TASCA 11

Last update: 2011-10-11

10th Workshop on
Recoil Separator for Superheavy Element Chemistry
October 14, 2011, GSI, Darmstadt, Germany

Final Program & Abstracts

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The length of all presentations will be 15 minutes + 10 minutes discussion time

New results for ^{48}Ca + ^{243}Am from Dubna

R. Henderson
for the
JINR / LLNL / ORNL / VU collaboration

Recently completed experiments carried out at the U-400 facility of the Flerov Laboratory at the Joint Institute for Nuclear Research in Dubna, Russia, have given additional data to the previous experiments carried out earlier. 21 new events in full agreement with the discovery experiment have been observed, which has provided us with the ability to generate very good data on the decay properties of 6 nuclides beginning with ^{288}115. We have also determined an excitation function for th production of this parent nuclide at three separate energies. At the end of the experiment we were able to observe a single decay chain quite similar with ^{289}115, which has been previously reported in our discovery experiments producing ^{293}117, through the ^{48}Ca + ^{249}Bk reaction.

Superheavy Element Research at the Berkeley Gas-Filled Separator

J.M. Gates

for the Heavy Element Nuclear and Radiochemistry Groups

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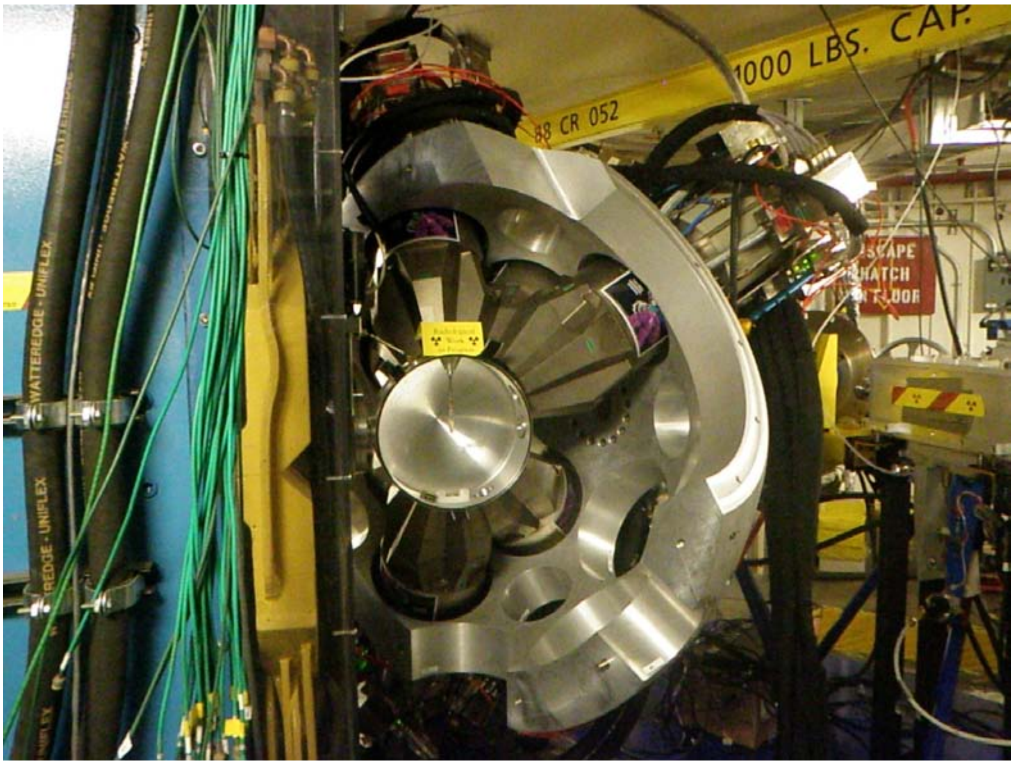
Studies have been undertaken at the Lawrence Berkeley National Laboratory using the Berkeley Gas-filled Separator (BGS) to test heavy element formation models. Lately, these studies have been extended to ^{48}Ca beams with actinide targets and nuclear structure studies. These experiments have led to the first confirmation of element 114 in the ^{242}Pu(^{48}Ca,3-4n) reaction and the production of Z=100-106 isotopes around the N~152 shell for nuclear structure studies. Most recently, GRETINA (the small Gamma-Ray Energy Tracking Array) was placed at the target position of the BGS. GRETINA is a novel gamma-ray detector system designed to study the structure and properties of atomic nuclei. In conjunction with the BGS, it will be used to investigate in-beam spectroscopy of nobelium and rutherfordium isotopes. Current developments in nuclear structure and superheavy element studies, as well as future plans and improvements at the BGS will be discussed.



