



target

Cancer therapy

It is still a glance into the future: The combination of carbon ion and immune therapy could become an effective tool in the fight against cancer (page 26).



Black hole

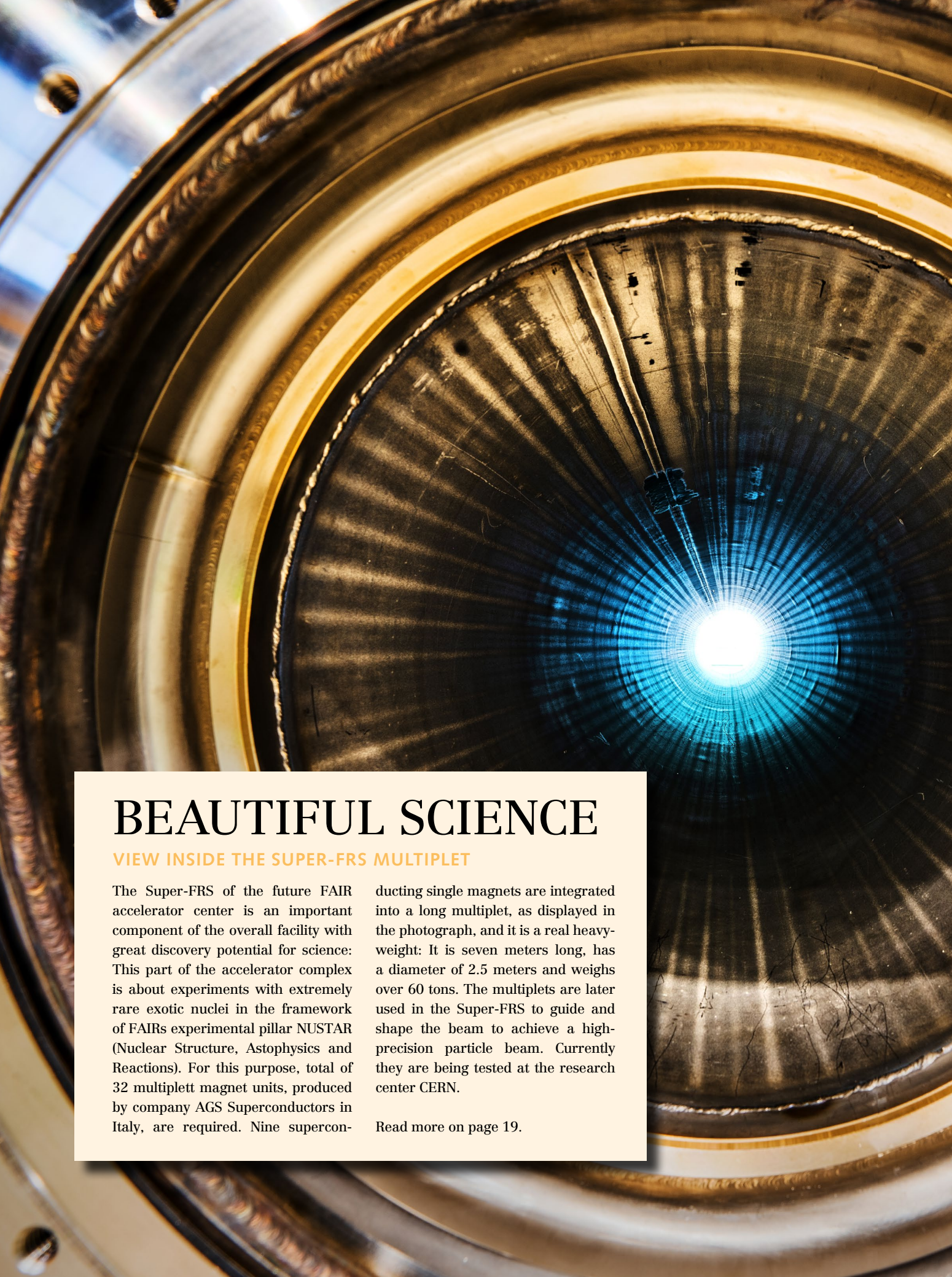
Computer simulations reveal new insights about neutron star mergers (page 49).

Element research

Spectroscopy of superheavy elements combines physical and chemical methods (page 36).

ALICE experiment

New insights about hadrons and their interactions in proton-proton collisions at LHC (page 44).



BEAUTIFUL SCIENCE

VIEW INSIDE THE SUPER-FRS MULTIPLLET

The Super-FRS of the future FAIR accelerator center is an important component of the overall facility with great discovery potential for science: This part of the accelerator complex is about experiments with extremely rare exotic nuclei in the framework of FAIR's experimental pillar NUSTAR (Nuclear Structure, Astrophysics and Reactions). For this purpose, total of 32 multiplett magnet units, produced by company AGS Superconductors in Italy, are required. Nine supercon-

ducting single magnets are integrated into a long multiplet, as displayed in the photograph, and it is a real heavy-weight: It is seven meters long, has a diameter of 2.5 meters and weighs over 60 tons. The multiplets are later used in the Super-FRS to guide and shape the beam to achieve a high-precision particle beam. Currently they are being tested at the research center CERN.

Read more on page 19.



Dear readers,

Almost a year has passed since I took office as Administrative Director at GSI and FAIR. It has been a very unusual year, marked in particular by the many challenges of the corona pandemic that we all had to face.

During this time, it has been important to keep up our work on campus and for the construction of FAIR in the best possible way — while, of course, maintaining all necessary safety measures. We have succeeded in digitizing many activities and processes and establishing reliable and high-performance structures for this purpose. Working from home has become an integral part of our daily routine. That way it has not only been possible to continue science and build FAIR, as can be seen from numerous examples of completed components and published research results here in the magazine. Also the infrastructure departments have been able to continue to reliably perform their duties for the campus. We want to continue these good results this year as well.

3,000 researchers from around the world work for FAIR, and GSI has long been an international center. Diversity and inclusion are natural goals. In this context, we have decided to reflect this linguistically in our daily work when using German language and as well in the German “target” issue by employing the asterisk to include all genders.

I hope you enjoy reading!

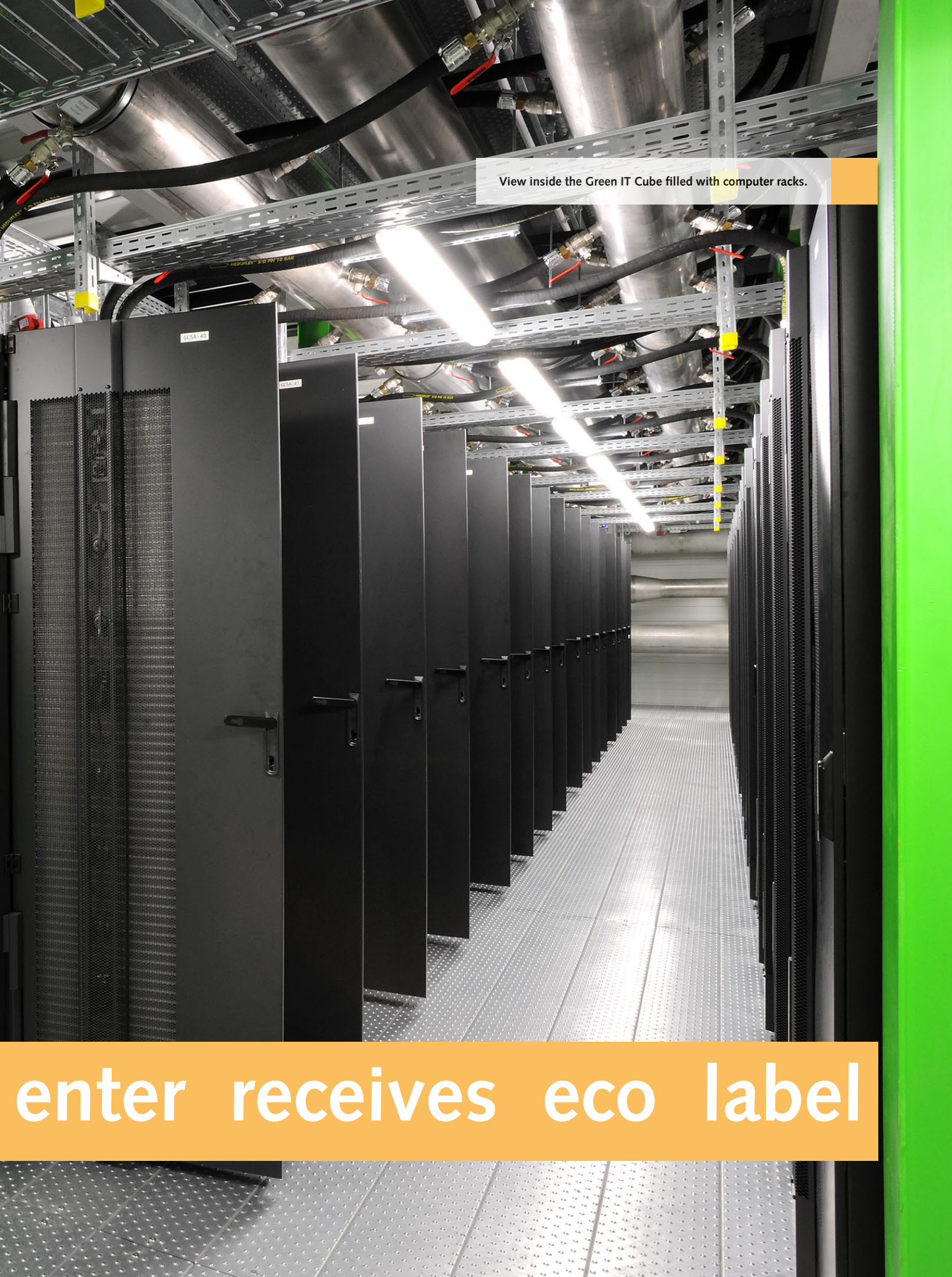
Dr. Ulrich Breuer
Administrative Managing Director of FAIR and GSI
on behalf of the Management Board



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Blue Angel

High-performance data c



View inside the Green IT Cube filled with computer racks.

enter receives eco label

The high-performance data center of GSI and FAIR, the Green IT Cube, was awarded the “Blue Angel” as a label of special environmental friendliness.

percent of the electrical power used for computing, instead of 30 up to 100 percent as is the case in conventional data centers with air cooling”.

Advanced Studies (FIAS). The powerful concept has already won several awards for innovation and environmental friendliness.

Cost efficient by saving energy and space

Currently, this makes it one of three data centers to receive the eco label of the German government. Thanks to a special cooling system, it is particularly energy efficient and conserves resources. The Green IT Cube is one of the most powerful scientific data centers in the world. It will provide enormous computing capacities for experiments at the accelerator facilities of GSI and, in the future, FAIR.

The Green IT Cube was built at GSI in Darmstadt and was financed with funds from the German Federal Government and the State of Hesse via Helmholtz investments in further expansion. The concept allows the realization and the particularly efficient operation of computer centers for large-scale research facilities, such as the international accelerator facility FAIR (Facility for Antiproton and Ion Research) being built at GSI.

“The Green IT Cube is an exceptionally energy-efficient data center because the energy required for cooling the computers is very low compared to conventional data centers,” explained Dr. Helmut Kreiser, who is head of the data centers on the GSI/FAIR campus. “The Green IT Cube cools its computers with an innovative air and water method. As a result, the energy required for cooling is less than seven

The effective cooling technology allows a space-saving placement of the computers in the Green IT Cube. In a cube-shaped building measuring 27 x 30 x 22 cubic meters, 768 computer racks in total can be arranged closely together on six floors. At present, two of the six floors are equipped with a maximum cooling power of four megawatts. In the final stage the Green IT Cube will be able to reach a cooling power of twelve megawatts. Due to saving energy and space, it is very cost-efficient. In addition, the waste heat of the Green IT Cube’s servers is already being used to heat a modern office and canteen building on the GSI/FAIR campus.

“We are very happy and of course proud to receive such a well-known and renowned label as the Blue Angel for our data center,” said Professor Paolo Giubellino, Scientific Managing Director of FAIR and GSI. “The technology for the cooling system is not only an example of the competence and the inventive spirit of our scientists, but also of the potential of a research center like ours to contribute to improving even already established technology in terms of sustainability and efficiency. Pursuing and expanding this potential is a major concern of our research at GSI and FAIR”.

Scientists use the Green IT Cube to perform simulations and develop detectors for FAIR. They also analyze measurement data recorded in experiments at the accelerator facilities at GSI and, in the future, FAIR, to gain fundamental insights into the structure of matter and the evolution of the universe. To this end, the Green IT Cube will be equipped in the long term with computer systems

Example of competence and inventive spirit

The technology was developed by Professor Volker Lindenstruth from Goethe University Frankfurt and at that time head of GSI-IT, and Professor Horst Stöcker, also from Goethe University and at that time Scientific Managing Director of GSI, in cooperation with the Frankfurt Institute for

that meet the scientists’ requirements in terms of computing power, storage capacity and access speed.

