Report on TransNational Activities at GSI

Publicity concerning the opportunities for access to TA02

The measures taken to publicise the opportunities for access are:

A dedicated web site: www.gsi.de/user/funding/ENSAR.html

On this web site the following information is offered:

- General information on GSI
- Research capabilities
- Access procedure
- Beam-time scheduling
- Support offered to user
    - Technical and logistic support
    - Accommodation and Housing
    - Health and liability insurances
    - Nurse for immediate medical help
    - Access to laboratories of GSI
        - Target laboratory offering deposition techniques (sputtering, evaporation), mechanical treatment (milling, sawing) and quality control for solid targets
        - Detector laboratory with clean rooms, ageing test stand for gaseous detectors and CNC milling machine for prototyping
        - Electronic laboratory with automatic placement machine and soldering oven
- Financial support within ENSAR
        - How to get access funding
        - Who can apply for access funding
        - Open calls for proposals and deadlines
- Application form
- User registration
- Instructions for reimbursement of travel costs and statement of travel costs

- Mails distributed either via the Research Deputies of GSI or sent directly to the users with scheduled beam times
- Mails to the spokespersons of ENSAR-related collaborations having approved beam time at GSI

Selection procedure

Selection Panel

GSI is open to national and international user groups. To apply for access to the accelerator and experimental facilities, a written project proposal has to be submitted to the GSI scientific director. The proposals are reviewed by an international Programme Advisory Committee, the GSI General Programme Advisory Committee (G-PAC). If a user group in addition applies for EC support under one of the Integrated Infrastructure Initiatives of FP7, a separate funding application has to be submitted.

The G-PAC presently has 12 members (all external), with more than half of them coming from universities or research institutes outside Germany. There are specialised PACs for some

research activities pursued at GSI (plasma physics P-PAC, biophysics BIO-PAC, and material science MAT-PAC). Regular All-PAC meetings have been introduced to improve the communication between the PACs, where the future beam-time contingents are discussed and decided.
GSI, together with national and international partner institutions, is planning the construction of a new large accelerator and research complex – the Facility for Antiproton and Ion Research (FAIR). FAIR enables a rich and multidisciplinary research programme covering a broad spectrum of research fields such as: QCD studies with cooled beams of antiprotons; QCD-Matter and QCD-Phase Diagram at highest baryon density; nuclear structure and nuclear astrophysics investigations with nuclei far off stability; precision studies on fundamental interactions and symmetries; high-density plasma physics; atomic and material-science studies; radio-biological investigations and other application-oriented studies.
During the construction phase GSI has taken over the responsibility not only for parts of the FAIR accelerator and storage rings but also for the link of the existing facilities to the FAIR complex. These tasks require major human and financial resources. Consequently, the GSI executive committee decided in April 2012 that GSI has to focus employees, infrastructure and financial resources on the building of FAIR. This had several consequences: Despite the fact that the beam time offered to users in 2012 was slightly larger than in 2011 (197instead of 174 days) there is still a substantial backlog of granted beam times (in the order of at least 100 days for each of the three main experimental accelerators at GSI). In addition, no beam time could be offered in 2013 due to major upgrade works on the accelerators of GSI.
As a consequence of the conditions enforced by the GSI executive committee beam time offered to the users had to be reduced severely, and the GSI directorate decided middle of 2012 to give up the Programme Advisory Committee Meetings (except for plasma physics) and the respective open calls for proposals. Instead of regular PAC Meetings the selection of new experimental proposals and scheduling of experiments already approved by a GSI PAC took place in close collaboration with the user groups, the head of the Wissenschaftliche Beirat WBR of GSI (Karlheinz Kampert, Univ. Wuppertal), the chairperson of the G-PAC (Paolo Giubellino, CERN) in close contact with the members of the G-PAC and the Board of FAIR Collaborations BFC (Chair Reinhold Schuch, Univ. Stockholm) and representatives of the four scientific pillars of FAIR. The chairperson of the G-PAC informed and/or contacted the G-PAC members in all issues relevant for the beam time scheduling.
Apart from evaluating a small number of new proposals this committee selected in essence projects which have been started already (e.g. the AGATA campaign) or proposals which have been granted beam time in former G-PAC meetings for being scheduled in 2014.