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News from TASCA

Ch.E. Düllmann

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Work at TASCA since the last Workshop was held in October 2010 was dominated by upgrades of various components of the gas-filled TransActinide Separator and Chemistry Apparatus TASCA [1-3] for the approved

-search for the new element 120 in the reaction ^{249}Cf(^{50}Ti,xn)$^{299\text{-}x}$120, and
-the "SHE fingerprinting" experiment with TASISpec [4].

Besides this, experiments using TASCA as a preseparator to study carbonyl complexes of 5d transition elements were performed, which will be reported in a separate contribution to this workshop [5].

The main emphasis of my report will be on the following (some of which will be discussed in more detail in dedicated contributions to the workshop):

-A new "high intensity" target wheel for transuranium targets, including ^{243}Am and ^{249}Cf (see also [6]).

-Measures for a significant reduction of unwanted background (while maintaining the high EVR efficiency) in the focal plane of TASCA, which include the installation of a stripper foil upstream of the target to increase the charge state of the beam, and the installation of two slits inside the vacuum chamber of TASCA.

-The implementation of a new digital acquisition system suitable for registering very short-lived isotopes with half-lives in the microsecond range (see also [7,8]).

The performance of the upgraded system was verified in beam-tests in 2011 and the reaction ^{249}Cf(^{50}Ti,xn)$^{299\text{-}x}$120 is currently being studied at TASCA..

[1] A. Semchenkov *et al*., Nucl. Instrum. Meth. B 266 (2008) 4153
[2] J.M. Gates *et al*., Phys. Rev. C 83 (2011) 054618.
[3] Ch.E. Düllmann *et al*., Phys. Rev. Lett. 104 (2010) 252701.
[4] L.-L. Andersson *et al*., Nucl. Instrum. Meth. A 622 (2010) 164, and contribution to this workshop.
[5] J. Even *et al*., contribution to this workshop
[6] J. Runke *et al*., contribution to this workshop
[7] N. Kurz, contribution to this workshop
[8] P. Wieczorek, contribution to this workshop

Recent TASISpec Results

L.-L. Andersson[1,2], R.-D. Herzberg[1], E. Parr[1], D. Rudolph[3], L. G. Sarmiento[3,4], C. Fahlander[3], U. Forsberg[3], P. Golubev[3], D. Ackermann[5], Ch.E. Düllmann[2,5,6], J. Dvorak[2], J. Gerl[5], F.P. Heßberger[2,5], E. Jäger[5], J. Khuyagbaatar[2,5], I. Kojouharov[5], J. Krier[5], N. Kurz[5], E. Merchán[5], I. Pysmenetska[2,6], M. Schädel[5], H. Schaffner[5], B. Schausten[5], H.-J. Wollersheim[5], A. Yakushev[5], K. Eberhardt[6], J. Even[6], J.V. Kratz[6], P. Thörle-Pospiech[6], and M. Saxena[7]

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The detector array TASISpec [1] (TAsca in Small Image mode Spectroscopy) aims to detect a variety of radiations with very high efficiency, providing a spectroscopy setup specifically tailored for multiple-coincidence studies of superheavy elements (SHE).

In Spring 2010 TASISpec was used in its complete configuration for the first time, comprising a compact cube of double and single sided silicon strip detectors surrounded by five composite Ge detectors with a total of 23 Ge crystals.

The reaction ^{207}Pb(^{48}Ca,$2n$)^{253}No was used to study *K*-isomeric states and the decay of ^{253}No, providing additional and new information to what is currently known [2,3]. For example, electron lines originating from internal conversion can, for the very first time, be observed in the Si-strip box detectors at the same time as γ-rays are observed in the surrounding Ge detectors. This allows multipolarities of these transitions to be determined, hence spin-parity assignments of excited states. Results from coincidence-spectroscopy of ^{253}No as well as daughters will be provided together with results and comparisons from detailed GEANT4 simulations.

