TASCA 08

7th Workshop on
Recoil Separator for Superheavy Element Chemistry
October 31, 2008, GSI, Darmstadt, Germany

last update: Oct. 29, 08

Final Program and Abstracts

TIME		TOPIC	Speaker	Page
08:45		**Welcome by the director of GSI**	H. Stöcker	
08:50		**TASCA commissioning summary report**	M. Schädel	
		TASCA Related Hot Topics		
09:15	§	**RIKEN GARIS for superheavy element chemistry**	H. Haba	2
09:30	§	**Element 114 chemistry: experimental status**	R. Eichler	3
09:45	§	**Element 114 chemistry: theoretical status**	V. Pershina	4
10:00		***Coffee Break***		
		Status + Future Program: Chemistry		
10:20	*	**Experiments on the chemistry of element 114**	A. Yakushev	4
10:40	*	**Electrodeposition experiments with hassium**	J.V. Kratz	5
11:00	*	**SISAK experiments with transactinides**	J.P. Omtvedt	6
11:20	*	**Organometallic compounds of transactinides: hassocene**	Ch.E. Düllmann	6
11:40		***Workshop photo** and Lunch***		
		Status + Future Program: Physics		
12:40	#	**Spectroscopy experiments with TASISpec**	L.-L. Andersson	7
13:10	#	**Hassium spectroscopy experiments**	A. Yakushev	8
13:40	#	**Toward element 117** 1) $^{48}Ca + ^{244}Pu \rightarrow$ element 114	Ch.E. Düllmann	9
	#	2) search for element 117		
14:40		***Coffee Break***		
15:00		**Plenary Discussion: the Future TASCA Program** Priorities of experiments; timeline for each experiment Participation / manpower ➔ Who writes which proposal by when and requests how much beamtime? ... and evaluates relevant commissioning data as a basis(!)?		
16:00		***End***		

§ allow 5 min discussion time

* allow 10 min discussion time

\# allow 15 min discussion time

** Meeting point: the yellow pavilion roof near guest house/pond or (if it rains) the lecture hall

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RIKEN GARIS for Superheavy Element Chemistry

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A gas-jet transport system for superheavy element chemistry was coupled to the gas-filled recoil ion separator GARIS at the RIKEN Linear Accelerator. The performance of the system was first appraised using ^{206}Fr, ^{245}Fm, and ^{255}No produced in the ^{169}Tm(^{40}Ar,3*n*)^{206}Fr, ^{208}Pb(^{40}Ar,3*n*)^{245}Fm, and ^{238}U(^{22}Ne,5*n*)^{255}No reactions, respectively [1,2]. During the last one year, we have developed the new recoil transfer chamber with the entrance Mylar window foil of 100 mm diameter and of 0.5 µm thickness. A rotating $^{248}Cm_2O_3$ target of 100 mm diameter and of 280 µg cm–2 thickness was prepared by an electrodeposition onto the 2-µm titanium backing foil. Recently, ^{261}Rf produced in the very asymmetric ^{248}Cm(^{18}O,5*n*)^{261}Rf reaction was successfully extracted to the rotating wheel system MANON for α-spectrometry after the preseparation with GARIS. Figure 1 shows the sum of the α-particle spectra measured in the seven top detectors of MANON for 210 s after the 30-s aerosol collection. A total of 58 time-correlated α pairs of ^{261}Rf and its daughter ^{257}No were registered in the α-energy range of interest. In the workshop, chemistry programs at RIKEN will be also proposed.

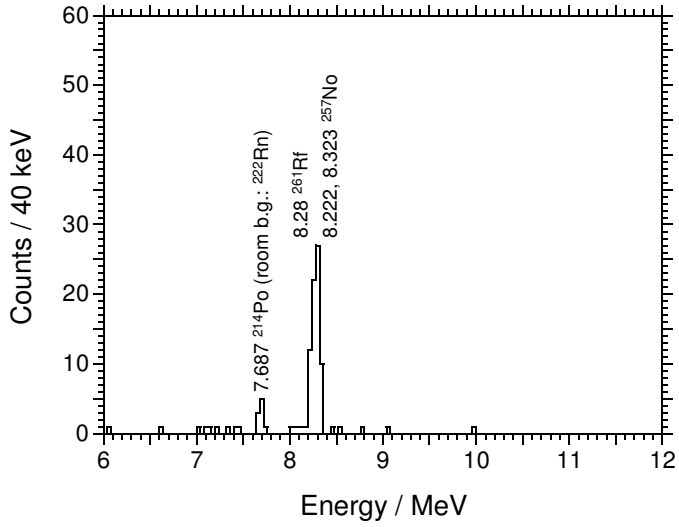

Figure 1. Sum of α-particle spectra measured in the seven top detectors of MANON for 210 s after the 30-s aerosol collection. The 30-s aerosol collection was repeated 697 times. The beam dose of 6.3×10^{17} was accumulated.