For over 40 years, the Blue Angel has been the environmental label of the German Federal Government and an orientation for sustainable purchas-

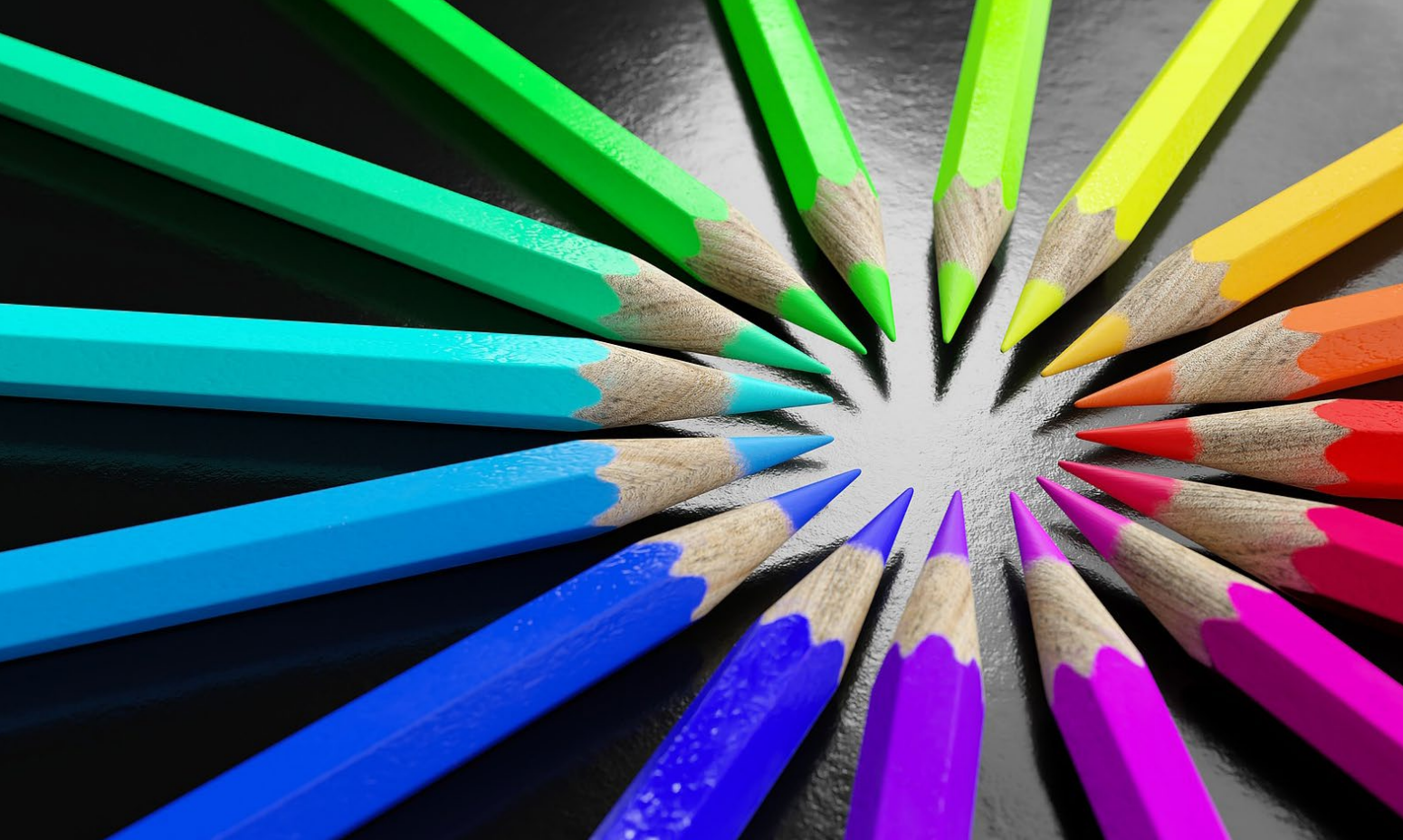


Outside view of the Green IT Cube on the GSI/FAIR campus.

ing. Independent and credible, it sets demanding standards for environmentally friendly products and services. The Blue Angel guarantees that products and services awarded with it meet high requirements of environmental, health and usage properties. The entire life

cycle must always be taken into account in the assessment. For each product group, criteria are developed which products and services labelled with the Blue Angel must fulfil. To reflect technical developments, the German Environment Agency reviews the criteria every

three to four years. In this way companies are required to make their products increasingly environmentally friendly. The Green IT Cube was the first data center to receive the eco label of the German government on the basis of the criteria changed in 2019. ■



Helmholtz Centers want to develop a common understanding of diversity, inclusion and a diversity-aware organizational culture.

Diversity and inclusion

The centers of the Helmholtz Association have agreed to develop and live a common understanding of diversity, inclusion and a diversity-aware organizational culture.

All 19 members of the Helmholtz Association, among them also GSI, have officially adopted a corresponding guideline in their Assembly of Members.

In large research infrastructures such as GSI, which has maintained strong international collaborations since its foundation, or the FAIR project, which is supported by several countries, cooperation with different people and cultures has long been part of everyday life. In this way, knowledge and know-how from all over the world can be brought together for research and high-tech developments in order to achieve the best results. The basis for this is now written down in the Helmholtz guideline in or-

der to create the framework conditions for reflecting diversity and inclusion in the processes, structures and conditions of the center.

The starting point is a simple insight: people are diverse. The current 40,000 employees of the Helmholtz Association and, of course, the approximately 1,500 employees of GSI and FAIR differ from each other in many ways: in their personal life plan or personal life situation, their gender, their world view, their biography and origins, their abilities and inclinations, their external appearance and many other aspects. The Helmholtz members recognize this sum of human differences, which is optionally referred

to as “diversity” or “variety”, as an irrefutable fact.

Inclusion is understood to mean the active shaping of the organizational culture in order to take all persons into account and to give them equal opportunities for influence, participation and individual development. Successful inclusion is demonstrated by the fact that the people who work in and with the centers experience an atmosphere of respect and fairness, appreciation and belonging, security and openness, and are convinced that they can fully develop their talents and grow personally. ■



From left: Dr. Stefan Kaufmann, member of the German Bundestag, Professor Grigory Trubnikov, First Deputy Minister of the Ministry of Science and Higher Education of the Russian Federation, Professor Otmar Wiestler, President of the Helmholtz Association, Professor Vladimir Kekelidze, Vice-Director of JINR for the NICA science project, Professor Paolo Giubellino, Scientific Managing Director of GSI and FAIR, Professor Wolf-Dieter Lukas, State Secretary of the Federal Ministry of Education and Research and Professor Andrey Fursenko, Advisor to the President of the Russian Federation.

Million Euro agreement

Intensifying research cooperation, strengthening cutting-edge research and promoting young researchers — these are some of the key goals of the “German-Russian Roadmap for Cooperation in Education, Science, Research and Innovation”, which Germany and Russia agreed on in December 2018. An important step in this context was the signing of an agreement between GSI and the Joint Institute for Nuclear Research (JINR).

One of the goals of the German-Russian Roadmap is to expand cooperation at major research infrastructures in Russia. One of the projects identified for this is the instrumentation and scientific usage of the future accelerator complex NICA (Nuclotron-based Ion Collider Facility), currently being built in Dubna at JINR. The German contributions to this cooperation are financed by the Federal Ministry of Education and Research (BMBF) and handled by GSI. For this purpose,

a cooperation agreement between JINR and GSI has been worked out, which has a total volume of about 20 million Euros. It was signed in Moscow during the “Helmholtz Winter Talks 2020”, a traditional event for the exchange of views between decision-makers from politics, science and society in Russia and Germany.

The agreement on technical cooperation between GSI and JINR consists of several subprojects: coordination and technical follow-up, stochastic cooling for the NICA collider, silicon tracking system for the NICA experiment BM@N as well as read-out electronics and data acquisition for this experiment, research and development for the superconducting high intensity ion injector Linacs@JINR and finally beam diagnostics and LLRF electronics for linear accelerators. As the next step, the details of these six subprojects are currently being worked out.

Professor Paolo Giubellino, who signed the agreement together with Professor Vladimir Kekelidze, JINR Vice-Director for the NICA science project, said: “I am very pleased about the new cooperation, which can build on an already existing, very solid foundation between our two institutes”. The collaboration between GSI and JINR has a long tradition and includes both research at the existing accelerator and experimental facilities of both partners as well as research and development activities for future research infrastructures such as the two accelerator centers FAIR and NICA, which are currently being built at GSI in Darmstadt and at JINR in Dubna. “The agreement offers excellent opportunities to further strengthen our cooperation in the future and to open up promising new perspectives in research and technological innovation”. ■

FAIR ring accelerator: From production to installation

The next decisive milestones for the FAIR ring accelerator SIS100 are set.

While the structural work on the construction site is progressing and the development and production of the high-tech components for the future FAIR accelerator center is running simultaneously, another crucial aspect is now moving more and more into focus: the assembly of the accelerator machine in the new buildings.

Although the current focus is still on the procurement of accelerator components, the first important steps towards machine assembly are currently being taken. The SIS100/SIS18 project group, consisting of the work package leaders, representatives of international providers and the subproject management, had placed their latest three-day closed meeting under the motto "From production to installation". Representatives of the new subproject "Site Management SMG" were also involved with the aim of jointly preparing the next phase of the project realization.

In which sequences should the installation of the machine take place? What is the best sequence for assembling the accelerator components? How will the heavy parts be moved to their correct position in the new buildings? These

are just a few of the questions to be answered with high precision. The focus is on the production of ready-to-install assemblies, the construction and testing of a complete SIS100 unit cell consisting of two dipole, two quadrupole and several correction magnets, the development of transport and lifting equipment and the consideration of technology-specific boundary conditions when defining installation sequences. In addition, other important milestones such as the completion of the technical building services (TGA), the completion of central facilities, the delivery dates and the readiness for installation of all accelerator components must be included in the planning.

Special attention is given to cryogenics. The ring accelerator SIS100 requires superconducting magnets to guide the extremely fast particles. Superconductivity can only be achieved with sophisticated cryotechnology: It has to constantly maintain a cryogenic temperature of minus 268.6 °C throughout the SIS100 ring system, which is required for operation.

The installation of such cryogenic systems, cryomagnetic modules and local cryogenics requires special quality assurance measures. European directives

must be complied with, for example the Pressure Equipment Directive, which is applied to numerous work steps.

Therefore, the recent meeting of the project group and the new subproject also discussed ways to efficiently exploit the extended installation phase of cryogenic systems by starting the hardware commissioning of warm systems in parallel. Efficient planning for the installation and commissioning of the individual technical systems is a precondition for timely cold commissioning, as well as for the commissioning of the main power supply in conjunction with the then superconducting magnetic chain.

Overall, these complex plans are driven by a decisive goal: the realization of a first pilot beam through SIS100, the heart of the future FAIR accelerator center. ■

DRONELAPSE



Three years
in fast motion:
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(scan QR-Code)



The shell construction on the construction site is progressing, and the assembly of the accelerator machine is moving more and more into focus.

Site Acceptance Test: Detector part for CBM successfully handed over

An important component for the future CBM experiment, one of the four central pillars of the FAIR research program, has successfully performed the Site Acceptance Test (SAT) on the GSI/FAIR campus. On behalf of a team from the Nuclear Physics Institute (NPI) of the Czech Academy of Sciences (CAS) and from the Czech Technical University in Prague (CTU), Dr. Petr Chudoba (NPI) handed over the manipulator for PSD detector, an in-kind contribution for FAIR. For CBM, this is the first in-kind contribution of a foreign partner delivered to Germany.

The Czech Republic is a partner state of the FAIR project and joined FAIR as an "Aspirant Partner" in spring 2019. At that time, the partnership could already build on a long-standing and very good

working cooperation between Czech research institutions and GSI/FAIR. Czech scientists are involved, for example, in the large detector HADES as well as in nuclear astrophysics and are active in all four FAIR research pillars, including CBM. Here, they are significantly contributing to research, development and construction of the PSD detector (Projectile Spectator Detector), which is part of the experimental setup of CBM.

The Projectile Spectator Detector (PSD) serves for measuring the geometry of heavy ion collisions at the CBM experiment. The now delivered component, the manipulator, is the movable part of this detector. PSD will be able to detect particles from the interaction of relativistic heavy ions with a target. Therefore, it will be located at a distance of

about eight to twelve meters from the interaction point around beam pipe. As the beam pipe is movable, also the detector has to be movable in several directions as well as able to rotate in the range of several degrees. The weight of PSD is about 25 tons, so it was a demanding task to design and build a corresponding support frame, the PSD manipulator.

The Czech team successfully achieved this complex requirement. The manipulator of PSD now allows horizontal and vertical movement with the precision of millimeters as well as rotation of the whole PSD detector. After installation, it will be able to support about 25 tons of calorimeter modules. After successful testing, the detector part is stored at GSI/FAIR until installation in the CBM cave. ■



Manipulator for the PSD detector of the CBM experiment at FAIR.



The bath in the copper electrolyte produces shine.

Large-scale copper plating

GSI Electroplating achieves important milestone for FAIR

An important success has been achieved in the Electroplating department of GSI: The copper plating of a cavity with two meter in diameter was successfully realized. This is also of great importance for the future accelerator center FAIR. In order to achieve the FAIR parameters, the existing linear accelerator UNILAC, which will serve as a pre-accelerator in the future, has to be partially upgraded with new cavities.

Cavities or cavity resonators are central elements of accelerators. Therein, strong electromagnetic fields oscillate, transferring their energy to the particles flying along the tube axis. To improve electrical conductivity, the surfaces are copper-plated. At GSI and FAIR, the Electroplating department is

responsible for coating the tanks and components of the particle accelerators with a layer of high-gloss copper from inside. The task of electroplating is challenging, the demands on surface quality are high.

Currently, the Alvarez accelerator structure, a section of GSI-UNILAC, has to be replaced for future top performance so that FAIR can deliver the planned high beam quality. One of the critical points in this upgrade is the copper plating of particularly large cavity sections. This is a challenge that was last faced at GSI more than 20 years ago. Nevertheless, the GSI Electroplating department has now succeeded in demonstrating its ability to copperplate a cavity of this size on the very first attempt. Thus, a

very crucial aspect of the Alvarez replacement has been addressed and positively solved.

The electroplating facility, which has developed in the course of the accelerator expansion on the GSI and FAIR campus, is unique. It allows high-polish copper plating of metal surfaces such as steel and stainless steel up to 200 micrometers thickness. It is above all the size of the elements to be copper-plated that makes the plant exceptional. Even a crane is used during maneuvering to move the heavy components back and forth between the various cleaning and coating baths. Elements can be copperplated up to a maximum length of 2.5 meters and a diameter of up to 2.5 meters. ■

The image shows a vast industrial interior, likely a particle accelerator facility. It features a complex network of metal beams, pipes, and electrical conduits. A person in a light-colored shirt and dark pants is standing in the center, working on a vertical support structure. The floor is polished and reflects the overhead lights. The ceiling is high with visible structural elements.

The FAIR storage ring CRYRING is ready for scientific experiments.

FAIR storage ring CRYRING ready for use

The first FAIR storage ring, the so-called CRYRING, is ready to conduct experiments for the scientific research community. CRYRING is an extremely successful ion storage ring that has enabled key research contributions in atomic and molecular physics in Stockholm for many years. It was brought to GSI and FAIR in Darmstadt as a Swedish in-kind contribution. Here it was modernized, adapted to FAIR standards and connected to the experimental storage ring ESR at GSI under the project name "CRYRING@ESR". Along with the al-

ready existing trapping facility HITRAP, the ESR and the future high-energy storage ring HESR, CRYRING will be part of the unique portfolio of trapping and storage facilities for heavy ions of FAIR.

CRYRING is a facility for storing highly charged heavy ions at low beam energy. With its high vacuum, the storage ring is particularly suitable for storing and cooling the ions at low energies. With low-energy ions, experiments of the highest precision, but also in a previously un-

attained regime of slow, adiabatic collisions are possible, allowing us to gain new insights into atomic, astrophysical and nuclear physics processes.

The recommissioning of CRYRING was started in 2015. In 2017, ion beams could be stored for the first time, initially from a local source. In recent years, work has been carried out on the optimization of the ring operation, beam cooling and diagnosis, the new FAIR control system and the experimental infrastructure. Commissioning is now



nearing completion and has progressed so far that the facility is ready to serve scientific experiments.

