TASCA 26
22nd Workshop on Recoil Separator for Superheavy Element Chemistry & Physics

(11 May 2026)

Program & Abstracts

Tuesday, May 19, 2026

TIME	Duration	TOPIC	Speaker	Page
10:00	30’	Welcome by the scientific managing director of FAIR & GSI	Thomas Nilsson (FAIR / GSI)	
		Highlights from GFS Labs and Physical Highlights (I)	Chair: Rolf-Dietmar Herzberg (University of Liverpool)	
10:30	25+5'	Toward the Discovery of New Elements	Jacklyn Gates (LBNL)	4
11:00	25+5'	Search for element 119 in the ^{248}Cm(^{51}V,xn) reaction at RIKEN *(via ZOOM)*	Kouji Morimoto (RIKEN)	4
11:30	25+5'	Recent results of SHANS2	Zaiguo Gan (IMP, Lanzhou)	5
12:00	120’	Lunch & free time for informal discussions KBW 2-27 & 2-28		
14:00	20’	Workshop Photo		
		Highlights from GFS Labs and Physical Highlights (II)	Chair: Juha Uusitalo (University of Jyväskylä)	
14:20	25+5'	Overview of the current scientific activities in superheavy element research at the FLNR *(via ZOOM)*	Dmitriy Solovyev (JINR Dubna)	5
14:50	25+5'	A TASCA focal-plane detection system: past and present	Jadambaa Khuyagbaatar (GSI)	6
15:20	25+5'	Research Activities at GSI’s SHIP Separator	Michael Block (GSI / HIM / JGU)	6
15:50	20’	Coffee		
		Nuclear Reactions	Chair: Julien Piot (CNRS / GANIL)	
16:10	25+5'	Nuclear Reaction Studies and Chemistry Experiments with Self-Assembled Monolayers Using the AGGIE Gas-Filled Separator	Charles M. Folden III (Texas A&M University)	7
16:40	15+5'	Investigation of ER-gated spin distributions for ^{16}O + ^{203,205}Tl systems	Jagdish Gehlot (IUAC, New Delhi)	8
17:00	5’	Closing remarks		

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

Wednesday, May 20, 2026

TIME	Duration	TOPIC	Speaker	Page
09:00	5’	Welcome	Jadambaa Khuyagbaatar (GSI)	
		Chemistry of SHE (I)	Chair: Yuichiro Nagame (JAEA / Tokai)	
09:05	25+5'	Nuclear chemistry research at IMP	Qin Zhi (IMP, Lanzhou)	9
09:35	25+5'	On the Stability of the $Sg(CO)_6$ Complex	Alexander Yakushev (GSI / HIM)	10
10:05	15+5'	Status of chemical investigation of Nh at IMP	Yang Wang (IMP, Lanzhou)	11
10:25	25’	Coffee		
		Chemistry of SHE (II)	Chair: Ephraim Eliav (Tel Aviv University)	
10:50	25+5'	Gas phase chemical studies of the superheavy elements at the SHE Factory with a focus on Cn and Fl *(via ZOOM)*	Nikolay Aksenov (JINR)	10
11:20	15+5'	Towards livermorium chemistry: Atom-at-a-time gas chromatography studies with polonium	Katharina Hermainski (JGU Mainz)	12
11:40	15+5'	Po and Hg adsorption on functionalized gold chips	Annie Bukowski (Texas A&M University)	13
12:00	150’	Lunch & free time for informal discussions KBW 2-27 & 2-28		
		Highlights from GFS Labs and Physical Highlights (III)	Chair: Jacklyn Gates (LBNL)	
14:30	25+5'	Alpha decay and proton emission studies using the in-flight separators MARA and RITU	Juha Uusitalo (University of Jyväskylä)	11
15:00	25+5'	*K*-isomerism in seaborgium	Pavol Mošat (GSI)	20
15:30	25+5'	Approaching the dominance of electron-capture delayed fission in Bk-234 and Am-230	Zhiyuan Zhang (IMP, Lanzhou)	12
16:00	25’	Coffee		
		Enabling SHE Research	Chair:	
16:25	25+5'	Production and Processing of Heavy Actinides at Oak Ridge National Laboratory *(via ZOOM)*	Cristian Celis-Barros (ORNL)	13
16:55	25+5'	Status and Perspectives of the HELIAC-Project	Maksym Miski-Oglu (GSI, Darmstadt)	14
17:25	5’	Closing Remarks		
18:30		Dinner (at *Bürgermeister Pohl Haus*, Wixhausen; at one's own charge; registration needed)		

Thursday, May 21, 2026

TIME	Duration	TOPIC	Speaker	Page
09:00	5’	Welcome	Jochen Ballof (GSI)	
		News from heavy-ion facilities	Chair: Benoit Gall (IPHC Strasbourg)	
09:05	25+5'	Overturning the Understanding of Superheavy Element Synthesis Reaction Dynamics Through Direct Measurements of Sequential Fission *(via ZOOM)*	Jacob Buete (ANU, Canberra)	15
09:35	25+5'	Study of deformed structure in Es-254 by Coulomb excitation	Eiji Ideguchi (RCNP, Univ. of Osaka)	17
10:05	25+5'	Microscopic Models of Fission Dynamics *(via ZOOM)*	Dario Vretenar (Physics Dept., Univ. of Zagreb)	16
10:35	25’	Coffee		
		Nuclear fission	Chair: Michael Block (GSI / HIM / JGU)	
11:00	25+5'	Study of fission for Md-258 *(via ZOOM)*	Katsuhisa Nishio (JAEA)	14
11:30	25+5'	Status of the Super Separator Spectrometer at GANIL	Julien Piot (CNRS/GANIL)	16
12:00	75’	Lunch		
		SHE Chemistry and Instrument development	Chair: Qin Zhi (IMP / Lanzhou)	
13:15	25+5'	Experimental priorities of the Heavy Element group in Switzerland	Patrick Steinegger (PSI / ETH Zürich)	18
13:45	15+5'	Start of commissioning of UniCell - A new fast and highly efficient buffer-gas stopping cell for superheavy element chemistry	Felix Sprunk (JGU Mainz)	18
14:05	15+5'	Sympathetic laser-cooling of a single heavy ion in a Penning trap	Manuel Almagro Cabeza (Univ. of Granada)	19
14:25	5’	Closing remarks		
14:30	30’	Coffee		
		End of TASCA 26		
15:00		Tour to the FAIR construction site (optional; tour is fully booked, registration closed!)		

