Mass Spectrometry Division
Fachverband Massenspektrometrie (MS)

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Overview of Invited Talks and Sessions

(Lecture halls H2 and H3; Poster P)

Invited Talks

MS 1.1	Mon	10:45–11:15	H3	**Precision Mass Measurements on Light Nuclei: The Deuteron's Atomic Mass** — •Sascha Rau
MS 2.1	Mon	14:00–14:30	H3	**Experiments with multiple-reflection time-of-flight mass spectrometers (MR-TOF-MS) at TRIUMF and GSI/FAIR** — •Christine Hornung, the FRS Ion Catcher Collaboration, the TITAN Collaboration
MS 4.1	Tue	10:45–11:15	H2	**Reaction studies with internally cold molecular ions in a storage ring** — •Oldřich Novotný
MS 6.1	Tue	14:00–14:30	H2	**The Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy and its potential for fast and highly selective mass separation** — •Stephan Malbrunot
MS 7.1	Thu	10:45–11:15	H3	**The new compact, multi isotope AMS system (MILEA) at ETH Zurich - performance and applications** — •Marcus Christl, Sascha Maxeiner, Arnold Müller, Philip Gautschi, Christof Vockenhuber, Hans-Arno Synal
MS 9.1	Fri	10:45–11:15	H2	**Spatially resolved ultra-trace analysis of actinides on hot particles by resonant laser-SNMS** — •Hauke Bosco, Martin Weiss, Manuel Raiwa, Nina Kneip, Klaus Wendt, Clemens Walther
MS 9.2	Fri	11:15–11:45	H2	**Multi-reflection time-of-flight mass spectrometry for cluster research** — •Paul Fischer, Lutz Schweikhard

Invited talks of the joint symposium Trends in atom interferometry (SYAI)

See SYAI for the full program of the symposium.

SYAI 1.1	Mon	14:00–14:30	Audimax	**Atom interferometry and its applications for gravity sensing** — •Franck Pereira dos Santos, Luc Absil, Yann Balland, Sébastien Merlet, Maxime Pesche, Raphaël Piccon, Sumit Sarkar
SYAI 1.2	Mon	14:30–15:00	Audimax	**Atom interferometry for advanced geodesy and gravitational wave observation** — •Philippe Bouyer
SYAI 1.3	Mon	15:00–15:30	Audimax	**3D printing methods for portable quantum technologies** — •Lucia Hackermüller
SYAI 1.4	Mon	15:30–16:00	Audimax	**Fundamental physics with atom interferometry** — •PAUL HAMILTON

Invited talks of the joint symposium SAMOP Dissertation Prize 2021 (SYAD)

See SYAD for the full program of the symposium.

SYAD 1.1	Tue	10:45–11:15	Audimax	**Attosecond-fast electron dynamics in graphene and graphene-based interfaces** — •Christian Heide
SYAD 1.2	Tue	11:15–11:45	Audimax	**About the interference of many particles** — •Christoph Dittel
SYAD 1.3	Tue	11:45–12:15	Audimax	**Supersolid Arrays of Dipolar Quantum Droplets** — •Fabian Böttcher

SYAD 1.4	Tue	12:15–12:45	Audimax	**Quantum Logic Spectroscopy of Highly Charged Ions** — •Peter Micke

Invited talks of the joint symposium The state of the art in actinide research (SYAR)

See SYAR for the full program of the symposium.

SYAR 1.1	Wed	10:45–11:15	Audimax	**Application of Inorganic Mass Spectrometry in Nuclear Forensics** — •Klaus Mayer, Maria Wallenius, Zsolt Varga, Magnus Hedberg, Michael Krachler
SYAR 1.2	Wed	11:15–11:45	Audimax	**Actinide elements and fundamental nuclear structure studies** — •Iain Moore
SYAR 1.3	Wed	11:45–12:15	Audimax	**Pushing the Limits: Detection of Long-Lived Actinides at VERA** — •Karin Hain, Michael Kern, Jixin Qiao, Francesca Quinto, Aya Sakaguchi, Peter Steier, Gabriele Wallner, Andreas Wiederin, Akihiko Yokoyama, Robin Golser
SYAR 1.4	Wed	12:15–12:45	Audimax	**Use of the actinides in medical research** — •Thomas Elias Cocolios

Invited talks of the joint symposium Awards Symposium (SYAW)

See SYAW for the full program of the symposium.

SYAW 1.1	Wed	13:30–14:15	Audimax	**Frequency comb spectroscopy and interferometry** — •Nathalie Picqué
SYAW 1.2	Wed	14:15–15:00	Audimax	**Capitalizing on Schrödinger** — •Wolfgang P. Schleich
SYAW 1.3	Wed	15:00–15:45	Audimax	**Quantum information processing with macroscopic objects** — •Eugene Polzik

Sessions

MS 1.1–1.7	Mon	10:45–12:45	H3	**Precision Mass Measurements I**
MS 2.1–2.5	Mon	14:00–15:30	H3	**Precision Mass Measurements II**
MS 3.1–3.2	Mon	16:30–18:30	P	**Poster**
MS 4.1–4.5	Tue	10:45–12:15	H2	**Storage Rings**
MS 5	Tue	12:15–13:15	MVMS	**Annual General Meeting of the Mass Spectrometry Division**
MS 6.1–6.5	Tue	14:00–15:30	H2	**New Developments I**
MS 7.1–7.6	Thu	10:45–12:30	H3	**Accelerator Mass Spectrometry I**
MS 8.1–8.5	Thu	14:00–15:15	H3	**Accelerator Mass Spectrometry II**
MS 9.1–9.3	Fri	10:45–12:00	H2	**New Developments II**

Annual General Meeting of the Mass Spectrometry Division

Tuesday 12:15–13:15 MVMS

- Bericht
- Wahl
- Verschiedenes

MS 1: Precision Mass Measurements I

Time: Monday 10:45–12:45 Location: H3

Invited Talk MS 1.1 Mon 10:45 H3

Precision Mass Measurements on Light Nuclei: The Deuteron's Atomic Mass — •Sascha Rau — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, Heidelberg

The rest masses of many light nuclei, e.g. the proton and the deuteron are of great importance for testing our current understanding of physics as well as in metrology. Recently discussed discrepancies in light ion mass measurements, carried out at different mass spectrometers and sometimes termed "light ion mass puzzle", give further motivation for independent measurements. Here I present progress and results of LIONTRAP (Light ION TRAP) [1], an ion trap setup dedicated to high-precision mass measurements of light ions, which has been constructed in an MPIK-GSI-University of Mainz collaboration. We recently measured the deuteron's atomic mass by comparing the cyclotron frequencies of a single deuteron and a bare carbon nucleus, achieving a relative mass uncertainty of 8.5×10^{-12}, a factor of 2.4 more precise than the CODATA-2014 value, and revealing a 4.8σ deviation with respect to this value [2]. Together with the LIONTRAP mass measurements of the proton [1] and the HD^+ molecular ion [2], as well as a measurement of the deuteron-to-proton mass ratio [3], this allows to determine the masses of the lightest nuclei with unprecedented precision. In this talk I will present these measurements and compare them with recent results from the spectroscopy of ro-vibrational states in HD^+.

[1] F. Heiße *et al.*, Phys. Rev. A **100**, 022518 (2019)
[2] S. Rau *et al.* Nature **585**, p. 43-47 (2020)
[3] D. J. Fink & E. G. Myers, Phys. Rev. Lett. **124**, 013001 (2020)

MS 1.2 Mon 11:15 H3

Latest results of high-precision mass measurements with Pentatrap — •Kathrin Kromer[1], José Ramon Crespo López-Urrutia[1], Menno Door[1], Sergey Eliseev[1], Pavel Filianin[1], Jost Herkenhoff[1,3], Wenjia Huang[4], Daniel Lange[1,3], Yuri Novikov[2], Alexander Rischka[1], Rima Xenia Schüssler[1], Christoph Schweiger[1], Sven Sturm[1], Stefan Ulmer[5], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Petersburg Nuclear Physics Institute, Gatchina, Russia — [3]Ruprecht-Karls-Universität Heidelberg, 69117 Heidelberg — [4]Advanced Energy Science and Technology Guangdong Laboratory, Huizhou 516003, China — [5]Ulmer Fundamental Symmetries Laboratory, RIKEN, Wako, Saitama 351-0198, Japan

The high-precision Penning-trap mass spectrometer Pentatrap[1] features a stack of five Penning traps and determines mass-ratios with a relative uncertainty below 10^{-11}. Mass-ratio determinations of stable and long-lived highly charged ions have numerous applications, among others, in neutrino physics [2] and the search of possible clock transitions in highly charged ions (HCI)[3]. The unique features of Pentatrap include access to HCI, a stablilized 7 T magnet, and a cryogenic detection system with single ion phase sensitivity. This is achieved by Fourier Transform Ion Cyclotron Resonance (FT-ICR) detection of the image-current induced in the trap electrodes. The latest measurements include the Q value of the β-decay of ^{163}Ho with a relative uncertainty of below $7 \cdot 10^{-12}$ and the mass of ^{208}Pb. In lead a long-lived metastable electronic state was discovered.

