic silver clusters — Klara Raspe[1], Norman Iwe[1], Madlen Müller[2], Franklin Martinez[1], •Josef Tiggesbäumker[1,3], Lutz Schweikhard[2], and Karl-Heinz MeiwesBroer[1,3] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23, 18059 Rostock — [2]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald — [3]Department life, Light and Matter, Universität Rostock, Albert-Einstein-Str. 25, 18059 Rostock

Polyanions are ubiquitous in nature, but usually a solvent is necessary to stabilize the complexes. Experiments in a molecular beam offer the possibility to exclude effects of the environment and, thus, give access to the properties of the bare systems. A general property of gas-phase polyanions is the presence of a Coulomb barrier, which allows for metastable electron states above the vacuum level. Therefore, electronic relaxation, i.e., electron tunneling through the barrier, has to be taken into account, in particular, after photoexcitation into weakly bound levels. We produce polyanions in a digital radio-frequency ion trap in order to conduct photoelectron spectroscopy on silver clusters Ag_N^{z-} (N up to 800, z=1..6). Tuning the laser photon energy and recording the corresponding electron spectra the optical spectra are extracted. The analysis reveals, that electron tunneling has to be taken into account in order to determine size and charge-state selective plasmon energies of silver cluster polyanions. The results on Ag_N^{z-} will be compared to measurements on singly charged Ag_N^+ and Ag_N^-.

Invited Talk MS 6.2 Wed 14:30 U A-Esch 2

Hitting proteins with a sledgehammer – mass spectrometry meets X-rays — •Charlotte Uetrecht — Heinrich Pette Institute, Hamburg, Germany — European XFEL, Schenfeld, Germany

Native ion mobility mass spectrometry (MS) is a perfect tool to study protein complexes in a mass and conformation specific manner, albeit with low structural resolution. On the other hand, it allows monitoring structural transitions, which cannot be purified and are inaccessible for crystallography. The European XFEL, the world's most intense hard X-ray free-electron laser (XFEL), has just become operational and offers an opportunity to obtain high resolution structures of single particles. The benefits of native MS for single particle imaging of transient intermediates at European XFEL and initial feasibility studies will be presented. Furthermore, we employed soft X-rays from synchrotrons and FELs for fragmentation in native MS. Our recent results show great potential for using soft X-rays in native top-down MS. The available intensity could alleviate proposed upper size limits for UV photo dissociation of protein complexes.

MS 7: New Developments and Techniques

Time: Wednesday 15:00–15:45 Location: U A-Esch 2

MS 7.1 Wed 15:00 U A-Esch 2

Towards the Ion Mobility Measurement of Actinides — •Elisabeth Rickert[1,2], Hartmut Backe[2], Michael Block[1,2,3], Christoph E. Düllmann[1,2,3], Tobias Kron[1,3], Mustapha Laatiaoui[1,2], Werner Lauth[2], Steffen Lohse[1], Sebastian Raeder[1,3], and Fabian Schneider[1,2] — [1]Helmholtz-Institut Mainz — [2]Johannes Gutenberg-Universität Mainz — [3]GSI Helmholtzzentrum für Schwerionenforschung

Ion mobility measurements are a powerful tool to investigate ion-atom interaction potentials. Their sensitivity to the electronic configuration has been demonstrated for many elements across the periodic table. Especially for heavy elements, the impact of relativistic effects on the electronic configuration may lead to deviations in the periodicity, hence to distinct ion mobilities. This opens up a new niche for isobaric purification and element identification in the research of actinides and transactinides. Systematic ion mobility spectrometry measurements performed in the lanthanides [1] are being extended to the actinides. Resonant two-step laserionization will provide an element-selective ion production from a sample filament in argon gas and thus ensure an element-selective detection. In the talk, the experimental approach, the first results and the future plans are presented.