During the year that has passed since the experiment TASISpec was upgraded to contain a fully pixellised Si "cube". In the upgraded configuration the detector array was used in the preparational beamtime for the E115 X-ray fingerprinting experiment in the beginning of June 2011. It will also be used in early October 2011 for a parasitic beam time behind SHIPTRAP in the so called TRAPSpec configuration for state-selective decay spectroscopy.

[1] L.-L. Andersson et al., Nucl. Instr. and Meth. A **622**, 164 (2010).
[2] F.P. Heßberger et al. Phys of Atom Nucl. **70**, 1445 (2007).
[3] A. Lopez-Martens et al. Nucl. Phys. A **852**, 15 (2011).

Absolute transmission and separation properties of the gas-filled recoil separator RITU

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The absolute transmission values of the RITU gas-filled recoil separator have been measured for several fusion evaporation products. Three different beams and several targets were used to create fusion evaporation residues in mass region A ~ 170–190 mainly in neutron evaporation channels. Measured absolute transmission values from around 7% up to round about 90% have been observed for very asymmetric and symmetric reactions, respectively. For the reactions studied it was observed that the angular spread of products after the target and the angular acceptance of RITU determine the transmission probability relatively accurately. Magnetic rigidities and equilibrium charges of the product ions were seen to systemically decrease and increase, respectively, with increasing gas pressure. The comparison of observed equilibrium charges to various formulae is carried out. Clear minima of image width were found in case of asymmetric reactions as a function of gas pressure. Effects of the position of an additional movable beam stopper and the field strength of the first quadrupole magnet on transmission have been studied. These results, published in [1], will be presented and discussed.

[1] J. Sarén et al.,Nuclear Instruments and Methods in Physics Research A 654 (2011) 508–521

The average charge states of heavy recoil ions in the rarefied gas

J. Khuyagbaatar

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HIM Helmholtz Insitutue Mainz

The knowledge on the charge state distribution of heavy ions moving in gas-filled regions is an important issue of heavy-ion beam related physics. Already decades ago, many experimental and theoretical investigations have been performed on charge-exchange collisions for light and medium heavy ions in rarefied gases. As results of these works many basic aspects of the charge-exchange collisions have been established.

A renewed interest in the understanding of charge states of heavy ions in rarefied gases has been motivated by the production of heavy and superheavy elements at gas-filled separators.

Semi-empirical expressions were derived, based on a parameterization of the experimental data according to the theoretical underpinnings of charge-exchange collisions, such as an influence of the atomic shell structure of the heavy ions. However, these investigations were often performed at different, but fixed gas pressures around 1 mbar, which were individually evaluated to be optimum values for each respective facility. In turn, the influence of a variation of the gas pressure has not been included in any of the above mentioned expressions.

In this contribution, we will present the results of the average charge states of heavy ions more specifically ^{252,254}No and ^{188}Pb, in various rarefied gases and their mixtures at the gas-filled TransActinide Separator and Chemistry Apparatus (TASCA).

A possible semi-empirical expression for the prediction of the average charge states will be discussed.

Metal-Carbonyl-Complexes: New perspectives in SHE chemistry and nuclear spectroscopy

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Up till now gas phase chemistry of transactinide elements focused on studies of rather simple, thermally stable inorganic compounds. This was mainly due to experimental limitations such as the presence of an intense plasma behind the target, which generally destroys any molecular reagents in the recoil chamber.

In the last years, this limitation could be overcome by physical preseparation.[1] This opened the door to study thermally less stable compounds. As a new compound, we chose metal-carbonyl complexes. Seaborgium hexacarbonyl has been predicted to be stable.[2] A stronger π-back bonding compared to the analogue complexes of the lighter homologous is predicted due to the relativistic expansion of the d-orbitals, which is most pronounced in SHE.[2]

First test experiments with fission products were performed at the TRIGA Mainz reactor. Fission products (4d transition metals) were thermalized in mixtures of either helium or nitrogen and carbon monoxide. “Hot” transition metal atoms formed complexes of the type $M(CO)_x$, which could be transported in the gas stream through a capillary to counting or gas chromatography setups.