[1] J. Repp, *et al.*, Appl. Phys. B **107** (2012) 983
[2] J. Gastaldo, *et al.*, Appl. Phys. B **226** (2017) 1623
[3] M.G. Kozlov, *et al.*, Rev. Mod. Phys. **90** (2018)

MS 1.3 Mon 11:30 H3

The transportable antiproton trap BASE-STEP — •Christian Smorra[1], Fatma Abbass[1], Matthew Bohman[2,3], Daniel Popper[1], Ron Moller[1], Markus Wiesinger[2,3], Christian Will[2,3], Jack Devlin[2,4], Stefan Erlewein[2,4], Markus Fleck[2,5], Julia Jaeger[2,3], Barbara Latacz[2], Peter Micke[2,4], Elise Wursten[2,4], Klaus Blaum[3], Yasuyuki Matsuda[5], Christian Ospelkaus[6,7], Wolfgang Quint[8], Anna Soter[9], Jochen Walz[1,10], Yasunori Yamazaki[2], and Stefan Ulmer[2] — [1]Johannes Gutenberg-Universität, Mainz, Germany — [2]RIKEN, Wako-shi, Japan — [3]Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany — [4]CERN, Geneva, Switzerland — [5]University of Tokyo, Japan — [6]Leibniz Universität Hannover, Germany — [7]PTB Braunschweig, Germany — [8]GSI, Darmstadt, Germany — [9]ETH Zürich, Switzerland — [10]Helmholtz Institute Mainz, Germany

High-precision comparisons of the proton's and antiproton's charge-to-mass ratios and magnetic moments constitute stringent tests of CPT invariance, one of the cornerstones in the Standard Model of particle physics. The BASE collaboration has advanced these tests by precision measurements on single trapped antiprotons in a multi-Penning trap system in the antiproton decelerator hall at CERN, where magnetic field noise from the facility operation have become a major concern. To further advance the precision, we have designed the transportable antiproton trap BASE-STEP to relocate antiproton precision measurements into other laboratories. I will present a design report and the status of the project.

MS 1.4 Mon 11:45 H3

Transportable Cryostat and Permanent Magnet Trap for STEP — •Daniel Popper[1], Fatma Abbas[1], Matthew Bohman[1,2], Steffen Gavranovic[1], Cristina Ibanez[1], Ron Moller[1], Samuel Ruhl[1], Markus Wiesinger[2,3], Christian Will[2], Jack Devlin[3,4], Stefan Erlewein[3,4], Markus Fleck[3,5], Julia Jaeger[2,3], Barbara Latacz[2], Peter Micke[3,4], Elise Wursten[3,4], Klaus Blaum[2], Yasuyuki Matsuda[5], Christian Ospelplaus[7,8], Wolfgang Quint[6], Jochen Walz[1,9], Stefan Ulmer[3], and Christian Smorra[1,3] — [1]Johannes Gutenberg University, Mainz, Germany — [2]Max-Plank-Institute for Nuclear Physics, Heidelberg, Germany — [3]RIKEN, Wako-shi, Japan — [4]CERN, 1211 Geneva, Switzerland — [5]University of Tokyo, Japan — [6]GSI, Darmstadt, Germany — [7]Leibniz Universität Hannover, Germany — [8]PTB, Braunschweig, Germany — [9]Helmholtz-Institut Mainz, Germany

STE$\bar{P}$, "Symmetry Tests in Experiments with Portable Antiprotons", is an addition to the BASE experiment. To enable antiproton measurements with improved precision, future measurements need to be conducted outside of the "Antiproton Decelerator" hall to circumvent limitations by magnetic field fluctuations. For this, we designed a transportable cryostat, a pulse-tube cooler and liquid helium tank to cool a Penning trap system down to 4K during transportation and periods were no power is available. Also a permanent magnet system will be used as an alternative approach to using a superconducting magnet to trap the particles. I will present and characterize the set-up of the transportable cryostat and the permanent magnet system.

MS 1.5 Mon 12:00 H3

An Accumulation Radio-Frequency Quadruple Cooler-Buncher for the PUMA Offline Ion Source — •Clara Klink[1], Frank Wienholtz[1], Carina Kanitz[2], Stephan Melbrunot[2], Markus Kristian Vilen[2], and Simon Lechner[2] — [1]TU Darmstadt, 64289 Darmstadt, Deutschland — [2]CERN, 1211 Meyrin, Schweiz

The antiProton Unstable Matter Annihilation (PUMA) experiment plans to utilise antiprotons to further characterise stable as well as radioactive nuclei. Antiprotons will be used to specify the isospin composition of the nuclei by analysing the reaction products of an antiproton-nucleon annihilation. Inter alia, PUMA plans on performing experiments with low-energy antiprotons from the ELENA facility of CERN with a broad range of stable isotopes from an offline ion source to observe their behaviour during antiprotonic annihilation. For a successful operation of PUMA a high event rate with a high-purity ion beam is crucial, to clearly differentiate from background annihilations, thus the offline ion source beamline must meet several requirements to transport and shape the ion beam. The purification of the ion beam is done with a multi-reflection time-of-flight mass spectrometer. For achieving a sufficiently high event rate and prevent the production of secondary particles in the experimental zone, the ion beam will be accumulated, bunched and buffer gas cooled in an RFQ. This talk will give an introduction on the principle of operation for the PUMA RFQ. The requirements for the RFQ will be defined and an overview of the PUMA offline ion source beamline is given.

MS 1.6 Mon 12:15 H3

Reduction of Measurement Uncertainty in MC-ICP-MS: A Precondition for the Dissemination of the SI Units Kilogram and Mole — •Axel Pramann and Olaf Rienitz — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

After the revision of the SI units in May 2019, one of the two methods

to realize and disseminate the kilogram and mole is the the X-ray-crystal-density (XRCD) method (1-2). Here, silicon atoms in a silicon sphere are *counted* combining the measurements of the volume, the lattice parameter, the surface properties, and the isotopic composition using the fixed Avogadro constant. A key experiment uses high resolution multicollector inductively coupled plasma mass spectrometry (HR-MC-ICP-MS) to measure isotope ratios in natural and in 28Si enriched silicon to determine the respective molar mass (M) (3). It is shown how the measurement uncertainty of the isotope ratios according to the *Guide to the Expression of Uncertainty in Measurement* influences the results when using natural or enriched silicon and how this has been, is, and will be treated in the near future combining established and new experimental techniques (4).

(1) K. Fujii et al., Metrologia, 53, A19 (2016). (2) B. Guettler, O. Rienitz, A. Pramann, Annalen der Physik, 1800292 (2018). (3) A. Pramann, T. Narukawa, O. Rienitz, Metrologia, 54, 738 (2017). (4) A. Pramann, J. Vogl, O. Rienitz, MAPAN J. Metrol. Soc. I, 35, 499 (2020).