[1]: Laatiaoui, M. et al., EPJD (2012) 66:232

MS 7.2 Wed 15:15 U A-Esch 2

A new gas-jet setup for laser spectroscopy of superheavy elements — •Steven Nothhelfer[1,3], Michael Block[1,2,3], Rafael Ferrer[4], Tobias Kron[2,3], Sebastian Raeder[2,3], Fabian Schneider[1,3], Piet Van Duppen[4], and Elise Verstraelen[4] — [1]Institut für Kernchemie, Johannes Gutenberg-Universität, Mainz, DE — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, DE — [3]Helmholtz-Institut Mainz, DE — [4]Instituut voor Kern- en Stralingsfysica, KU Leuven, Leuven, Belgium

Experimental data on the hyperfine structure in superheavy elements (SHE) is important to obtain valuable information about their nuclear structure. In addition, the atomic properties of SHE are of special interest because they are difficult to predict by theoretical calculations due to complex relativistic effects. Therefore, a new gas-jet experiment is being developed, which aims to enable precise investigation of electronic states of rare atoms with the use of laser spectroscopy in a supersonic gas-jet. The study of SHE is realized by stopping fusion evaporation residues in a buffer gas cell after their production and separation at SHIP at GSI, Darmstadt. Subsequently, the fusion evaporation residues are transferred into a supersonic gas-jet, which is produced by a de Laval-nozzle. Laser spectroscopy in this jet enables a higher resolution compared to the previous RADRIS setup, resulting in spectral linewidths of few hundred MHz, granting access to valuable information on nuclear moments and spins which can be derived from the hyperfine structure and isotope shifts. This talk will summarize the current status of the experiment.

MS 7.3 Wed 15:30 U A-Esch 2

Studies of lanthanide desorption enthalpies and filament work functions for laser spectroscopic investigations of the heaviest actinides — •Tobias Murböck[1,2], Brankica Andelić[1,3], Michael Block[1,2,4], Premaditya Chhetri[5], Julia Even[3], Francesca Giacoppo[2], Oliver Kaleja[2,4,6], Tobias Kron[1,2], Mustapha Laatiaoui[4], Andrew Mistry[1,2], Steven Nothhelfer[4], Sebastian Raeder[2], Elisabeth Rickert[4], and Fabian Schneider[4] — [1]HI Mainz — [2]GSI — [3]KVI-CART, RU Groningen — [4]Uni Mainz — [5]TU Darmstadt — [6]MPIK Heidelberg

To probe the atomic shell structure of the heaviest actinides with $Z > 100$, the sensitive RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) technique is applied at the SHIP velocity filter at GSI. After production in high-energy fusion-evaporation reactions the recoil products are stopped in a buffer-gas cell and collected onto a filament. Subsequent thermal evaporation as neutral atoms allows the atomic structure to be probed using laser spectroscopy. The desorption enthalpy of these elements and the filament work function are crucial for determining the efficiency of the evaporation and the background created by surface ions, respectively. In this talk, a setup for mass spectrometry of surface ionized and laser ionized lanthanides evaporated from different sample filaments is presented. The desorption enthalpies of ytterbium and lutetium from a larger variety of surfaces are discussed with regard to the prospects of laser-spectroscopic investigations of their heavier homologes, nobelium ($Z = 102$) and lawrencium ($Z = 103$).