Selection-Panel meetings

Selection-panel meeting: Firenze, June 6, 2013
Discussion on procedure to select experiments for the beam time 2014 by representatives of G-PAC, WBR, BFC and scientific directorate of GSI

Selection-panel meeting: July/August 2014
Proposal evaluation and decision on beam-time scheduling via E-mail circulation

Selection-panel meeting: June 2014
Proposal evaluation of a sub-committee of the G-PAC via E-mail circulation

Selection criteria

The Selection Panel based its selection on scientific merit and relevance, but also on the importance for the future FAIR facility. For Transnational Access within ENSAR only user projects positively evaluated by the G-PAC were considered. Since the number of experiments which were finally scheduled was rather limited, every user group related to ENSAR and fulfilling the rules of the contract could be supported. The majority of the eligible user groups had active projects already and were allowed to continue or asked to write a new proposal if their scientific goals had to change because of the beam-time restrictions. This affected only experiments in the field of super-heavy elements, since all proposals with especially long beam time requirements had to be postponed to a later time.

Transnational access activity during the reporting period

Beam was available during this reporting period from March 2014 to November 2014. The accelerator operation was characterised by rapid changes of ion species and experiments to fulfil the demands of groups testing accelerator components and detectors for FAIR – such tests being the key aspect of this beam time – and scientific experiments. Already at the very beginning of the beam period it turned out that an aperture problem in the SIS18 prevented high beam intensities. This problem influenced scientific experiments with extremely neutron-rich radioactive beams relying on the maximum beam intensities available at GSI. The AGATA collaboration – being affected by this issue – decided to give up one experiment with particular high demands on the primary beam intensities to guarantee the success of others. As a consequence, the user project 70Kr/Sahin could not be finalised. Experiments at the UNILAC were not influenced and beam was delivered to various experiments without problems. The SIS focusing problem was fixed later during a maintenance break.
Achievements from the accelerator and instrument side during this reporting time period: The proton microscope PRIOR started operation, an EBIT source was integrated to the HITRAP facility, the installation of the CRYRING as a low energy storage ring for radioactive ions was started, Uranium 28+ beams at 1.4 MeV/u were produced with an intensity of 7.8 mA and an excellent beam quality. This intensity value is approximately 50 % higher than the highest intensities measured so far at GSI. This beam intensity is a major step towards the beam parameters which are required for FAIR and will offer new experimental possibilities at GSI before FAIR becomes operational once – after another two-year break of the accelerator – SIS18 will be available again in 2017.
Despite the long shutdown of the accelerator beam failures have been recorded only with 6% at UNILAC and 14% at SIS, which is comparable to previous years. In summary, the beam time 2014 was – apart from the focusing problems in the SIS18 described above – very successful for the experimentalist in the fields of nuclear, hadron and atomic physics as well as materials sciences and biophysics.

A total of 15 projects have been supported during the reporting period:

(1) **AGATA/Scheidenberger:** Special funds for AGATA campaign at GSI
(2) **115decay/Rudolph:** X-ray fingerprinting of element 115 decay chains by Dirk Rudolph et al.
(3) **70Kr/Sahin:** AGATA@GSI: Breaking isospin symmetry in the mass 70 region: Study of the T_z=1 nucleus ^{70}Kr by Eda Sahin et al.

