

MS 7: Poster

Time: Thursday 16:30–19:00

Location: Empore Lichthof

MS 7.1 Thu 16:30 Empore Lichthof

Doppler- and sympathetic cooling for the investigation of short-lived radionuclides — ●FRANZISKA MARIA MAIER^{1,2} and SIMON SELS¹ — ¹ISOLDE/CERN — ²Universität Greifswald

For the MIRACLS collaboration.

Ever since its introduction in the mid 1970s, laser cooling has become a fundamental technique to prepare and control ions and atoms for a wide range of precision experiments. Nevertheless, because of its simplicity and element-universality, buffer-gas cooling in a linear, room-temperature Paul trap is more commonly used at contemporary radioactive ion beam (RIB) facilities. Recent advances in experimental RIB techniques, especially in laser spectroscopy and mass spectrometry, would however strongly benefit from ion beams at much lower beam temperature as in principle attainable by laser cooling.

Within the MIRACLS low-energy apparatus, we demonstrate that laser cooling is compatible with the timescale imposed by short-lived radionuclides as well as with existing instrumentation at RIB facilities[1]. Despite an initial kinetic energy of the externally-produced hot ions of several eV at the trap's entrance, temporal widths of the extracted ion bunches corresponding to an ion-beam temperature of around 6 K are obtained within a cooling time of 200 ms.

I will present the experimental results of our laser cooling studies, including the improvement of mass resolving power of an MR-ToF device (electrostatic ion beam trap), and give an outlook to future opportunities for high-precision measurements at RIB facilities.

[1] S. Sels, F.M.Maier et al, Phys.Rev.Res. 4, 033229 (2022).

MS 7.2 Thu 16:30 Empore Lichthof

Atomic Vapor Laser Isotope Separation of ⁴⁸Ca — ●DOMINIK STUDER^{1,2,3}, TOM KIECK^{1,2}, SEBASTIAN RAEDER^{1,2}, MICHAEL BLOCK^{1,2,4}, CHRISTOPH E. DÜLLMANN^{1,2,4}, and KLAUS WENDT³ — ¹Helmholtz-Institut Mainz — ²GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — ³Institut für Physik, JGU Mainz — ⁴Department Chemie - Standort TRIGA, JGU Mainz

Due to its high neutron excess, ⁴⁸Ca is a highly favorable nuclide for accelerator-based production of superheavy elements (SHE) in fusion-evaporation reactions. Elements with atomic numbers >113 can exclusively be produced with this projectile. Consequently, the SHE programme at, e.g., GSI Darmstadt depends critically on the availability of gram amounts of this isotope. Since ⁴⁸Ca has a low abundance of 0.187% in natural calcium, an isotope enrichment process is mandatory. In order to assess local production capabilities, a tabletop Atomic Vapor Laser Isotope Separation (AVLIS) setup is being tested at JGU Mainz. A highly collimated atomic beam of calcium is produced from an array of heated microcapillaries and ⁴⁸Ca is selectively ionized in a three-step photoionization process by pulsed laser radiation. Ions are separated by an electric field and collected on a metal plate. The efficiency, selectivity and scalability of this setup is studied. The present status is presented in this contribution.

MS 7.3 Thu 16:30 Empore Lichthof

Towards deterministic ionization and loading of molecules for quantum logic spectroscopy — ●RENÉ NARDI, STEFAN WALSER, BRANDON FUREY, ZHENLIN WU, GUANQUN MU, and PHILIPP SCHINDLER — Institut für Experimentalphysik, Universität Innsbruck

Our group studies the complex rovibrational structure of trapped molecular ions. These states are inaccessible to standard quantum information readout methods, but can be explored by co-trapping them with an atomic ion for which a convenient cooling and qubit level scheme exists. The molecular states can then be coupled to an electronic state of the atomic ion via quantum logic spectroscopy. To prepare and load arbitrary molecular species, we are developing a system where a molecular gas is leaked in, photoionized, and then accelerated towards a linear Paul ion trap. Ion optics are then used to steer the molecules through a differentially pumped region and into our UHV chamber. Molecules can be injected into the trapping region by adjusting the accelerating voltage and aligning the molecular beam through an aperture in the trap end cap. Here they can interact with an atomic ion crystal, cooling the molecules and resulting in their entrapment. We are building a setup to test this approach and we use time-of-flight mass spectrometry to map out the molecular ion species produced from

photoionization of various gasses.