Toward the Discovery of New Elements

J.M. Gates

Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA

In the past two decades, significant progress has been made with the discovery of elements Z=114-118 through reactions between ^{48}Ca beams and actinide targets, achieving production rates of atoms-per-day or more. Unfortunately, the pursuit of elements beyond Oganesson (Z=118) faces substantial challenges. The synthesis of elements with Z=119 or 120 using ^{48}Ca would necessitate targets of Es (Z=99) or Fm (Z=100), but these elements cannot be produced in sufficient quantities. This limitation necessitates exploring new reaction pathways.

Numerous theoretical studies have aimed at predicting production rates for new elements using actinide targets and heavier ion beams. While these models reliably reproduce excitation functions for SHE production with ^{48}Ca beams, predictions diverge significantly for reactions involving heavier beams. For instance, the predicted cross sections for reactions to produce Z=120 vary by more than three orders of magnitude and tens of MeV. These discrepancies hinder experimental efforts, as the low expected cross sections suggest the detection of only one event every few weeks or months under ideal conditions.

Berkeley Lab has been proactively addressing these challenges to push beyond E118. By testing theoretical predictions, we have begun the ^{50}Ti $+^{2}$ ^{44}Pu experiment to understand the impact of using ^{50}Ti instead of ^{48}Ca beams on cross sections. This presentation will highlight significant upgrades to our experimental facilities, including ion sources, target setups, detectors, and electronics, aimed at enhancing our capability to produce and detect elements beyond E118. We will also present the initial results from the ^{50}Ti + ^{244}Pu experiment, showcasing our progress in this ambitious endeavor.

Financial Support was provided by the Office of High Energy and Nuclear Physics, Nuclear Physics Division under Contract No. DE-AC02-05CH11231

Search for element 119 in the ^{248}Cm(^{51}V,xn) reaction at RIKEN

Kouji Morimoto[1] on behalf of the nSHE collaboration

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Following the successful synthesis of Nihonium (Nh, Z = 113), the RIKEN Nishina Center for Accelerator-Based Science (RNC) launched a new program to produce even heavier elements—specifically elements 119 and 120—using hot fusion reactions. To enable this program, RNC upgraded its superconducting linac accelerator (SRILAC) and superconducting ECR ion source, thereby increasing both the beam intensity and the maximum acceleration energy. A new gas-filled recoil ion separator, GARIS-III, was also constructed and optimized for hot fusion reactions [1]. Commissioning of these upgrades was completed in 2017, achieving ^{51}V beam energies of up to 6.5 MeV/u.

Subsequently, the nSHE collaboration was established, bringing together researchers from Japan, the USA, France, Poland, Australia, and China. Highly enriched $^{248}Cm_2O_3$ material was provided to RNC under a Material Transfer Agreement with Oak Ridge National Laboratory. Using high-intensity beams, we carried out an experiment to synthesize element 119 via the $^{51}V + {}^{248}Cm \rightarrow {}^{299\text{-}x}119 + xn$ reaction. After reaching the planned cross-section sensitivity, we have temporarily concluded this experimental campaign and are now formulating the next strategy.

In this presentation, we report on the current status of the experiment, including the experimental setup, the methodology used to determine the optimal irradiation energy, and the progress made toward the detection of element 119.

References

[1] H. Sakai, H. Haba, K. Morimoto and N. Sakamoto, Eur. Phys. J. A 58, 238 (2022).

Recent results of SHANS2

Z. Gan[1,2,3], Z. Zhang[1,3], M. Huang[1,2,3], J. Wang[1,2], L. Ma[1,2], H. Yang[1], X. Wu[1,2], M. Zhang[1], Y. Tian[1,2], Y. Wang[1], C. Yang[1], J. Wang[1]

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The report will summarize a series of experiments carried out in 2025 on SHANS2. Experiments such as ^{54}Cr + ^{238}U, ^{54}Cr + ^{232}Th, ^{40}Ar + ^{238}U were conducted using ^{54}Cr and ^{40}Ar beams, the cross-sections of these reaction channels were investigated. The cross-section of Bh isotopes were measured by cold fusion reaction using ^{52}Cr beam, and the influence of N=152 subshell in this region was studied.

References

[1] Yu.Ts.Oganessian et al., Phys.Rev. C **113**, 014614 (2026)
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Overview of the current scientific activities in superheavy element research at the FLNR

D.I. Solovyev

Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Russia

Results from recent experiments with ^{50}Ti and ^{54}Cr beams [1,2] conducted at the SHE Factory will be presented. The estimated drop in cross-sections resulting from the changing the ion beam from Ca to Ti/Cr will be discussed, with the aim of identifying the optimal target–beam combination and beam energy for future experiments on the synthesis of new elements. Preliminary results obtained from the ^{48}Ca + ^{237}Np reaction will also be presented.