Various experiments by scientific users with international participation were already planned for this spring at the CRYRING. However, due to the corona pandemic they had to be cancelled for the time being and postponed to future operating periods. Nevertheless, work continued on the full commissioning of the facility. This involved not only transporting highly charged, heavy lead ions (beryllium-like Pb^{78+} and later also Pb^{82+} with completely removed electron shell) from the GSI linear accelerator UNILAC via the ring accelerator SIS18 and the experimental storage ring ESR to CRYRING, but also storing, cooling and using them for tests of the experimental infrastructure. The lifetimes and electron

cooling of the stored beams were in line with previous estimates.

In the first tests, X-ray detectors at the so-called electron cooler registered the characteristic X-ray spectrum of the highly charged heavy ions, which is of particular interest for the fundamental understanding of the electromagnetic force in extremely strong fields (quantum electrodynamics). Ions stored in the CRYRING fly through a cold, dense cloud of electrons of the same speed in the electron cooler, which is primarily used for beam cooling. A secondary side effect is that also a small fraction of the ions capture an electron from the cloud and release the energy gained in this process as X-rays. Researchers can use this radiation to study quantum electrodynamics. Due to the twelve-sided geometry of the CRYRING, the X-ray detectors can be

placed in an ideal position exactly on the axis in front of and behind the ion beam and yet very close to the interaction area with the cooling electrons. This largely eliminates uncertainties in the observation angle caused by the Doppler shift. The low beam energy of the stored ions already helps to reduce this shift per se, so that X-ray spectra can be recorded with unprecedented precision and clarity.

For the future, it is planned to reschedule the experiments that could currently not be conducted due to COVID-19 as soon as possible. Furthermore, a completion of the commissioning is planned. For this purpose, the extraction process will be implemented, which will allow the cooled, slowed-down ions to be removed from the ring and enable material and biophysical experiments with solid targets. ■

Full speed ahead

Series production of SIS100 accelerator cavities, power amplifiers and power supply units completed — All components delivered

The heavy ion accelerator SIS100 with a circumference of 1.1 kilometers is the heart of the future accelerator facility FAIR which is currently being built at GSI. In the future, it will accelerate the heaviest ions to their maximum velocity within half a second. All the necessary cavities, power amplifiers and power

supply units have now been delivered to GSI/FAIR. This completes the series production of the SIS100 main acceleration systems.

The fast acceleration time of the SIS100 is a major difference compared to other superconducting synchrotrons, in

particular the large collider synchrotrons, whose acceleration ramp typically takes several minutes. To enable this, SIS100 is equipped with a large number of high-frequency accelerator units. For the initial commissioning, 14 cavities were planned and ordered for the acceleration of the heavy ions; in



Cavity realised by RI Research Instruments including the electronics mainly developed by the GSI department "Ring RF" in the background.



Representatives of the GSI/FAIR team in the SIS100 acceleration project in front of some of the SIS100 acceleration cavities in the storage facility in Weierstadt (from left to right: Dr. Niels Pyka, Elena Reitz, Dr. Peter Spiller, Dr. Janet Schmidt, Robert Balß, Dr. Dieter Etienne Lens, Dr. Hans Günter König).

the final configuration, 20 cavities will be needed. In addition to the radio-frequency systems for beam acceleration, SIS100 has another nine cavities for compression of the accelerated ion pulses and four other special systems. The latter are used on the one hand to stabilize the beam at high intensities and on the other hand to create radio-frequency barriers that enclose a rectangular beam pulse prior to extraction. With this equipment of high-frequency systems, the straight lines of SIS100 are more like a linear accelerator than a synchrotron.

The design and construction of the accelerating cavities was contracted to RI Research Instruments GmbH. A design phase, in which RI worked closely with specialists from GSI's Ring RF depart-

ment, was followed by the production and acceptance of the first-of-series system. Based on the results of these activities, manufacturing of the 13 series systems, consisting of cavities and power amplifiers, started last fall. At the same time, the associated power supply units were produced in Switzerland by RI's cooperation partner, Ampegon Power Electronics AG, now part of the Aretè & Cocchi Technology Group.

In the beginning of December, the final components for the SIS100 acceleration system were delivered by RI. As a result, all components of the procurement — 14 cavities and power amplifiers each from RI and 14 power supply units from Ampegon — have now arrived at GSI/FAIR. Together with the "low level RF", the electronic system

for control and synchronization, they form the acceleration system of the SIS100 synchrotron, which can generate a total peak acceleration voltage of 280,000 volts at the ceramic gaps of the cavities.

Production and acceptance testing faced unexpected challenges in early 2020 due to the corona pandemic, but thanks to shift work, flexible customization, and, most importantly, close cooperation among the teams at GSI/FAIR, RI, and Ampegon, the activities were successfully completed despite the difficult circumstances. In addition to the completion of the series production of the superconducting dipole modules, another important milestone for the construction of the SIS100 synchrotron has thus been reached. ■



The HADES detector was part of the tour with State Secretary Wolf-Dieter Lukas. In the photo from left: The Scientific Managing Director of GSI and FAIR, Professor Paolo Giubellino, State Secretary Professor Wolf-Dieter Lukas and the scientists Professor Hannah Elfner and Professor Tetyana Galatyuk.

Achievements and prospects: BMBF State Secretary visits GSI and FAIR

The research at FAIR and the ongoing research activities in the run up to its construction were the focus of a visit by Professor Wolf-Dieter Lukas, State Secretary at the Federal Ministry of Education and Research (BMBF). Together with further senior staff from the BMBF, he heard all about the outlook for the future at the FAIR and GSI campus. The guests were welcomed by Professor Paolo Giubellino, Scientific Managing Director of GSI and FAIR, Dr. Ulrich Breuer, Administrative Managing Director, and Jörg Blaurock, Technical Managing Director.

The guests enjoyed presentations and a guided tour, giving them comprehensive insights into current and planned research activities at the FAIR facilities. State Secretary Lukas was impressed by the achievements of GSI, by the outstanding activities carried out as part

of the current "FAIR Phase 0" program and by the promising scientific prospects that will emerge once FAIR becomes operational: "Fundamental scientific research forms a crucial foundation for development and progress in a society. Supporting such research is therefore a key priority of the Federal Ministry of Education and Research. Today, I have seen for myself what excellent, cutting-edge research is being done here at GSI and the compelling scientific potential of the future FAIR facilities."

The unique possibilities of FAIR and future challenges were also the focus of a tour of the existing accelerator facility. Young researchers and senior scientists gave the guests insight into their work at various parts of the facility, including the experimental storage ring ESR, the medical radiation unit of the biophysics department, the large-scale experiments

R3B and HADES as well as the high-performance computer center Green IT Cube. Summarizing his visit State Secretary Lukas stressed, "I am particularly impressed by the high level of expertise and the enthusiasm shown by the young researchers I met during the visit for their work at GSI."

At the international accelerator center FAIR, which is being built at GSI, extreme forms of matter that usually only exist in neutron stars, supernovae, stars or large gas planets are to be produced and researched in the lab. FAIR will thus investigate "the universe in the laboratory". FAIR's future research work will build on the successful research at GSI. Scientists from all over the world will use the different areas of GSI and FAIR to carry out unique experiments and obtain new insights into the structure of matter and the evolution of the universe. ■

Long multiplet for Super Fragment Separator in the test stand

The first long multiplet for the superconducting fragment separator (Super-FRS) of the new FAIR accelerator, produced by the company ASG Superconductors in Italy, was delivered to the test stand at the European research center CERN in Switzerland. A cooperation agreement exists between GSI/FAIR and CERN for the testing of accelerator magnets, under which the multiplet will undergo a series of detailed quality tests before delivery to Darmstadt.

A total of nine superconducting single magnets are integrated into the multiplet, and it is a real heavyweight: It is seven meters long, has a diameter of 2.5 meters and weighs over 60 tons. Accordingly, the delivery to CERN was made by means of a heavy goods transport on a low loader. Following installation in the test stand, the multiplet will be cooled and subjected to extensive testing of operating parameters and magnetic field qualities, which is expected to take about six to nine months. After successful completion of the acceptance tests, the multiplet is to be transported to GSI and prepared for the subsequent tunnel installation as part of a pre-assembly. Until the final installation, the multiplet and also its successors will be temporarily stored.

The multiplets are later used in the Super-FRS to guide and shape the beam to achieve a high-precision particle beam. The Super-FRS of the future FAIR accelerator center is an important component of the overall facility with great discovery potential for science: This part of the accelerator complex is about experiments with extremely rare exotic nuclei in the framework of FAIR's experimental pillar NUSTAR (Nuclear Structure, Astrophysics and Reactions). For this purpose,

ions of the heaviest elements are initially accelerated onto a material sample (target) and crushed by the impact. Among the resulting fragments are exotic nuclei, which are sorted out at the Super-FRS and made available for further experiments. With the new separator, nuclei up to uranium can be produced at relativistic energies, monoisotopically separated and analyzed. Since this entire process takes only a few hundred nanoseconds, the Super-FRS allows access to very short-lived nuclei.

The multiplets produced in La Spezia, Italy, as well as the subsequent test procedure, are an important contribution (in-kind) of GSI to the FAIR project. GSI is the main German shareholder in the international FAIR GmbH. All supercon-

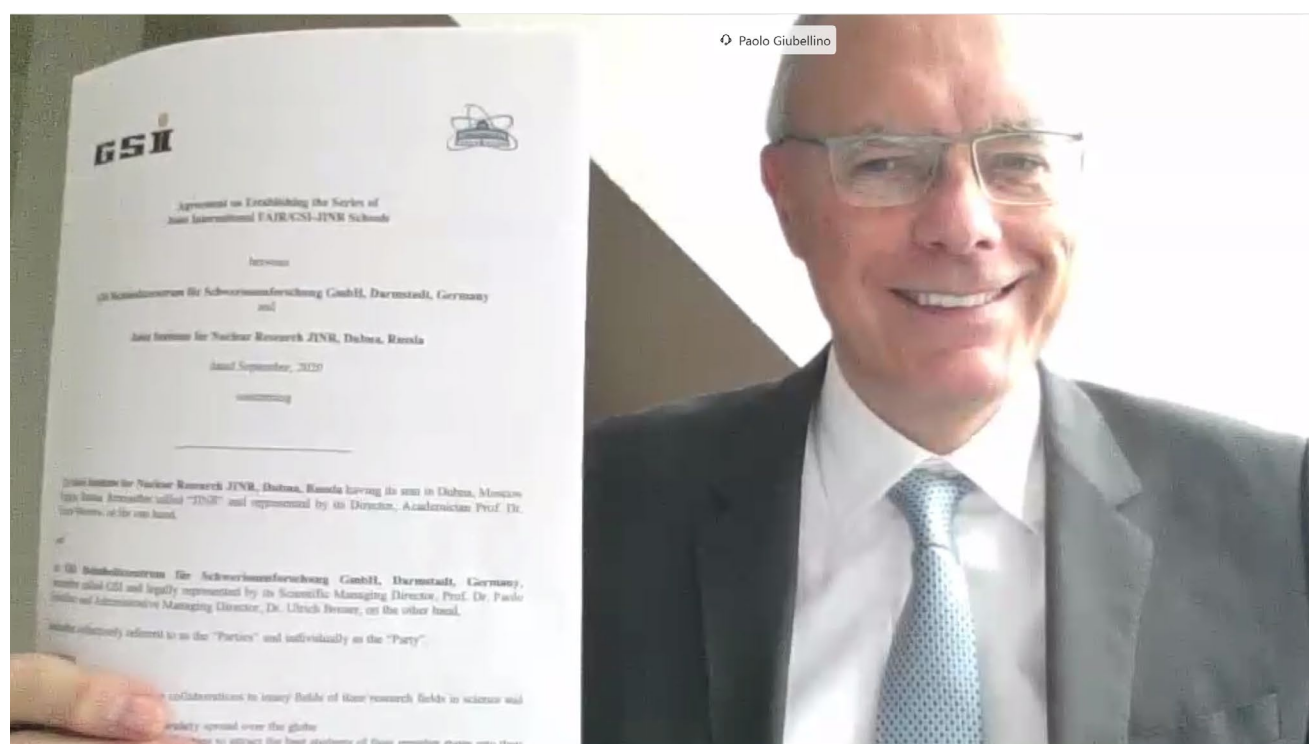
ducting magnets required for the Super-FRS will be tested in the new test facility at CERN in alternating sequence. This includes both the total of 32 multiplet units as well as 24 superconducting dipole magnets, which are needed for deflecting the particle beam. A first short multiplet had already been delivered to CERN in 2019, used for commissioning of the first of a total of three test stands. In the meantime, the acceptance test of the short multiplet was successfully completed despite difficult conditions due to the corona pandemic. Currently, the second test stand is being commissioned with the multiplet in preparation for series testing of all multiplets. From spring of this year, further multiplet deliveries are planned at approximately monthly intervals. ■



The long Super-FRS multiplet on site at the CERN test stand.

Promoting young scientists: GSI/FAIR and JINR establish joint international school

It is a strong signal for the future: GSI/FAIR and the Joint Institute for Nuclear Research (JINR) are promoting young talents in international co-operation and therefore jointly establish the “International Joint FAIR/GSI-JINR School”. Representatives of both institutions have now concluded a corresponding agreement.



Screenshot from the videoconference: Professor Paolo Giubellino presents the contract between GSI/FAIR and JINR.

The very good collaboration between GSI and JINR has a long tradition and includes science and technology at the existing accelerator and experimental facilities of both partners as well as research and development activities for the two accelerator centers FAIR and NICA, currently being built at GSI in Darmstadt and at JINR in Dubna. The new school shall cover the current and future scientific programs and its high

underlined the importance of scientific education: "The school will offer excellent opportunities and open up promising new perspectives. That is essential. Because the students from today are the FAIR scientists of tomorrow. With our new offer, we will attract the researchers of the future. Moreover, the new offer will further strengthen the close and very good cooperation between the two institutes in Darmstadt and Dubna".

where the students will solve problems and tackle projects in the presence of the lecturers. Participants are selected based on individual applications and recommendation letters by their scientific supervisors. The focus will lie also on getting a good mix of nationalities in order to consistently foster more international collaboration. The offer aims at PhD students, who will be able to gain concentrated experience in small groups with direct feedback from their supervisors and will get a full overview far beyond their own field of research.

Scientific scope for young researchers

quality offer is addressed to young participants from all member states of GSI/FAIR and JINR/NICA.

The school is organized alternately once a year for a period of ten to 14 days in Germany or Russia or one of the FAIR or JINR member states. It offers 40 to 50 PhD students the unique opportunity to immerse themselves in the research areas and technological developments at FAIR/GSI and JINR, especially in the topics hadron and nuclear physics, atomic physics, plasma physics, materials research, biophysics and radiation medicine, accelerator physics, detector research and development, micro-/nanoelectronics, information technology and high-performance computing and more. Thus, the young scientists will learn about the entire scientific and technological scope of the research programs pursued at FAIR/GSI and JINR.