MS 7.4 Thu 16:30 Empore Lichthof

A Faraday cup for absolute ion beam current determination at the RISIKO mass separator — ●RAPHAEL HASSE¹, SEBASTIAN BERNDT¹, VADIM GADELISHIN¹, CHRISTOPH E. DÜLLMANN^{1,2,3}, TOM KIECK^{2,3}, NINA KNEIP⁴, and KLAUS WENDT¹ — ¹Johannes Gutenberg-Universität Mainz — ²GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — ³Helmholtz-Institut Mainz — ⁴Leibniz Universität Hannover

Faraday cups are commonly used for ion beam current measurements. They provide an easy and robust way to quantitatively determine ion currents for different applications in mass spectrometry, accelerator operation and others. Based on comparative measurements using γ spectroscopy, which indicated a systematic underestimation of the ion beam current in earlier measurements, a new Faraday cup was developed and characterized at the RISIKO mass separator of the Johannes Gutenberg-University Mainz. During this work several target shapes and repeller configurations were investigated in simulations, optimized to compensate and minimize errors due to the loss of charged secondary particles, i. e., secondary electrons and sputtered secondary ions. Calibration measurements with ¹⁶⁵Ho using resonance ionization mass spectrometry confirm an absolute quantification of ion beams in the range of 100 pA to 100 nA with a precision of better than 5%.

MS 7.5 Thu 16:30 Empore Lichthof

Fe-55 ion implantation by resonance ionization mass spectrometry for the PrimA-LTD project — ●THORBEN NIEMEYER¹, SEBASTIAN BERNDT¹, HOLGER DORRER¹, NINA KNEIP², DENNIS RENISCH^{1,3}, DOMINIK STUDER^{1,3,4}, CHRISTOPH E. DÜLLMANN^{1,3,4}, and KLAUS WENDT¹ — ¹Johannes Gutenberg Universität Mainz, 55099 Mainz — ²Leibniz Universität Hannover, 30060 Hannover — ³Helmholtz-Institut Mainz, 55090 Mainz — ⁴GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt

New activity standardisation techniques for radionuclide metrology are developed within the scope of the the PrimA-LTD project. Low temperature micro calorimeters will be implanted with 100 Bq Fe-55 to measure its fractional electron-capture probabilities in the K-, L- and M-shell with high precision. This will allow experimental assessment of high-precision theoretical calculations.

The implantation of Fe-55 into the absorbers of the microcalorimeters is underway at the RISIKO mass separator at Mainz University. The resonance ionisation mass spectrometry method will be used due to its outstanding element selectivity and efficiency. Fully-automated pulsed Ti:Sa lasers are used to probe the atomic spectrum below and above the ionization potential. Measurements of Rydberg series allow the verification of the known ionization potential while strong auto-ionizing states will be used for the identification of a new element-selective two-step ionization scheme later to be used for the implantation. Laser spectroscopy and efficiency measurements of RISIKO are performed with stable Fe-56.

MS 7.6 Thu 16:30 Empore Lichthof

MOCCA: a 4k-pixel molecule camera for the position and energy resolved detection of neutral molecule fragments — ●DANIEL KREUZBERGER¹, CHRISTIAN ENNS¹, ANDREAS FLEISCHMANN¹, LISA GAMER², LOREDANA GASTALDO¹, CHRISTOPHER JAKOB², ANSGAR LOWACK¹, OLDŘICH NOVOTNÝ², ANDREAS REIFENBERGER¹, DENNIS SCHULZ¹, and ANDREAS WOLF² — ¹Heidelberg University — ²Max 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 neutral molecule fragments with keV kinetic energies. 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.

We present a new read-out scheme which uses only 32 SQUID chan-

nels for the 4096 pixels of the detector as well as some new fabrication details including copper-filled through-wafer vias to heat-sink the detector to the wafer backside. In addition we present the results of first characterization measurements.

MS 7.7 Thu 16:30 Empore Lichthof

Novel use of Actinide Resin[®] for multi-actinide analysis with AMS — ●THOMAS ROTH¹, FRANCESCA QUINTO¹, MARKUS PLASCHKE¹, KARIN HAIN², PETER STEIER², and HORST GECKEIS¹ — ¹Institute for Nuclear Waste Disposal (INE), Karlsruhe Institute of Technology (KIT), Germany — ²Faculty of Physics, University of Vienna, Austria

