TASCA 23

April 25 - 27, 2023

20th Workshop on Recoil Separator for Superheavy Element Chemistry & Physics

Program & Abstracts

Last update: April 20, 2023

Tuesday, April 25, 2023

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14:00	**Welcome**	P. Giubellino (FAIR / GSI) C. Düllmann (JGU Mainz / GSI Darmstadt / HIM)	
	News from Gas-Filled Recoil-Separator Laboratories (Part 1) *	**Chair:** Michael Block (GSI)	
14:10	High-precision direct mass measurement of (super)heavy nuclides with MRTOF via GARIS-II and KISS setups	Toshitaka Niwase (KEK)	3
14:35	In-beam fission study at ASRC, JAEA	Kentarou Hirose (JAEA)	3
15:00	Status of the gas-filled separator SHANS2	Zaiguo Gan (IMP, Lanzhou)	4
15:25	Status report of the JYFL-ACCLAB in-flight separators MARA and RITU	Juha Uusitalo (Univ. of Jyväskylä)	4
15:50	**Coffee Break**		
	News from Gas-Filled Recoil-Separator Laboratories (Part 2) *	**Chair:** R.-D. Herzberg (Univ. Liverpool)	
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16:45	Recent experiments/developments with AGFA	Dariusz Seweryniak (ANL)	5
17:10	Heavy Element Research at Texas A&M University	Charles M. Folden III (Texas A&M Univ.)	6
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	Physics: Theory *	**Chair:** Dieter Ackermann (GANIL)	
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14:35	Effect of neutron evaporations in fission process with dynamical model and mass distribution of fission fragments of Superheavy nuclei	Yoshihiro Aritomo (Kindai Univ.)	8
15:00	Considerations on the validity of GEF in an extended region	Karl-Heinz Schmidt	8
15:25	Hindered fission and alpha decay of superheavy nuclei in high-K states	M. Kowal (National Centre for Nuclear Research, Warsaw)	8
15:50	**Workshop photo**		
16:05	**Coffee Break**		
	Chemistry: Theory and Experiment *	**Chair:** C.M. Folden III (Texas A&M Univ.)	
16:30	Theoretical chemistry of superheavy elements in support of experiment	Valeria Pershina (GSI)	9
16:55	Development of high-temperature chromatography for the heaviest elements	Georg Tiebel (PSI)	9
17:20	Chemistry of heaviest Group 13 Elements	Jennifer Wilson (PSI)	10
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18:30	**Dinner** Location and exact time to be announced (at one's own charge; registration required via tasca@gsi.de)		

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14:00	**Welcome**	Alexander Yakushev (GSI)	
	Physics: Experiment and Developments	**Chair:** Hiromitsu Haba (RIKEN)	
14:10	Reaction parameter studies of the ^{51}V beam onto deformed target: $^{51}V+^{151}Tb$ reaction *	Pierre Brionnet (RIKEN)	11
14:35	Investigation of the role of multi-neutron transfer channels on sub-barrier fusion enhancement **	Rinku Kumar Prajapat (IIT Roorkee)	12
14:55	Recent progress of the Laser Spectroscopy the Heaviest Actinides at GSI *	Sebastian Raeder (GSI)	13
15:20	Status of the Low Energy Branch at SPIRAL2-S^3 **	Vladimir Manea (IJCLab, Orsay; GANIL, Caen)	14
15:40	Status of the SIRIUS detector array **	Rikel Chakma (GANIL, Caen)	15
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	Chemistry and Miscellaneous**	**Chair:** Matthias Schädel (GSI)	
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16:50	Simulation and experiment for heavy element gas phase chromatography	Dominik Dietzel (Univ. Mainz)	17
17:10	Status and Perspectives of the HELIAC-Project	Maksym Miski-Oglu (GSI)	16
17:30	**EURASIS** – towards a secure **EU**ropean **RA**re **S**table **I**sotope **S**upply	Dieter Ackermann (GANIL, Caen)	16
17:50	Concluding remarks		
18:00	**End of TASCA 23 workshop**		

* 20 minutes presentation + 5 minutes discussion time
** 15 minutes presentation + 5 minutes discussion time