MS 1.7 Mon 12:30 H3

Development and Characterization of a Multi-Reflection Time-of-Flight Mass Separator (MR-ToF MS) for the Offline Ion Source of PUMA — •Moritz Schlaich and Frank Wienholtz — TU Darmstadt, Darmstadt, Deutschland

The antiProton Unstable Matter Annihilation (PUMA) project aims at investigating the nucleon composition in the matter density tail of short-lived as well as stable isotopes by studying antiproton-nucleon annihilation processes. For this purpose, low-energy antiprotons provided by the Extra Low Energy Antiproton (ELENA) facility at CERN will be trapped together with the ions under investigation. While the unstable ions will be supplied by the Isotope mass Separator On-Line DEvice (ISOLDE) at CERN, the stable ions are taken from an offline ion source that should be able to provide a cooled and bunched as well as isotopically pure ion beam. It is used by means of comparison with known isotopes to benchmark the antiproton nuclear annihilation process as well as for development and reference measurements at ELENA. The ion source contains a radio-frequency quadrupole cooler-buncher for ion accumulation and bunching. To purify the beam, an MR-ToF MS will be used. The talk will give an overview of the working principle and the design of the MR-ToF MS for the PUMA offline ion source.

MS 2: Precision Mass Measurements II

Time: Monday 14:00–15:30 Location: H3

Invited Talk MS 2.1 Mon 14:00 H3

Experiments with multiple-reflection time-of-flight mass spectrometers (MR-TOF-MS) at TRIUMF and GSI/FAIR — •Christine Hornung[1], the FRS Ion Catcher Collaboration[1,2], and the TITAN Collaboration[3] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [2]II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Gießen, Germany — [3]TRIUMF, Vancouver, Canada

MR-TOF-MS have been developed for the TITAN experiment at TRIUMF and for the FRS/Super-FRS at GSI/FAIR at the JLU Giessen. The systems incorporate several novel and unique concepts. The design enables world class performance, including a mass resolving power up to 1,000,000, mass accuracies down to $1.8 \cdot 10^{-8}$ and a background suppression of greater than 7 orders of magnitude.

Experiments contributing to different fields from nuclear astrophysics and structure were performed at the FRS Ion Catcher experiment at the in-flight fragment separator FRS at GSI and the TITAN experiment at the ISOL facility ISAC at TRIUMF, Canada.

In addition, the use of these MR-TOF-MS goes even beyond precision mass measurements, e.g., they can be employed to identify and analyze ions independent of their decay properties unambiguously. This enables novel and universal approaches to measure reaction cross sections, fission yields, half-lives, and branching ratios. Recent highlights and perspectives from both experiments at GSI and TRIUMF will be presented focusing on different regions of the chart of nuclei.

MS 2.2 Mon 14:30 H3

Latest improvements on TITAN*s Multiple-Reflection Time-Of-Flight Mass-Spectrometer — •Ali Mollaebrahimi[1,2], Timo Dickel[1,3], Andrew Jacobs[2,4], Ania Kwiatkowski[2,5], Tobias Murböck[2], Moritz Pascal Reiter[6], and Coulter Walls[2] — [1]University of Gießen, Gießen, Germany — [2]TRIUMF, Vancouver, Canada — [3]GSI, Darmstadt, Germany — [4]University of British Columbia, Vancouver, Canada — [5]University of Victoria, Victoria, Canada — [6]University of Edinburgh, Edinburgh, United Kingdome

TRIUMF*s Ion Trap for Atomic and Nuclear science (TITAN) is specialized in high-precision mass measurement and isobaric separation of exotic nuclei by using different electromagnetic and electrostatic traps: A precision Penning trap for the highest-precision mass measurements, EBIT (Electron Beam Ion Trap) for charge breeding and gamma spectroscopy measurements of radioactive nuclei and MR-TOF-MS (Multiple-Reflection Time-Of-Flight Mass Spectrometer) for high-precision mass measurement as well as for monitoring and identification of ISAC beam. MR-TOF-MS can be also used as an isobar separator for beam purification with a high separation power and send the isobarically-purified beam toward the penning trap or other downstream experiments. MR-TOF MS is one of the crucial setups enables the studies of short-lived and exotic nuclei far away from the valley of stability. Mass measurements of these isotopes are demanded for studies of nuclear structure and nuclear astrophysics processes. In this work, the performance, the capabilities and the latest technical improvements of MR-TOF-MS is going to be presented.

MS 2.3 Mon 14:45 H3

High-Precision Mass Spectrometry of Superheavy Elements — •Oliver Kaleja[1,2], Brankica Andelic[2,3,4], Luisa Arcila Gonzalez[4], Joacquín Berrocal[5], Lennart Blaauw[4], Klaus Blaum[6], Michael Block[2,3,7], Pierre Chauveau[2,3], Stanislav Chenmarev[3,6], Premaditya Chhetri[2,3], Christoph E. Düllmann[2,3,7], Martin Eibach[1], Julia Even[4], Pavel Filianin[6], Francesca Giacoppo[2,3], Manuel J. Gutiérrez Torres[5], Fritz P. Hessberger[2,3], Nasser Kalantar-Nayestanaki[4], Jacques J. W. van de Laar[3,7], Mustapha Laatiaoui[3,7], Steffen Lohse[3,7], Enrique Minaya Ramirez[8], Andrew Mistry[2], Elodie Morin[8], Yury Nechiporenko[9,10], Dennis Neidherr[2], Steven Nothhelfer[3,7], Yuri Novikov[9,10], Sebastian Raeder[2,3], Elisabeth Rickert[3,7], Daniel Rodríguez[5], Lutz Schweikhard[1], Peter G. Thirolf[11], Jessica Warbinek[2,7], and Alexander Yakushev[2,3] — [1]Univ. Greifswald — [2]GSI Darmstadt — [3]HIM Mainz — [4]Univ. of Groningen — [5]Univ. of Granada — [6]MPIK Heidelberg — [7]JGU Mainz — [8]IJCLab Orsay — [9]PNPI Gatchina — [10]St. Petersburg Univ. — [11]LMU Munich

One of the keys in understanding the existence of superheavy elements with proton numbers $Z \geq 104$ is the study of phenomena like nuclear shell effects far from stability. For these studies, one has to measure atomic masses at the borders of the nuclear chart very accurately. In 2021, the performance of the mass spectrometer SHIPTRAP at the GSI in Darmstadt was significantly improved. As a result, the atomic masses of several heavy At, Bi, Cf, Fr, Rn, Th, Po and Pb isotopes and the superheavy nuclides ^{257}Rf ($Z = 104$) and ^{258}Db ($Z = 105$) were measured directly. For many of these nuclides also long-lived isomeric states were observed allowing us to determine their excitation energy. In this contribution, an overview of the experimental improvements and results will be given.

MS 2.4 Mon 15:00 H3

Investigation of ground and metastable nuclear states in the heaviest nuclei at SHIPTRAP — •Francesca Giacoppo[1,2], Brankica Anđelić[1,2,3], Luisa Arcila Gonzalez[3], Joaquín Berrocal Sánchez[4], Lennart Blaauw[3], Klaus Blaum[5], Michael Block[1,2,6], Pierre Chauveau[1,2], Stanislav Chenmarev[2,5], Premaditya Chhetri[1,2], Christoph E. Düllmann[1,2,6], Martin Eibach[1], Julia Even[3], Pavel Filianin[5], Manuel Jesús Gutiérrez Torres[1,2,4], Fritz P. Hessberger[1,2], Nasser Kalantar-Nayestanaki[3], Oliver Kaleja[1,7], Jacques W. van de Laar[2,6], Mustapha Laatiaoui[2,6], Steffen Lohse[2,6], Enrique Minaya Ramirez[8], Andrew Mistry[1], Elodie Morin[8], Yury Nechiporenko[9,10], Dennis Neidherr[1], Steven Nothhelfer[2,6],

Yuri Novikov[9,10], Sebastian Raeder[1,2], Elisabeth Rickert[2,6], Daniel Rodríguez[4], Lutz Schweikhard[7], Peter Thirolf[11], Jessica Warbinek[1,2,6], and Alexander Yakushev[1,2] — [1]GSI Darmstadt, Germany — [2]HIM Mainz, Germany — [3]University of Groningen, the Nederlands — [4]University of Granada, Spain — [5]MPIK Heildeberg, Germany — [6]JGU University Mainz, Germany — [7]Universiy of Greifswald, Germany — [8]IJCLab Orsay, France — [9]PNPI Gatchina, Russia — [10]Saint Petersburg State University, Russia — [11]LMU University Munich, Germany

In a very recent experimental campaign performed with the Penning trap spectrometer SHIPTRAP at GSI the superheavy isotopes ^{257}Rf and ^{258}Db were investigated despite their low production rates. The masses of the ground state and isomeric states as well as for several nuclides with $Z = 82 - 98$ were directly measured with high accuracy.