Professor Paolo Giubellino was enthusiastic about the new cooperation and

The "International FAIR/GSI-JINR School" benefits from the experience of both institutions with such offers, for example the joint Helmholtz-Rosatom Schools dedicated to FAIR physics and

Professor Giubellino stressed, "This, together with the very open discussion culture of the event, leads to discussions across the border of research groups, disciplines and countries. We jointly promote new talents, bring together young people from all over the world and even in COVID times go forward in a focused way building the future".

"We jointly promote new talents."

several international FAIR schools. The new project will bring together excellent young students and familiarize them with FAIR/GSI and JINR research and technologies. As the experiences from the existing offers show, students and lecturers highly appreciate this multidisciplinary structure.

The International FAIR/GSI-JINR School combines excellent pedagogical lectures given by international GSI, FAIR, and JINR experts with workshop sessions

In their agreement, the two partner institutions emphasize, "Especially in today's environment of a more and more global world, the competence to discuss, collaborate and cooperate within international teams will become increasingly more important. The community of scientists always has been on the forefront of global partnership and will continue to do so". The International Joint FAIR/GSI-JINR School will make an important contribution to this. ■

COMpact

FROM THE BEGINNING OF LIFE TO THE ORIGIN OF THE UNIVERSE

Does life exist only on earth? How did the universe we live in come into being? And what holds matter together at its core? Researchers at the Bergische Universität Wuppertal are getting to the bottom of these questions using various large-scale experiments. The astroparticle physicists receive funding for their research from the Federal Ministry of Science and Research, the Federal Ministry of Economics and Energy, represented by the project management organizations DLR and PT-DESY (Deutsches Elektronen-Synchrotron), and GSI. For their projects, the Wuppertal researchers, led by astroparticle physicists Professor



Professor Karl-Heinz Kampert (l.) and Professor Klaus Helbing (3 .f. r. .) with the subproject leaders.

Karl-Heinz Kampert and Professor Klaus Helbing, will get a total of around two

million euros in funding. Several major projects are associated with this. ■

GSi AND FAIR SUPPORT "YOUR STORY COUNTS"

On the campus of GSI and FAIR, one of the symbolic desks of the campaign "Your story counts" was located. They are supposed to raise attention for the topic of violence against women in the district of Darmstadt-Dieburg. The campaign which was initiated on the occasion of Women's Day 2020 is supported by Frauen helfen Frauen e.V., the women's home "Notwaende" and "Mäander – individuelle Jugendhilfe".

Symbolic desks can be seen at various locations in the Darmstadt-Dieburg district as part of the campaign "Your story counts — Letters against violence against women". They encourage people who experienced violence against women and girls to write down their story. On the campus of GSI and FAIR a desk with a mailbox was located until 18 December 2020. "We want to create awareness that violence against

women happens everywhere and at all times and that behind every experience of violence there is an individual story and thus also a fate. The desk should attract attention and sharpen the view for everyday aggression and violence," says the equal opportunities committee of GSI and FAIR.

The project was inspired by the action "Cartas de Mujeres" from Quito in Ecuador, where many thousands of women addressed politics with letters and messages. The letters received at the desks in Darmstadt-Dieburg are treated in strict confidence and are only read and evaluated by employees of the project cooperation. For Women's Day 2021, the results are to be brought to public space through art initiatives. Ideas and demands to politicians are to be passed on to the local political committees. The goal is to reach as many people as possible with the campaign "Your story counts" and to initiate changes. ■



The symbolic desk for "Your story counts" was located on the GSI/FAIR campus.

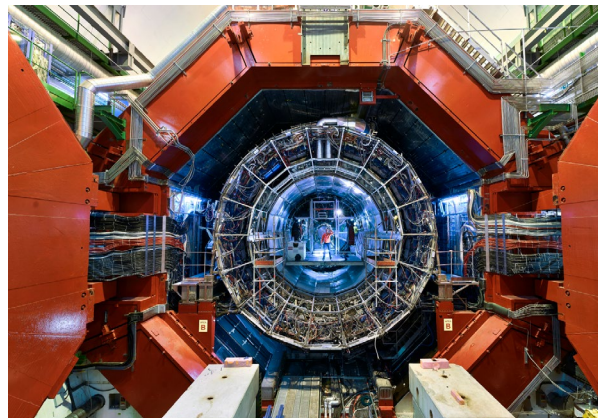
SATURDAY MORNING PHYSICS — VIRTUAL GSI/FAIR EVENT



Screenshot from the video tour — linear accelerator UNILAC.

The popular event series “Saturday Morning Physics” was also held in 2020, but due to the corona pandemic in a purely virtual format. Around 200 high-school students from all over the State of Hesse took the opportunity to participate and gain exciting insights into current physics research. The long-standing series organized by the Technical University of Darmstadt also included the traditional visit of GSI and FAIR, this time, however, via a guided video tour to the linear accelerator UNILAC, the main control room, the heavy ion synchrotron SIS18, the storage ring ESR, the tumor therapy and the large experiment HADES. There was also a virtual visit to the test facility for superconducting FAIR magnets and to the viewpoint of the FAIR construction site. ■

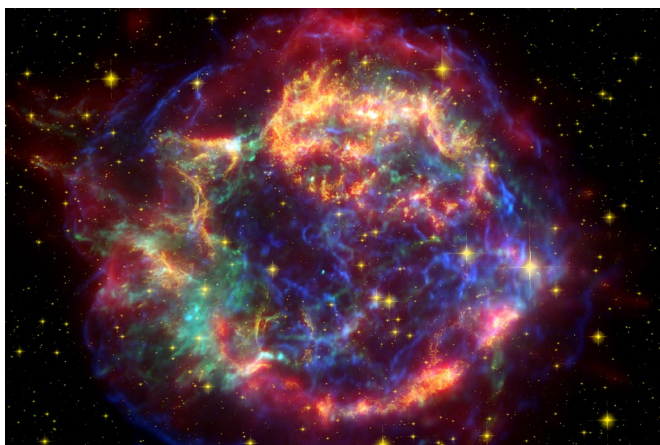
VIRTUAL ALICE MASTERCLASS AT SCHULDORF BERGSTRASSE



View inside the ALICE detector at the research center CERN.

How was the universe created? What are we made of? What does CERN investigate? These were the questions pursued during the “Week of the Particle World” in November 2020. All over Germany, the locations of Netzwerk Teilchenwelt invited visitors to explore research in the field of particle physics. GSI and FAIR also took part in an online Masterclass for the analysis of measurement data from the CERN experiment ALICE, which was conducted together with the “AG MINT-Zentrum” at the school Schuldorf Bergstraße. In addition to data analysis, the program included an exchange with other Masterclass groups via video conference as well as a virtual tour of the ALICE experimental site. ■

LECTURE SERIES “WISSENSCHAFT FÜR ALLE” BY GSI AND FAIR GOES DIGITAL



Lectures in the first half of 2021 will focus on space, in the picture the supernova remnant Cassiopeia A.

As part of corona prevention, GSI and FAIR had decided to suspend the lectures of the public series “Wissenschaft für Alle”. Since the events can still not be held on campus, a digital offer is now taking their place. The speakers will offer their lectures as video conferences. Interested parties can join in via a dial-in link using a web-enabled device such as a laptop, smartphone or tablet. The lecture series “Wissenschaft für Alle” is aimed at all persons interested in current science and research. The lectures report on research and developments at GSI and FAIR, but also on current topics from other fields of science and technology. ■

Further information (German only) at: www.gsi.de/wfa
(scan QR code)



Professor Friedrich-Karl Thielemann

received the Karl Schwarzschild Medal, the most prestigious award in Germany in the field of astronomy and astrophysics, for his research at the interface between nuclear physics and astronomy. Following his retirement, Thielemann stays a visiting scientist at GSI and continues his award-winning research on the origin of elements in the universe in collaboration with his theory colleagues since 2018. His work is of great importance for the future experimental program at FAIR and also already for the ongoing FAIR Phase 0 program.

You were awarded the Karl Schwarzschild Medal 2020. What does that mean for you?

The award is of course a great honor for me! There are nine Nobel Prize winners on the list of previous winners. I originally come from nuclear physics and did my PhD at the TU Darmstadt. In the course of my career, I have increasingly focused on astrophysics. That is why the Karl Schwarzschild Medal of the Astronomical Society is now a special honor.

Which discovery would you describe as the personal highlight of your career?

In principle, I am proud of all my discoveries and papers, but measured by the number of citations for my publications, one could pick out the results around the exploration of Type Ia supernovae. Together with Japanese colleagues we predicted the element formation in these supernovae. Apart from the fact that they produce two thirds of the iron that is found in our solar system (and our galaxy) today, this type of supernova also plays an important role in determining the Hubble constant

and thus the expansion of the universe. This is possible because the apparent luminosity of these supernovae can be utilized for distance measurements in cosmology.

I am also personally proud of the fact that my team and I were the first in 1999 to make predictions about the formation of heavy elements during the merger of neutron stars, and that we recently came closer to answering the question which massive stars will end up as core-collapse supernovae and which ones as black holes. In general, I am pleased that we were able to close the circle from nuclear physics input via its use in astrophysical simulations to comparisons with astronomical observations.

Together with international colleagues, you just published a review article in Reviews of Modern Physics about the r-process, which plays a crucial role in the synthesis of the heaviest elements in the universe. What do you see when you look at the starry sky on a clear summer night?

In fact, I live in a place with low light pollution, so I am happy to see the

Milky Way on a clear night. My wife, who regularly reads news about the night sky, tells me usually which planets can be seen where and when. But actually I am not one of those who were already enthusiastic about stars as a child. I grew up in the Ruhr area and you often couldn't tell whether the sky in the west was red because of the sunset or because of steel furnaces. I came to astrophysics for other reasons. At the TU Darmstadt the group around E. Hilf and W. Hillebrandt in theoretical nuclear physics was particularly active, had many international visitors and was characterized by an excellent group atmosphere. This convinced me to do my dissertation in this group with an interdisciplinary attitude. That environment and later employments improved my astrophysical knowledge, especially when I gave astrophysics lectures at Harvard University. Today I focus mainly on the question how, where and when the chemical elements in the universe and in our galaxy were made in stars and stellar explosions. The last comprehensive study related to the heavy elements is our review article in Reviews of Modern Physics, you mentioned. By the way,



two further GSI colleagues are among the eight authors. The two experimental co-authors also have close relations to GSI.

What opportunities does GSI offer you as a guest researcher?

I have been closely connected with GSI for a very long time. Even during my studies I spent some time on the campus and used the GSI computers for my diploma thesis and the early phase of my PhD research. In 2009, I returned to Darmstadt for a longer period as a Humboldt Award Winner and since then I am spending time in my former place of study on a regular basis. Above all, GSI offers a very enriching environment. I know my colleagues in the theory department well and enjoy joint collaborations. I knew Karlheinz Langanke already during my student days when he was still in Münster, and we have often worked together since then. One of our special concerns was to support highly talented young researchers. Gabriel Martínez-Pinedo and Almudena Arcones were both first in Karlheinz's team and then in my Basel research

group before they both received their positions at GSI and at the Darmstadt Technical University. Andreas Bauswein and Stephan Typel cover important fields related to my research such as neutron star mergers and the equation of state of matter at highest densities. There is also a lively exchange with the experimental colleagues. Even if this is currently limited due to corona, GSI offers the possibility of a close and direct exchange of knowledge with colleagues working in the same and related fields. This motivates us all! And of course the experiments that are carried out at GSI, e.g. at the storage rings, are also essential for my work.

What significance does the future FAIR facility have for you in this context?

FAIR will produce exotic nuclei much further off stability than accessible so far. And with the CBM experiment (Compressed Baryonic Matter) the equation of state can be tested at extremely high densities. This means that, once FAIR is up and running, there will be an extraordinary amount of exciting new input for us, which will certainly lead to a deeper

understanding of the universe and the processes taking place within it.

What are your plans for the future?

There still exist many open questions in my field of research, for example related to core-collapse supernovae. However, at the moment the question which is catching most of my attention is the production site of the heaviest elements in nature. For a long time it was thought that they originated mainly in supernovae. Now we know that mergers of neutron stars play an important role. But it seems that the abundance distribution of the elements in the universe cannot, yet, be fully explained this way. Probably additional sources are required. Very old stars with a still small amount of iron and other heavy elements are especially interesting. They originate from the earliest phases of galactic evolution and are probably only affected by a single "element production event". Their "pattern", i.e. their abundance distribution of elements, could therefore give us a clue about this source. Here too, I expect FAIR to make decisive contributions to the nuclear physics involved. ■

Tumor treatment: Combination of carbon ion and immunotherapy

It is still a glance into the future: the combination of carbon ion and immunotherapy could become an effective tool in the fight against cancer.

Promising results for the potential benefit of this treatment combination have now been published in the renowned radiation therapy journal *International Journal of Radiation Oncology, Biology, Physics* of the American Society for Therapeutic Radiation Oncology (ASTRO). The authors are an international team of researchers, led by the Biophysics department at GSI, and including the Parthenope University of Naples and the Japanese National Institute for Radiological Sciences (NIRS-QST) in Chiba.

Even though the results are only preclinical and the way to clinical application is still long, the current findings point into a promising direction: It was shown that carbon ions, as used in the cancer therapy developed at GSI, can be very effective when used in combination with specific molecules, called checkpoint

blockers, that stimulate the immune system against the tumor metastases.

The aim of the published research work was to compare the efficacy of conventional radiation therapy (high-energy X-rays) and carbon ion therapy in combination with immunotherapy. The immune system plays an important role in the prevention of cancer. Usually, it recognizes degenerated cells and can "sort them out". At the same time, it is equipped with highly complex control mechanisms to avoid overreactions. This is exactly what cancer cells can sometimes use to their advantage and to down-regulate immune surveillance. They disappear from the radar, so to speak. Immunotherapy can reactivate the immune system in the fight against cancer. It is now frequently used for advanced malignancies and metastatic pa-

tients, but unfortunately is effective only in some tumor types.

In the other cases, conventional radiation therapy is added as a second component, which under certain conditions can release such brakes on the immune system. The radiation-induced triggering of an immune response and its amplification by immunotherapy can lead to good results especially in the control of metastases, such as a slow-down of growth. But only parts of the patients respond to this combination of therapies.

Can radiotherapy with carbon ions, which was developed very successfully at GSI and is now in clinical application in Heidelberg and Marburg and in other nine centers worldwide, for certain types of tumors, open up new perspec-



Work with cell cultures is an important part of tumor research on the GSI/FAIR campus, here Dr. Alexander Helm from the Biophysics department.

tives and help to control metastases? It is possible that this form of therapy is more immunogenic, i.e. it could trigger an even stronger immune response than conventional radiation therapy and, together with immunotherapy, might result in more patients responding to this therapy combination. Based on such considerations, the team with lead author Dr. Alexander Helm (GSI) in the current experiment, conducted at the accelerator in Chiba, Japan, for the first time has directly compared carbon ions with conventional X-rays in a mouse model.