Time corresponds to Central European Summer Time (CEST / UTC+02:00h)

High-precision direct mass measurement of (super)heavy nuclides with MRTOF via GARIS-II and KISS setups

Toshitaka Niwase

KEK Wako Nuclear Science Center

The multi-reflection time-of-flight mass spectrograph (MRTOF-MS) is one of the tool for high-precision direct mass measurement of the nuclides. We have operated several MRTOFs in the RIKEN RIBF facility. The SHE-Mass facility, which couples MRTOF-MS + α-TOF detector with gas-filled recoil ion separator GARIS-II, is working on the mass measurement of heavy and superheavy nuclides produced in fusion reactions. The MRTOF-MS connected to the KEK isotope separation system KISS allows the mass measurement of neutron-rich nuclides produced via multi-nucleon transfer reaction. Recently, KISS-MRTOF has successfully measured the masses of 19 actinide nuclides, including the new isotope ^{241}U, in a first attempt to explore the southeast region of uranium.

In this talk, I would like to explain the overview result of our recent activity of the mass measurement of heavy and superheavy nuclides.

In-beam fission study at ASRC, JAEA

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From the measurements of fission-fragment mass distributions for nuclides around A=258 for spontaneous fission, a unique sharp change from asymmetric fission to symmetric fission mode was found by moving from ^{256}Fm to ^{258}Fm [1]. To understand such specific phenomenon will give a unique opportunity to study the fission mechanism. At the Tokai tandem accelerator facility of Japan Atomic Energy Agency, we have performed the ^{4}He+^{254}Es experiment producing ^{258}Md whose fission has not been observed ever. The mass-TKE correlation at 15, 16, 18 and 20-MeV excitation energies were obtained. Decomposition were performed by standard (asymmetric) mode, short and superlong (symmetric) modes and their excitation energy dependence will be discussed.

Another topic is the angular momentum transfer in the multi-nucleon transfer (MNT) reaction. MNT are expected one of viable reactions to produce super-heavy nuclei with more neutrons [2]. The angular momentum is an important property of a compound nucleus which has an effect on its survival probability. In MNT reactions, the axis of the angular-momentum transfer can be identified to be perpendicular to the reaction plane. Thus, the fission-fragment angular distribution measured with respect to this axis is strongly reflected by the angular momentum. We performed the fission-fragment angular distribution measurements in the ^{18}O+^{237}Np reaction, and the results for produced compound nuclei of $^{236\text{-}240}$Np, $^{237\text{-}242}$Pu, $^{238\text{-}245}$Am, $^{243\text{-}245}$Cm will be presented.

References

[1] D.C. Hoffman et al., Radiochimica Acta 70/71, 135 (1995).
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Status of the gas-filled separator SHANS2

Z.G. Gan[1,2], Z.Y. Zhang[1,2], M.H. Huang[1,2], H.B. Yang[1], L. Ma[1,2], J. G. Wang[1], M.M. Zhang[1], Y.L. Tian[1], Y.S. Wang[1], C.L. Yang[1]

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A new gas-filled recoil separator (SHANS2) has been constructed at the Institute of Modern Physics, CAS. In 2022, the separator was commissioned and targets such as ^{175}Lu and ^{169}Tm were bombarded with ^{40}Ar and ^{40}Ca beams. In these experiments, the decay of ^{205}Ac was remeasured while observing ^{204}Ac. I will report on the results of these experiments.

References

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Status report of the JYFL-ACCLAB in-flight separators MARA and RITU

Juha Uusitalo

Nuclear Spectroscopy Group, Accelerator Laboratory, Department of Physics, University of Jyväskylä

The Nuclear Spectroscopy Group (NSG) at JYFL-ACCLAB is employing two complementary in-flight separators in their spectroscopic studies. Recoil Ion Transport Unit (RITU) [1] is a gas-filled recoil separator and has been in operation for almost 30 years. Mass Analyzing Recoil Apparatus (MARA) [2], is a vacuum-mode double focusing mass separator and in operation about six years. Since the last TASCA workshop (2022) in total 90 days of beamtime has been used by the NSG group utilizing above mentioned recoil separators. A new plunger device, APPA, was commissioned and successfully used both at MARA and RITU target positions. In addition, conventional-focal plane spectroscopic studies were performed using both separators. Status report and some recent experimental highlights will be presented.