Valuable information on the nuclear shell structure, its strength and evolution in the region of the heaviest elements can be directly derived from our experimental findings.The latter, therefore, complement results achieved in decay spetroscopy studies. Furthermore, such accurate masses in the vicinity of the superheavy element region serve as anchor points to determine the masses of heavier nuclei which are crucial for nuclear models attempting to pinpoint the position of the predicted island of stability.

In this contribution an overview of the results will be given.

MS 2.5 Mon 15:15 H3

Status report on the TRIGA-TRAP experiment — •Jacques J. W. van de Laar[1,2], Klaus Blaum[3], Michael Block[1,2,4], Stanislav Chenmarev[3,5], Christoph E. Düllmann[1,2,4], Steffen Lohse[1,2], and Szilard Nagy[3] — [1]Department Chemie - Standort TRIGA, Johannes Gutenberg-Universität Mainz, DE — [2]Helmholtz-Institut Mainz, DE — [3]Max-Planck-Institut für Kernphysik, Heidelberg, DE — [4]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, DE — [5]Petersburg Nuclear Physics Insitute, Gatchina, RU

Experimental data of ground-state properties of exotic nuclei are important for nuclear structure studies and can test the reliability of nuclear mass models. The TRIGA-TRAP experiment is a double Penning-trap mass spectrometer used to perform high-precision measurements on long-lived transuranium isotopes and fission produced neutron-rich radionuclides at the research reactor TRIGA Mainz. Recently, a new cylindrical measurement trap was installed and characterized. After recommissioning, a mass measurement campaign started with several long-lived actinide isotopes. The data evaluation is still ongoing. The current status and first results will be presented.

MS 3: Poster

Time: Monday 16:30–18:30 Location: P

MS 3.1 Mon 16:30 P

Current status of the LIONTRAP experiment — •Sangeetha Sasidharan[1,2], Olesia Bezrodnova[1], Sascha Rau[1], Wolfgang Quint[2], Sven Sturm[1], and Klaus Blaum[1] — [1]MPIK, Heidelberg, Germany — [2]GSI Helmholtzzentrum, Darmstadt, Germany

Atomic masses with high precision are essential parameters for sensitive tests of fundamental physics. LIONTRAP (Light-Ion Trap) is a dedicated mass spectrometer aiming for various light ion mass measurements with a relative precision of a few 10^{-12} (ppt). Our latest results include the atomic masses of the proton [1], the deuteron and the HD^+ molecular ion [2]. These show an excellent agreement with values extracted from laser spectroscopy of HD^+ [3] and the comparison is limited by the precision of the relative mass of the electron, A_r(e). This brings in a motivation to measure the atomic mass of ^{4}He which along with a g-factor measurement can improve the electron mass. Furthermore, the masses of ^{3}He and ^{3}T [4] can be used as an important cross-check for the determination of the electron antineutrino mass which is being investigated by the KATRIN experiment [5]. In this contribution I will discuss the efforts to measure the alluded systems at LIONTRAP.

[1] F. Heiße *et al.*, Phys. Rev. A **100**, 022518 (2019)
[2] S. Rau *et al.*, Nature **585**, p. 43-47 (2020)
[3] Alighanbari, S. *et al.*, Nature **581**, 152-158 (2020)
[4] E.G. Myers *et al.*, Phys. Rev. Lett. **114**, 013003 (2015)
[5] M. Aker *et al.*, Phys. Rev. Lett. **123**, 221802 (2019)

MS 3.2 Mon 16:30 P

MOCCA: a 4k-pixel molecule camera for the position and energy resolved detection of neutral molecule fragments at the Cryogenic Storage Ring CSR — •Ansgar Lowack[1], Dennis Schulz[1], Steffen Allgeier[1], Christian Enss[1], Andreas Fleischmann[1], Lisa Gamer[2], Loredana Gastaldo[1], Sebastian Kempf[1], Oldrich Novotný[2], and Andreas Wolf[2] — [1]Kirchhoff-Institute for Physics, Heidelberg University — [2]Max-Planck-Institute for Nuclear Physics, Heidelberg

MOCCA is a 64 x 64-pixel detector based on metallic magnetic calorimeters (MMCs), enabling a spatially- and energy-resolved detection of neutral massive particles with keV kinetic energies on a detector area of 4.5 cm x 4.5 cm with 99.5% filling factor. MOCCA was developed for the investigation of dissociative recombination, a fundamental process in interstellar chemistry, at the Cryogenic Storage Ring CSR at the Max-Planck Institute for Nuclear Physics in Heidelberg. For this purpose, a high detection efficiency for molecule fragments with kinetic energies between 1 and 300 keV, rates up to several hundred hits per second and multi-hit capability are required. We present the detector design and recent measurements showing the full functionality of the detector. Measurements with 6 keV X-ray photons yielded an energy resolution of 88 eV (FWHM). With this, MOCCA meets all the requirements for its use at the CSR. MOCCA is presently the largest and most complex MMC-based detector.

MS 4: Storage Rings

Time: Tuesday 10:45–12:15 Location: H2

Invited Talk MS 4.1 Tue 10:45 H2

Reaction studies with internally cold molecular ions in a storage ring — •Oldřich Novotný — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

In last decades room-temperature ion storage rings have proven to be unique tools for investigating properties and reaction dynamics of molecular ions, in particular the low-energy electron-ion collisions in merged beams. This is mainly due to 1) the long storage of the ions allowing relaxation of the internal ion states and 2) the ion beam target preparation for experiments at high collision-energy resolution by, e.g., electron cooling. The recently built Cryogenic Storage Ring (CSR) [1] in Heidelberg, Germany, with its < 6 K vacuum wall temperature brings these advantages to a new level: the low radiation field allows the molecules to relax down to their ro-vibrational ground-state. Studying collisions of cold molecular ions with electrons, photons, and atoms give access to unprecedented details on the respective reaction dynamics. Also, the CSR environment mimics well the conditions in the cold interstellar medium, which makes CSR an outstanding experimental set-up for laboratory astrochemistry.

In the talk the measurements from the first five years of CSR operation will be reviewed, with an emphasis on the recent rotational-state resolved dissociative recombination studies [2].

[1] R. von Hahn et al. Rev. Sci. Instr. 87 063115 (2016)
[2] O. Novotny et al., Science 365, 676 (2019)

MS 4.2 Tue 11:15 H2

Integration of the 4k-pixel molecule camera MOCCA into the Cryogenic Storage Ring CSR and a CSR-independent experimental setup — •Lisa Gamer[1], Christian Enss[2], Andreas Fleischmann[2], Ansgar Lowack[2], Michael Rappaport[3], Dennis Schulz[2], Abhishek Shahi[3], Yoni Toker[4], Andreas Wolf[1], and

Oldřich Novotný[1] — [1]MPIK Heidelberg — [2]KIP Heidelberg University — [3]Weizmann Institute of Science, Rehovot, Israel — [4]Bar-Ilan University, Ramat Gan, Israel

The Cryogenic Storage Ring CSR at the Max Planck Institute for Nuclear Physics, Heidelberg, can store heavy molecular ions in their rotational and vibrational ground states, thus enabling to investigate electron-ion interactions such as dissociative recombination in laboratory environment at conditions that are close to those in cold interstellar plasmas. To reconstruct the full kinematics of these processes, a position and energy sensitive coincident detection of multiple reaction products is necessary. For this purpose, MOCCA, a 4k-pixel molecule camera based on magnetic calorimeters with a detection area of 45 mm × 45 mm, was developed and fabricated at the Kirchhoff-Institute for Physics in Heidelberg. We present the plans for integrating MOCCA and its ^{3}He/^{4}He dilution refrigerator into CSR as well as a CSR-independent experimental setup where MOCCA will be used to study collision- and photon-induced ion fragmentation processes.