A new gas-filled separator based on a superconducting solenoid is currently under construction at FLNR [3]. The main purpose of the setup is to increase efficiency and event rates in gas-phase chemistry experiments with superheavy elements. Simulation results of the SHE image size at the focal plane of GASSOL will be discussed, and the benefits of using a solenoidal magnet will be demonstrated. The current status of the construction, expected experimental challenges, and a preliminary plan for test experiments will be presented and discussed.

References

[1] Yu. Ts. Oganessian, et al., Investigation of reactions with ^{50}Ti and ^{54}Cr for the synthesis of new elements, Phys. Rev. C **112**, 014603 (2025).
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[3] D.I. Solovyev, et al., Simulation of ion optics in a gas-filled solenoid GASSOL, NIM A **1052**, 168263 (2023)

A TASCA focal-plane detection system: past and present

J. Khuyagbaatar

GSI Helmholtzzentrum für Schwerionenforschung, 64291, Darmstadt, Germany

Twenty years ago, the gas-filled recoil separator TASCA was commissioned at GSI within the Nuclear Chemistry Department, with contributions from both national and international collaborators. Since then, TASCA has been successfully employed in studies of the chemical and physical properties of superheavy elements and nuclei.
In this talk, I will speak on the evolution of TASCA's focal-plane detection system and share my personal experience.

Research Activities at GSI's SHIP Separator

M. Block[1,2,3]

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The velocity filter SHIP at the GSI in Darmstadt separates the intense heavy-ion beams delivered by UNILAC from the products of complete heavy-ion–induced fusion reactions. SHIP was among the first experimental devices to become operational at the GSI accelerator facility in 1976, and this year marks its 50th anniversary. Initially, SHIP was primarily dedicated to the synthesis of superheavy elements, leading to the discovery of six new chemical elements, from hassium to copernicium.
Over time, the scientific program has continuously evolved and, in recent years, has expanded to include pioneering experiments in high-precision mass spectrometry with the SHIPTRAP Penning trap, as well as laser spectroscopy studies using the RADRIS and JetRIS setups. Recent highlights include high-precision mass measurements of superheavy nuclides including long-lived isomeric states [1], laser spectroscopy investigations of isotope shifts in fermium and nobelium isotopes [2], and high-resolution laser spectroscopy of ^{254}No [3].
In this presentation, I will briefly introduce the experimental methods and review selected highlights from recent experimental campaigns.

References

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[2] J. Warbinek *et al.*, Nature **634** (2024) 1075.
[3] J. Lantis *et al.*, Phys. Rev. Res. **6**, (2024) 023318.

Nuclear Reaction Studies and Chemistry Experiments with Self-Assembled Monolayers Using the AGGIE Gas-Filled Separator

C. M. Folden III[1,2]

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[2] *Cyclotron Institute, Texas A&M University, College Station, Texas 77843 USA*

The Heavy Elements Group at Texas A&M University is focused on the study of fusion-evaporation reactions to understand compound nucleus survival, the use of functionalized detector surfaces to tune interactions with surfaces, and the development of strong external collaborations. In recent years, we have measured excitation functions of the ^{44}Ca + ^{154,156,157,160}Gd reactions [1] to understand the role of neutron number on survival, which appears to be the most important factor affecting the success of fusion-evaporation reactions. More recently, we have also studied the ^{48}Ti + ^{156,157,158,160}Gd, ^{162,163,164}Dy reactions using the AGGIE gas-filled separator to better understand the influence of projectiles with atomic numbers greater than 20. These studies will continnue with another study of ^{52}Cr projectiles reacting with similar targets.

Our group has also pioneered the use of self-assembled monolayers (SAMs) as new surfaces for chemical studies of heavy elements. SAMs are composed of organic compounds that have been carefully chosen to form a single molecular layer on an Au surface. After spectroscopic characterization of the surfaces using a variety of techniques, we have successfully employed them in an experiment to study the adsorption of Er, Po, and At. Future experiments will focus on short-lived Hg isotopes and ^{254}No.

Our recent research has been enhanced by highly effective collaborations. Prof. Patrick Steinegger's group has traveled to Texas A&M three times for experiments, and these included the use of isothermal vacuum chromatography to chemically study nuclides with half-lives less than 1 s [2]. More recently, we have worked with Prof. Pavel Bartl's group at Czech Technical University in Prague to study the interaction of Po and Hg on various SAMs at the Nuclear Physics Institute in Řež, Czech Republic.

A number of upgrades are also planned for the Cyclotron Institute and AGGIE. In 2026, we will add a new commercial ion source for the K150 cyclotron to increase the available beam intensities. Also in 2026, we will add a new refrigeration system to provide liquid He for cryopanels in the K150 cyclotron to improve its vacuum. Finally, we are in the process of increasing the maximum field of the final AGGIE dipole to increase our maximum magnetic rigidity.

This talk will discuss our most recent results and future plans.