References

[1] H. Haba *et al.*: J. Nucl. Radiochem. Sci. **8**, 55 (2007).
[2] H. Haba *et al.*: J. Nucl. Radiochem. Sci. **9**, 27 (2008).

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Chemical investigation of element 114

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Element 114 is an element of group 14 in the periodic table together with carbon, silicon, germanium, tin, and lead. With increasing atomic number Z a typical trend observed along the main groups 13-17 of the periodic table is the enhancing metallic character [1-3]. On the other hand, relativistic calculations of the electronic structure of SHE predict an increased chemical stability of the elemental atomic state for element 114, having an electronic ground state configuration of Rn:$5f^{14}6d^{10}7s^{2}7p_{1/2}^{2}$ [3-9]. Therefore, a high volatility and a chemical inertness were postulated. Modern relativistic calculation models predict atomic properties for element 114, representing a higher chemical inertness but still a chemical similarity to the lighter group 14 metal lead [9-11]. We present first experimental evidence for a noble-gas like behavior of element 114 in contact with a gold surface.

[1] Eichler, B. Kernenergie 19, 307-311 (1976) (in German).
[2] Eichler, B. PSI Report 00-09, Metal chemistry of transactinides. Villigen (2000) ISSN 1019-0643.
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[10] Seth M. et al. Angew. Chem. Int. Ed. 37, 2493-2496 (1998).
[11] Pershina, V. et al. J. Chem. Phys. in press, (2007).

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Element 114 chemistry: theoretical status

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The latest results of the fully relativistic, 4*c*-Density Functional Theory calculations of "M – large gold cluster" systems (M = Hg, Pb, 112 and 114) are discussed. On their basis, the adsorption behaviour of these elements on various sites of the gold (100) and (111) surfaces is compared.

Experiments on the chemistry of element 114 at TASCA

Alexander Yakushev for the TASCA collaboration

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More than 30 nuclei of superheavy elements with Z up to 118 have been synthesized in the vicinity of the long-predicted island of stability [1]. The increased stability of heavier isotopes of superheavy elements allows studying them by chemical means. Commissioning experiments at TASCA have demonstrated that this separator is suited for experiments on physics and chemistry of superheavy elements. One of the most exiting goals is studying chemical properties of element 114. First results of recent experiments on the chemistry of element 114 performed at FLNR Dubna by the PSI – University of Bern - FLNR – LLNL collaboration will be presented at this workshop [2]. Further experiments are very valuable for more precise definition of chemical properties of element 114.
Element 114 belongs to group 14 in the periodic table, where with increasing atomic number Z enhancement of metallic character and volatility is observed. Relativistic calculations of the electronic structure of element 114 predict stabilization of the valence shell electrons $7s^2 7p_{1/2}^2$ [3], and on the other hand a rather strong bonding with transition metals [4]. Physics experiments aiming at detecting evaporation residues from the $^{244}Pu(^{48}Ca,xn)^{292-x}114$ reaction in a new focal plane detection system need to be performed before chemistry experiments with element 114 can be conducted [5]. The following chemistry experiments will make use of a new, specially designed version of the **C**ryo **O**n-line **M**ultidetector for **P**hysics **A**nd **C**hemistry of **T**ransactinides (COMPACT) that can be directly connected to the **R**ecoil **T**ransfer **C**hamber (RTC) of TASCA. Two types of PIPS diodes mounted in two different COMPACT detectors, SiO_2 or Au covered, allow measuring both, the volatility and reactivity of element 114.

[1] Oganessian, Y. J. Phys. G **34**, R165 (2007).
[2] Eichler, R. Contribution to this workshop.
[3] Pitzer, K.S. J. Chem Phys. **63**, 1032 (1975); Int. J. Quantum Chem. **25**, 131 (1984).
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[5] Düllmann, Ch. E. Contribution to this workshop.