MS 4.3 Tue 11:30 H2

First isochronous mass spectrometry in an electrostatic storage ring — •Viviane C. Schmidt[1], Manfred Grieser[1], Klaus Blaum[1], Ábel Kálosi[1,2], Holger Kreckel[1], Damian Müll[1], Oldřich Novotný[1], Felix Nuesslein[1], and Andreas Wolf[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Columbia Astrophysics Laboratory, Columbia University, New York, 10027 New York, USA

In magnetic storage rings isochronous mass spectrometry is a vital tool for radionuclei mass measurements. These experiments require relativistic beam energies and low beam emittance and momentum spread, reachable only by means of additional phase-space cooling. Here, we report the first isochronous operation of an electrostatic storage ring, achieved at the Cryogenic Storage Ring facility at the Max-Planck-Institut für Kernphysik in Heidelberg. At non-relativistic energies of a few hundred keV and using beams with typical momentum spreads of 10^{-3} and emittance of a few mm·mrad high resolution measurements were performed without the need of phase space cooling. Mass resolutions of $\frac{\Delta m}{m} < 10^{-5}$ could be reached and isobaric contaminations well below relative beam fractions of 10^{-4} could be identified at $A \sim 20$ u. Both the time-of-flight method and revolution frequency measurements using a Shottky pick-up were successfully employed. Due to the purely electrostatic storage, this method furthermore has the distinct advantage over magnetic storage rings of providing a nearly unlimited mass operation range, enabling measurements from small atoms to complex molecule and cluster systems.

MS 4.4 Tue 11:45 H2

High resolution and fast Schottky spectroscopy of short-lived fragments in isochronous heavy ion storage rings — •Shahab Sanjari[1,2], Klaus Blaum[3], Dmytro Dmytriiev[1,4], David Freire Fernández[1,3], Yuri A. Litvinov[4], and Wolfram Korten[5] — [1]GSI Helmholtz Center, D-64291 Darmstadt, Germany — [2]Aachen University of Applied Sciences, D-52005 Aachen, Germany — [3]Max Planck Institute for Nuclear Physics, D-69117 Heidelberg, Germany — [4]Heidelberg University, D-69117 Heidelberg, Germany — [5]IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France

Using non-destructive Schottky detectors, precise determination of masses and lifetimes of exotic nuclear species and their isomeric states can be performed at the experimental storage ring ESR (GSI / FAIR) on cooled fragments (standard mode of operation) and hot fragments (isochronous mode). Single ion sensitivity has regularly been achieved in the past using the former mode of operation. Up to now only destructive detection methods were employed in the latter mode. In this work we describe how the limits of time resolution can be pushed in conjunction with non-destructive and time-resolved frequency analysis of signals acquired from recently developed detectors. These detectors deliver higher sensitivity as well as a higher frequency resolution. This approach will open new opportunities to explore highly charged exotic nuclei with lifetimes down to several tens of milliseconds and energies as low as 100 keV. It is as well a milestone achievement towards the realization of precision mass and lifetime spectrometry at future Collector Ring of FAIR.

MS 4.5 Tue 12:00 H2

Mass-spectrometry assisted measurement of the bound-state beta decay of ^{205}Tl^{81+} ions — •Rui-Jiu Chen, Ragandeep Singh Sidhu, Yuri A Litvinov, and E121 collaboration — GSI Helmholtzzentrumfr Schwerionenforschung, Planckstrae 1, 64291 Darmstadt, Germany

Beta decay of highly charged ions [1] has attracted much attention in recent years. The studies of beta decay of highly charged ions can be performed solely at ion storage rings and ion traps where their high atomic charge states can be preserved for extended periods of time (up to several hours) and the decay products can be identified by using precision mass spectrometry. In this talk, we will report on the recent results from the first direct measurement of the bound-state beta decay of bare ^{205}Tl^{81+} ions. The experiment was performed in March-April 2020 at GSI. The experiment is associated with two major physics motivations. One is linked with the LOREX [2] project (acronym of LORandite EXperiment) wherein the measurement is needed to determine the matrix element for the pp neutrino capture by the ground state of ^{205}Tl to the 2.3 keV excited state in ^{205}Pb. This capture reaction has by far the lowest threshold (E > 53 keV) and is thus of utmost significance for extending the neutrino flux to lower energies. The second physics case is associated with the ^{205}Pb-^{205}Tl pair as a s-process cosmochronometer. The measurement is crucial for the clarification of the fate of ^{205}Pb in the early solar system. Reference: [1] Yu. A. Litvinov, F. Bosch, Rep. Prog. Phys. 74, 016301, (2011). [2] M.K. Pevićević et al., Nucl. Instr. and Meth. A 621, 282 (2010).

MS 5: Annual General Meeting of the Mass Spectrometry Division

Time: Tuesday 12:15–13:15 Location: MVMS

Mitgliederversammlung

MS 6: New Developments I

Time: Tuesday 14:00–15:30 Location: H2

Invited Talk MS 6.1 Tue 14:00 H2

The Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy and its potential for fast and highly selective mass separation — •Stephan Malbrunot — CERN, ISOLDE, Experimental Physics Department, CH-1211 Geneva 23, Switzerland

Collinear laser spectroscopy (CLS) is a powerful tool to access nuclear ground state properties of short-lived radionuclides such as spin, charge radius, and electromagnetic moments. Conventional CLS is based on the detection of fluorescence from laser-excited ions or atoms. It is limited to radioactive ion beams with yields of more than 100 to 10,000 ions/s, depending on the specific case and spectroscopic transition.

To reach radionuclides with lower production yields, we have developed the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy (MIRACLS) [1,2]. It is based on a Multi Reflection Time of Flight (MR-ToF) device in which ions bounce back and forth between electrostatic mirrors. The trapped ions are probed by the laser during each revolution inside the MR-ToF device which largely enhances the sensitivity of CLS.

As part of MIRACLS, we are developing new cooling schemes as well as an unprecedented 30-keV MR-ToF device. These techniques also open new possibilities for fast and highly selective mass separation beneficial for a wide range of applications. This talk will present the MIRACLS concept and its first experimental highlights.

[1] S. Sels et al., Nucl. Instr. Meth. Phys. Res. B, 463, 310 (2020) [2] V. Lagagki et al., Nucl. Instr. Meth. Phys. Res. B, in press (2021)

MS 6.2 Tue 14:30 H2

Advancing radiation detected resonance ionization towards heavier elements and more exotic nuclides — •Jessica Warbinek[1,2], Brankica Andelić[1,3], Michael Block[1,2,4], Premaditya Chhetri[1,4], Arno Claessens[5], Rafael Ferrer[5], Francesca Giacoppo[1,4], Oliver T. Kaleja[1,6], EunKang Kim[2], Mustapha Laatiaoui[2], Jeremy Lantis[2], Andrew Mistry[1,7], Danny Münzberg[1,2,4], Steven Nothhelfer[1,2,4], Sebastian Raeder[1,4], Emmanuel Rey-Herme[8], Elisabeth Rickert[1,2,4], Jekabs Romans[5], Elisa Romero-Romero[2], Marine Vandebrouck[8], and Piet Van Duppen[5] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Germany — [2]Johannes Gutenberg-Universität, Mainz, Germany — [3]KVI-CART, Groningen, The Netherlands — [4]Helmholtz Institut Mainz, Germany — [5]KU Leuven, IKS, Belgium — [6]Universität Greifswald, Germany — [7]TU Darmstadt, Germany — [8]CEA Saclay, France

RAdiadtion Detected Resonance Ionization Spectroscopy (RADRIS) is a versatile method for highly sensitive laser spectroscopy of the heaviest actinides. Here, most of the nuclides need to be produced at accelerator facilities in fusion-evaporation reactions and are studied immediately after production and separation due to their short lifetimes and low production rates of only a few atoms per second or less. Only recently, the first laser spectroscopic investigation of nobelium (Z=102) was performed by applying the RADRIS technique in a buffer-gas filled stopping cell at the GSI in Darmstadt. To expand this technique for the search of the first atomic levels in the heaviest actinide, lawrencium (Z=103), the sensitivity of this setup needs to be improved. Therefore, a new movable detector design was added increasing the RADRIS efficiency by about 75 %. Further development work was performed to enable the study of longer-lived (>1 h) and shorter-lived nuclides (<1 s) with the RADRIS method.