References

[1] J. Sarén, J. Uusitalo, M. Leino, and J. Sorri, Nucl. Instr. Meth. Phys. Res. A 654, 508 (2011).
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Nuclear-spectroscopy performance of ANSWERS@TASCA

P. Mosat and J. Khuyagbaatar for the SHE Chemistry department

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A novel experimental technique for nuclear spectroscopy (alpha, electron, photon) [1], named ANSWERS (Adsorption-based Nuclear Spectroscopy Without Evaporation Residue Signal), was built in 2020 at the SHE Chemistry department, GSI, and is currently in successful operation.
The results of the first commissioning experiments, in which alpha-decay fine structures of ^{211}Bi and ^{253}No were studied, showed the great potential of ANSWERS for measuring multi-coincident events with high efficiency.
Large-sized experimental data taken with ANSWERS, where all signals are processed by the fast digital electronics, have required significant developments in the data-evaluation and data-interpretation process. These developments, including the implementation of GEANT4 simulations, are being undertaken together with further upgrades of ANSWERS.
In this talk, results of the GEANT4 simulations for the ANSWERS-detectors' responses in cases of alpha decay fine structures of ^{211}Bi and ^{253}No will be presented and compared with the experimental data. In addition, recent results from the ^{48}Ca + ^{209}Bi reaction will be presented.
We are grateful for GSI's the Experimental Electronics department and Target Lab for their continuous support of the experimental program at TASCA. We acknowledge the ion-source and UNILAC staff for providing the stable and high intensity ^{48}Ca beam. The results are based on the experiment U308, which was performed at the beam line X8/TASCA at the GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt (Germany) in the frame of FAIR Phase-0.

References

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Recent experiments/developments with AGFA

Dariusz Seweryniak on behalf of the AGFA collaboration

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After a break due to the GRETINA campaign at ATLAS the experimental program with the Argonne Gas-Filled Analyzer was restarted in summer 2022. Several AGFA experiments in stand-alone mode were performed since then. The ^{22}Ne+^{238}U reaction was used to produce ^{256}No to test performance of AGFA for asymmetric reactions. Search for proton emission in proton-rich At isotopes was carried out: the α decay of the new isotope ^{190}At was observed and a search for ^{189}At, which a candidate for the heaviest proton emitter to date, was carried out. Beam discrimination in these experiments was challenging due to symmetric reactions which were used. In a very recent experiment, the odd dubnium isotopes ^{255,257}Db were studied. Preliminary results from these experiments will be presented. Plans for experimental program with AGFA in near future will be also discussed. It is anticipated that a campaign of experiments with AGFA and Gammasphere will take place this year following the completion of upgrade of Gammasphere. A new implantation station optimized for the AGFA focal plane, which is currently under construction, will be also presented.
This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under contract number DE-AC02-06CH11357. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.

Heavy Element Research at Texas A&M University

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At the Cyclotron Institute at Texas A&M University, our Heavy Elements Group has been working in three main areas in recent years: developing new techniques to study chemical properties of heavy elements, investigating the factors that influence compound nucleus survivability, and increasing the sensitivity of the AGGIE gas-filled separator. We have been working to modify Si detectors with organic monolayers in order to create chromatographic surfaces and tune the interaction between a heavy atom and the surface. In recent years, we have studied the adsorption of Er, Ir, and At on two different self-assembled monolayer (SAM) surfaces, and we are planning a future experiment to study the adsorption of Po on a SAM created with 1,9-nonanedithiol. An offline source of ^{216}Po is being used for developmental experiments and an online experiment utilizing ^{196}Po is planned. After completing a study of the influence of compound nucleus deformation on the ^{44}Ca + ^{154,156,157,160}Gd reactions, we have begun to study reactions of the same targets bombarded by ^{48}Ti. Finally, we are in the process of upgrading the maximum magnetic rigidity of AGGIE to enable future experiments with heavier elements, including a potential study of No adsorbed on a SAM. This talk will discuss the most recent results from these projects and future plans.