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Electrodeposition experiments with hassium

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The scientific case for electrodeposition experiments with superheavy elements has been published by H. Hummrich et al. [1]. Recently, applications to short-lived Ru isotopes produced in ^{249}Cf(n_{th},f) were conducted at the TRIGA Mainz reactor, and electrodeposition of short-lived Os isotopes produced in the ^{nat}Ce(^{40}Ar,xn) reaction was performed as the first ever chemistry coupled on-line to TASCA [2]. An automated electrodeposition system involving a metallic tape that is stepped through the electrolysis cell and subsequently through a phalanx of 2x8 silicon detectors is under construction. Its control is done by a SIMATIC processor and the data acquisition involves 2x16-ch Mesytec amplifiers (α and SF) delivering the data to a 32-ch CAEN ADC contained together with a trigger box and a scaler in a VME crate communicating with the GO4 software, see Figure 1.

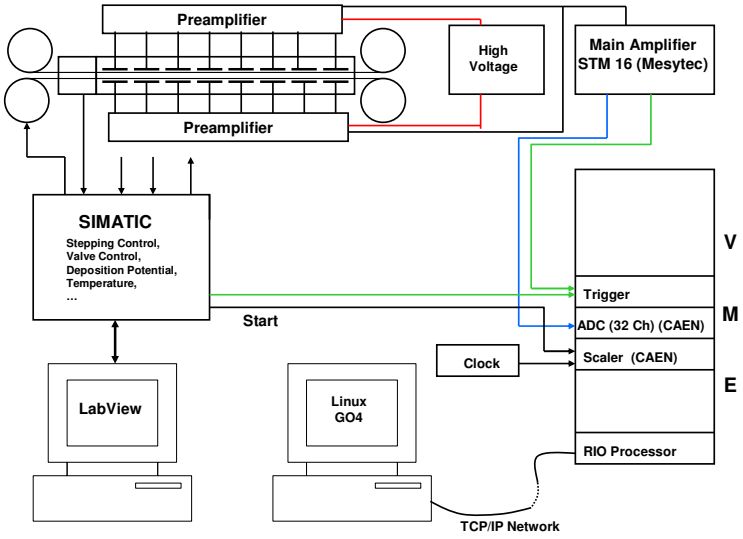

Figure 1: Schematic of the electrodeposition system with electrolysis cell, tape and detection system, the processor and data acquisition system

For preparatory experiments with $^{172\text{-}174}$Os from the ^{nat}Ce(^{40}Ar,xn) reaction in 2009, using the newly constructed system shown in Figure 1, 2x3 days of beam time (U182) will be requested. For 2010, production and electrodeposition of ^{270}Hs from the ^{226}Ra(^{48}Ca,4n) reaction (σ = 9 pb) is envisaged. At a beam intensity of 0.8 pμA, 5.4 days of beam time are estimated to be required for the detection of 1 event. Thus, a total of ≥ 27 days of beam time is required. If this experiment is successful at -500 mV, a second one at a more positive potential is envisaged. Collaboration partners that we like to invite are GSI, TUM, and other interested groups.

[1] H. Hummrich et al., Radiochim. Acta **96**, 73 (2008)
[2] J. Even, Unterpotentialabscheidung von Ruthenium und Osmium, Diplomarbeit, (2008)

SISAK experiments with transactinides

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The liquid-liquid extraction system SISAK has been successfully used to study the chemical behavior of rutherfordium (using the 4-s isotope ^{257}Rf) after preseparation with the Berkeley Gas-filled Separator (BGS) at LBNL. Recently it was also demonstrated that the SISAK detector system is sensitive enough to enable chemical experiments with dubnium (the 4-s ^{258}Db was successfully detected at the BGS). This marks the end of a series of successful SISAK-BGS experiments pioneering the study of transactinides after physical preseparation and on-line transfer to a chemistry system using a Recoil Transfer Chamber.

This opens up a large number of possible transactinide experiments in liquid phase in the future, using the SISAK technique. Since the RTC technique was developed in Berkeley, the GSI TASCA separator has been fitted with a RTC. Thus, it's now possible to do transactinide experiments with preseparated activity both at GSI and at LBNL. This presentation will outline the possibilities and current plans for SISAK experiments at both places.

Investigation of group 8 metallocenes @ TASCA

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The technique of preseparation is expected to give access to compound classes of the transactinides that could not be investigated in conventional setups, e.g., organometallic compounds. An interesting chemical system, namely the group 8 metallocenes, has been presented at the last workshop of the series, TASCA 07 held in Davos [1].
In the contribution to the current workshop, TASCA 08, a more detailed plan on how to start up this program will be presented along with a possible time-line. This will serve as a basis to decide on how to proceed with writing a proposal and aligning the experiments with the rest of the experimental program at TASCA and the experiments of other TASCA collaborators.