References

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[2] G. Tiebel et al., J. Phys. Chem. C 130, 3058 (2026). doi:10.1021/acs.jpcc.5c06930

Investigation of ER-gated spin distributions for ^{16}O + $^{203, 205}Tl$ systems

Gonika[1], J. Gehlot[1,*], S. Nath[1], I. Mazumdar[2], T. Varughese[1], T. Banerjee[1,**], A. Shamlath[3], P. V. Laveen[3], M. Shareef[3], P. Jisha[4], P. S. Devi[5], G. Naga Jyothi[5], Yashraj[1], V. I. Chepigin[6], M. L. Chelnokov[6], A. V. Yeremin[6,***], A.M. Vinodkumar[4], and N. Madhavan[1]

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Evaporation residues (ERs), being the clearest signature of compound nucleus (CN) formation, serve as an effective probe for studying fusion dynamics. Their spin distributions provide insight into the angular momenta contributing to the fusion process. Although angular momentum distributions have been studied for several light and medium-mass systems, data for heavy nuclei ($A \gtrsim 200$) remain limited, where fission and quasifission strongly affect reaction dynamics. Systematic studies of ER cross sections and spin distributions in this mass region would help investigate the fusion–fission competition, the role of nuclear deformation and shell effects on ER formation, and their survival against fission [1].

In our previous work, ER cross sections were measured for the systems ^{16}O+$^{203,205}Tl$, where evidence of non-compound nuclear fission (NCNF) was observed in both reactions [2]. A detailed investigation of the partial waves contributing to CN and NCNF processes is therefore of considerable interest. In the present study, we aim to investigate the ER-gated spin distributions for the reactions^{16}O+$^{203,205}Tl$.

The experiment was carried out using pulsed ^{16}O beam, from the 15 UD Pelletron accelerator at IUAC, New Delhi [3], on ^{203}Tl and ^{205}Tl targets [4]. ERs were separated from the background using the first stage of the HYbrid Recoil mass Analyzer (HYRA) [5] operated in gas-filled mode. The TIFR 4π spin spectrometer [6], with 32 NaI detectors surrounding the target chamber, measured γ-fold distributions from the de-exciting compound nuclei ^{219}Ac and ^{221}Ac. The raw γ-fold spectra were gated with ERs at each Elab to obtain ER-gated γ-fold distributions.

ER-gated γ-fold distributions were converted to γ-multiplicity distribution using a detector response matrix generated through a recursive algorithm [7]. The ℓ- distribution was derived from the γ-multiplicity distribution using a generalized relation [8] between the mean γ-multiplicity ⟨Mγ⟩ and the mean angular momentum ⟨ℓCN⟩, based on the CN decay scheme. Fig. 1 illustrates typical multiplicity and spin distributions for the ^{16}O + ^{203}Tl system at Elab 92.33 MeV. Complementary theoretical calculations are expected to provide a more comprehensive understanding of the fusion reaction dynamics, which are ongoing.

References

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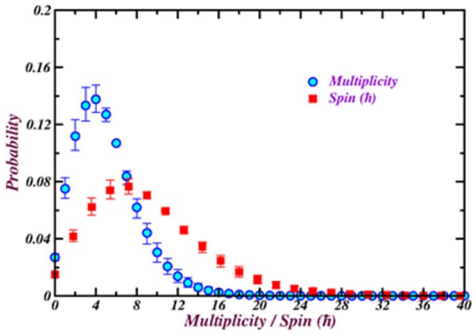

FIG. 1: γ-multiplicity and spin distributions for ^{16}O + ^{203}Tl at E_{lab} = 92.33 MeV.

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Nuclear chemistry research at IMP

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Research on the nuclear chemistry has been continuously conducted at IMP (Institute of Modern Physics, Chinese Academy of Science) for over 20 years. Remarkable achievements have been achieved from cutting-edge fundamental research on the chemical property of superheavy elements (SHEs) to advanced medical radioisotopes (RI) production and purification. Status and prospect of the SHE and RI study based on the HIRFL (Heavy Ion Research Facility in Lanzhou) will be presented in this work.

Platform for SHEs chemistry research coupled with the China Accelerator Facility for Superheavy elements (CAFE2) and the gas-filled recoil separator SHANS2 [1] has been constructed recently. Heavy ions of all species with a maximum energy of 7 MeV/u and mass-to-charge ratio A/Q=3 can be provided. Thin radio source [2], as well as targets of all lanthanide elements [3] and radioactive americium can be prepared in the local laboratory. The thermochromatography LEGEND system contained the classic silicon detectors and advanced 4H-SiC detectors [3, 4] and gas purification system were developed for the chemical investigation of Nh (Z=113). Investigation into Bh (Z=107) carbonyls is also scheduled for the upcoming research phase.

As the core of the nuclear medicine, medical RI have been profoundly embedded in multiple critical segments, including disease diagnosis, precision therapeutics, and healthcare security, thereby assuming an irreplaceable role in the global healthcare system [5]. At IMP, efforts are actively advancing technologies for the accelerator-based production of medical isotopes, including ^{99m}Tc/^{99}Mo, ^{68}Ge/^{68}Ga, ^{211}At, ^{225}Ac, ^{223}Ra, ^{212}Pb [6, 7, 8, 9]. The HIRFL can accelerate high energy hydrogen ions, providing a platform for researching on the production of ^{225}Ac. Building on this capability, the research team leveraged HIRFL's beam to bombard metallic ^{232}Th targets, generating ^{225}Ac through spallation reactions. In this experiment, an independently designed remote-controlled target-unloading robot was developed to upload and transport the high-radiation-dose ^{232}Th target. More importantly, about 40 μCi of ^{225}Ac was efficiently obtained using a self-developed fully automated multi-chromatography separation system with the recovery of 80%, radioactive nuclide purity exceeding 98%, radiochemical purity reaching over 99%, and chemical impurity content below 2.5 μg/mL.