(4) **Commiss/Korten:** AGATA@GSI: Scientific and technical commissioning proposal for the AGATA – PreSpec campaign by Wolfram Korten et al.
(5) **E039/Indelicato:** Precision X-ray spectroscopy in one- and two-electron heavy ions by Paul Indelicato et al.
(6) **ESR/FRS Trassinelli:** Measurement of bound-state beta decay of bare ^{205}Tl ions
(7) **Ice/Domaracka:** Ion induced sputtering and phase transitions in water ice
(8) **Isospin/Recchia:** AGATA@GSI: isospin symmetry-breaking transition rates and mirror energy differences in isobaric multiplets by Francesco Recchia et al.
(9) **Pyg-64Fe/Wieland:** AGATA@GSI: The Pygmy dipole resonance in ^{64}Fe and the properties of neutron skin (S430) by Oliver Wieland et al.
(10) **R3B/Gil:** R3B demonstrator test
(11) **S426/Rainovski:** AGATA@GSI: Relativistic Coulomb M1 excitation of neutron rich ^{85}Br by Georgi Rainovski et al.
(12) **U253/Kozul:** Study of shell effects and clustering in the giant nuclear system U+U
(13) **U259/Rudolph:** Chemical study of element 114 (follow up of E115/Rudolph)
(14) **U278/Antal:** Decay properties of ^{258}Db using the SHIP separator
(15) **U279/Zimmer:** Single-event transient measurements in asynchronous logic for the project FATAL.

Some former projects were included into the TNA database to add publications which arose from those experimental campaigns, for which data analysis has been completed.

(1) **BetaFiss/Andrey:** Identification and systematic studies of the beta-delayed fission in the lead region
(2) **b-neutron/Redondo:** Measurement of beta-delayed neutrons around the third r-process peak
(3) **E105/Kalantar:** Start-up of part of the EXL physics programme with ^{56}Ni
(4) **Interact/Patera:** High-precision carbon fragmentation cross sections for medical applications
(5) **Ionisat/Rothard:** Ionisation dynamics

1938 (+279 in parallel mode) hours of beam time were delivered; 97(111) individual users (users in projects) visited the facility and spent 924 person-days at GSI.

User project acronym	**Users**	**Scientific field**	**Number of days spent at the infrastructure**
115decay/Rudolph	1	Physics/Nuclear Physics	6
70Kr/Sahin	10	Physics/Nuclear Physics	30
AGATA/Scheidenberger	36	Physics/Nuclear Physics	280
Commiss/Korten	3	Physics/Nuclear Physics	40
E039/Indelicato	1	Physics/Nuclear Physics	4
ESR-FRS/Trass	10	Physics/Nuclear Physics	81

Ice/Domaracka	3	Physics/Material Sciences	24
Isospin/Recchia	10	Physics/Nuclear Physics	76
Pyg-64Fe/Wieland	6	Physics/Nuclear Physics	37
R3B/Gil	10	Physics/Atomic Physics	89
S426/Rainovski	1	Physics/Nuclear Physics	8
U253/Kozul	5	Physics/Nuclear Physics	77
U259/Rudolph	10	Physics/Nuclear Physics	108
U276/Antal	3	Physics/Nuclear Physics	44
U278/Zimmer	2	Physics/Nuclear Physics	20

In Annex 2 (Database) the User Projects for which costs have been incurred in 2014 are tabulated. The users are listed in Annex 3 (Database).

Significant achievements obtained by the users during the reporting period

A number of scientific results were obtained. Some of these results are of particular importance for future nuclear physics studies later at FAIR or were even mentioned in the international press.

(1) **AGATA/Scheidenberger:** With the establishment of FAIR, the European nuclear structure community is now heavily committed to a future programme of in-flight spectroscopy of highly exotic nuclei produced from the Super-FRS. Ground-breaking experiments are encompassed by the HISPEC project (Hi-resolution In-flight SPECtroscopy), which groups around AGATA (Advanced Gamma-Tracking Array), and which represents one of the first experiments of the entire FAIR facility to take beam at day one. To position the research community to take full advantage of this unique opportunity, and to build up the vital experience of the novel techniques and methodologies offered by both the HISPEC and the decay-spectroscopy (DESPEC) campaigns, the pre-cursor experiment PRESPEC has been established, which builds on the successful RISING project.
The scientific programme for the PRESPEC-AGATA in-flight campaign comprises exclusively topics of major significance in contemporary nuclear structure physics. These include the evolution (and modification) of shell structure with increasing neutron excess, the breakdown of isospin symmetry, the exploration of the limits of nuclear existence near the drip-lines, the onset of collectivity in yet unexplored mass regions and the study of electric and magnetic dipole strength in nuclei. Table 1 shows a list of all experiments performed in the campaign during 2012 and 2014.