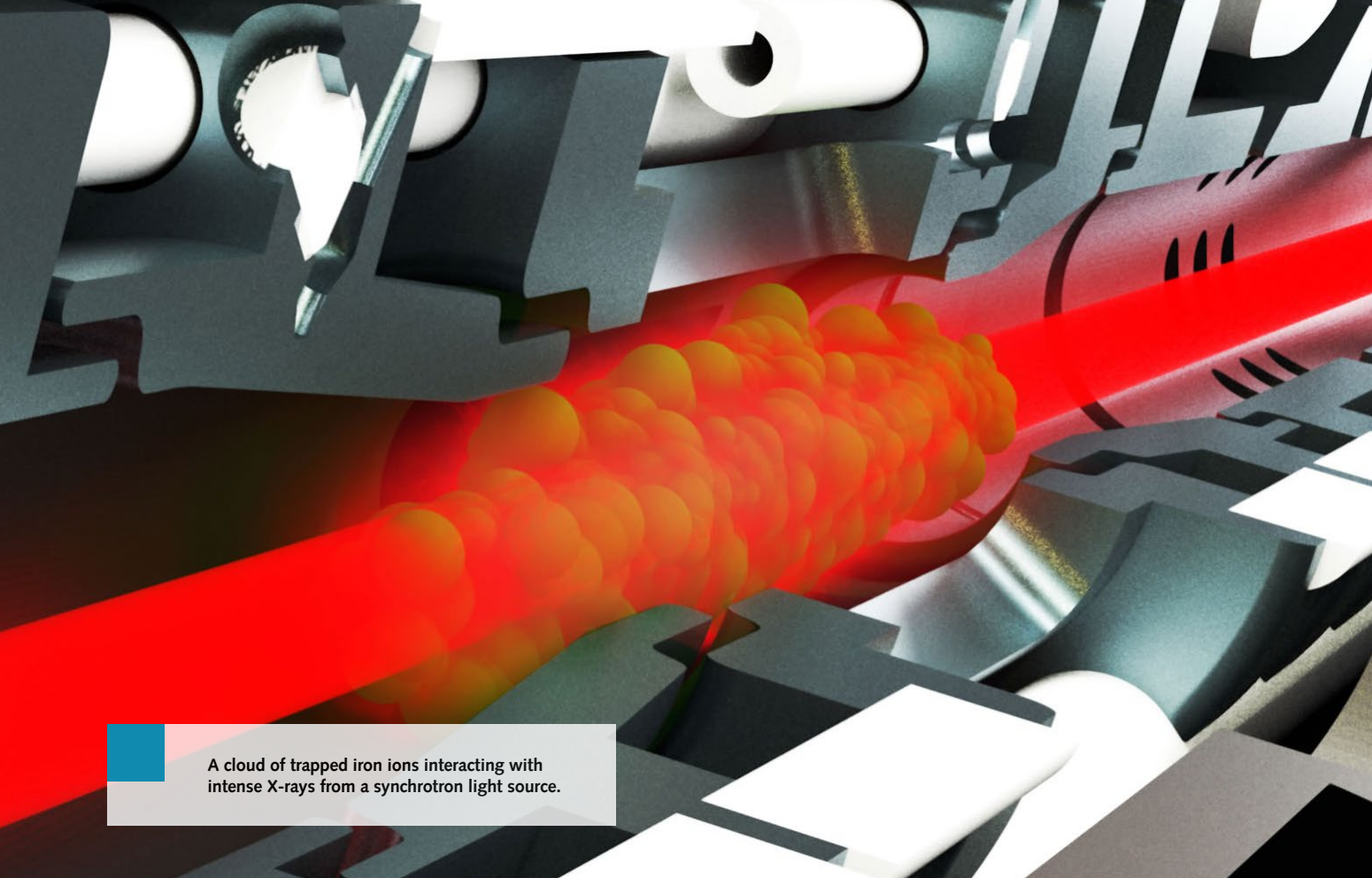
In the control of the primary tumor (here osteosarcoma, a bone tumor), carbon ions and X-rays, each combined with immunotherapy, produced similar results. However, when looking at the growth of metastases, the results show

that metastases are significantly reduced if the primary tumor is treated with carbon ion radiation and a following immunotherapy. The researchers were able to demonstrate that carbon ions plus immunotherapy is more effective in controlling lung metastases than both therapies alone and more effective than X-rays plus immunotherapy.

In order to better assess this potential, further research has to be conducted and finally, together with international partners, the application in clinical studies must be tested. Professor Marco Durante, head of the GSI Biophysics research department, explained the future research: "At GSI/FAIR, the focus of our research is on understanding the cellular and molecular mechanisms that trigger a strong immune response. The goal is to answer the central question: How should

irradiation be applied to achieve the most efficient, the best immune response in the fight against cancer."

The possibilities of combining cutting-edge molecular biology with high-energy heavy ion physics at the GSI/FAIR campus and the future accelerator center FAIR promise unique scientific knowledge. The Scientific Managing Director of GSI and FAIR, Professor Paolo Giubellino, emphasized "The present results show the great potential of carbon ion therapy, which is far from being exhausted. Together with our national and international partners, we will continue to conduct research on this highly relevant topic in the coming years. The first stage of the FAIR experimental program, FAIR Phase 0, already offers outstanding opportunities in this field". ■



A cloud of trapped iron ions interacting with intense X-rays from a synchrotron light source.

New measurement exacerbates old problem

Two prominent X-ray emission lines of highly charged iron have puzzled astrophysicists for decades: their measured and calculated brightness ratios always disagree. This hinders good determinations of plasma temperatures and densities.

New, careful high-precision measurements, together with top-level calculations now exclude all hitherto proposed explanations for this discrepancy, and thus deepen the problem. Researchers from GSI and the Helmholtz Institute Jena (HIJ), a branch of GSI, are also involved in the investigations. The results are now published in the journal *Physical Review Letters*.

Hot astrophysical plasmas fill the intergalactic space, and brightly shine in stellar coronae, active galactic nuclei, and supernova remnants. They contain charged atoms (ions) that emit X-rays observable by satellite-borne instruments. Astrophysicists need their spectral lines to derive parameters such as plasma temperatures or elemental abundancies. Two of the brightest X-ray

lines arise from iron atoms that have lost 16 of their 26 electrons, Fe^{16+} ions – also known in astrophysics as Fe XVII. Iron is rather abundant in the universe; it lets stars similar to our Sun burn their hydrogen fuel very slowly for billions of years by nearly stopping the energy flowing as radiation from the fiery fusion core to the, in comparison only mildly hot, stellar surface.

For more than forty years, X-ray astronomers have been bothered by a serious problem with the two key Fe^{16+} lines: the ratio of their measured intensities significantly disagrees with theoretical predictions. This also holds for laboratory measurements, but uncertainties in experiment and theory have been too large for settling the issue.

An international team of 32 researchers led by groups from the Max Planck Institute for Nuclear Physics (MPIK) and the NASA Goddard Space Flight Center has just published the outcome of its renewed massive effort to resolve this discrepancy. They have performed both the highest-resolution measurements thus far reported, and several top-level quantum-theoretical calculations.

Steffen Kühn, PhD student at MPIK and responsible for the setup, describes the effort: “To resonantly excite highly charged iron ions, we continuously generate them with our compact mobile electron beam ion trap (PolarX-EBIT) and irradiate them with X-rays from the PETRA III synchrotron at DESY. We find resonance with the lines by scanning the synchrotron energy over the range where they should appear and observing the fluorescence light. To handle the experimental data flow, we had colleagues from 19 institutions working at DESY, and painstakingly analysing and cross-checking results for more than one year.”

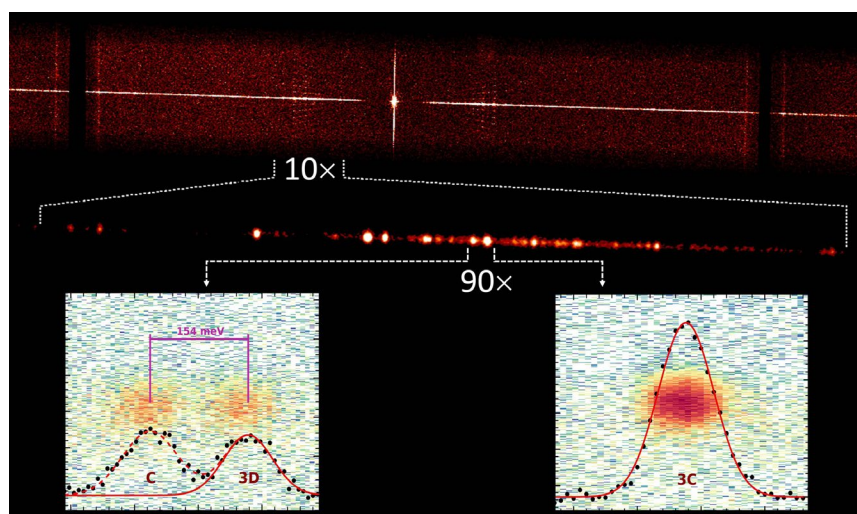
To make sure that everything is consistent, the researchers combined three different measurement procedures to determine the intensity ratio of the two Fe^{16+} lines, dubbed 3C and 3D. First, overall scans revealed line positions, widths and intensities. Second, the experimentalists set the energy of the X-ray photons to match the peak fluorescence yield while cyclically turning the photon beam off and on to get rid of the strong background. Third, they

scanned the lines again, but using the on-off trick at the same time in order to reduce instrumental effects. “This way, we could derive the presently most accurate value of the brightness ratio, and this with ten times higher spectral resolution than earlier work”, states Chintan Shah, NASA postdoctoral fellow. “And the properties of the PETRA III beam avoided possible non-linear effects depending on the flux of synchrotron photons that may have affected earlier measurements”, adds Sven Bernitt, researcher at the Helmholtz Institute Jena and one of the project leaders, who is working in the group of Thomas Stöhlker, HIJ Director and Deputy Research Director of GSI and FAIR. Remarkably, the resulting intensity ratio confirms earlier astrophysical and laboratory measurements with much reduced uncertainty.

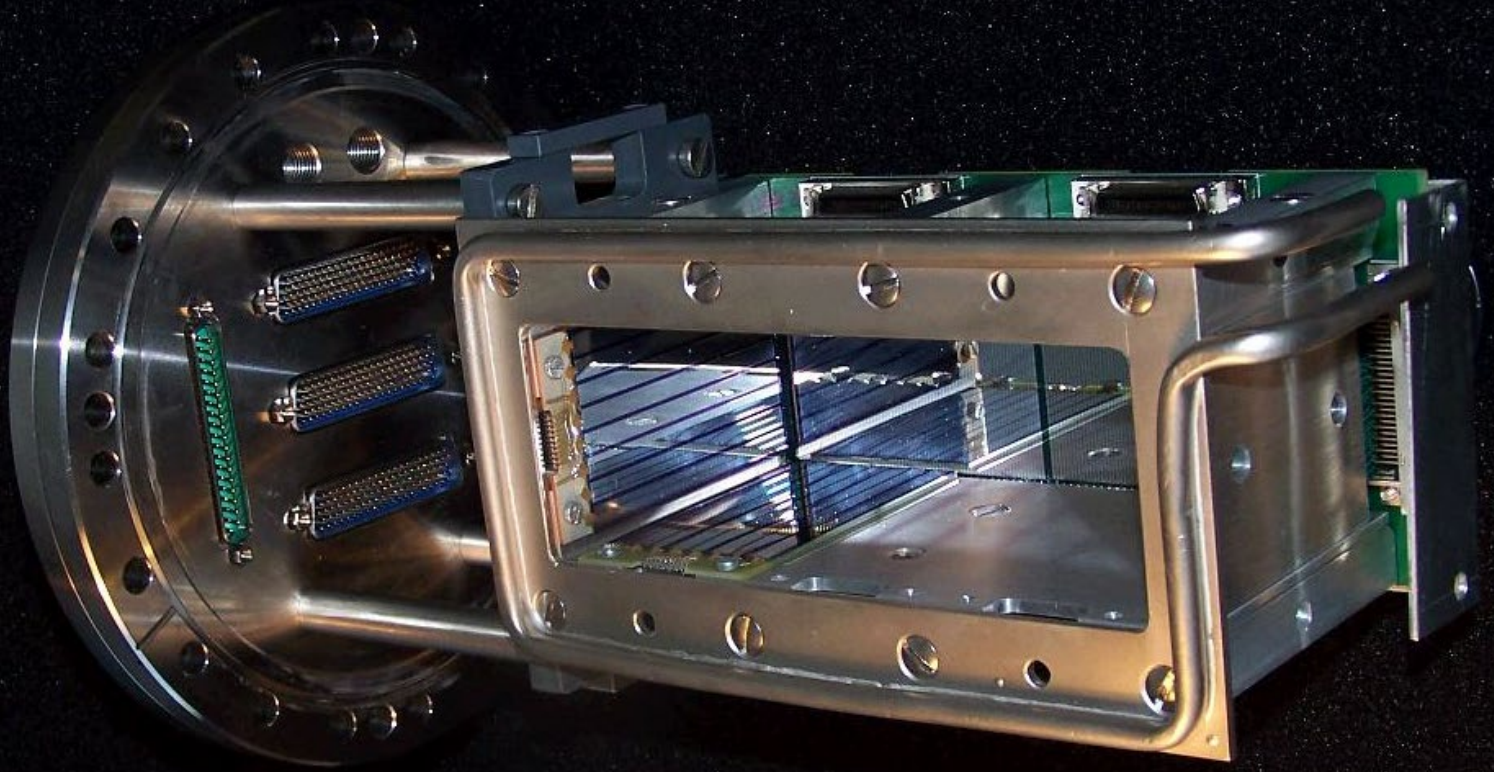
Theory teams around Natalia Oreshkina at the MPIK, from Australia, USA and Russia applied three independent very-large-scale relativistic quantum-theoretical methods, letting clusters of hundreds of processors run hot for weeks. This computational marathon delivered concordant results at

high numerical precision. However, while the calculated energy difference between the two lines agrees well with the measured value, the intensity ratio clearly departs from the experimental result.