Fe(OH)₃ co-precipitation and conversion to an Fe₂O₃ specimen is an effective procedure for group separation (without subsequent column separation) and concurrent determination of actinides in aqueous environmental samples using AMS. However, matrix elements like Al and Si can also be precipitated in the process and thus increase the AMS specimen's mass. As previously observed, the overall detection efficiency of the actinides decreases with increasing matrix content of the AMS specimen, partly due to a dilution effect. A novel procedure employing Actinide Resin[®] has been tested and compared to the Fe(OH)₃ co-precipitation for preparation of two sets of six Rhine River water samples (each 2 L volume) collected near the French Fessenheim NPP. Preliminary results for separation efficiency indicate that the use of Actinide Resin[®] reduces the Al and Si content of the AMS specimen by ca. 80%. Such a result is supported by a similar reduction of the specimen mass. The results obtained with the two preparation methods were consistent with each other, indicating global fallout as origin with concentrations of ca. 10⁷ atoms/L for ²³⁷Np, ca. 10⁷ atoms/L for ²³⁶U and Pu at background level.

MS 7.8 Thu 16:30 Empore Lichthof

Super-SIMS - from the idea to first measurements — ●RENÉ ZIEGENRÜCKER¹, GEORG RUGEL¹, DOMINIK KOLL¹, JOHANNES LACHNER¹, AXEL D. RENNO¹, CARLOS VIVO VILCHES¹, ANTON WALLNER¹, and MICHAEL WIEDENBECK² — ¹Helmholtz-Zentrum Dresden-Rossendorf, Dresden — ²Deutsches GeoForschungsZentrum GFZ, Potsdam

The Dresden Super-SIMS is a combination of the DREAMS facility and a CAMECA IMS7f-auto as the ion source, and combines the advantages of both worlds: on one hand the suppression of molecular isobaric background with a 6 MV tandem accelerator and on the other the special and depth resolved information about the origin of the measured signals in the sample. This is possible without the samples undergoing any chemical treatment, and a polished surface (< a few nm) is sufficient for the measurement. While former attempts were intended to analyse semiconductor samples, the primary aim of Super-SIMS is the measurement of geological samples.

Nevertheless, first experiments were done with silicon to characterise the system and compare it with former attempts. Several samples with known content of phosphorus, including the blank, from the former URI-Project (Ultra clean injector) at the Technical University of Munich were measured. The sample with highest P content was used as internal reference material and the measurements showed a good agreement between measured concentrations by Super-SIMS and URI.

MS 7.9 Thu 16:30 Empore Lichthof

ISOLTRAP's new Mini-RFQ buncher for beam purification — ●DANIEL LANGE ON BEHALF OF THE ISOLTRAP COLLABORATION — Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany

High-precision mass measurements of radioactive ions are used to determine nuclear binding energies, which reflect all forces in the nucleus and are used to study among others nuclear structure, nuclear astrophysics and weak interaction. Far away from stability, production cross-sections drop and beams are contaminated with isobars and molecules, impeding precision measurements.

For this, the ISOLTRAP mass spectrometer at ISOLDE/CERN [1] uses various ion traps, including a tandem Penning-trap system and multi-reflection time-of-flight mass spectrometer (MR-ToF MS). The latter is suitable of both mass separation and fast, precise mass measurements. These two different modes of operation can be used in succession to enable measurements of extremely contaminated beams when a re-trapping system is used [2].

The new Mini-RFQ behind the MR-ToF MS should not only recapture the ions of interest, but also re-bunch them. Additionally, a cryogenic approach is pursued to further improve the precision of the mass measurement with the MR-ToF MS. The current setup of the ISOLTRAP

experiment is presented together with the future re-bunching design. For this purpose, the experimental test-setup with initial simulations will be outlined in more detail.

[1] Lunney D. et al., J. Phys. G: Nucl. Part. Phys. 44 (2017) 064008

[2] Dickel T. et al., J. Am. Soc. Mass Spectrom., 28 (6) (2017)

MS 7.10 Thu 16:30 Empore Lichthof

Design of a tandem mass spectrometer with ion trap to study particle nucleation under multicollisional conditions. — ●ANASTASIYA KHRAMCHENKOVA, YIHUI YAN, and JOZEF LENGYEL — TUM School of Natural Sciences, Technical University of Munich, Garching, Germany

The goal of our research is to describe the essential molecular factors of one of the most critical atmospheric processes - the first steps of new particle formation. During aerosol formation, small clusters can grow and dissociate at any time, but only few reach the critical size at which further growth of the particle becomes spontaneous. However, the size and chemical composition of such critical nuclei have yet to be characterized, as there is currently no suitable analytical method. To this end, we are developing a tandem mass spectrometer for investigating particle nucleation at close to ambient pressures, combining precise control over cluster size with in situ real-time monitoring of complex kinetic analysis. The hydrated particles are generated by electrospray ionization, mass selected in a quadrupole mass filter, subsequently stored and exposed to precursor molecules in a ring electrode ion trap. After a variable storage time, an ion packet is extracted and focused into a perpendicularly mounted TOF MS, where the spectra are recorded with an MCP detector. Herein, we will discuss the instrumentation - design and implementation of each component. We will describe the characteristics of different RF ion guides, including stacked ring ion guides and multipoles, supplemented by ion trajectory simulations probed by the software package SIMION.