Updates from the BGS superheavy element program

R. Orford[1], J.M. Gates[1], R.M. Clark[1], H.L. Crawford[1], P. Fallon[1], F.H. Garcia[1], P. Golubev[2], J.A. Gooding[1,3], S. Kaplan[1,4], M. McCarthy[1,3], J.L. Pore[1], D. Rudolph[2], G. Sonderegger[1,5], and M.A. Stoyer[6]

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At Lawrence Berkeley National Laboratory the nuclear properties of heavy and superheavy elements produced at the 88-inch cyclotron facility are studied using the Berkeley Gas-filled Separator (BGS) and FIONA (*for the study of nuclide A*) spectrometer [1]. In this presentation I will give an overview of the current experimental setup and discuss some experimental results including the recent searches for new isotopes of Es [2] and Db [3]. A series of upgrades are also underway in preparation for future new element discovery experiments with the BGS. I will highlight our recent commissioning of a new focal plane detector and digital data acquisition system [4] and give updates on recent beam development at the 88-inch cyclotron.

References

[1] J.M. Gates *et al.*, Phys Rev Lett **121**, 222501 (2018)
[2] R. Orford *et al., in prep* (2023)
[3] J.L. Pore *et al., in prep* (2023)
[4] P. Golubev *et al., in prep* (2023)

Probing the fission-landscape of superheavy nuclei

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To date, superheavy nuclei (SHN) with proton and neutron numbers up to Z = 118 and up to N = 177, respectively, are known. They were synthesized mostly in the heavy-ion induced reactions with atom-at-a-time rates and identified predominantly by their alpha-particle emission and rarely by fission. Corresponding experimental data, e.g., partial half-lives of these radioactive decays confirm the concept of the island of stability against the fission, which was initially predicted to exist at around the Z=114 and N=184.

On the other hand, properties of SHN related to fission process, i.e., fission half-life, fission hindrance, the fragments mass distribution etc., are still scarcely known [1]. This circumstance has a primary reason, which is due to the lack of a comprehensive experimental data on the fission, which is well-known to be a quite complex process having a stochastic nature [2].

This circumstance has a primary reason, which is due to the lack of a comprehensive experimental data on the fission, which is well-known to be a quite complex process having a stochastic nature [2].

At the SHE-Chemistry department (GSI) a research program with a focus on exploring the fission-landscape of SHN is actively ongoing [3-6]. One of the main goal is the measurement of the comprehensive experimental data on the fission-observables that will be useful to be used in the theoretical descriptions of fission process. First steps towards this goal is the construction and fulfill of the well-pronounced systematics for the fission-observables and its explanation/interpretation within the semi-empirical approach [7-9].

I will present the current status and results of this research program.

References

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Effect of neutron evaporations in fission process with dynamical model and mass distribution of fission fragments of Superheavy nuclei

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Through joint research by the Japan Atomic Energy Agency (JAEA) [1,2] and Kindai University, it has revealed that the yield distribution of fission products (fission fragments) changes significantly depending on the neutrons emitted from the compound nucleus. This multi-chance fission (MCF) effect is particularly important to treat high energy fissions [1,3]. In this work, we have introduced the neutron evaporation during fission process in the Langevin model [4] and aimed to describe the entire reaction process in a unified manner. Fission fragment mass distribution of $^{234-240}$U, $^{236-242}$Np, and $^{238-244}$Pu were calculated in the initial excitation energy range of the excitation energy E^{*}=15-55 MeV. The results show that the double-peak structure is maintained even at the highest excitation energies and successfully reproduced the experimental data taken at the JAEA tandem facility.
Moreover, recently we have developed the calculation code to investigate the mass distribution of fission fragments of Superheavy nuclei. In this talk, we present new results using the code.