Thus, the cause for the discrepancy between the experimental and theoretical intensity ratios of the 3C and 3D lines of Fe^{16+} remains puzzling, since also all effects that could perturb the measurements were suppressed as far as possible, and the remaining uncertainty understood. As a consequence, astrophysical parameters derived on the basis of X-ray line intensities are, to some degree, uncertain. While this is unsatisfactory, “the new accurate experimental result may be immediately used to empirically correct the astrophysical models”, recommends Maurice Leutenegger, also a NASA researcher. “Upcoming space missions with advanced X-ray instrumentation, such as ESA's Athena X-ray Observatory, will soon start sending an incredible stream of high-resolution data to ground, and we have to be prepared to understand it and squeeze the maximum value from those billion-dollar investments.” ■



The X-ray observatory Chandra's LETG (Low Energy Transmission Gratings) spectrum of Capella (MPE) and the present PolarX-EBIT high-resolution laboratory spectrum of the key Fe^{16+} soft X-ray lines together with line C of Fe^{16+} .



Focal plane detector of the TASCA separator, into which the mendelium-244 isotope was implanted and its decay registered.

MENDELEVium-244 AND A PUZZLING SHORT-LIVED FISSION ACTIVITY

Gaining a better understanding of the limiting factors for the existence of stable, superheavy elements is a decade-old quest of chemistry and physics.

Superheavy elements, as are called the chemical elements with atomic numbers greater than 103, do not occur in nature and are produced artificially with particle accelerators. They vanish within seconds. A team of scientists from GSI, Johannes Gutenberg University Mainz (JGU), Helm-

holtz Institute Mainz (HIM) and the University of Jyväskylä, Finland, led by Dr. Jadambaa Khuyagbaatar from GSI and HIM, has provided new insights into the fission processes in those exotic nuclei and for this, has produced the hitherto unknown nucleus mendeleevium-244. The

experiments were part of "FAIR Phase 0", the first stage of the FAIR experimental program. The results have been published in the journal *Physical Review Letters*.

Heavy and superheavy nuclei are increasingly unstable against the fission

process, in which the nucleus splits into two lighter fragments. This is due to the ever-stronger Coulomb repulsion between the large number of positively charged protons in such nuclei, and is one of the main limitations for the existence of stable superheavy nuclei.

BETA-DELAYED FISSION PROCESS IS RELEVANT DECAY MODE

The nuclear fission process was discovered more than 80 years ago and is being studied intensely to this day. Most experimental data on the spontaneous fission are for nuclei with even numbers of protons and neutrons – called “even-even nuclei”. Even-even nuclei consist entirely of proton and neutron pairs and their fission properties are rather well describable by theoretical models. In nuclei with an odd number of either neutrons or protons, a hindrance of the fission process when compared to the properties of even-even nuclei has been observed and traced back to the influence of such a single, unpaired constituent in the nucleus.

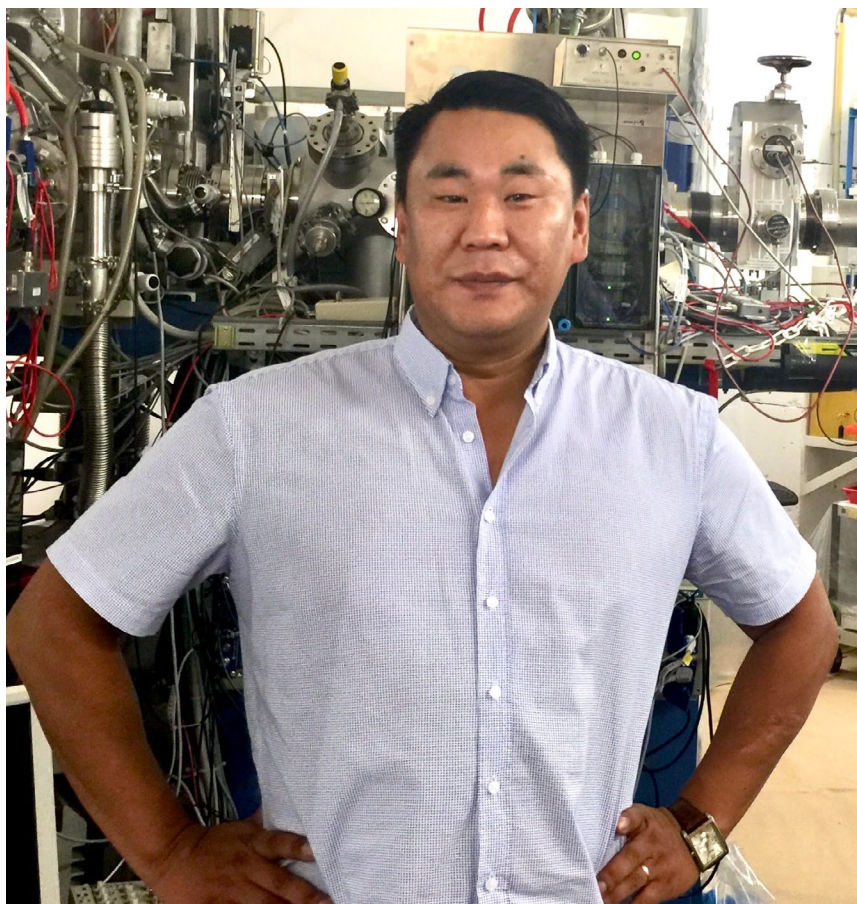
However, the fission hindrance in “odd-odd nuclei”, containing both, an odd number of protons and an odd number of neutrons, is less well known. Available experimental data indicate that the spontaneous fission process in such nuclei is greatly hindered, even more so than in nuclei with only one odd-numbered type of constituents.

Once the fission probability is most reduced, other radioactive decay modes like alpha decay or beta decay become probable. In beta decay, one proton transforms into a neutron (or vice versa) and, accordingly, odd-odd nuclei turn into even-even nuclei, which typically have a high fission probability. Accordingly, if a fission activity is observed in

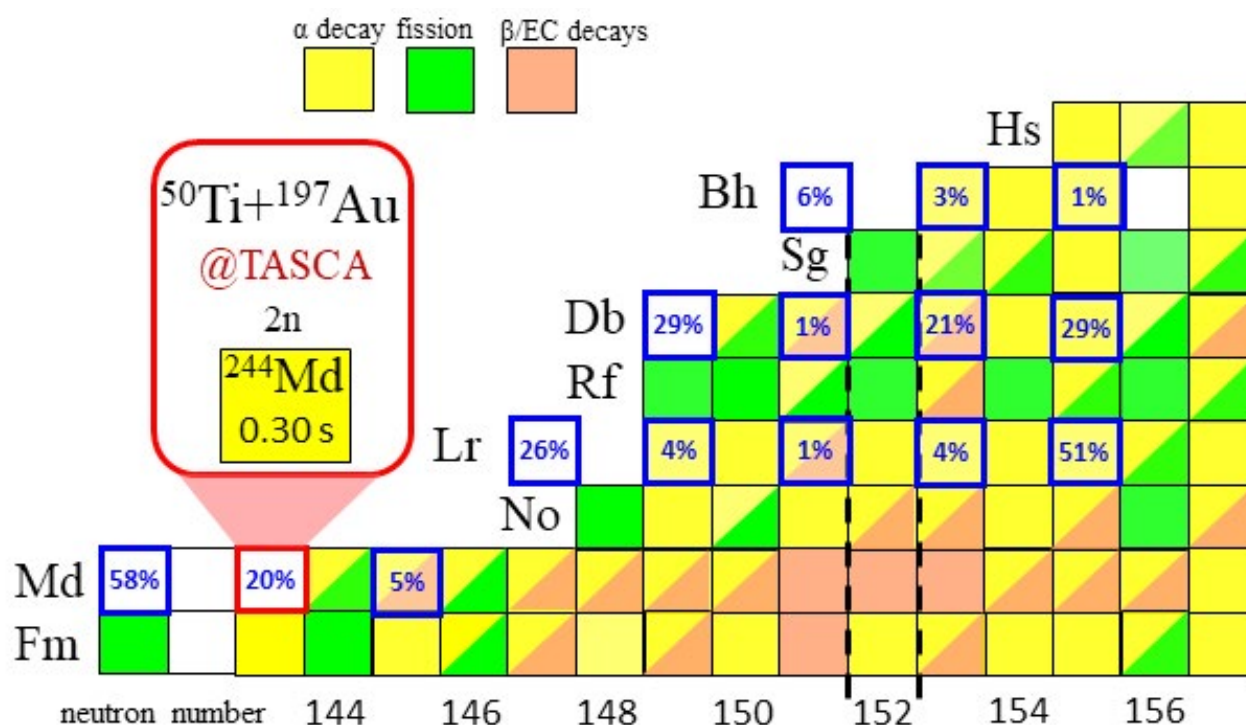
experiments on the production of an odd-odd nucleus, it is often difficult to identify whether fission occurred in the odd-odd nucleus, or not rather started from the even-even beta-decay daughter, which can then undergo beta-delayed fission. Recently, Dr. Jadambaa

Khuyagbaatar from GSI and HIM predicted that this beta-delayed fission process may be very relevant for the heaviest nuclei and, in fact, may be one of the main decay modes of beta-decaying superheavy nuclei.

In superheavy nuclei, which are exceedingly difficult to be produced experimentally, beta-decay has not yet been observed conclusively. For instance, in the case of the heaviest element produced at GSI, tennessine (element 117), only two atoms of the odd-odd nucleus tennessine-294 were observed in an experiment that lasted about one month. This small production rates limit the verification and detailed study of the beta-decay delayed fission process. Still, new experimental data to shed light on this process are best gained in exotic nuclei, like those which have an extremely unbalanced ratio of protons to neutrons. For this, the team from GSI, JGU, HIM and University of Jyväskylä has produced the hitherto unknown nucleus mendelevium-



The leader of the experiment, Dr. Jadambaa Khuyagbaatar, standing in the experimental hall X8 in front of the TASCA separator used in the mendelevium-244 experiment.



Cut out of the chart of nuclei in the region of the mendelevium nuclei. Each box represents an atomic nucleus, with the numbers of protons increasing in the vertical direction and the numbers of neutrons in the horizontal direction. Known nuclei are shown by colored boxes, where the color indicates the nuclear decay mode: alpha decay (yellow), beta decay (pink), spontaneous fission (green). Thick-framed boxes indicate odd-odd nuclei, in which beta-delayed fission has been predicted to occur with less than one percent probability among all beta decays.

vium-244, an odd-odd nucleus consisting of 101 protons and 143 neutrons.

The theoretical estimate suggests that beta decay of this nucleus will be followed by fission in about one out of five cases. Due to the large energy release of the fission process, this can be detected with high sensitivity, whereas beta decays are more difficult to measure. The researchers used an intense beam of titanium-50 available at GSI's UNILAC accelerator to irradiate a gold target. The reaction products of titanium and gold nuclei were separated in the Transactinide Separator and Chemistry Apparatus TASCA, which guided mendelevium nuclei into a silicon detector suitable to register the implantation of the nuclei as well as their subsequent decay.

A first part of the studies, performed in 2018, led to the observation of seven

atoms of mendelevium-244. In 2020, the researchers used a lower titanium-50 beam energy, which is insufficient to lead to mendelevium-244 production. Indeed, signals like those assigned to mendelevium-244 in the 2018 study were absent in this part of the data set, corroborating the proper assignment of the 2018 data and confirming the discovery of the new isotope.

All of the seven registered atomic nuclei underwent alpha decay, i.e., the emission of a helium-4 nucleus, which led to the daughter isotope einsteinium-240, discovered four years ago by a preceding experiment carried out at the University of Jyväskylä. Beta decay was not observed, which allows establishing an upper limit on this decay mode of 14 percent. If the 20 percent fission probability of all beta-decaying nuclei were correct, the total probability for beta

delayed fission would be at most 2.8 percent and its observation would necessitate the production of substantially more mendelevium-244 atoms than in this discovery experiment.

In addition to the alpha-decaying mendelevium-244, the researchers found signals of short-lived fission events with unexpected characteristics concerning their number, production probability, and half-life. Their origin cannot currently be pinpointed exactly, and is in fact not readily explicable with current knowledge of the production and decay of isotopes in the region of mendelevium-244. This motivates follow-up studies to get more detailed data, which will help shed further light on the fission process in odd-odd nuclei. ■



The authors of the publication about the new method for the verification of treatment plans — from left: Gianmarco Camazzola (GET_INInvolved participant and former Summer Student), Dr. Martina Fuss (supervisor from GSI's Biophysics department), Dea Aulia Kartini (GET_INInvolved participant).

Verification of treatment plans in tumor therapy

GET_INInvolved student and Summer Student take part in publication

In the tumor therapy with ion beams developed by GSI as well as in other radiation therapies, so-called treatment plans are prepared prior to the treatment of individuals. Their validity is checked on models to guarantee a correct and safe procedure. The investigation of a new test option has now been published in the scientific journal *Physics in Medicine and Biology*. What's special about this: Dea Aulia Kartini and Gianmarco Camazzola, GET_INInvolved participant and summer student at GSI and FAIR, are among the authors of the publication.

Treatment plans for radiotherapy are calculated with special software. So-called phantoms are used to verify the plans. They can consist simply of water or be prepared cell cultures which are irradiated under the same conditions under which the therapy is to be performed on humans. Subsequently, it is checked how many of the cells have survived at which location in the cultures. This allows to assess whether the treatment plan has been optimized in the best possible way. In research, they are especially relevant to test new treatment planning strategies or

optimizations before they are applied in the clinical environment. Until now, phantoms from monolayered cell cultures have been used for this purpose. The new technique makes it possible to irradiate three-dimensional cell volumes.

"Instead of allowing the cells to grow flat, we place them into three-dimensional containers. For this we use multiwell plates, a standard accessory from laboratory supplies, with 96 wells — these are the small indentations that are on the plates," explains Dea Aulia Kartini, who is in charge of the experiment. "They are first filled with a layer of a substance called Matrigel, then with an added cell and Matrigel mixture, and then sealed again with another layer of Matrigel. In this way we make sure that there really is a volume of cells inside". Kartini, who originally comes from Indonesia and is studying in Thailand, is currently writing her PhD thesis and this is her third visit to GSI and FAIR in the framework of the GET_INInvolved Programme. The program promotes international exchange for students and researchers and supports their education and career.

"Our experiments show that the new phantoms work flawlessly and could improve the verification of treatment plans in the future", Kartini adds. Further experiments with 3D phantoms are planned in the near future both at GSI and in cooperation with the Marburger Ionenstrahl-Therapiezentrum MIT.

The publication also features the name of Gianmarco Camazzola, who came to GSI and FAIR in 2019 as part of the Summer Student Program, where he spent eight weeks gaining insight into the research of the Biophysics department. The Summer Student Program is aimed at international students before graduation and allows them to get a taste of the research at GSI and FAIR independently from the universities. During his stay, he mainly worked on software modeling for the experiments at the 3D phantoms. Currently he has also returned to the GSI/FAIR campus within the GET_INInvolved Programme. The publication clearly shows the success and the importance of the student and scientific exchange programs, which give the participants an early insight and entry into the research community. ■



Dea Aulia Kartini

comes from Indonesia, studies physics in Thailand and is working on her PhD. She's in Germany for the third time in the framework of the GET_INvolved Programme of FAIR and GSI and conducts research in the Biophysics department of GSI, working on the radiobiological verification of treatment plans.