References

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On the stability of the $Sg(CO)_6$ complex

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for the $Sg(CO)_6$ collaboration at TASCA:

GSI Darmstadt (DE) - HI Mainz (DE) - JGU Mainz (DE) - CTU in Prague (CZ) - University of Liverpool (UK) - IIT Roorkee (IN) - JAEA Tokai (JP) - University of Jyväskylä (FI)

Chemical properties of the superheavy elements (SHE) are unique due to the strong relativistic effects, which influence their properties, e.g., the stability of the metal-ligand bonding in carbonyl complexes, which are SHE compounds featuring a metal-carbon bond as is typical for organometallic compounds. The formation of the carbonyl complex of Sg (Z = 106) and its interaction with a silicon oxide surface was reported more than 10 years ago [1]. Further developments to study this compound class have been performed to prepare measurements of the stability of $Sg(CO)_6$ [2], and the synthesis of a carbonyl complex with Bh (Z = 107) [3]. A new study of the carbonyl complex formation with ^{259}Sg, produced in the cold-fusion nuclear reaction ^{52}Cr(^{208}Pb,1n)^{259}Sg, has been performed at the TASCA separator at GSI Darmstadt, Germany. An advanced detection setup for the detection of non-volatile and volatile products was applied in this study, which provides new information on the stability of $Sg(CO)_6$ complex.

References

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Gas phase chemical studies of the superheavy elements at the SHE Factory with a focus on Cn and Fl

N.V. Aksenov[1], A.S. Madumarov[1], A.I. Golczman[1], A.A. Astakhov[1], G.A. Bozhikov[1], A.Yu. Bodrov[1], L.S. Porobanuk[1], I.V. Muravyov[1], I. Chuprakov[1], A.V. Sabelnikov[1], Y.A. Popov[1], O.N. Malyshev[1], A.I. Svirikhin[1], Y. Wang[2], Z. M. Jia[2], S. W. Cao[2], Y.F. Cui[2], X. J. Yin[2], Z. Qin[2]

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The chemistry of Cn and Fl has been the subject of long-term studies by two collaborations, which formed scientific chemistry programs at the accelerator laboratories FLNR and GSI [1,2]. Despite the obtained outstanding results, both experimental series are not conclusive due to the unpredicted observation of two adsorption zones in gas thermochromatography. The small number of observed Fl atoms also introduces an element of uncertainty in the interpretations of this observation. In the first series of experiments at the SHE Factory, before further detailed speciation studies, we repeat the TASCA experiment with the FLNR improved chemical setup behind the GRAND separator. Experiments on the synthesis of ^{286,287}Fl in the reaction ^{242}Pu(^{48}Ca,3-4*n*) using the DGFRS-2 and GRAND separators were preceded chemical studies [3,4]. The setup called Cryodetector, previously used for Nh studies [5], was equipped with a new RTC designed for the focal plane of the GRAND separator. New gold coated detectors array with an extended temperature gradient down to –170 ºC were fabricated. 8 decay chains assigned to adsorption of ^{287}Fl and ^{283}Cn were detected indicating two deposition zones at room temperature and around –100 ºC, confirming previous observations. The report briefly discusses research prospects related to the creation of an experimental base at the SHE Factory: a superconducting separator GASSOL for radiochemical research, a cryogenic gas ion trap, and a new chemical setup.

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Statues of chemical investigation of Nh at IMP

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The nihonium (Nh, Z = 113) and moscovium (Mc, Z = 115) are presently in the focus of superheavy elements (SHEs) chemistry studies [1, 2]. According to relativistic quantum chemistry models, Nh and Mc may exhibit higher chemical reactivity than their neighbors, copernicium (Cn, Z = 112) and flerovium (Fl, Z = 114). This increased reactivity results from unpaired electrons in their $7p^{1/2}$ and $7p^{3/2}$ orbitals. Studies on the chemical properties of Nh and Mc have advanced significantly in the past decade. Experiments were performed at JINR and GSI using the Si detector based thermochromatography. However, not a well-defined deposition peaks for Nh or Mc on the quartz surface have been achieved thus far.

The development of heavy ion research facilities in IMP offered us the opportunity to perform experiments on the chemistry of SHEs in China. According to the Monte Carlo simulation results with the adsorption enthalpy of -58 kJ/mol for Nh [3], a temperature gradient from about +60 ℃ to -60 ℃ may help us to obtain a clear deposition peak for Nh on quartz surfaces [4]. Therefore, high performance 4H-SiC detectors covered with Si_xN_y layers were prepared to develop the thermochromatography-LEGEND system. The first beamtime experiment using ^{48}Ca ions and ^{243}Am targets were performed at IMP. Then the analysis and characterization of the detector surface morphology, along with subsequent theoretical calculations were conducted.

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Alpha decay and proton emission studies using the in-flight separators MARA and RITU

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For three decades Nuclear Spectroscopy Group (NSG) has performed spectroscopic studies utilizing the in-flight separators RITU [1] and MARA [2]. The gas-filled recoil separator RITU has been in operation since 1994 and the activity with the vacuum-mode double focusing MARA started 2016. To perform spectroscopic studies the separators, need various efficient detector setups alongside. Continuous development work is needed to stay in the front line of research. A big fraction of the research program has been the alpha particle decay and proton emission studies. Some resent highlights from these studies will be presented.