References

[1] K. Hirose, K. Nishio, S. Tanaka, et al., Phys. Rev. Lett. 119, 222501 (2017)
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[3] S. Tanaka, Y. Aritomo, Y. Miyamoto, et al., Phys. Rev. C 100, 064605 (2019)
[4] Y. Miyamoto, Y. Aritomo, S. Tanaka, et al., Phys. Rev. C99, 051601 (2019)

Considerations on the validity of GEF in an extended region

Karl-Heinz Schmidt

An attempt is made to estimate the fission properties of systems in an extended region on the chart of the nuclides by use of the semi-empirical GEF model. The GEF model has proven to describe the fission yields from neutron-deficient mercury isotopes to rutherfordium rather well. This has been achieved by assuming that the fission yields are given by the statistical population of the states in the fission valleys, which are formed by the macroscopic potential and four proton shells in the nascent fragments. The shells are connected with peaks in the measured fragment Z distributions near Z=36, 52, 55, and 60, and the measured yields of the corresponding fission channels are related to their strengths.
The validity of calculated fission yields of very heavy and very neutron-rich systems and an eventual influence of the Z=82 shell are discussed.

Hindered fission and alpha decay of superheavy nuclei in high-K states

M. Kowal

National Centre for Nuclear Research, Pasteura 7, 02-093 Warsaw, Poland

I will analyze a problem relevant to the fission and alpha decay hindrance of odd-A nuclei and high-K (multi-quasiparticle) isomers. I will provide candidates for relatively stable superheavy nuclear configurations. Longer-lived systems could open new possibilities for studying related elements' chemical/atomic properties.

Theoretical chemistry of superheavy elements in support of experiment

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[2]*Helmholtz Institute Mainz, Mainz, Germany,* [3]*Matej Bel University, Banska Bystrica, Slovakia*

Results of the calculations of adsorption properties of the 7p elements and their compounds on surfaces of gold and quartz are presented. The aim of the work is to support gas-phase chromatography experiments on SHEs.

Development of high-temperature chromatography for heaviest elements

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Online gas-adsorption thermochromatography experiments have been successfully used for the chemical characterization of superheavy elements at the one-atom-at-a-time level [1]. In these experiments, the covered temperature range, applied along the chromatographic channel, defines which chemical elements or associated compounds can be investigated on the provided stationary phase. As the gas-chromatographic channel of state-of-the-art experiments consists of Si-based semiconductor solid-state detectors for time-resolved, event-by-event α- and fission fragment spectroscopy, experimentalist face an upper temperature threshold of approximately 50°C. Hence, they are currently limited to comparably volatile chemical species such as elemental copernicium and flerovium. Single-crystal, chemical vapor deposition diamond and 4H-SiC are two promising wide bandgap semiconductors, suitable to extend the technique towards less volatile chemical species by increasing the starting point temperature of the negative temperature gradient.
Here, we present the results of continued measurements targeting the spectroscopic response of 4H-SiC-based sensors for α-spectroscopy up to 500°C [2] and beyond to 700°C. In addition to the general spectroscopic behavior of the sensors, we will address additional difficulties, such as the electrical contacting of the sensors at higher temperatures.

References

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Chemistry of heaviest Group 13 Elements

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Fundamental chemistry experiments with superheavy elements (SHEs) are instrumental for furthering our understanding of relativistic effects and their effects on the physicochemical properties of predominantly heavy elements. After the chemical characterization of copernicium (Cn, Z = 112) and flerovium (Fl, Z =114) [1,2] in their elemental states, the focus has shifted towards nihonium (Nh, Z = 113) for it to be chemically characterized. The first Nh chemistry experiments revealed rather unspecific results [3,4]. Thus, online experiments with the lighter homolog thallium have since become the focus to address these shortcomings and to complement past offline investigations [5]. The outcome of these studies revealed the importance of preparatory, online studies with the lighter homolog(s) before further Nh experiments are conducted. Presented here will be the recent on- and offline experiments with Tl focusing on the stability of fused silica surfaces as the stationary phase.

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Reaction parameter studies of the ^{51}V beam onto deformed target: ^{51}V+^{159}Tb reaction

Pierre Brionnet

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In the super heavy element synthesis, the use of ^{50}Ti, ^{51}V and ^{54}Cr are becoming mandatory to access to element beyond the Oganesson (Z = 118) due to the lack of target material beyond the Californium. However, the reaction parameters using these beams on deformed target are not yet studied as only reaction on Pb and Bi target have been performed using these beams. In addition, the different cross sections prediction can only be extrapolated from the reaction performed using the ^{48}Ca beam, leading to wide range of prediction based on the model used. The systematic studies of reaction parameters using these beams could thus improve the prediction in the case of new element search.