Table 1: *Experimental programme of the PRESPEC-AGATA campaign.*

Title	No.	Spokespersons	Run
Performance Commissioning	S424	W. Korten / J. Gerl	^{86}Kr ^{54,56}Fe
Relativistic *M*1-Coulomb excitation of ^{85}Br	S426	G. Rainovski / N. Pietralla/ J. Gerl	^{85}Br
Shape evolution in neutron-rich Zr	S428	S. Pietri	$^{102-106}$Zr
Quadratic evolution of collectivity around ^{208}Pb	S429	D. Rudolph /Zs. Podolyák / J. Gerl	$^{196-206}$Pb ^{206}Hg ^{200}Pt $^{204-208}$Po ^{205,207}Po
Pygmy Dipole Resonance in ^{64}Fe and the properties of neutron skin	S431	O. Wieland / M. Gorska	^{64}Fe ^{62}Fe
Coulomb excitation of the band-terminating 12^+ yrast trap in ^{52}Fe	S433	A. Gadea / M. Gorska	^{52}Fe
Transition rates and mirror energy differences in isobaric multiplets	S434	F. Recchia / M. Bentley	^{46}Ti/Cr/V
Slow-down Beam test	S386	P. Boutachkov	^{46}Cr

All the experiments profited from the unique combination of (i) relativistic energy beams from the SIS synchrotron, (ii) high-intensity exotic beams produced and selected by the FRS, and (iii) high-efficiency and high-resolution gamma detection with the AGATA Ge detector array. The exotic beams were produced at relativistic energies (β~0.4-0.5) in fragmentation or fission reactions of relativistic projectiles delivered from the UNILAC-SIS accelerator complex. The GSI Fragment Separator (FRS) was employed to select the fragments of interest. A thick secondary target positioned at the final focal plane of the FRS (S4) was used for Coulomb excitation or (secondary) fragmentation of the separated nuclei. Gamma-rays emitted in these reactions were detected by the AGATA and HECTOR arrays. The fragments produced at the secondary target were identified and tracked by the Lund-York-Cologne Calorimeter Array (LYCCA), a HISPEC development already available in its early implementation LYCCA-0.

A major step forward with respect to the RISING Cluster array is the tracking ability of AGATA which allowed placing the array much closer to the target, thus gaining in gamma-ray efficiency and peak-to-background performance, while at the same time also improving on the achievable energy resolution for in-flight gamma-ray emission. Along with the recently achieved upgrade of primary beam intensities at GSI and the improved capabilities of the FRS detectors the AGATA-PRESPEC setup provided a very significant improvement over RISING with a sensitivity gain of up to a factor of 10.

The analysis of the experiment data obtained in the PRESPEC-AGATA campaign will require several years. First physics results from the early runs are expected later in 2015. Already now it can be stated that all runs performed in 2012 and 2014 reveal new, interesting nuclear structure

data. Moreover, experience gained in the campaign is very valuable and will be used to further improve the instrumentation, the analysis algorithms and the experiment methodology for later in-beam gamma-spectroscopy experiments with HISPEC at the FAIR facility.