MS 7.11 Thu 16:30 Empore Lichthof

Spatially resolved trace analysis of radionuclides with laser ionization mass spectrometry — ●PAUL HANEMANN¹, TOBIAS WEISSENBORN¹, NINA KNEIP¹, LAURA LEIFERMANN¹, DARCY VAN EERTEN¹, MANUEL RAIWA¹, FELIX BERG², and CLEMENS WALTHER¹ — ¹Institute of Radioecology and Radiation Protection, Leibniz University Hannover — ²Institute of Nuclear Chemistry, University Mainz

Resonant laser secondary neutral mass spectrometry (rL-SNMS) combines the high spatial resolution of traditional time of flight secondary ion mass spectrometry (ToF-SIMS) with the advantage of element selectivity. Multiple grating-tuned Ti:Sa lasers allow access to a range of resonant ionization schemes. Combined with mass spectrometry, the method can detect actinides in single radioactive particles from the environment, down to 10⁷ atoms of a single isotope [1]. In micrometer-sized particles from the Chernobyl exclusion zone, the relative ²³⁸Pu content can be determined by suppressing the dominant ²³⁸U in spent fuel. This is achieved quasi non-destructively without chemical preparation of the sample. The current capabilities of the rL-SNMS system are presented in this poster, with an outlook on further developments of the method and application to ultra-trace analysis.[1] DOI:10.1126/sciadv.abj1175

MS 7.12 Thu 16:30 Empore Lichthof

Assessment of anthropogenic actinide background levels on the ground of the new 1-MV compact AMS system HAMSTER at HZDR — ●SEBASTIAN FICHTER¹, ANTON WALLNER¹, KARIN HAIN², and MICHAEL HOTCHKIS³ — ¹Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Dresden, Germany — ²University of Vienna, Faculty of Physics, Isotope Physics, Vienna, Austria — ³Australian Nuclear Science and Technology Organisation, Lucas Heights, Australia.

The new multi-purpose 1-MV AMS facility HAMSTER (*Helmholtz Accelerator Mass Spectrometer for Tracing Environmental Radionuclides*) is built within the HZDR research campus in Dresden-Rossendorf starting in 2022. The new machine is especially dedicated to the analysis of ultra-trace levels of actinides in environmental samples. Therefore, eventual contamination of the site where the new accelerator building is being constructed should be avoided and clarified. Hence, several soil samples close to the construction site of the new accelerator building have been analyzed to assess the content and isotopic ratios of the actinides U, Np and Pu. The samples have been processed in the existing chemistry labs of HZDR's 6-MV DREAMS facility showing low background levels. Overall, the samples show expected signatures of global fallout in Pu concentrations and ^APu/²³⁹Pu ra-

tios. However, in some samples increased ^{236}U concentrations and relatively low $^{233}\text{U}/^{236}\text{U}$ atomic ratios have been detected pointing to an additional source of ^{236}U . Additional analysis is currently ongoing.

MS 7.13 Thu 16:30 Empore Lichthof

Preparation of a Pa-233 tracer for accelerator mass spectrometry of Pa-231 in environmental samples — •JANIS WOLF, ASTRID BARKLEIT, SEBASTIAN FICHTER, ROBIN STEUDTNER, and ANTON WALLNER — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

The measurement of Pa-231 ($t_{1/2} = 3.28 \cdot 10^4$ a) by accelerator mass spectrometry (AMS) has many applications including nuclear foren-

sics, U/Pa dating and radiological risk assessment of the U-235 decay chain. The measurement requires the addition of an isotopic spike and as Pa-231 is the only long-lived Pa isotope, the short-lived isotope Pa-233 ($t_{1/2} = 26.98$ days) is used. This enables the measurement of the isotopic ratio Pa-231/Pa-233 and monitoring of the efficiency of the sample preparation and measurement procedure.

The Pa-233 spike is typically separated from a solution of its long-lived mother nuclide Np-237 using an ion-exchange resin. Due to the tendency of Pa to attach to surfaces, different procedures for this separation are tested with the aim to find a procedure with high Pa-233 yields that can be performed quickly and without additional safety precautions during AMS sample preparation.