The search of the element Z = 119 is currently ongoing in RIKEN using the ^{248}Cm(^{51}V,xn)$^{299-x}$119 on the SRILAC + GARIS-III experimental setup [1]. As stated in [2], the selection of the beam energy for the search of new elements is crucial to the success of the experiment. The goal of this work is thus to extend the systematic study of reaction parameters with deformed target using the ^{51}V beam, by using lighter surrogate systems.

This work studied the effect of the incident beam energy and nuclear deformation in the reaction ^{159}Tb(51V,xn)$^{210-x}$Ra by producing both the barrier distribution and the detail excitation functions. The goal is to extend the systematic study of the quasielastic (QE) barrier distribution with ^{51}V and compared it to the results obtain in [2,3] as well as theoretical prediction and interpretation using the Couple Channel Calculation (CCFULL [4]).

In addition, the production of the full and detail excitation function for the *x*n, *px*n and *αx*n, also allow us to study the correlation between the barrier distribution and the maximum cross section of production. The main goal is to study the effect of the tip vs side collision effects on the maximum cross section of production.

The experimental setup, analysis and preliminary results of both studies will be presented in this presentation.

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Investigation of the role of multi-neutron transfer channels on sub-barrier fusion enhancement

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The heavy-ion fusion reactions are greatly influenced by various degrees of freedom of colliding partners, e.g., inelastic excitations, deformation, and positive Q-value neutron transfer (PQNT) channels, below the Coulomb barrier [1,2]. However, the role of PQNT channels in sub-barrier fusion enhancements is somewhat dramatic and not yet fully understood. Thus, an experiment has been performed to measure the fusion excitation functions for $^{28,30}Si+^{158,156}Gd$ reactions, which forms the same compound nucleus $^{186}Pt^*$ at energies well below to above the Coulomb barrier using the Heavy-Ion Reaction Analyzer (HIRA) at Inter University Accelerator Center (IUAC), New-Delhi, India. The measured fusion cross sections and derived fusion barrier distribution have been analyzed within the coupled channel (CC) calculations framework using the CCFULL and ECC [3,4]. The measured sub-barrier fusion cross sections for both reactions were enhanced compared to the one-dimensional barrier penetration (1D-BPM) model. Thus, the systematic effect of PQNT channels and inelastic excitations in colliding partners have been investigated to decipher the role of neutron transfer channels on sub-barrier fusion. Detailed analysis and the obtained results will be discussed during the talk.

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Recent progress of the Laser Spectroscopy the Heaviest Actinides at GSI

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The heaviest elements are of interest to nuclear and atomic physicists due to their peculiar properties. While nuclear shell structure effects are responsible for their very existence stabilizing them against spontaneous fission, the structure of their electronic shells is affected by strong relativistic effects leading to different atomic and chemical properties compared to their lighter homologs. The atomic structure can be probed by laser spectroscopy which is a powerful tool to unveil fundamental atomic and, from the determination of subtle changes in atomic transitions, nuclear properties. The lack in atomic information on the heavy element of interest, the low production rates, and the rather short half-lives make experimental investigations challenging and demand very sensitive experimental techniques.

The transfermium element Nobelium (No, Z=102) became only accessible for optical spectroscopy in a pioneering experiment employing the RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) technique coupled to the velocity filter SHIP at GSI, Darmstadt [laat]. Measurements of an atomic transition in the isotopes $^{251-255}$No as well as resolving the hyperfine splitting in ^{253,255}No gave access to nuclear moments and differential charge radii [4]. In recent measurement a novel mode of the RADRIS technique was established, where the desired nuclides are bred by radioactive decay on the capture filament extending the reach of the method to ^{255}No and, for the first time, to on-line produced Fm isotopes. In addition was an extended level search for an atomic transition of the next heavier element lawrencium (Lr, Z=103) performed. Here the laser were scanned over two predicted.