In further experiments at the gas-filled recoil separator TASCA, the synthesis and chemical properties of 5d transition metal carbonyl complexes were studied. The evaporation residues were thermalized in mixtures of helium and carbon monoxide in a Recoil Transfer Chamber (RTC)[3] and transported with the gas stream to the thermochromatography detector COMPACT. The formation of the carbonyl complexes of the α-decaying isotopes ^{163}W, ^{164}W, ^{170}Os, and their adsorption on SiO_2 surface were studied in these experiments.[4]

The results of our experimental studies indicate that $Sg(CO)_6$ and $Hs(CO)_5$ are now within reach for transactinide chemistry. These compounds are suitable for chemical characterization by thermochromatography and appear highly promising for nuclear spectroscopy under low background conditions.

A new type of detection system called AlBeGa (Alpha-Beta-Gamma spectroscopy), which is suitable for volatile, chemically separated samples, is currently under development. This will allow α-β-γ-X-ray multicoincidence spectroscopy with high efficiency. Very interesting would be the investigation of ^{265}Sg, in which the presence of an isomeric state was inferred[5], which is not explained by current nuclear structure calculations (see refs. in [5]).

[1] Ch. E. Düllmann, C. M. Folden III, K. E. Gregorich, D. C. Hoffman, D. Leitner, G. K. Pang, R. Sudowe, P. M. Zielinski, H. Nitsche, *Nucl. Instr. Meth. A* **2005**, *551*, 528–539.

[2] C. S. Nash, B. E. Bursten, *J. Am. Chem. Soc.* **1999**,*121*, 10830-10831

[3] J. Even, J. Ballof, W. Brüchle, R.A. Buda, Ch.E. Düllmann, K. Eberhardt, A. Gorshkov, E. Gromm, D. Hild, E. Jäger, J. Khuyagbaatar, J.V. Kratz, J. Krier, D. Liebe, M. Mendel, D. Nayak, K. Opel, J.P. Omtvedt, P. Reichert, J. Runke, A. Sabelnikov, F. Samadani, M. Schädel, B. Schausten, N. Scheid, E. Schimpf, A. Semchenkov, P. Thörle-Pospiech, A. Toyoshima, A. Türler, V. Vicente Vilas, N. Wiehl, T. Wunderlich, and A. Yakushev, Nucl. Instr. Meth. A. **638**, 157-164 (2011).

[4] J. Even, A. Yakushev, Ch.E. Düllmann, J. Dvorak, R. Eichler, O. Gothe, D.Hild, E. Jäger, J. Khuyagbaatar, J.V. Kratz, J Krier, L. Niewisch, H. Nitsche, I. Pysmenetska, M. Schädel, B. Schausten, A. Türler, N. Wiehl, D. Wittwer, *submitted to Angew.Chem. Int. Ed.* **2011**.

[5] Ch. E. Düllmann, A. Türler, *Phys. Rev. C* **2008**, *77*, 64320.

Future Direction of the SuperHeavy Element Program at the 88-inch Cyclotron: Upgrades to the Berkeley Gas-Filled Separator

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The Berkeley Gas-Filled Separator (BGS) at LBNL separates the compound nucleus of interest from unwanted reaction products and the scattered beam. The existing SuperHeavy element (SHE) program has been successful with regards to synthesis, chemical study, and nuclear structure. A future plan to simultaneously measure the Z and A of SHEs will involve a rf gas catcher at the focal plane of the BGS and an upgrade to the focal plane detector. The rf gas catcher will thermalize the compound nuclei in a chamber filled with high-purity He gas in which the thermalized ions will retain their +1 and +2 charge states. Using a combination of rf and dc-electric fields, the ions will be directed towards the extraction orifice of the chamber and the gas flow will sweep the ions out of the catcher into a linear radiofrequency quadrupole (rfq) trap. Following the linear rfq trap, the ions will be directed to a mass separator with single mass unit resolution and then finally delivered to a detector station for positive identification of Z and A. The new focal plane detector, (C^3) composed of three Double-Sided Silicon Strip Detectors (DSSSDs) forming the corner of a cube will result in improved detection efficiency. The new focal plane detector will be coupled with three Ge clover gamma-ray detectors for the detection of gamma-rays and x-rays.