(2) **115decay/Rudolph**: In November 2012, three weeks of beam time for experiment U261 were scheduled. Despite the limited beam time thirty correlated alpha-decay chains were observed following the reaction ^{48}Ca+^{243}Am. Decay schemes arising from high-resolution spectroscopic coincidence data, in conjunction with comprehensive Monte-Carlo simulations, open the door for direct nuclear structure insights of these heaviest man-made atomic nuclei. Previous assignments linking the majority of the decay chains to the decay of ^{287,288}115 are confirmed. This includes first candidates for Z fingerprinting of the Meitnerium-decay by means of characteristic K-X-ray detection. There is clear evidence for direct determination of the atomic number of the descendants of super-heavy elements. Spectroscopic means and results were detailed in a number of publications, and a second article has been submitted to Phys. Rev. C challenging the connection between isotopes of element 117 and element 115 based on improved and more precise data from U261 on recoil-alpha-(alpha)-fission decay chains. A comprehensive summary article (and PhD thesis) is due 2015. **U259/Rudolph** is the follow up project of this experiment.

(3) **Commiss/Korten:** The installation and commissioning of the AGATA array have been successfully accomplished. All detectors were verified in their performance and the analysis was tested. After restarting operation of the whole Setup after more than one year of standstill the second part of the experimental programme was started. During the shutdown period in 2013 detectors had to be replaced or repaired and several travels have been undertaken in this period.

(4) **E039/Indelicato:** For the accurate determination of the 1s Lamb shift of H-like gold via X-ray spectroscopy of the Lyman alpha transitions it is necessary to investigate the different systematic effects that are crucial for metrology of the experiment. The accurate determination of the position of the gas-jet target and the effect of the X-ray penetration in the position-sensitive detectors is indispensable. To measure the position, the diameter and the density distribution of the gas target of the ESR a new device has been designed and built. After a measurement campaign, we were able to determine the gas-jet position with an accuracy of few tenths of millimetre. This measure is crucial because a misalignment of it with respect to the X-ray spectrometers used in the experiment can generate a systematic shift on the recorded photon energy due to the Doppler Effect as a result of the fast motion of the ions during the collision with the target. An investigation of the effect of the X-ray penetration in the spectrometer detectors has been also performed. The X-rays have a small incidence angle with respect to the position-sensitive detector. Due to the penetration of the X-rays in the position-sensitive detector, this incidence angle induces a spatial asymmetry of the spectral line. This effect has been studied with the support of X-ray – matter interaction simulations and the implementation of adapted profile modelling for the 1D and 2D fits of the position-sensitive detector outputs. Asymmetries in the spectral line profiles (simulated and measured) are now completely understood.
The complete check of the systematic effects and uncertainty is still not completed.

(5) **ESR-FRS/Trass:** Initially planned for September 2014, the experiment on bound-state beta decay of fully ionised ^{205}Tl was suspended on recommendation of the G-PAC in favour of a similar experiment on two-body beta decay of hydrogen-like ^{142}Pm ions conducted in the ESR. Single-particle spectroscopy with a newly developed data-+acquisition system was applied resulting in about 10000 precisely measured orbital

electron-capture decays. Furthermore, a novel in-ring position and charge-sensitive particle detector was taken into operation showing excellent mass and position resolution. The obtained data will be sufficient to answer the long-standing question on the existence of *modulated* two-body weak decays which might give rise to exciting new physics. The data analysis is presently performed by the user groups in Vienna and Paris. The groups met during the beam time and defined a common strategy for the data analysis and interpretation of the results. In particular, results from the groups will be compared to older data corroborating the robustness of the different analysis methods.

The second experiment suggested by this user group on proton-capture reactions in the ESR was commissioned in the ESR with Xe beam. Form the accelerator operation point of view this is a complex experiment, which requires injection, storage, slowing down and cooling at the maximum intensity of the beam in the storage ring in conjunction with an internal gas target at lowest beam energies. Specially built detector manipulator together with in-vacuum particle detectors were successfully taken into operation showing the feasibility of such experiments in future at the ESR as well as at CRYRING.