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Towards livermorium chemistry: Atom-at-a-time gas chromatography studies with polonium

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The chemistry of the radioelement polonium has gained growing interest due to its formation in accelerator-driven systems, but it is scarcely studied owing to its pronounced radiotoxicity. As the lighter homologue of the superheavy element livermorium, whose chemical behaviour is unknown experimentally, investigations of polonium are also needed to prepare future experimental studies of livermorium. Thus, we have investigated the volatility and reactivity of atom-at-a-time quantities of polonium by applying gas-solid thermochromatography. ^{204}Po was produced at the Nuclear Physics Institute of the Czech Academy of Sciences in Řež (Czech Republic) by irradiating ^{206}Pb targets with a ^{3}He beam. Experiments were performed in helium gas or oxygen-containing gas mixtures on quartz surfaces with different degrees of reactivity, i.e., hydroxylation. On quartz glass with a low OH-concentration in helium, a volatile species with an adsorption enthalpy of 85^{+3}_{-2} kJ/mol was found and assigned to elemental polonium. On a highly hydroxylated quartz glass, an additional deposition zone of a less-volatile species was observed and attributed to a polonium species formed by chemical reaction with the surface. In oxygen-containing atmosphere and on a quartz glass with lower hydroxylation, elemental polonium and two additional species with lower volatilities, probably oxides of polonium, were observed. The chemical yield of the formed species was found to depend on the temperature and the water vapour content in the carrier gas. The results of the reported measurements will support preparations for future experiments with the superheavy element livermorium.

Approaching the dominance of electron-capture delayed fission in ^{234}Bk and ^{230}Am

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The first identification of the exotic decay process of Electron-Capture Delayed Fission (ECDF) of the very neutron-deficient isotope ^{234}Bk was performed, and improved ECDF properties for its alpha-decay product ^{230}Am were obtained at the gas-filled recoil separator SHANS2. The isotope ^{234}Bk was produced in the fusion-evaporation reaction ^{40}Ar + ^{197}Au ➞ ^{237}Bk* ➞ ^{234}Bk + 3n.
By using the method of temporal and position correlations, different decay channels of ^{234}Bk and ^{230}Am isotopes were investigated and a wealth of new experimental information was obtained.
The highest ECDF probabilities among all beta- or EC-delayed fission cases known so far are reported, showing the tendency of approaching the expected saturation towards P(ECDF)=1. The comparison of the P(ECDF) systematics with two theoretical fission models shows significant discrepancies in respect of corresponding fission barrier values. Meanwhile, the analysis of the ECDF probabilities in the heavy actinides and lead region suggests the similar ECDF mechanism in both cases. The need for a theoretical framework that can provide realistic beta-delayed fission probabilities for astrophysical predictions is strongly underlined.

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Po and Hg adsorption on functionalized gold chips

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Experiments studying the adsorption enthalpies of superheavy elements (SHEs) on various surfaces use isothermal or thermal gas phase chromatography. Typical challenges faced during these experiments include low count rates and the potential for strong adsorption of the SHEs on the surfaces, particularly Au-based surfaces. To address some of the challenges in these one-atom-at-a-time set-ups, our group has developed a method to change the interactions of heavy elements with Au-coated detectors, namely by the addition of self-assembled monolayers (SAMs). The functionalization of Au surfaces with SAMs aims to tune the adsorption of products on the detector surface, providing further information on the adsorption enthalpy of heavy elements. SAMs selectivity has been previously tested in online gas-phase experiments for Ir, Er, and At with both 1-(11-mercaptoundecyl)imidazole and 12-mercaptododecanoic acid SAMs [1], as well as with offline experiments with Po.
Recent experiments were performed in the SHEs homologues laboratory at the U120M accelerator in Řež (Czech Republic), demonstrating that ^{204,205}Po adsorption changed between a bare Au surface and a 12-mercaptododecanoic acid (MDDA) functionalized gold surface in an isothermal gas chromatography column. Continuing with ^{204,205}Po, two more SAMs were chosen to compare to the first results: benzyl mercaptan (BMT) and 1-dodecanethiol (DDT). In addition, the previously tested MDDA and bare Au surfaces were again tested, but with a more volatile element, ^{192}Hg, to determine the impact of element volatility and reactivity on SAMs adsorption. Work has begun on creating Monte Carlo simulations to model the adsorption process of Po and Hg on these surfaces. This work discusses our latest results and future plans.

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Production and Processing of Heavy Actinides at Oak Ridge National Laboratory

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As the primary producer of transplutonium isotopes for the Western world, Oak Ridge National Laboratory (ORNL) plays a critical role in industrial applications and fundamental research. The lab's main transplutonium product, ^{252}Cf, is used as a neutron source in oil exploration, in initiation of nuclear reactors, in power generation, for detection devices, and in medical research. Additionally, the subproducts ^{249}Bk, ^{254}Es, and ^{257}Fm are in high demand for performing fundamental studies and discovering superheavy elements. Current purification methods rely heavily on established knowledge of these elements, whose chemistry - unlike that of earlier-series members - is predominantly governed by the trivalent oxidation state. This presentation focuses on the recovery of ^{249}Bk, ^{254}Es, and ^{257}Fm from the C81 ^{252}Cf campaign.

Status and Perspectives of the HELIAC-Project

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The linear accelerator HELIAC will deliver heavy ions with particle energies of 3.5–7.6 MeV/u (A/Z = 6) at the GSI Helmholtzzentrum für Schwerionenforschung. Thanks to superconducting radio-frequency technology, it will provide high average beam currents in continuous-wave operation. The radio-frequency resonators of the Crossbar H-mode (CH) type are being developed in cooperation with the IAP of Goethe University Frankfurt. Their suitability for ion-beam acceleration was successfully demonstrated in an earlier phase of the project. The subsequent advanced demonstrator phase aimed to perform a beam test of a fully equipped series cryomodule; this test has recently taken place at GSI. During beam commissioning, the design energy of 2.7 MeV/u for argon ions was reached. This talk will present the current status of the project and recent activities, as well as the design of the complete HELIAC accelerator.