MS 8: Precision Mass Spectrometry

Time: Thursday 10:30–12:30 Location: U A-Esch 2

Invited Talk MS 8.1 Thu 10:30 U A-Esch 2

Penning-Trap Mass Spectrometry of the Heaviest Elements with SHIPTRAP — •Oliver Kaleja[1,2,3], Brankica Andjelić[4,5], Olesya Bezrodnova[6,7], Klaus Blaum[1], Michael Block[2,3,5], Stanislav Chenmarev[2,6], Premaditya Chhetri[3,8], Christian Droese[9], Christoph E. Düllmann[2,3,5], Martin Eibach[3,9], Julia Even[4], Sergey Eliseev[1], Pavel Filianin[1], Francesca Giacoppo[3,5], Stefan Götz[2,3,5], Yuri Gusev[6], Manuel Gutiérrez[10], Frank Herfurth[3], Fritz-Peter Hessberger[3,5], Nasser Kalantar-Nayestanaki[4], Jadambaa Khuyagbaatar[3,5], Jacques J.W. van de Laar[2,5], Mustapha Laatiaoui[5], Steffen Lohse[2,5], Natalia Martynova[6,7], Enrique Minaya-Ramirez[11], Andrew Mistry[3,5], Tobias Murböck[3], Yuri Novikov[6,7], Sebastian Raeder[3], Daniel Rodriguez[10], Fabian Schneider[2,5], Lutz Schweikhard[9], Peter Thirolf[12], and Alexander Yakushev[3,5] — [1]MPIK Heidelberg — [2]JGU Mainz — [3]GSI Darmstadt — [4]KVI-CART/Univ. Groningen — [5]HI Mainz — [6]PNPI KI Gatchina — [7]SPbSU St. Petersburg — [8]TU Darmstadt — [9]Univ. Greifswald — [10]Univ. de Granada — [11]IPN Orsay — [12]LMU München

Superheavy elements (Z≥104) owe their very existence to an enhanced stability resulting from nuclear shell effects. Direct high-precision Penning-trap mass spectrometry (PTMS) in this region can provide indispensable knowledge on the nuclear binding energy of these elements. This will eventually help to constrain theoretical predictions for the so-called island of stability, a region of long-lived nuclides expected around Z=114-126, N=184. However, due to their low production rates, PTMS of these elements requires the highest levels of efficiency and sensitivity. In a beam-time campaign in 2018, recent developments at SHIPTRAP allowed us to extend PTMS to heavier and more exotic nuclides with production rates as low as one ion per minute. For the first time, direct mass spectrometry of ^{251}No, ^{254}Lr and the superheavy nuclide ^{257}Rf (Z=104) were performed using the Phase-Imaging Ion-Cyclotron Resonance technique. The latter allowed to directly resolve the low-lying isomeric states ^{251m,254m}No and ^{254m,255m}Lr from their ground states. In this contribution an overview of the recent measurements will be given.

MS 8.2 Thu 11:00 U A-Esch 2

Improved ion thermalization and preparation with the cryogenic buffer-gas stopping cell of SHIPTRAP — •Francesca Giacoppo[1,2], Brankica Andelić[1,3], Klaus Blaum[4], Michael Block[1,2,5], Premaditya Chhetri[6], Christian Droese[7], Christoph E. Düllmann[1,2,5], Martin Eibach[2,7], Julia Even[3], Stephan Götz[1,2,5], Nasser Kalantar-Nayestanaki[3], Oliver Kaleja[2,4,5], Mustapha Laatiaoui[1,2,5], Andrew K. Mistry[1,2], Enrique Minaya Ramirez[8], Tobias Murböck[1,2], Sebastian Raeder[1,2], Lutz Schweikhard[7], and Peter G. Thirolf[9] — [1]HIM Mainz — [2]GSI Darmstadt — [3]KVI-CART, RU Groningen — [4]MPIK Heidelberg — [5]JGU Mainz — [6]TU Darmstadt — [7]Univ. Greifswald — [8]IPN Orsay — [9]LMU München

During summer 2018 direct mass measurements of very heavy elements such as ^{251}No (Z=102), ^{254}Lr (Z=103) as well as the first superheavy element ^{257}Rf (Z=104) have been successfully achieved, for the first time, with the SHIPTRAP mass spectrometer. Such challenging experiments face the problem of very low production rates, down to few ions per hour(s) and demand a very efficient ion preparation and manipulation. In particular the ion thermalization after production and prior to transfer to the Penning traps is the most crucial step. The latter is achieved slowing down the ions into a buffer-gas stopping cell. In this talk the latest optimization of the recently implemented SHIPTRAP cryogenic buffer-gas stopping cell and its enhanced performance in term of efficiency and purity will be presented.