An improvement in the experimental observables can be achieved by performing laser spectroscopy not inside the high pressure buffer gas cell, but inside a hypersonic gas jet effusing from the stopping cell [Yuri]. Here the low density and cold environment improve the spectral resolution of the laser spectroscopy. For this investigation the JetRIS setup was developed at HIM in Mainz and a first online commissioning of JetRIS was performed during the last beamtime at GSI. Recent experiments of our laser spectroscopy program as well as obtained results will be discussed together an outlook to the future in view of the next beamtime campaign.

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Status of the Low Energy Branch at SPIRAL2-S^3

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The Super Separator Spectrometer (S^3) is a new-generation recoil separator currently under construction at SPIRAL2-GANIL, which will enable the study of fusion-evaporation reaction products using the intense heavy-ion beams delivered by the SPIRAL2 linear accelerator [1]. The S^3 Low Energy Branch (S^3-LEB) is an experimental setup which will be installed at the focal plane of S^3, aiming to stop the nuclei in a gas cell and extract them for subsequent measurements by laser spectroscopy, mass spectrometry and decay spectroscopy [2]. An important part of the S^3-LEB scientific program will be dedicated to the study of the isotopes of heavy elements. The setup will employ the in-gas laser ionization and spectroscopy technique in the supersonic jet emerging from the gas cell, which will allow reaching the spectral resolution required for measuring the isotope shifts and hyperfine structures of rare isotopes [3].
Currently, the S^3-LEB setup is being commissioned off-line in preparation for first experiments with S^3 [4]. This contribution will present an update of recent results, including the first in-gas-cell and in-gas jet laser spectroscopy performed with stable erbium isotopes, while separating and counting the photo-ions using the integrated multi-reflection time-of-flight mass spectrometer [5].

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Preparation of Nihonium chemistry at IMP

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China Accelerator Facility for Superheavy Elements (CAFE2) has been developed at the Institute of Modern Physics (IMP). The heavy ions beam (such as ^{40}Ar, ^{40}Ca, ^{55}Mn and ^{54}Cr) with energy of 5-7 MeV/u and beam intensities of several puA were successfully commissioning last year. New gas-filled recoil separator, SHANS2 (Spectrometer for Heavy Atoms and Nuclear Structure-2), with five magnets arranged in a Qv-D-Q -Qv-D configuration is constructed behind CAFE2. The verification experiment of element Mc with ^{48}Ca+^{243}Am reaction will be performed near future, and it will give us the chance to investigate the chemical properties of nihonium at IMP. An on-Line Experiment in Gas-phasE for Nihonium Detector array (LEGEND) is developing, and the test experiment with ^{225,227}Ac sources will be reported in presentation. The LEGEND array with temperature gradient will be established and the different detector surface materials such as SiO_2, Al, carbon and SiC will be employed

Status of the SIRIUS detector array *

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The superconducting LINAC (LINear ACcelerator) of SPIRAL2-GANIL will deliver very intense heavy-ion beams up to uranium by virtue of the additional NEWGAIN (NEW GAnil Injector) with mass to charge ratio (A/Q = 7) [1]. The S^3 (Super Separator Spectrometer) of SPIRAL2 was designed to have high transmission, high beam rejection and high mass resolving power capabilities to study rare isotopes like superheavy and exotic nuclei far from the stability with very lowproduction cross-sections [2]. At the focal plane of S^3, a state-of-art detector array called SIRIUS (Spectroscopy and Identification of Rare Isotopes Using S3) [3] will be installed to perform decay spectroscopic studies in the region of the very heavy and superheavy nuclei where very little spectroscopic data [4] is available. SIRIUS will be capable of detecting heavy ions and their subsequent decay products : alpha particles, beta particles, internal-conversion electrons, gamma rays, X rays and fission fragments. It is composed of an ion tracker to track the ERs (Evaporation Residues) passing through it and also to measure their time of flights, a DSSD (Double-Sided-Silicon-Strip Detector) for implanting the ERs and to establish their spatial and temporal correlations with their successive decays, four stripy pad silicon detectors in a tunnel configuration placed upstream to the DSSD to detect the escaping charged particles from the DSSD thus allowing performance of internal-conversion-electron spectroscopy, five clover detectors placed in a close geometry around the silicon detectors to carry out detailed gamma spectroscopy. The setup was brought to GANIL in March 2021 and is in the commissioning phase now. In this conference, I will present the current status of the SIRIUS project.