Study of fission for ^{258}Md

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To understand fission process is important for super-heavy-element (SHE) research as the stability of nucleus against fission regulates the existing limit of atomic nuclei. In the production of SHEs, fission barrier height significantly changes the production cross-sections for SHEs. However, our knowledge on fission is marginal, especially for the SHE region. It was found in spontaneous fission (SF) that fission-fragment mass distributions (FFMDs) show a dramatic change from mass-asymmetric fission of ^{256}Fm to sharp symmetric fission of ^{258}Fm [1], indicating an unique feature in fission for heavy- and neutron-rich nuclei.

At JAEA, we have studied fission of ^{258}Md (atomic number Z=101) from excited states. The fissioning nucleus is populated by bombarding ^{4}He beam from JAEA tandem accelerator to einsteinium target ^{254}Es ($T_{1/2}$=256 day). The ^{254}Es was obtained from ORNL, US. The experimental data shows the mass-asymmetric fission modes, similar to lighter actinide fissions. Also, symmetric fission mode with higher TKE was found. By the increase of excitation energy from 15 MeV to 18 MeV, the yield asymmetric fission mode enhances.

We carried out a Langevin calculation based on the Cassini-oval nuclear shape parametrization. Here, we introduced 6-shape dimensions, i.e. the highest dimension ever achieved in this type of calculation. The results show that at very low excitation energy, the symmetric fission mode, originating from the shell structure close to ^{132}Sn, is dominant, which is, however, quickly smeared with excitation energy. On the other hand, mass-asymmetric mode is robust against excitation energy.

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Overturning the Understanding of Superheavy Element Synthesis Reaction Dynamics Through Direct Measurements of Sequential Fission

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Accurately predicting the reaction cross section for forming superheavy elements presents a significant challenge to their synthesis. The largest uncertainty remains the determination of the probability of compound nucleus formation, which is severely limited by quasifission.

In hot fusion superheavy element synthesis reactions, there is a long-observed quasifission mass yield peak near ^{208}Pb [1--5]. This was initially attributed to the doubly-magic nature of ^{208}Pb [6]. Time-dependent Hartree-Fock calculations of these reactions have also found mean yields to be located at the same mass, strengthening the conclusion that this is a result of microscopic shell effects [4].

However, an alternate explanation for this phenomenon attributes the peak at ^{208}Pb not to shell effects halting mass flow, but to a decrease in yield of binary events above ^{208}Pb due to their fission [6--8]. Known as ``sequential fission'', this process occurs when fragments heavier than ^{208}Pb formed by fast quasifission have excitation energy above their fission barrier --- producing a three-body reaction outcome. This process cannot be directly measured by an experiment designed for binary quasifission and therefore produces an anomalous peak once the fission barrier increases near ^{208}Pb. The conflict between these possible explanations represents a significant gap in our understanding of the mechanism of quasifission and its role in suppressing the formation of a compound nucleus for $Z_{CN} > 110$.

In this talk I present the results of a direct measurement of the three-body reaction outcomes of ^{50}Ti with ^{238}U, ^{244}Pu, ^{248}Cm, and ^{249}Cf at the Heavy Ion Accelerator Facility at the Australian National University. I will discuss the identification and reconstruction of sequential fission events into the intermediate fast quasifission outcome, which when combined with the simultaneous measurements of the binary quasifission shows no evidence of increased yield at ^{208}Pb in any system measured. The analysis indicates a smooth evolution between deep inelastic scattering and quasifission and provides significant insight into the dynamics of mass and kinetic-energy equilibration during the first few moments following capture.

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Microscopic Models of Fission Dynamics

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The process of spontaneous or induced fission presents an example of large-amplitude collective motion in self-bound mesoscopic systems, exhibiting an interplay between classical and quantum effects. A wealth of experimental results has been accumulated, and a basic understanding of fission mechanism gained. In recent years, major progress has been achieved in the development of time-dependent microscopic approaches that offer a more comprehensive and predictive description of the fission process. These advances encompass the calculation of fission fragment yields [1], the characterization of energy dissipation mechanisms and total kinetic energy distributions [2,3], the study of neck formation and rupture dynamics [4], the treatment of quantum fluctuations and symmetry restoration [5], the microscopic origin of fragment angular momentum, and the analysis of quantum entanglement between the emerging fragments [6].

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Status of the Super Separator Spectrometer at GANIL

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The in-depth study of the regions of Superheavy elements and the proton dripline around ^{100}Sn are two major challenges of todays' Nuclear Physics. Performing detailed spectroscopic studies on these nuclei requires a significant improvement of our detection capabilities.
The Super-Separator-Spectrometer S^3 is part of the SPIRAL2 facility at GANIL. Its aim is to use the high stable beam currents provided by the new LINAC to reach rare isotopes by fusion-evaporation.
S^3 is designed to provide the best rejection power along with a high transmission and a mass resolution of around 400. The use of high-acceptance superconducting multipoles provides a high transmission thanks to large gaps and higher-order optical corrections. These features, connected to a high-power target station, will provide access to nuclei with fusion-evaporation cross section down to the picobarn region and below.
This presentation will describe the technical capabilities of S^3 and give a status of the construction of all systems and its commissioning plan.

Study of deformed structure in ^{254}Es by Coulomb excitation

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Exploring the new elements toward the high end of the nuclear chart is one of the most interesting topics in nuclear physics. The key ingredient to stabilize nucleus in this region is a nuclear shell structure and Z=114, 120, N=184 [1-4] are predicted to be new magic numbers. However, the access to such nuclei and study of their shell structure is limited by the very low cross sections. To investigate and understand the shell structure there, we are focusing on the nuclei in the A~250 heavy mass region including ^{254}Es. By studying the excited states, spin and parity, and deformation, we will be able to access the single-particle orbitals relevant to new shell structure at Z=114, 120, N=184 in the super-heavy mass region.