MS 8.3 Thu 11:15 U A-Esch 2

Improving the laser ablation ion source at SHIPTRAP — •Brankica Andelić[1,2], Michael Block[2,3,4], Premaditya Chhetri[3,5], Holger Dorrer[2,4], Christoph Düllmann[2,3,4], Julia Even[1], Francesca Giacoppo[2,3], Nasser Kalantar-Nayestanaki[1], Oliver Kaleja[2,3,6], Andrew Mistry[2,3], Tobias Murböck[2,3], Sebastian Raeder[2,3], Fabian Schneider[2,4], and Klaus Blaum[6] — [1]KVI-CART, RU Groningen — [2]HI Mainz — [3]GSI Darmstadt — [4]JG University Mainz — [5]TU Darmstadt — [6]MPIK Heidelberg

One of the possible approaches to determine the neutrino mass is to study the electron capture process where the nucleus decays by capturing an atomic electron and emitting an electron neutrino. Its calorimetrically measured energy spectrum allows to investigate the electron neutrino mass in the sub-eV range if the Q-value of this decay is known with sufficient precision. To eliminate systematic uncertainties, an independent determination of the Q-value is necessary and can be achieved only using Penning-trap mass spectrometry.

The Penning-trap mass spectrometer SHIPTRAP coupled to a laser ablation ion source allows mass measurements with the required precision. To enable measurements on rare isotopes, the laser ablation and injection of the ions have to be efficient. Therefore, we capture the laser-ablated ions in a gas-filled miniature Radio-Frequency Quadrupole that was recently implemented. In this contribution, an overview of the technical developments and optimization of the laser ion source will be given.

Invited Talk MS 8.4 Thu 11:30 U A-Esch 2

Comissioning of and Preparations for First Experiments at CRYRING@ESR — •Michael Lestinsky — GSI Helmholtzzentrom für Schwerionenforschung GmbH, Darmstadt, Germany

The CRYRING@ESR project has been started about six years ago by moving and mordernizing the original parts of the former Stockholm-installation of the low-energy heavy-ion storage ring CRYRING to Darmstadt. Installed behind ESR, the synergy of the combined facilities yields access to a hitherto unavailable low-energy-domain and intensity for heavy, highly charged ions in isotopically pure beams with well-defined charge state and quantum level.

The project is quickly progressing towards full operation as an experimental facility and first measurements will already be performed in 2019. A prospective research program on unique experiments has been initiated and first new experiments are becoming available. These include e.g. atomic collisions spectroscopy in strong fields of high-Z atoms, nuclear physics at the Coulomb barrier and p-process nucleosynthesis, furthermore also materials science with surface modifications and biophysics.

This talks shall give an overview of the CRYRING@ESR facility, it*s performance, status, and a glimpse at the future experiments.

MS 8.5 Thu 12:00 U A-Esch 2

Studying of the position-sensitive resonant Schottky cavity — •Dmytro Dmytriiev[1], Shahab Sanjari[1], Yuri Litvinov[1,2], and Thomas Stöhlker[1,3] — [1]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [2]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [3]Helmholtz-Institut Jena, 07743 Jena, Germany

Studying the r-process in stellar environment, that leads to the creation of elements heavier than 56-Fe, remains one of the fundamental questions of modern physics and therefore an active field of research within nuclear astrophysics. Apart from other key measurables like neutron capture cross section and decay lifetimes, nuclear masses are of outmost importance for pinpointing the r-process using theoretical and experimental approaches. Exotic nuclides which participate in the r-process due to their low production yield and short half-life can efficiently be investigated in storage rings. Due to the low signal level the detectors should be very sensitive and fast. Resonant Schottky cavity pickups fulfill such requirements. Apart from their applications in the measurements of beam parameters, they can be used in non-destructive in-ring decay studies of radioactive ion beams. In addition, position sensitive Schottky pick-up cavities can enhance precision in the isochronous mass measurement technique. The goal of this work is to construct and test such a position sensitive resonant Schottky cavity pickup based on theoretical calculations and simulations. A brief description of the detector and its application in mass and lifetime measurements will be provided in this contribution.