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TASISpec - Test Results and First Ideas[1]

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A new nuclear spectroscopy setup called TASISpec (TAsca Small Image mode Spectroscopy) has been designed and was tested in a first experiment. It exploits TASCA's unique so-called small image mode. The fact that the produced SHE can be focused into an area of less than 3 cm in diameter in this ion-optical mode provides the possibility to place composite Ge-detectors very closely around the focal plane, resulting in an unprecedented, highly efficient detection of γ-rays and *X*-rays in coincidence with implanted SHE. The test set-up as used in August 2008 is illustrated in Fig. 1. Conversion electron, γ, and α sources as well as parasitically the reactions ^{150}Nd(^{64}Ni,xn)$^{214-x}$Ra, ^{206}Pb(^{48}Ca,2n)^{252}No, ^{207}Pb(^{48}Ca,2n)^{253}No, and ^{244}Pu(^{48}Ca,4n)^{288}114 will be (October 2008) or have been (August 2008) used to start to characterise TASISpec. Detection efficiencies, energy thresholds of particle- and γ-ray detectors, dead times and data rates of the first, crude data acquisition system, etc. were tested. First results of the offline analyses are going to be presented along with upgrades or improvements on the electronics side, the necessary completion on the mechanical side, and, of course, ideas for first full-scale experiments, which are anticipated to start in 2009.

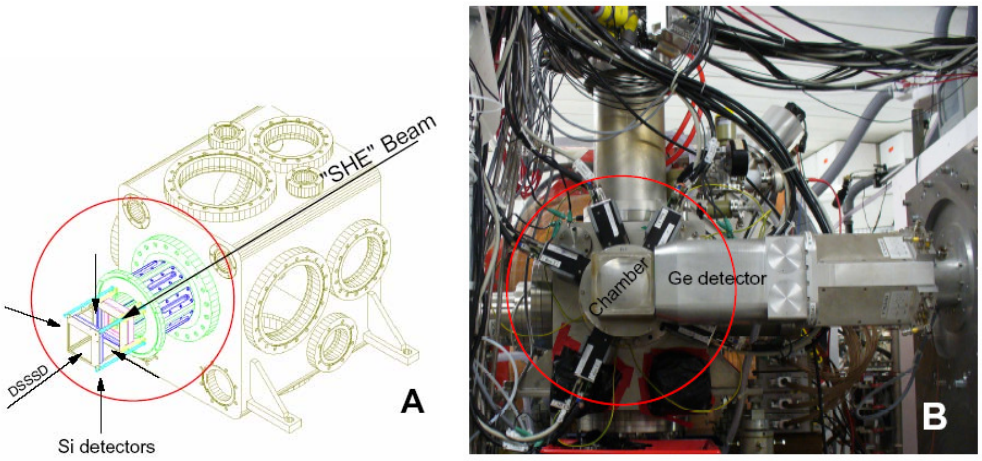

Figure 1: The TASISpec set-up installed at the focal plane of TASCA.

[1]Thanks to the RISING collaboration for the use of detectors and electronics.
[2] On leave from Universidad Nacional de Colombia, Bogotá, Colombia.

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Hassium spectroscopy experiments at TASCA

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Synthesis and studies of hassium isotopes near and at the closed deformed shells with Z = 108 and N = 162 produced in the ^{26}Mg + ^{248}Cm reaction have been performed recently [1,2]. The very high overall efficiency and sensitivity after the chemical separation using the **C**ryo **O**n-line **M**ultidetector for **P**hysics **A**nd **C**hemistry of **T**ransactinides (COMPACT) have been demonstrated in these experiments. Most recently studies of different nuclear reactions leading to the same compound nucleus have been started: i) ^{48}Ca + ^{226}Ra at the Dubna Gas Filled Separator, ii) ^{36}S + ^{238}U at GSI Darmstadt using chemical separation. These studies allow to choose the most effective way for production of hassium isotopes.
The combination of physical pre-separation in TASCA and chemical separation opens an unique possibility to perform studies of nuclear structure in the region around Z = 108 and N = 162. An extremely pure chemistry and very high detection efficiency allow to measure spectroscopic properties of single decay chains using a new detection device for **AL**pha-**BE**ta-**GA**mma **S**pectroscopy (ALBEGAS). The new detection system consists of a "sandwich-like" pixelized cryo-detector with a gas channel for detecting alpha particle and fission fragments, surrounded by two segmented detectors for conversion electrons and two clover Ge detectors (see Figure).