How did you both come to GSI and FAIR?

Dea Aulia Kartini: After her visit to GSI and FAIR in 2017, Her Royal Highness Princess Maha Chakri Sirindhorn of Thailand initiated the construction of a facility for proton therapy in Bangkok. In this context, my current professor was looking for a student and then suggested a stay here in Germany. I didn't know GSI before, but now I am here for the third time.

Gianmarco Camazzola: During the preparation of the bachelor's thesis at the University of Trento, by reading some papers, I realized the primary role played by the GSI in the medical physics field. Afterwards, during the master's period at Heidelberg University, a former summer student told me about the International Summer Student Program. So I applied and was able to participate in 2019. It was a really great experience. That's why I applied for GET_INvolved and for a PhD position here and I hope to start next year if everything works out.

What exactly is your research about?

DAK: I'm trying to improve the verification of treatment plans for ion beam tumor therapy. To verify biological endpoints, so-called phantoms are used. These are cell cultures that are "treated", i.e. irradiated, in the same way as one would do it with a person. Afterwards, one looks at the cell survival in order to assess the correctness of the plan. Of course, this is just as relevant for research applications, for example for the creation of software for treatment planning. The phantoms used so far use single cell layers for this, which are also called monolayers. I am researching a method with three-dimensional phantoms. This could improve the accuracy and allow the assessment of the cell survival in depth and lateral distribution. I have prepared the corresponding experiments and carried them out with the help of the research team. We subsequently wrote a publication on the subject. Gianmarco is also a co-author.

GC: Some parts of my task overlapped with Dea's research, but I was working

more on the software side: calculations and data analysis. The particle type and energy, the oxygen enhancement ratio or the relative biological effectiveness — all this must be included in the treatment planning system TRiP98, which is in use here. And following the experiment you have to verify whether the data obtained matches the prediction. I compared Dea's dosimetry results with the data produced by TRiP98 predictions. That was partly my job as a summer student, but fortunately I was also allowed to get a taste of laboratory work and look over Dea's shoulder back then.

Is this the first time that a GET_INvolved or a summer student is on a scientific publication?

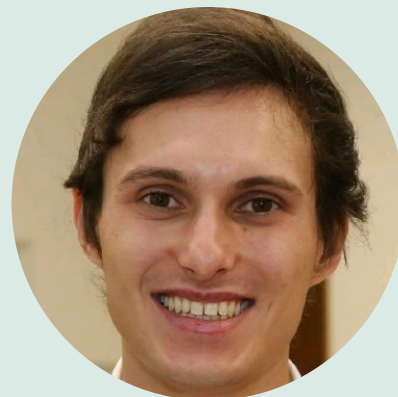
DAK: As far as I know, it is the first time in relation to GET_INvolved.

GC: With the Summer Student Program, I can't say for sure. But I think that at least it hasn't happened very often yet.

To what extent was and is the Corona pandemic a problem for your work?

Gianmarco Camazzola

has left his home country Italy to pursue his master's degree in physics in Heidelberg. During the Summer Student Program 2019 he was a guest at GSI and FAIR for eight weeks and worked in the Biophysics department. He has now returned via GET_INvolved and plans to also work here for his PhD thesis.



DAK: For me it was a very big problem. I wanted to come in March, I had applied for a visa, but then all borders were closed because of Corona. So I was waiting for a call from the embassy. In July they finally said that I was allowed to come. Within a week I packed everything up and was in Germany very quickly. Everyone here was surprised that I could come in such a short time. And now, as an Indonesian foreigner, it's complicated to go back to Thailand, although I actually live there. They have strict rules to enter which are not easy to fulfill. It's all quite difficult right now.

GC: It wasn't too difficult for me because I was already in Heidelberg anyway. However, I had to return to Italy from March to August. So I couldn't work in the lab, I could only work on the computer from home. But that went quite well.

How do you actually like it in Germany?

DAK: For me it's like a third home next to Indonesia and Thailand. I like being

here very much. The work and the team are great, life is good and I like meeting new people. Only the bureaucracy is a bit exhausting, there are so many rules and laws in the EU. In our country the stores are always open, even on Sundays and public holidays — in contrast to Germany, where there are fixed opening hours and on some days nothing is open at all.

GC: This is my third year here and I really enjoy it. I had to adapt to the food a bit. You always have to say if you don't want any sauce! Fortunately, I'm already used to the bureaucracy, it's no different in Italy.

And when you're not working? What do you do in your free time?

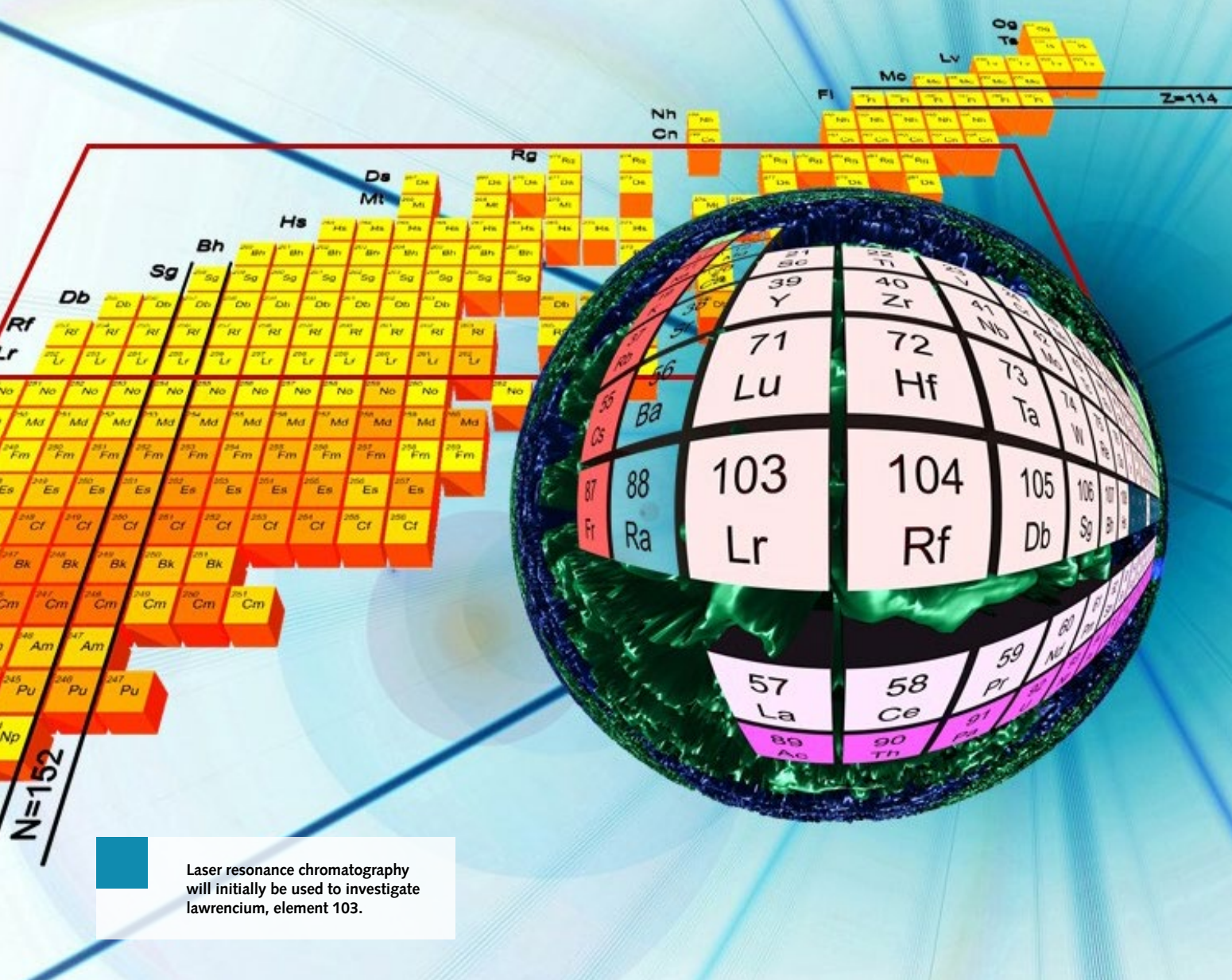
DAK: I like cooking and baking, listening to music or watching Korean series.

GC: In my free time I want to have as little stress as possible. I relax, read or watch videos. And preparing something to eat with my flatmates is also great fun.

What are the plans for your work in the near future?

DAK: I have to write my PhD thesis now. And a second publication is also planned, I need it for my scholarship. I'm about halfway done, the rest is being done now. The experiments are also continuing, cell irradiations are planned again soon. We will use other cell types that are more sensitive to the radiation

GC: I will soon continue work on another topic. The goal is to further extend the TRAX-CHEM software which has been developed at GSI to simulate the physical and chemical stages of radiation effects in matter. The planned extension will study the interaction of the final radicals produced with the biological environment, like proteins, lipids, enzymes and so on. At the moment I'm reading a lot about this. I hope to implement it in my PhD thesis. ■



nance Chromatography (LRC) should enable such investigations even at minute production quantities. The proposal has recently been published in two articles in *Physical Review Letters* and *Physical Review A*.

Superheavy elements (SHEs) are found at the bottom part of the periodic table of elements. They represent a fertile ground for the development of understanding on how such exotic atoms can exist and work when an overwhelming number of electrons in atomic shells and protons and neutrons in the nucleus come together. Insights into their electronic structure can be obtained from optical spectroscopy experiments unveiling element-specific emission spectra. These spectra are powerful benchmarks for modern atomic-model calculations and could be useful, for example, when it comes to searching for traces of even heavier elements, which might be created in neutron-star merger events.

Although SHEs have been discovered decades ago, their investigation by optical spectroscopy tools lack far behind the synthesis. This is because they are produced at extremely low rates at which traditional methods simply do

not work. So far, optical spectroscopy ends at nobelium, element 102 in the periodic table. "Current techniques are at the limit of what is feasible," explained Laatiaoui. From the next heavier element on, the physicochemical properties change abruptly and impede providing samples in suitable atomic states."

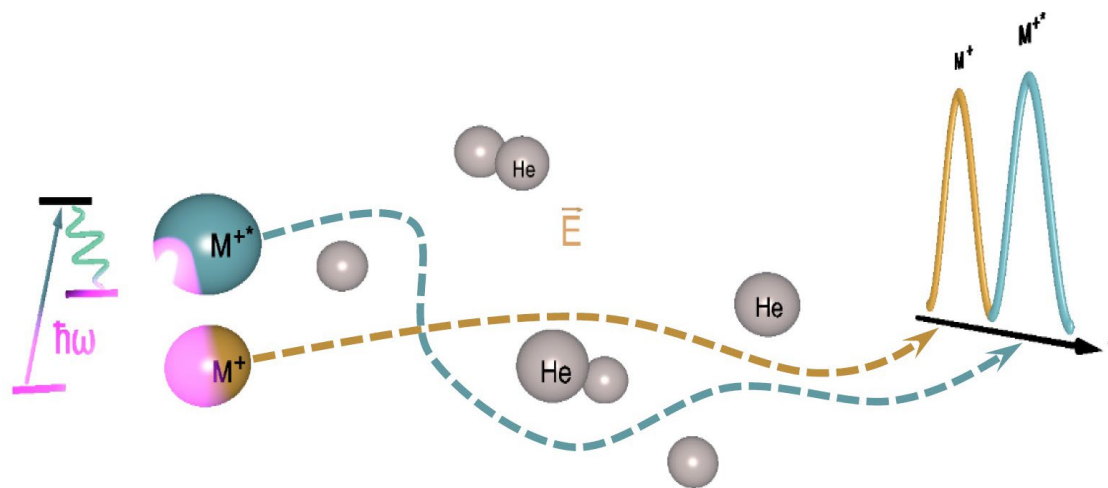
Together with research colleagues, the physicist has therefore developed the new LRC approach in optical spectroscopy. This combines element selectivity and spectral precision of laser spectroscopy with ion-mobility mass spectrometry and merges the benefits of a high sensitivity with the "simplicity" of optical probing as in laser-induced fluorescence spectroscopy. Its key idea is to detect the products of resonant optical excitations not on the basis of fluorescent light as usual, but based on their characteristic drift time to a particle detector.

In their theoretical work, the researchers focused on singly charged lawrencium, element 103, and on its lighter chemical homolog. But the concept offers unparalleled access to laser spectroscopy of many other monoatomic ions across the periodic table, in particular of the

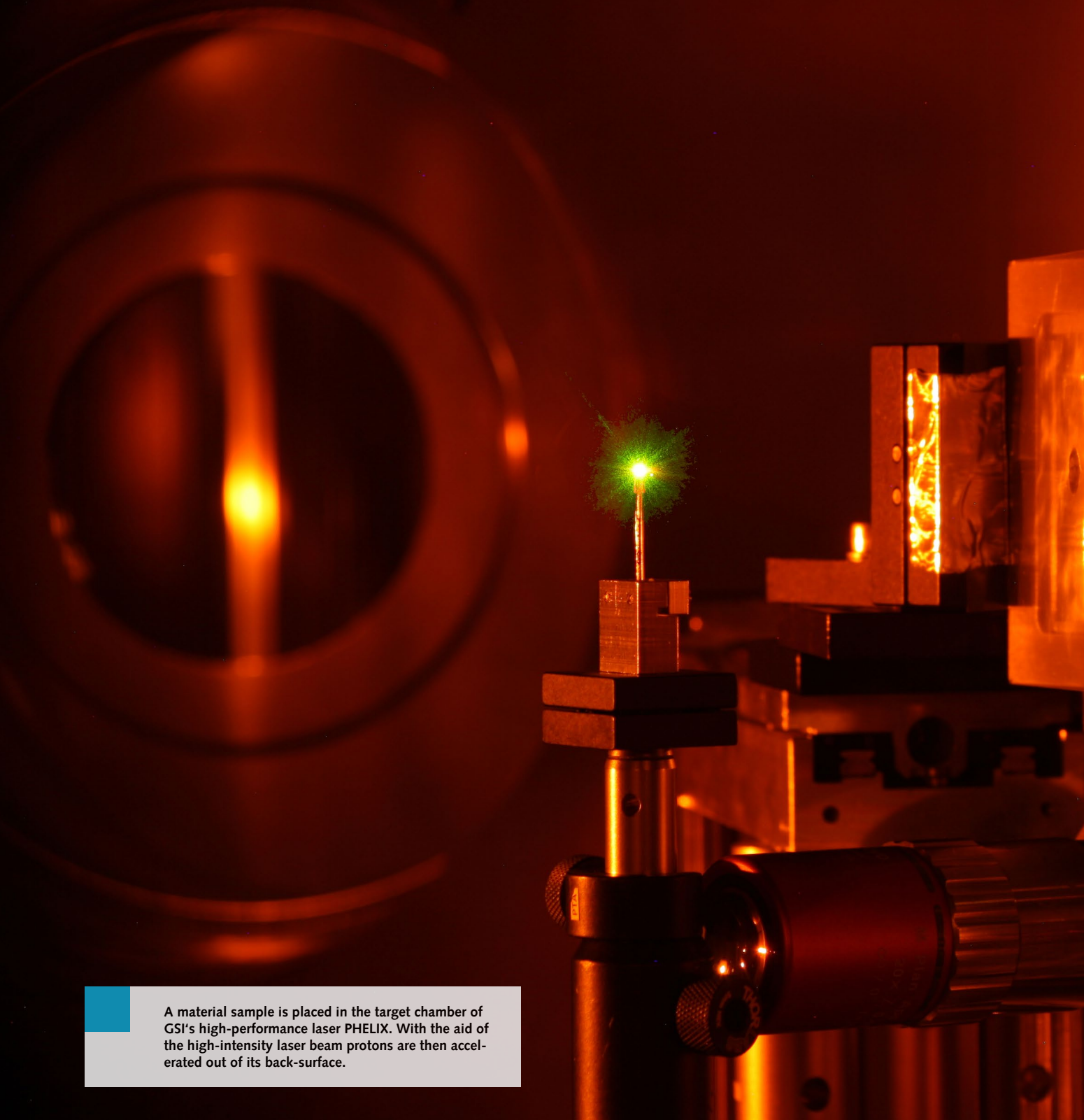
transition metals including the high-temperature refractory metals and elements beyond lawrencium. Other ionic species like triply charged thorium shall be within reach of the LRC approach as well. Moreover, the method enables to optimize signal-to-noise ratios and thus to ease ion mobility spectrometry, state-selected ion chemistry, and other applications.