Preparation of ^{249}Cf targets for the synthesis of element 120

J. Runke[1], Ch.E. Düllmann[1,2,3], K. Eberhardt[2], P.A. Ellison[4,5], K.E. Gregorich[4], E. Jäger[1], B. Kindler[1], J. Krier[1], B. Lommel[1], C. Mokry[2], H. Nitsche[4,5], M. Schädel[6], P. Thörle-Pospiech[2], N. Trautmann[2], A. Yakushev[1]

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For the synthesis of the so far unknown element with atomic number Z = 120, the fusion reaction of ^{50}Ti with ^{249}Cf is used. A rotating target wheel assembly is applied to accept high beam intensities up to 2 μA (particle). Molecular plating (MP) is employed for the preparation of ^{249}Cf layers on thin metallic backing materials because the deposition yields are exceeding 80 % [1].

About 30 mg of ^{249}Cf originating from the decay of ^{249}Bk were provided from Lawrence Berkeley National Laboratory. Prior to deposition a chemical separation procedure, based on ion exchange chromatography, was used to ensure high purity of the deposited target material. The preparation of ^{249}Cf targets on thin Ti-backing foils for experiments at the separator facilities TASCA [2] at GSI was performed from isobutanolic solution at a current density of 0.3 mA/cm^2. Deposition yields of ≥ 90 % were achieved, as determined by α-particle and γ-ray spectroscopy. Target densities of about 500 μg/cm^2 have been obtained in a single deposition step.

Acknowledgments

We would like to thank Robert F. Fairchild II, Naomi E. Reeves, John A. van Wart and LBNL's entire Radiation Protection Group of the Environmental Health and Safety Division for their leadership and active support with the preparation and execution of the ^{249}Cf shipment to Germany.

References

[1] K. Eberhardt et al., Nucl. Instrum. Meth. Phys. Res. A590, 134 (2008)

[2] Ch. E. Düllmann et al., Phys. Rev. Letters 104, 252701 (2010)

The 120 and 119 Data Acquisition Systems at TASCA

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For the search of element 120 in 2011 a MBS data acquisition system (daq) has been setup from existing components. Although composed ad hoc of two sub-systems based on the MBS daq system used for the 114 search in 2009 and 48 new digital electronic channels, it provides nevertheless full detection capabilities for element 120. For the forthcoming experiments, namely the search for element 119, a new MBS daq system is currently setup at the Experiment Electronics (EE) department of GSI. This new system is based on 640 fully digital electronic channels for 320 detector channels. An overview for both systems will be given and its trigger -, data supression - and dead-time features will be discussed.

Signal processing and digitization of the analog front-end data

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For the TASCA experiment a new readout and DAQ system was developed at GSI. The used silicon strip detector at the TASCA experiment will be read out with an ASIC named APFEL developed at GSI. This ASIC collects the charge from the strips and send a differential output signal to the digitizer board named FEBEX. The fast charge collection and the resulted short pulse width of about 1 us allows to measure with a rate up to 350 kHz without any pileup. The first stage on the digitizer board was an input buffer stage which fits the input impedance from the ASIC to the 12 bit ADC. The digitized data are send to the central unit FPGA. This FPGA collects the trace information of 16 channels in parallel and has an self-trigger decision for each channel. The reduced data are send via an optical link to the DAQ system MBS. The data analysis will be done with Go4.

The developed and mounted setup consists of 320 detector/640 ADC channels. The analog and digital data processing will be presented as well as first detector measurements. .

A new sc cw-LINAC – for Superheavy Element research (SHE)

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A new superconducting (sc) continuous wave (cw) LINAC at GSI is desired by a broad community of future users. Especially the Super Heavy Elements (SHE) program at GSI and at the Helmholtz Institute Mainz (HIM) benefits highly from such a dedicated machine. The proposed sc cw-LINAC is expected to reduce the beam time significantly. With a new 28 GHz ECR source and a new cw capable RFQ, an upgrade for a competitive machine was started. Now, the cw linac is planned with a sc Crossbar-H (CH) cavity as its key component; the conceptual layout was developed at the Institute for Applied Physics (IAP) at Goethe University Frankfurt. Nine superconducting cavities accelerate the (heavy) ions to energies between 3.5 MeV/u and 7.5 MeV/u. Seven superconducting solenoids provide for the required beam focusing. The multi-gap cavity is operated at 217 MHz. The technical design and the realisation of such an sc cw-LINAC in parallel to the existing UNILAC at GSI is assigned to a collaboration of GSI, the IAP, and the Helmholtz-Institute Mainz (HIM), which was founded in 2009. The first proposal for the sc cw linac submitted in 2009 to the HGF was rated “excellent”.