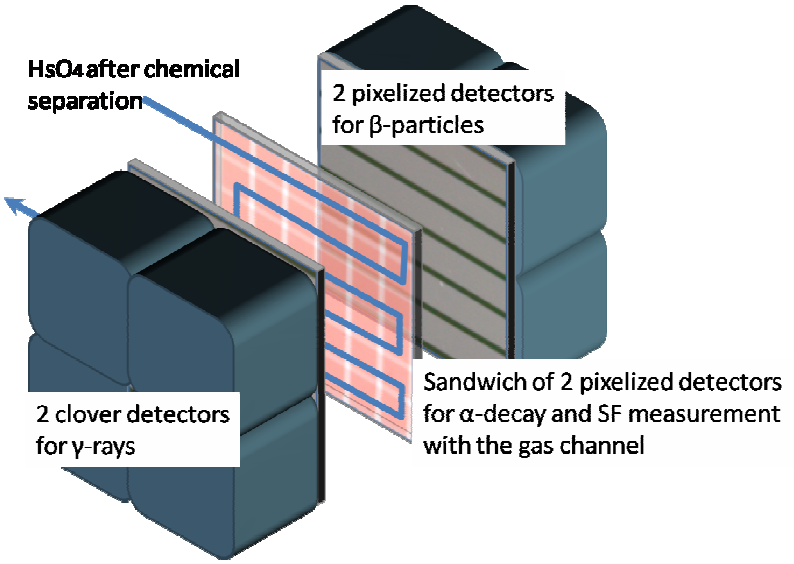

Figure. Proposed detector design for α-β-γ-spectroscopy measurements of Hs nuclei and daughters.

[1] Dvorak, J. Phys. Rev. Lett. **97**, 242501 (2006).
[2] Dvorak, J. Phys. Rev. Lett. **100**, 132503 (2008).

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Toward element 117

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Detection of elements with Z up to 118 has been reported [1], with element 117 still being undiscovered. Commissioning experiments at TASCA have shown this separator to be one of the best suited devices for experiments aiming at discovering element 117: it can exploit the high beam currents from the UNILAC accelerator, offers the possibility to irradiate any kind of targets – including neutron-rich radioactive actinide ones – and, of paramount importance, has superior transmission, also for hot fusion reactions such as ^{48}Ca induced ones as used in the discovery of the heaviest currently known elements. The possibility to operate TASCA with various fill gases makes it a very versatile device.
During the commissioning, the efficiency for the reaction ^{208}Pb(^{48}Ca,2n)^{254}No was measured and found to be in agreement with expectations based on Monte-Carlo simulations. Actinide targets (including ^{244}Pu) have been irradiated over extended periods of time and their stability under irradiation conditions has been shown.

Step 1: ^{244}Pu(^{48}Ca,*x*n)$^{292-x}$114
A mandatory final step before a search experiment for a new element can be undertaken is to demonstrate that the facility is ready and performs as expected in a system similar to the one to be studied. In our opinion, the best suited reaction for that is ^{244}Pu(^{48}Ca,xn)$^{292-x}$114. After the successful commissioning program, many aspects of such an experiment are already well under control and ready. On the technical side, the implementation of an advanced focal plane detection system is the most urgent task. This is currently under way, in a collaborative effort of different institutes within the TASCA collaboration. The status of this development will be discussed and the details to be addressed before a ^{48}Ca+^{244}Pu experiment will be presented. This will serve to lay out a detailed scheme concerning the distribution of the remaining tasks.
A successful ^{48}Ca+^{244}Pu experiment represents the final step before a search experiment for element 117.

Step 2: search for element 117
A major experimental effort at TASCA in 2009 could be devoted to a search for element 117. The pertinent aspects to be discussed include i) choice of the nuclear reaction (taking into account constraints such as availability of target material and beams from the UNILAC), ii) expected detection rate and implications for the amount of requested beamtime, iii) needed manpower from within the TASCA collaboration to run an experiment over very long periods of time.

The presentations will serve as a basis to i) discuss the substantial beamtime- and manpower needs of both, a ^{48}Ca+^{244}Pu experiment as well as a search for element 117, and ii) write a proposal for this research program.

[1] Oganessian, Y.: Heaviest nuclei from ^{48}Ca induced reactions. J. Phys. G **34**, R165 (2007).