In A∼250 nuclei, experimentally observed rotational bands indicate the existence of deformed structure in this region, however the studies of deformation, such as determination of quadrupole moment, are not performed well. To understand single-particle structure, it is important to determine the size of ground state deformation systematically.

To study nuclear deformation in the A~250 region, we have performed Coulomb excitation experiments to determine the deformation of low-lying states of ^{254}Es. The experiment was performed at the JAEA-Tokai Tandem accelerator using a 240-MeV ^{58}Ni beam irradiating a ^{254}Es target. Particle-gamma coincidence measurements were conducted using segmented CD-silicon detectors placed backward and forward from the target and an array of Ge and $LaBr_3$ detectors. From the gamma-ray spectrum analysis, a rotational band structure in ^{254}Es was observed. In the presentation, recent experimental results will be discussed.

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Experimental priorities of the Heavy Element group in Switzerland

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Over the past five years, the Heavy Elements group at PSI / ETH Zurich has focused its attention on two main topics, namely (1) homolog experiments with thallium on fused silica for the future chemical characterization of Nh, and (2) isothermal vacuum chromatography (IVAC) for the investigation of the shortest-lived isotopes and enabling higher stationary-phase temperatures. For both topics, the development of high-temperature α-spectroscopy using the wide-bandgap semiconductor 4H-SiC is instrumental. Together with our collaborators, we have made significant progress in these areas (see, e.g., [1,2]). While pursuing the next Nh chemistry experiments in collaboration with the Institute of Modern Physics, Chinese Academy of Sciences, in Lanzhou, China, we plan to rework the IVAC setup to meet the requirements for a first Mc experiment *in vacuo* at RIKEN (in collaboration with the Folden group at Texas A&M University, USA, and others). Furthermore, our group strives to revive the CO collaboration for next $Sg(CO)_6$ decomposition studies and is probing the waters for first electrochemistry experiments with roentgenium (together with colleagues from CTU in Prague, Czech Republic). These efforts have evolved out of experiments directed to radioanalytical applications [3,4]. This talk will highlight the current status of the projects of the Heavy Elements group at PSI / ETH Zurich and discuss the next steps we plan to take together with our collaborators.

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Start of commissioning of UniCell - A new fast and highly efficient buffer-gas stopping cell for superheavy element chemistry

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Investigations of the chemical behavior of superheavy elements have recently reached element 115, moscovium. While 195-ms ^{288}Mc is just barely sufficiently long-lived for studies with established methods at TASCA, no isotopes of the subsequent element, livermorium, with half-lives exceeding about 60 ms are currently known. Since the existing setup requires extraction times of several hundred milliseconds, faster extraction techniques are required to enable future studies of this heavier element.
For this purpose, a buffer-gas stopping cell designed to provide fast and efficient extraction of superheavy element ions, UniCell, has been proposed. In contrast to many other stopping cells, UniCell stops ions in atmospheric pressure helium and extracts them through a funnel using strong DC gradients, supported by an RF field to suppress wall interactions and maximize efficiency. Simulations yielded extraction times as short as 2 ms and efficiencies approaching 100 %.
A prototype has been constructed, which is currently being commissioned offline. The current status of UniCell will be presented.

Sympathetic laser-cooling of a single heavy ion in a Penning trap

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Single-ion sympathetic laser cooling is typically performed with ions that are created directly inside an ion trap, most often a linear Paul trap. This technique has been widely applied in optical clock research through the implementation of quantum logic spectroscopy [1, 2]. In contrast, the cooling of ions produced outside the trap is less common; an example is the sympathetic cooling of thorium ions within a linear chain of $^{40}Ca^{+}$ ions [3]. Earlier studies using the Penning trap platform have been comparatively scarce, with only demonstrations involving clouds composed of two ion species [4]. At the University of Granada, we are investigating sympathetic laser cooling of individual ions in a 7 T Penning trap with the goal of forming a two-ion hybrid Coulomb crystal for pure photon- based mass spectroscopy [5, 6]. In this contribution, we present the status of sympathetic laser cooling in a 7 T Penning trap installed in a cryogen-free magnet, in combination with the photon-based identification techniques. Although the present target ion has a mass relatively close to that of the sensor ion, the production of thorium ions in the laboratory will soon enable the extension of these techniques to research opening prospects for experiments involving ions from heavy and superheavy elements.

References

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K-isomerism in seaborgium

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Excited states with high *K* quantum numbers provide valuable information on the underlying nuclear structure. Due to the conservation of the *K* quantum number in deformed nuclei, transitions requiring large changes in *K* are strongly hindered, and thus those excited states exist as isomers [1,2]. Of special interest are superheavy nuclei, where the high-*K* states are significantly stable against fission [3,4]. This enables access to nuclei whose ground states would otherwise be too short-lived to be experimentally studied [5].
K isomers are spread over in nobelium (Z=102) and rutherfordium (Z=104) isotopes, however, in the heavier elements, only two alpha-decaying cases have been observed [^{270}Ds (Z=110) and ^{266}Hs (Z=108)] [2]. Only recently, at TASCA, a strong indication of a *K*-isomeric state was observed in seaborgium (Z=106) isotopes, i.e., in ^{259}Sg [6].
Inspired by this observation [6], all experimental data on seaborgium isotopes accumulated at SHIP during 2003-2009 were revisited. In this talk we will present the results from the reanalysis of those experimental data.

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