MS 8.6 Thu 12:15 U A-Esch 2

Electron-ion merged beam experiments at the Cryogenic Storage Ring (CSR) — •Daniel Paul[1], Patrick Wilhelm[1], Oldřich Novotný[1], Sunny Saurabh[1], Ábel Kálosi[1,3], Klaus Blaum[1], Manfred Grieser[1], Robert von Hahn[1], Claude Krantz[1], Holger Kreckel[1], Daniel Zajfman[2], and Andreas Wolf[1] — [1]Max Planck Insitute for Nuclear Physics, Heidelberg, Germany — [2]Weizmann Institute of Science, Rehovot, Israel — [3]Visitor from Charles University of Prague, Czech Republic

Molecules up to water and organic species are produced in binary collisions in the cold interstellar medium (ISM), i.e. at ambient temperatures of $\approx 10 - 100$ K. They influence the cooling of gas clouds and the formation of stars and planets. One of the key molecular reactions in the ISM is dissociative recombination (DR). Laboratory studies on DR are needed for understanding molecular evolution in space.

The cryogenic storage ring (CSR) provides a nearly perfect environment for DR studies at ISM-relevant conditions. With internal wall temperatures of 6 K most stored molecular ions radiatively cool to their rovibrational ground state. Moreover, a technically challenging, low-energy electron cooler was recently implemented into CSR that allows to perform electron-ion merged beam experiments in a cryogenic environment. Here we report on its electron cooling capabilities as well as on first rovibrational-state-selected DR rate coefficient measurements.

MS 9: Resonance Ionization Mass Spectrometry

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

Invited Talk MS 9.1 Thu 14:00 U A-Esch 2

Precision Spectroscopy of Boron Atoms — •Bernhard Maass[1], Jason Clark[2], Thomas Hüther[1], Phillip Imgram[1], Simon Kaufmann[1], Kristian König[1], Jörg Krämer[1], Jan Krause[1], Alessandro Lovato[2], Peter Müller[2], Krzysztof Pachucki[3], Mariusz Puchalski[3], Robert Roth[1], Rodolfo Sánchez[4], Guy Savard[2], Robert Wiringa[2], and Wilfried Nörtershäuser[1] — [1]IKP, TU Darmstadt, DE — [2]ANL, Lemont, IL, USA — [3]University of Warsaw, PL — [4]GSI Darmstadt, DE

We report on the first determination of the nuclear charge radius of stable boron isotopes by resonance ionization mass spectrometry (RIMS). By combining high-resolution measurements of the isotope shift in an atomic ground state transition and high-accuracy *ab initio* mass-shift calculations of the five-electron system, the difference in the mean-square charge radius between the stable isotopes ^{10,11}B can be extracted. The result is then used to benchmark new *ab initio* nuclear structure calculations using the no-core shell model and Greens-Function Monte Carlo approaches. In near future, collinear laser spectroscopy will be performed in the same transition on the short-lived (770 ms) proton halo candidate ^{8}B at Argonne National Laboratory. The difference in mean-square charge radius will deliver a model-independent test of its proton halo character.

This work is supported by the U.S. DOE, Office of Science, Office of Nuclear Physics, under contract DE-AC02-06CH1135, and by the Deutsche Forschungsgemeinschaft through Grant SFB 1245.

MS 9.2 Thu 14:30 U A-Esch 2

On-line results from ISOLDE's Laser Ion Source and Trap LIST — •Reinhard Heinke[1], Valentin Fedosseev[2], Bruce Marsh[2], Sebastian Raeder[3], Sebastian Rothe[2], and Klaus Wendt[1] — [1]Institute of Physics, JGU Mainz — [2]EN Department, CERN — [3]HIM Mainz

Laser resonance ionization today is a well-established core technique for efficient and highly selective radioactive ion beam production at the worldwide leading facilities. Nevertheless, in experiments demanding highest beam purity, suppression of beam contaminations from competing ionization processes inside the hot ion source cavity is essential. Corresponding techniques therefore imply spatial separation of the high temperature atomization region from a fully shielded clean and cold laser ionization volume located inside an RFQ ion guide structure: The Laser Ion Source and Trap LIST.