MS 6.3 Tue 14:45 H2

Development of an apparatus for in gas-jet laser spectroscopy of the heaviest elements — •Danny Münzberg[1,2,3], Michael Block[1,2,3], Arno Claessens[4], Piet Van Duppen[4], Rafael Ferrer[4], Jekabs Roman[4], Sandro Kraemer[4], Jeremy Lantis[3], Mustapha Laatiaoui[3], Steven Nothhelfer[1,2,3], Sebastian Raeder[1,2], Simon Sels[4], and Thomas Walther[5] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, DE — [2]Helmholtz-Institut Mainz, DE — [3]Department Chemie, Johannes Gutenberg-Universität, Mainz, DE — [4]Instituut voor Kern- en Stralingsfysica, KU Leuven, Leuven, Belgium — [5]Technische Universität Darmstadt

Laser spectroscopy is a commonly used technique for determining basic nuclear and atomic properties. At GSI-Darmstadt, we focus on studying elements in the heavy actinide region. Due to low production rates in these experiments, high efficiency and sensitivity are necessary. The Radiation Detected Resonance Ionization (RADRIS) technique has been used to study isotopes of Nobelium. However, with this technique the spectral resolution is limited to a few GHz, preventing the determination of nuclear properties from hyperfine spectra. To overcome this problem, an in-gas-jet-spectroscopy apparatus is being developed. It combines features of the RADRIS and the in-gas-jet technique to minimize typical broadening mechanisms and improving the spectral resolution by about an order of magnitude. Laser induced fluorescence measurements on Yb and Dy samples have been performed to compare different hypersonic nozzles with respect to the obtained gas-jet conditions for high resolution laser spectroscopy. Recent results will be discussed and an update on the status of the gas jet apparatus will be given.

MS 6.4 Tue 15:00 H2

Conceptual design of an actinide ion mobility spectrometer — •Elisabeth Rickert[1,2,3], Hartmut Backe[3], Michael Block[1,2,3], Christoph E. Düllmann[1,2,3], Mustapha Laatiaoui[1,3], Werner Lauth[3], Sebastian Raeder[2], and Philipp Sikora[3] — [1]Helmholtz-Institut Mainz, Mainz, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [3]Johannes Gutenberg-Universität Mainz, Mainz, Germany

Chemical and physical properties of the heaviest elements are strongly influenced by relativistic effects which can result in deviations from the periodicity predicted by the periodic table of elements. Systematic mobility measurements on monoatomic lanthanide ions previously proved a dependence of ion-atom interactions on the underlying electronic configuration, providing a way to measure these deviations [Laatiaoui2012]. Mobility studies are presently being extended to the actinides which are expected to have more pronounced deviations from periodicity. In our experiment, element-selective ion production is provided by two-step photo ionization from a filament sample in an argon filled drift cage. In my talk, experimental approach, first results and future plans are presented.

[Laatiaoui2012]: Laatiaoui, M. et al., EPJD (2012) 66:232

MS 6.5 Tue 15:15 H2

Design of an isotope separator for target production — •Dominik Studer[1], Rugard Dressler[2], Ulli Köster[3], Dorothea Schumann[2], and Klaus Wendt[1] — [1]JGU Mainz — [2]PSI Villigen — [3]ILL Grenoble

With the rising demand for isotopically pure targets for the study of specific nuclear reactions, the construction of a high-throughput isotope separator is foreseen within the SANDA project. Specifically the handling and purification of radioisotopes is mandatory and will be enabled by installation of the whole setup within a radioactivity monitoring area in close contact to a hot lab. In the current project phase the design of the apparatus and establishment of a suitable facility, located at PSI, is planned. The design will be derived from experiences with the RISIKO isotope separator at Mainz University, which has been successfully used for radioisotope purification and implantation, e.g. within the ECHo project. It features a hot-cavity laser ion source. The laser system is based upon tunable pulsed Ti:sapphire lasers with high repetition-rate. Ion extraction from the source region with about 30 kV, electrostatic beam focussing and separation with a conventional double focussing sector field magnet seem most suitable for the task. After passing the separation slit, the ion beam can be re-focused to well below mm size for implantation into detectors, collectors or targets with sub mm control and resolution. In this contribution we present the principles, capabilities and limitations of the RISIKO separator using experimental and simulation data. Improvements which can be implemented in the new SANDA isotope separator are discussed.

MS 7: Accelerator Mass Spectrometry I

Time: Thursday 10:45–12:30 Location: H3

Invited Talk MS 7.1 Thu 10:45 H3

The new compact, multi isotope AMS system (MILEA) at ETH Zurich - performance and applications — •Marcus Christl[1], Sascha Maxeiner[2], Arnold Müller[2], Philip Gautschi[1], Christof Vockenhuber[1], and Hans-Arno Synal[1] — [1]ETH Zürich, Switzerland — [2]Ionplus AG, Dietikon, Switzerland

The prototype version of a new, compact, multi-isotope, low energy accelerator mass spectrometry system (MILEA) was built in collaboration with Ionplus AG and set into operation at ETH Zurich in late 2018. The system is based on a 300 kV power supply and was optimized for small footprint (3.5 x 7 m^2) and to reach optimal performance for ^{10}Be, ^{14}C, ^{26}Al, ^{129}I, and actinide measurements at low energies. During the past years the system was thoroughly tested and it is now increasingly being used for routine AMS operations.

In the first part of the presentation, the layout of the system, its properties and setup for the different nuclides will be presented and the performance of the system will be discussed for the different nuclides. In the second part of the presentation some recent results of our actinide and heavy ion program will be presented including a $^{236}U/^{238}U$ record from sea shells in the Northeast Atlantic Ocean and $^{233}U/^{236}U$ data from the Arctic Ocean.

MS 7.2 Thu 11:15 H3

Integration of the EA-IRMS system to the CologneAMS facility — •Martina Anna Gwozdz, Gereon Hackenberg, Stefan Heinze, Susan Herb, Timm-Florian Pabst, Markus Schiffer, Alexander Stolz, and Alfred Dewald — Institute for Nuclear Physics, University of Cologne, Germany

Recently a new elemental analyser (EA) and an isotope ratio mass spectrometer (IRMS) for stable isotopes have been installed at the 6MV AMS device of CologneAMS. In addition to the ^{14}C content of a sample this will provide precise values of stable isotopic ratios like δ^{13}C or δ^{15}N.

A direct connection to the existing gas interface as well as the implementation of the new devices into the control software of the existing AMS system were realized. In this way it is possible to measure quasi-simultaneously the ^{14}C concentration with the 6MV AMS system and the δ^{13}C value with the IRMS device.

We will also investigate whether this new set-up will enable improved fractionation correction which are used in the ^{14}C data evaluation as proposed by Ravi Prasad et al. [1].

[1] G.V. Ravi Prasad et al., 2019, δ^{13}C correction to AMS data: Values derived from AMS vs IRMS values., Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, v. 455, p.244-249

MS 7.3 Thu 11:30 H3

Investigation of the beam trajectory and beam profile development in the 135° gas-filled magnet at the AMS device for medium mass isotopes at the Cologne University — •Susan Herb, Gereon Hackenberg, Markus Schiffer, Stefan Heinze, and Alfred Dewald — Institute of Nuclear Physics, University of Cologne, Germany

First ^{53}Mn and ^{60}Fe test measurements revealed that improvements of the AMS set-up at the FN tandem accelerator should be made to enable the measurement of lower level isotopic ratios of 10^{-13} and 10^{-16}, respectively. Therefore, we aim to improve the isobar separation of the high energy mass spectrometer and its transmission. The beam profile along the ion paths through the 135° gas-filled magnet was measured in the dispersive direction (x-axis) with homemade silicon pin diode detector arrays. It was measured at 4 locations along the flight path in x direction and two-dimensional (x/y) at the exit of the magnet. We also investigated the effect of using nitrogen or helium gas. The measured data was used to test our in-house developed Monte-Carlo simulation code, which simulates the ion transport in a gas-filled magnet. The first version of the code was designed for nitrogen gas and was now adapted for helium. The comparison of the calculated and the measured beam trajectories revealed that the gas density effect influencing the ion charge has to be considered [1]. The contribution will report on details of the conducted measurements and compare it with the calculations. Ongoing developments of the simulation code will be discussed. [1] Betz, 1972, Reviews of Modern Physics, 44.