(6) **Ice/Domaracka:** In September 2014, we have performed two types of experiments with 4.8 MeV/u Xe^{q+} (q= 21, 38) ion beams. The first one was dedicated to study sputtering of CO, CO_2 and D_2O ices under UHV conditions by means of time of flight and quadrupole mass spectrometry. In the second one, CO_2 ice was irradiated, and the induced effects monitored as a function of projectile fluence via infrared absorption spectroscopy in order to obtain information about the destruction cross section and the sputtering yield of CO molecules and chemical modification of the ice. The analysis of the data is in progress. Preliminary results for CO_2 ice confirms that the sputtering yield (Y) shows indeed a quadratic increase with electronic stopping power (S_e).

(7) **R3B/Gil:** The R3B setup at FAIR will allow kinematically complete measurements of peripheral nuclear reactions with radioactive beams. Demonstrators of three major components of this setup have been tested successfully in this beam period: the neutron detector NeuLAND performs within the anticipated parameters necessary for detecting multiple neutron events with high precision and resolution, the operation of the CALIFA calorimeter demonstrator was verified in beam in different modes of operation, and the close to final version of the Silicon tracking station behind the secondary target war taken into operation.

(8) **U253/Kozul:** First observation of long-living (up to about 10^{5} $^{-20}$s) nuclear molecules which rotate by angles of 180 degrees in systems with proton numbers up to Z=136 and detailed studies of their properties. This confirms a basic assumption of theoretical models which describe the fusion process in (super) heavy systems. Even in the giant system U+U (Z=184) the typical signatures from deep inelastic processes and noticeable time delays up to several times 10^{-21} s were observed. The observations demonstrate the still large nuclear stability of systems with proton numbers far beyond the ones of heaviest known elements and a rather slow fading of stability with increasing proton number.

(9) **U278/Antal:** In this measurement exceptionally high statistics for the ^{258}Db was collected, which allowed the first detailed gamma-spectroscopy study of this isotope and its daughter products. A unique result was the direct proof of an electron capture decay of ^{258}Db and experimental evidence for excited states populated via this decay mode of ^{258}Db.

(10) **U279/Zimmer:** In our experiments we have investigated the pulse shapes of single-event transients (SETs) arising from particle hits in 90 nm CMOS logic cells. These single-event transients are one of the major error sources in modern semiconductor technologies, especially in environments with increased radiation levels, as in space and aviation technologies. A better understanding of the generation and propagation of these SETs may help developing electronics that is less susceptible to radiation hits in future. Especially for asynchronous logic it is important to know the shape of the single-event transients in order to estimate their impact on different circuits. It was revealed that there is a strong influence of the input state of a single inverter on the susceptibility of these devices to radiation hits. Former experiments with alpha particles showed that for input voltages close to half of the supply voltage the resulting SETs get larger and longer compared to the standard high and low state. However, with alpha particles, the resulting pulses are relatively small and are not very probable to cause any error. The experiments performed at the GSI resulted in much larger SETs that are definitely capable of causing errors in electronics. Including increased pulse heights and widths a tremendous increase of the sensitive area was found for an input voltage close to half of the digital supply voltage. This may at least partly explain why the susceptibility to radiation induced failures depends on the operating frequency for different circuits. During changing from one state to the other the inverter has to pass this very sensitive intermediate input state of half of the supply voltage. With increased operating frequency this state is passed more often per time period.

(11) **E105/Kalantar:** Determination of the matter radius of ^{56}Ni by proton elastic scattering in inverse kinematics and investigation of the isoscalar Giant Resonance in ^{58}Ni. The experiment is the first of its kind and represents an essential milestone towards the realisation of the EXL project at FAIR. By using DSSDs as active windows, it was possible to operate these detectors directly in the UHV without compromising a low energy threshold.

The current list of peer-reviewed publications of all user projects published in this reporting period is part of Annex 4 (Database).

Users meetings

One user meeting took place during the reporting period at GSI to discuss the beam time scheduling in 2014.