Derived from previous operation experiences, systematic off-line studies and simulations, a next generation of the LIST went on-line at ISOLDE in 2018. Highly pure ^{22}Mg beams were provided for measurements on its super-allowed branching ratio and half-life. Exceptional contamination suppression of up to a factor of 10^6 was shown. Moreover, the LIST unit undergoes additional tests to eventually further increase its performance: Using high-resistance cavity materials and a LIST body of well adapted length as field-free drift volume also enables time-of-flight operation mode with shortest ion bunches and offers the possibility for subsequent beam purification by laser pulse synchronized ion beam gating. Implementation at ISOLDE is in progress.

MS 9.3 Thu 14:45 U A-Esch 2

Automated Grating-Tuned Intra-Cavity Doubled Ti:Sapphire Laser for Fast Element Switching in RIMS — •Felix Weber, Vadim Gadelshin, Dominik Studer, Tom Kieck, and Klaus Wendt — Johannes Gutenberg Universität, Mainz

Laser resonance ionization mass spectroscopy is a versatile technique for efficient and selective ionization, used for atomic and nuclear physics studies of exotic species as well as for elemental ultra-trace analysis. This technique uses the unique atomic energy level systems for a multi-step ionization scheme in combination with mass spectrometry for selection of the isotope of interest. All lanthanide elements can be easily and efficiently ionized by two-step excitation schemes using second harmonic generation (SHG) of Ti:sapphire laser light. An automated grating-tuned laser with intra-cavity second harmonic generation provides high output power up to 1W over a wavelength range from 375 nm to 475 nm with a single BBO crystal. The combination of grating tuning with closed loop operation of the SHG piezo actuator allows rapid switching between different excitation wavelengths. The

successive addressing of a specific element in one sample with switching times of just a few seconds has been demonstrated on mixtures of nine lanthanide elements. The properties of the laser system, excitation scheme development and results for a successive extraction of a single lanthanide from the mixture will be discussed.

MS 9.4 Thu 15:00 U A-Esch 2

Highly selective 2-step ionization schemes for analyis of actinide mixture — •Nina Kneip, Dominik Studer, and Klaus Wendt — Institute of Physics, JGU Mainz

In order to perform ultra trace analysis of radionuclides in environmental samples based on resonance ionization mass spectrometry (RIMS), efficient and highly element-selective laser excitation schemes are required. To analyze different all-relevant actinides within a single sample during one measurement, simple and versatile 2-step ionization schemes were developed at the Mainz Atomic Beam Unit. The use of fully automated grating assisted Ti:sapphire lasers featuring intracavity SHG allow for an easy instantaneous change of the ionization scheme and therefore the element of interest during the measurement. The new ionization schemes were tested in synthetic actinide mixture containing actinide cocktails consisting of 10^{16} uranium atoms, 10^{12} plutonium atoms and 10^{12} americium atoms.

Transitions between different quantum states are constrained by optical dipole transition selection rules. Thus, for even isotopes as e.g. ^{244}Pu, with $J = 0$ at the ground state and nuclear spin of $I = 0$, the J of the final auto-ionizing state was determined using different relative polarization of the incident laser beams. Exploiting this dependence also opens up an additional path to discriminate even Z isotopes against interfering background.

MS 9.5 Thu 15:15 U A-Esch 2

TOF-SIMS and resonant laser-SNMS analysis for isotope ratio measurements on insulators — •Hauke Bosco[1], Martin Weiss[1], Manuel Raiwa[1], Klaus Wendt[2], and Clemens Walther[1] — [1]Institute of Radioecology and Radiation Protection, Leibniz University Hannover — [2]Institute of Physics, Johannes-Gutenberg University Mainz