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Status and Perspectives of the HELIAC-Project

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The linear accelerator HELIAC will provide heavy ions with particle energies of 3.5 MeV/u to 7.6 MeV/u (A/Z = 6) at the GSI Helmholtzzentrum für Schwerionenforschung. Thanks to superconducting radio-frequency technology, it will be able to deliver high average beam currents in continuous-wave mode.
The radio-frequency resonators of the so-called Cross-bar H-mode type are being developed in cooperation with the IAP of Goethe University Frankfurt. The suitability of these resonators in principle for ion beam acceleration was successfully demonstrated in an earlier phase of the project. In the current, advanced demonstration stage an extended beam test with a first fully equipped series cryomodule is to take place shortly at GSI. The infrastructure for this has been created in recent years. In addition to setting up a radiation-shielding area with a link to the existing 4 K helium liquefier on site, this also includes vital preparations at the Helmholtz Institute Mainz. There, the superconducting resonators were tested for their performance one at a time and a spacious ISO-class 4 clean room providing the high-purity environment required for the adequate assembly of superconducting RF structures was commissioned.
This talk will present the current status of the project and recent activities, as well as the design of the complete HELIAC accelerator.

EURASIS – *towards a secure EUropean RAre Stable Isotope Supply*

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The shortage of **E**nriched rare **S**table **I**sotopes (**ESI**) supply, severely aggravated by the Russian aggression against Ukraine and its consequences, calls for a solution with the aim to warrant a secure provision of European research institutions with this basic material without which essential fundamental research activities will come to a halt when the yet limited reserves will be consumed. The situation is affecting not only the nuclear physics community and a concerted action plan is urgently needed, in synergy with all disciplines and communities concerned, like e.g. the community of medical research and application, the Mössbauer spectroscopy and neutrinoless double-β decay communities. The international character of fundamental research and the respective scientific collaborations demands for an international effort to attack this global problem.
For some production schemes, like the electromagnetic isotope separation (EMIS), hitherto Russia had a monopoly. Measures to mitigate this dilemma could include the implementation of an EMIS facility in Europe, ideally embedded in an international network.
In our view this is a burning issue and finding a solution should and will be a prominent topic of the NuPECC LRP. We pursue this initiative under the acronym **EURASIS** (***EU**ropean **RA**re **S**table **I**sotope **S**upply*). Its aim is to define a European strategy to warrant ESI supply for European research in Nuclear Physics and beyond.

Simulation and experiment for heavy element gas phase chromatography

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In preparation of gas phase chemical experiments with element 115, we studied the chemical behavior of single short-lived ^{211}Bi atoms in rare gases (helium and argon) and in oxygen atmosphere. For that purpose, we performed off-line isothermal gas chromatography experiments at room temperature. The short-lived volatile ^{219}Rn precursor, provided from an ^{227}Ac-source, was transported into the mini**COMPACT** setup (mini **C**ryo-**O**nline **M**ulti detector for **P**hysics **a**nd **C**hemistry of **T**rans-actinides), using different carrier gases. The internal chromatograms were modeled by Monte Carlo simulations, which account for the precursor effect of beta-decaying ^{211}Pb that decays to the detected alpha-decaying ^{211}Bi and compared them to experimental results to determine a lower limit of the adsorption enthalpy of bismuth on silicon dioxide. Furthermore, we present a new advance of the Monte Carlo code that has been adapted to study the chemical properties of superheavy elements and their lighter homologs in greater detail. The inclusion of an activation energy barrier that enables the simulation of physisorption and chemisorption, substitutes the simple mobile adsorption surface process. By applying this code to the analysis of gas chromatography experiments, valuable insights into the behavior of SHE and lighter homologs can be obtained. Our results demonstrate the potential of the new Monte Carlo simulations to advance our understanding of these systems and suggest promising directions for future research.