MS 7.4 Thu 11:45 H3

Measurements of volatile radioactive isotopes in reactor graphite — •Timm-Florian Pabst[1], Gereon Hackenberg[1], Stefan Heinze[1], Susan Herb[1], Yannik Jacobi[1], Markus Schiffer[1], Alexander Stolz[1], Erik Strub[2], and Alfred Dewald[1] — [1]Institute for Nuclear Physics, University of Cologne, Germany — [2]Department of Chemistry, University of Cologne, Germany

Activated graphite, e.g. from graphite moderated reactors, contains several radioactive nuclides like ^{14}C, ^{36}Cl, or ^{3}H. For the final disposal of such material a quantitative characterization is demanded.
We are aiming for a system which enables automated measurements using the AMS technique with gaseous samples, for ^{14}C, ^{36}Cl, and ^{3}H, The planned system should provide a high sample throughput as well as the possibility of sample dilution in cases of high activity. Therefore a new gas-interface was built which uses two syringes for the transport of the sample gas into the ion source and a separate reservoir for blank gas which can be used for the dilution.
For the measurement of the tritium concentration, we expanded our ion source test bench. A 100 kV accelerator stage with a carbon stripper foil in the centre was installed along with an additional 90° analysing magnet and a silicon detector. This will allow efficient and accurate characterisation of the activity in reactor graphite material, which is foreseen be stored in repositories like e.g. the mine Konrad where activity limits have to be considered. In this contribution we will present the layout of our systems as well as its present status.
Supported by BMBF under contract number 15S9410B.

MS 7.5 Thu 12:00 H3

Developments towards the detection of ^{135}Cs and ^{137}Cs by AMS — •Alexander Wieser[1], Johannes Lachner[1,2], Dorian Zok[3], Martin Martschini[1], Peter Steier[1], Alfred Priller[1], and Robin Golser[1] — [1]University of Vienna, Faculty of Physics - Isotope Physics, Vienna, Austria — [2]Helmholtz-Zentrum Dresden-Rossendorf, Accelerator Mass Spectrometry and Isotope Research, Dresden, Germany — [3]Leibniz Universität Hannover, Institute of Radioecology and Radiation Protection, Hannover, Germany

The isotopic ratio ^{135}Cs/^{137}Cs can be used to assign sources of anthropogenic cesium input, or as a geochemical tracer, or for modifying anthropogenic radionuclide dispersion models. Due to the long half-life of ≈ 2.3 Ma, ^{135}Cs is hard to detect via radiometric methods, while mass spectrometry has to deal with isobaric interferences, i.e. ^{135}Ba and ^{137}Ba for Cs detection. The new method of Ion Laser InterAction Mass Spectrometry (ILIAMS) at the Vienna Environmental Research Accelerator (VERA) overcomes this problem by exploiting differences in the electron affinities of CsF_2^- and BaF_2^-. A $^{133}CsF_2^-$ current on the order of 50 nA from a mixed Cs_2SO_4 and PbF_2 - matrix is extracted from the ion source. At VERA two sputtering processes are currently investigated: Rubidium sputtering and negative ion production without external sputter agent. First results show reproducible detection of ^{135}Cs and ^{137}Cs in an in-house reference material, while reaching blank levels of ^{135,137}Cs/^{133}Cs = $6{\cdot}10^{-12}$. We aim to reduce this value by at least two orders of magnitude for measuring environmental samples.

MS 7.6 Thu 12:15 H3

First studies on ^{99}Tc detection using Ion Laser InterAction Mass Spectrometry (ILIAMS) — •Johanna Pitters[1,2], Fadime Gülce[1], Karin Hain[1], Martin Martschini[1], and Robin Golser[1] — [1]University of Vienna, Faculty of Physics — [2]Vienna Doctoral School in Physics

Minute environmental concentrations of the anthropogenic radionuclide ^{99}Tc ($t_{1/2}$=$2.1{\cdot}10^5$ a) can serve as a tracer for transport processes e.g. in oceanography. However, detection of environmental ^{99}Tc presently requires Accelerator Mass Spectrometry (AMS) at the largest facilities available in order to adequately suppress the strong interference from the isobar ^{99}Ru.

As part of an FWF-funded project, we aim at making ^{99}Tc accessible for measurement at the 3-MV facility VERA (Vienna Environmental Research Accelerator) with the novel isobar suppression technique of ILIAMS (Ion Laser InterAction Mass Spectrometry). For this development, laser photodetachment, chemical sample preparation, sample matrix material and ion source output all require optimization. As there is no stable Tc isotope, a normalization to an isotopic Tc spike material, e.g. ^{97}Tc, or a stable reference isotope of another element needs to be established as well.

This contribution presents the ongoing development and preliminary results, which yield a laser-suppression of Ru by up to 5 orders of magnitude and a ^{99}Tc-detection limit of less than 10^6 atoms.

MS 8: Accelerator Mass Spectrometry II

Time: Thursday 14:00–15:15 Location: H3

MS 8.1 Thu 14:00 H3

Status of the Project LISEL@DREAMS — •Oliver Forstner[1,2,3], Thomas Weber[1], Vadim Gadelshin[4], Kurt Stiebing[5], Dominik Studer[4], and Klaus Wendt[4] — [1]Friedrich-Schiller-Universität Jena, Jena — [2]Helmholtz-Institut Jena, Jena — [3]GSI Holmholtzzentrum, Darmstadt — [4]Johannes Gutenberg-Universität Mainz, Mainz — [5]Goethe-Universität Frankfurt, Frankfurt

The LISEL setup (Low-energy Isobar SEparation by Lasers) is currently being built at the University of Jena in the framework of a BMBF funded project. It comprises a gas-filled radio frequency quadrupole cooler where negative ions will be slowed down to thermal energies and overlapped with a laser beam. This allows an elemental selective suppression of isobars by laser photodetachment by careful selection of the photon energy. The tuneable Ti:Sapphire laser system is currently being developed at the University of Mainz. After

commissioning the setup LISEL will be transferred to the DREAMS (DREsden AMS) facility at the Helmholtz Center Dresden Rossendorf (HZDR).

To get the required spectroscopic data especially for negative molecular ions a measurement program is currently being established at the low-energy electrostatic storage ring FLSR at the University of Frankfurt. This allows to study vibrationally cold molecules and acquire photodetachment data to establish further suppression schemes. This allows to study currently unavailable new isotopes and extends AMS to many new applications.

MS 8.2 Thu 14:15 H3

A new radio frequency quadrupole ion cooler for Accelerator Mass Spectrometry — •Markus Schiffer[1], Oscar Marchhart[2], Susan Herb[1], Martin Martschini[2], Robin Golser[2], and Alfred Dewald[1] — [1]University of Cologne, Institute for Nuclear Physics, Germany — [2]University Vienna, Faculty of Physics, Vienna Environmental Research Accelerator (VERA), Austria

Ion Laser Interaction Mass Spectrometry (ILIAMS) has demonstrated a high isobar suppression capability for a variety of radionuclides by selective laser photodetachment of decelerated ion beams in a gas-filled radio frequency quadrupole cooler (RFQ). Furthermore, the admixture of O_2 gas to the helium buffer gas has revealed an impressively high isobar suppression, larger 10^5 in the case of $^{90}Sr/^{90}Zr$, at the Vienna Environmental Research Accelerator (VERA), even without the use of the laser. Therefore, we started to develop a radio frequency quadrupole cooler designed for the deceleration and trapping of ion beams with high beam emittance like heavy molecular anions, e.g. $^{90}SrF_3$. The new ion cooler will be used with gas reactions and is intended to be improved by the addition of a laser in a later phase. This contribution will present details of the RFQ, like the ion optic calculation of the injection electrodes and the guiding field. Different guiding field structures will be compared by the calculation of multipole expansion coefficients. Additionally, a radio frequency resonance tuning and impedance matching system for heavy radionuclide applications will be presented.