Radionuclides can interact with natural minerals via, e.g., sorption or incorporation. It is a key interest of radioecology to determine binding strengths and preferred sorption sites. Static SIMS is a well-suited and quasi non-destructive technique for measuring these properties by imaging spatial correlations of radionuclides with different mineral phases. By bombarding the surface with highly energetic ions, atomic and ionic fragments are ejected from the surface. The composition and distribution of isotopes is analyzed subsequently by MS. Isobaric interferences, however, can hinder precise isotope identification, as is the case for Pu-241 and its radioactive daughter isotope Am-241. Instead of analyzing the sputtered secondary ions, the secondary neutrals are resonantly post ionized by absorbing the light of precisely tuned lasers, selecting one element only (so called resonant laser secondary neutral mass spectrometry, rl-SNMS). While the spatial resolution of the sputter process of typically down to 70 nm is retained, isobaric interferences can be suppressed by several orders of magnitude. However, many of the samples of interest, e.g. the aforementioned minerals, are non-conducting, causing surface charging during the analysis. At the IRS such a setup has been developed and successfully tested.

MS 9.6 Thu 15:30 U A-Esch 2

In-situ extraction and TOF-SIMS-characterization of uranium-containing particles — •Paul Hanemann, Hauke Bosco, Martin Weiss, Manuel Raiwa, Laura Leifermann, and Clemens Walther — Institute of Radioecology and Radiation Protection, Leibniz University Hannover

Uranium bearing particles are omnipresent in the environment. However, they can be of natural or anthropogenic origin. Thus, identification poses a challenge. By combining SEM, EDX and micromanipulation, single particles are separated from the sample and deposited on um-diameter tungsten needles. The method does not require any sample preparation. Non-destructive mapping of elemental composition and isotopic ratios is performed by static time-of-flight secondary-ion mass-spectrometry (TOF-SIMS). This technique combines lateral resolution on the 100nm scale with ultratrace sensitivity and minimal invasiveness. A commercial IONTOF instrument has been modified and improved at the IRS [1, 2]. A broad spectrum of forensic data, including particle morphology and isotopic fingerprints of single particles was obtained. Extraction of uranium-containing particles was successfully performed on samples from the Chernobyl exclusion zone. The isotopic ratios of U-235, U-236 and U-238 were determined by TOF-SIMS measurements on the extracted particles. Comparing the obtained results to published data gives information on the origin and history of the particles. After the analysis, particles remain intact and are available for further experiments. [1] Franzmann et al., DOI: 10.1039/C7JA00423K [2] Franzmann et al., DOI: 10.1016/j.ijms.2017.10.003

MS 9.7 Thu 15:45 U A-Esch 2

MELISSA at CERN-MEDICIS: current status and recent results — •Vadim Gadelshin[1], Vincent Barozier[2], Roberto Formento Cavaier[3,4,5], Valentin Fedosseev[2], Ferid Haddad[3,4], Bruce Marsh[2], Thierry Stora[2], Dominik Studer[1], Felix Weber[1], and Klaus Wendt[1] — [1]Johannes Gutenberg-Universität Mainz — [2]CERN, Switzerland — [3]GIP ARRONAX, France — [4]SUBATECH, Nantes University, France — [5]Advanced Accelerator Applications, Novartis Group, France

2018 was the first operational year of the CERN-MEDICIS facility, which aims for a regular production of 500 MBq batches of innovative medical radionuclides. During this year, several important milestones were achieved: the production of a high specific activity of Er-169, the delivery of Tb-149 and Tb-155 for medical R&D to members of the MEDICIS Collaboration, successful tests of new types of highly efficient production targets, and Machine Development runs, preparing future upgrades.

The first year of the operation confirmed the necessity to optimize the output to reach a high separation efficiency and a best possible purity. As an effect, the construction and installation of the MEDICIS Laser Ion Source MELISSA were strongly boosted.

In the talk, the current status of the MELISSA is introduced. An overview on the accomplished work as well as the ongoing and planned activities is presented. Key benefits of the laser ion source are highlighted, possible modifications for the design of the target ion source unit are discussed. (EU H2020 grant #642889 MEDICIS-PROMED)