MS 8.3 Thu 14:30 H3

Relative Formation Probabilities for Fluoride and Oxyfluoride Anions of U, Np, Pu and Am in Accelerator Mass Spectrometry Measurements at VERA — •Andreas Wiederin[1], Robin Golser[1], Karin Hain[1], Michael Kern[1], Aya Sakaguchi[2], and Peter Steier[1] — [1]University of Vienna, Faculty of Physics - Isotope Physics — [2]University of Tsukuba, Faculty of Pure and Applied Science

The relative formation probabilities for a range of (oxy-)fluoride molecular anions of uranium, neptunium, plutonium, and americium during the sputtering process in an AMS ion source from an iron oxide matrix mixed with PbF_2 have been systematically investigated at VERA. Identifying this distribution is an important step towards the separation of U and Np isobars via element selective photodetachment and reactive gases in the ILIAMS ion-cooler. A suitable choice of extracted molecular anions can be used to suppress U by an order of magnitude compared to Np. Finally, the distribution and in particular the AF_4^- to AF_5^- ratio can help to identify isobaric contaminations for the mentioned actinides. This method was used to estimate the co-production of ^{236}U during Th irradiation which is considered for the production of ^{236}Np, a potential isotopic spike for ^{237}Np.

MS 8.4 Thu 14:45 H3

Increasing the ionization yield for the detection of ^{236}U and ^{233}U by AMS — •Michael Kern, Karin Hain, Peter Steier, Andreas Wiederin, and Robin Golser — University of Vienna, Faculty of Physics - Isotope Physics, Vienna, Austria

The detection efficiency of Accelerator Mass Spectrometry for uranium isotopes ^{236}U or ^{233}U is mainly limited by the rather low yield of the corresponding negative ions extracted from a caesium sputter ion source ($\approx 10^{-4}$). With our new sample preparation method environmental U is embedded in only 200 μg Fe_2O_3 matrix which is then mixed with PbF_2. Extracting U as UF_5^- instead of UO^- yields an improvement in detection efficiency of up to a factor of 10. Thus significantly shortened measurement duration can be obtained, while maintaining the same statistical uncertainty. UF_5^- extraction seems advantageous for the suppression of molecular isobaric background ($^{233}ThH^{3+}$, $^{233}UH^{3+}$) and allows operation at lower He stripper gas pressure. This presentation will give detailed insights on the new sample preparation as well as ion current characteristics and method verification.

MS 8.5 Thu 15:00 H3

Low-level ^{166m}Ho measurements with AMS for the ECHo-project — •Georg Rugel[1], Sebastian Berndt[2], Christoph E. Düllmann[2,3,4], Holger Dorrer[2], Oliver Forstner[5,6], Tom Kieck[2,7], Nina Kneip[2,7], Johannes Lachner[1], Silke Merchel[1,8], Carlos Vivo-Vilches[1], Anton Wallner[1], and Klaus Wendt[7] — [1]Accelerator Mass Spectrometry and Isotope Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden — [2]Department of Chemistry, Johannes Gutenberg University, Mainz — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [4]Helmholtz Institute Mainz, Mainz — [5]Friedrich-Schiller-University Jena — [6]Helmholtz Institute Jena, Jena — [7]Institute of Physics, Johannes Gutenberg University — [8]Isotope Physics, Faculty of Physics, University of Vienna, Vienna, Austria

The Electron Capture in ^{163}Ho experiment (ECHo) aims at measuring the mass of ν_e by analysing the EC spectrum of the long-lived radionuclide ^{163}Ho ($T_{1/2} = 4570$ a) with a metallic magnetic calorimeter (MMC). For the determination of a reasonable upper limit for the neutrino mass it is mandatory to keep any contamination with the long-lived radionuclide ^{166m}Ho nine orders of magnitude below the ^{163}Ho content. The ion-implantation of ultra-pure ^{163}Ho into a MMC for the experiment is carried out by the RISIKO mass separator. The separation from ^{166m}Ho, however, cannot be quantified to such low levels as needed. Here we present our approach to determine the corresponding low isotopic ratio with accelerator mass spectrometry (AMS). This requires the formation of negative ions, we find the highest negative ion yield for the anion HoO_2^-. For first tests ^{165}Ho was implanted by RISIKO in various metal foils and we obtained results for the Ho detection efficieny. This allows for extrapolations for the expected measurement limit of the $^{166m}Ho/^{163}Ho$ ratio.

MS 9: New Developments II

Time: Friday 10:45–12:00 Location: H2

Invited Talk MS 9.1 Fri 10:45 H2

Spatially resolved ultra-trace analysis of actinides on hot particles by resonant laser-SNMS — •Hauke Bosco[1], Martin Weiss[1], Manuel Raiwa[1], Nina Kneip[2], 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

A titanium:sapphire resonance excitation laser system for element selective ionization of sputtered neutrals has been linked to a commercial TOF-SIMS for spatially resolved ultra-trace isotope detection [1]. The system allows analysis of stable and radioactive isotope ratios with 70 nm spatial resolution. Synthetic as well as environmental samples are measured on either conducting or non-conducting samples. As an example, investigations of hot particles from the Chernobyl exclusion zone will be presented and discussed with respect to isotopic ratios of uranium, plutonium, americium and strontium. By suppression of isobaric interferences minor acitinide isotopes on the scale of a few fg were detected within the analyzed fuel matrix. Additionally, Pu-238 was unambiguously identified despite five orders of magnitude of U-238 isobaric contamination. Ongoing excitation scheme development, influences of the plutonium hyperfine structure on the resulting isotope signal and single particle analysis will be presented as a part of the BMBF funded project SIRIUS.

[1] Franzmann et al., Resonant laser-SNMS for spatially resolved and element selective ultra-trace analysis of radionuclides, JAAS 2018

Invited Talk MS 9.2 Fri 11:15 H2

Multi-reflection time-of-flight mass spectrometry for cluster research — •Paul Fischer and Lutz Schweikhard — Institut für

Physik, Universität Greifswald, 17487 Greifswald, Germany

Multi-reflection time-of-flight mass spectrometry (MR-ToF MS) is known as a powerful tool for precision mass measurements [1] and high-resolution isobar separation [2] in nuclear physics. In atomic and molecular physics, MR-ToF devices are appreciated for their characteristics as electrostatic ion traps [3]. However, they are often operated in non-bunching mode, abandoning high resolving powers in favor of easier interaction prerequisites.

At the University of Greifswald, MR-ToF MS is applied for high-resolution investigations of atomic clusters. Techniques for in-trap photodissociation, tandem MR-ToF MS, and the study of time-delayed dissociation processes have been developed. Examples include the dissociation behavior of bismuth clusters [4], the change thereof resulting from doping with a single lead atom [5], and the delayed dissociation of indium clusters [6].

[1] F. Wienholtz et al., Nature 498:346-349 (2013)
[2] R.N. Wolf at al., Phys. Rev. Lett. 110:041101 (2013)
[3] D. Zajfman et al., Phys. Rev. A 55:R1577-R1580 (1997)
[4] P. Fischer at al., Eur. Phys. J. D 73:105 (2019)
[5] P. Fischer at al., Phys. Rev. Research 1:033050 (2019)
[6] P. Fischer at al., Phys. Rev. Research 2:043177 (2020)

MS 9.3 Fri 11:45 H2

Development of a Python application for isotope pattern analysis of small metal complexes measured with an Orbitrap analyzer and electrospray ionization — •Anna Kogiomtzidis, Julia Stadler, Michael Steppert, and Clemens Walther — Institute of Radioecology and Radiation Protection, Leibniz University Hannover, Germany

Isotope pattern analysis is a well established method for the evaluation of mass spectral data. Especially in metabolomics and proteomics it is widely used. While these research fields concentrate mainly on relatively large biomolecules, this work focuses on metal ions complexed by anorganic or small organic ligands. This type of compound is relevant for instance in the context of radioecology when studying the transport behavior of radionuclides in different chemical environments.

A Python module plus graphical interface was developed to assist with the investigation of metal complexes by mass spectrometry. The application includes two main functionalities. First, an algorithm was implemented to scan mass spectra for peak groups matching a given isotope pattern in order to identify compounds possibly containing an element of interest. Second, it is possible to search for specific chemical species defined by molecular formulas. Further, some additional features including data preprocessing and calculation of possible sum formulas for a given signal are available.

The software was tested with several solutions of europium, zirconium and uranium with natural isotope abundances to examine a range of different isotopic configurations.