Dr. Mustapha Laatiaoui came to JGU and HIM in February 2018. In late 2018, he received an ERC Consolidator Grant from the European Research Council (ERC), one of the European Union's most valuable funding grants, for his research into the heaviest elements using laser spectroscopy and ion mobility spectrometry. The current publications also included work that Laatiaoui had previously carried out at GSI in Darmstadt and at KU Leuven in Belgium.

This work was conducted in cooperation with Alexei A. Buchachenko from the Skolkovo Institute of Science and Technology and the Institute of Problems of Chemical Physics, both in Moscow, Russia, and Larry A. Viehland from Chatham University, Pittsburgh, USA. ■



Laser resonance chromatography is based on optical excitations of ions and subsequent detection of their arrival at the detector.



A material sample is placed in the target chamber of GSI's high-performance laser PHELIX. With the aid of the high-intensity laser beam protons are then accelerated out of its back-surface.

Understanding astrophysics with laser-accelerated protons

Bringing huge amounts of protons up to speed in the shortest distance in fractions of a second — that's what laser acceleration technology, greatly improved in recent years, can do.

An international research team from GSI and the Helmholtz Institute Jena, a branch of GSI, in collaboration with the Lawrence Livermore National Laboratory, USA, has succeeded in using protons accelerated with the GSI high-power laser PHELIX to split other nuclei and to analyze them. The results have now been published in the journal *Scientific Reports of Nature Research* and could provide new insights into astrophysical processes.

For less than one picosecond (one trillionth of a second), the PHELIX laser shines its extremely intense light pulse onto a very thin gold foil. This is enough to eject about one trillion hydrogen nuclei (protons), which are only slightly attached to the gold, from the back-surface of the foil, and accelerate them to high energies. "Such a large number of protons in such a short period of time cannot be achieved with standard acceleration techniques," explains Pascal Boller, who is researching laser acceleration in the GSI research department Plasma Physics/PHELIX as part of his graduate studies. "With this technology, completely new research areas can be opened that were previously inaccessible".

Spatial separation of production and measurement

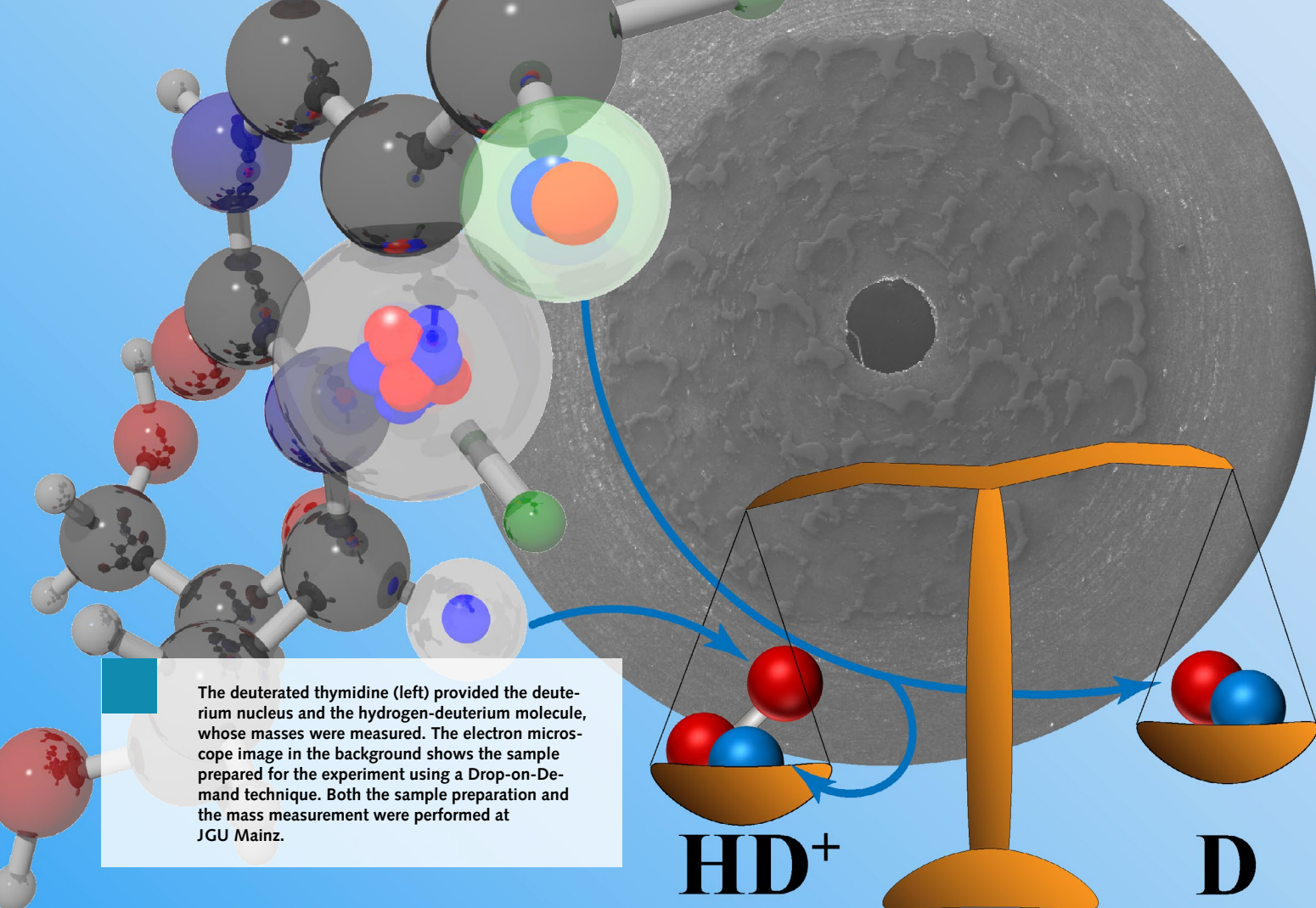
These include the generation of nuclear fission reactions. For this purpose, the researchers let the freshly generated fast protons impinge on uranium material samples. Uranium was chosen as a case study material because of its large reaction cross-section and the availability of published data for benchmarking purposes. The samples have to be close to the proton production to guarantee a maximum yield of reactions. The protons generated by the PHELIX laser are fast enough to induce the fission of uranium nuclei into smaller fission products, which remain then to be identified and measured. However, the laser impact has unwanted side effects: It gen-

erates a strong electromagnetic pulse and a gamma-ray flash that interfere with the sensitive measuring instruments used for this detection.

At this stage, the researchers are assisted by the expertise of another GSI research group. For the chemical investigation of superheavy elements, a transport system has been in use for quite some time that can transport the desired particles over long distances from the reaction area to the detector. The reaction chamber is flushed through by a gas which — in the case of fission experiments — carries the fission products with it and, within only a few seconds, transports them via small plastic tubes to the measuring apparatus, which is now several meters away. In this way, production and measurement can be spatially separated and interference can be prevented.

For the first time, it was possible in the experiments to combine the two techniques and thus to generate a variety of cesium, xenon and iodine isotopes via the fission of uranium, to reliably identify them via their emitted gamma radiation and to observe their short life time. This provides a methodology for studying fission reactions in high-density plasma-state matter. Comparable conditions can be found, for example, in space inside stars, stellar explosions or neutron star mergers. "Understanding the reaction processes of nuclei interacting with each other in plasma can give us insights into the origin of atomic nuclei, the so-called nucleosynthesis, in our universe. Nucleosynthesis processes such as s-process or r-process take place in exactly such media," explains Boller. "The role fission reactions play in these processes has not yet been researched in detail. Here, the laser-accelerated protons can provide new information".

Further measurements with the methods are planned for future experiments of the PHELIX laser at GSI as well as at other research centers around the world. The investigation of highly dense matter with ion and laser beams will also be one of the topics pursued at the future research facility FAIR. FAIR is currently being built at GSI in international cooperation. With its motto "The Universe in the Laboratory", it is intended to reproduce conditions as they occur in astrophysical environments on Earth, thus expanding the knowledge about our cosmos. ■



Deuteron mass corrected

High-precision measurements of the mass of the deuteron, the nucleus of heavy hydrogen, provide new insights into the reliability of fundamental quantities in atomic and nuclear physics.

This is reported in the journal *Nature* by a collaboration led by the Max Planck Institute for Nuclear Physics Heidelberg, and partners from the Johannes Gutenberg University Mainz, GSI and the Helmholtz Institute Mainz, Germany. Thus, data directly related to the atomic mass standard, are now available for hydrogen H, deuterium D and the molecule HD, which the scientists have also reweighed.

The masses of both atomic nuclei and electrons influence numerous properties of atoms and molecules, for example their spectra, i.e., which light colours they absorb or emit. Physicists like values of these masses to be as accurate as possible, because only with their knowledge precise calculations using atomic physics are possible for these spectra. Calculations are then confronted to direct measurements,

which, for example, allows drawing conclusions about the reliability of basic physical theories.

Hydrogen and its isotopes are of particular interest in this context, because their simple electron shell with only a single electron allows extremely precise calculations and thus very sensitive tests of fundamental physical theories. Furthermore, the mass of the deuteron

can also be used to derive the mass of the neutron — the second component of atomic nuclei besides the proton. After having already precisely weighed the electron and the proton, the nucleus of the ordinary hydrogen atom, in recent years, researchers around Klaus Blaum and Sven Sturm from the MPI for Nuclear Physics have now also put the deuteron, the nucleus of heavy hydrogen consisting of a proton and a neutron, and the HD^+ molecular ion on the “precision scale”. Since deuterium is rare and is usually easily replaced by the much more common normal hydrogen, Christoph Düllmann’s research group in Mainz produced a tailor-made deuterium sample that fits the used apparatus perfectly.

TRAP is located in a superconducting magnet in nearly perfect vacuum at a temperature of about 4 degrees above absolute zero (minus 269 °C). We prepared a deuteron (D^+) and a carbon ion ($^{12}\text{C}^{6+}$) in the apparatus, alternately transferred one of them from its storage trap to the precision trap located between the storage traps and measured its movement with highest precision,” says Sascha Rau, who carried out the measurements in the context of his PhD, explaining the measuring principle. “The ratio of the frequencies of both ions obtained in this way directly gives the mass of the deuteron in atomic units.” So, the carbon ion acts as a reference weight on the “beam balance”.

in excellent agreement with our directly measured value. In addition, the mass ratio of deuteron to proton derived from our data fits very well with the value directly measured by another group,” says Sven Sturm with satisfaction. This consistency of the data underpins the used measurement methodology and suggests that the reference values should be corrected. In addition, the new data considerably reduces the discrepancies that previously existed among the masses of light nuclei. However, in order to fully resolve these discrepancies, further high-precision mass measurements – directly in atomic units — of super-heavy hydrogen (tritium) and of light helium are required. ■

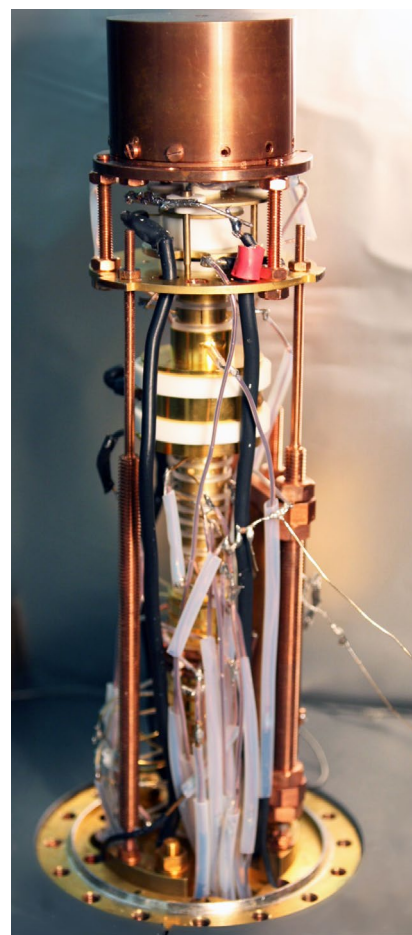
Sophisticated measurement technology for maximum precision

Penning traps have proven to be the best precision scales for ions. In such a trap, single charged particles can be trapped for a long time with the help of electric and magnetic fields. The trapped particle performs a characteristic motion in the trap, which is described by a frequency. This frequency depends on the mass of the trapped particle — heavier particles oscillate more slowly than lighter ones. If two different, individual ions are measured one after the other in the same trap, the ratio of the masses can be determined exactly — similar to a classical mechanical beam balance.

The mass standard for atoms is the carbon isotope ^{12}C , which by definition weighs twelve atomic mass units. “Our Penning trap apparatus called LION-

When evaluating the measurement data, the physicists had to consider very carefully the influence of many unavoidable systematic effects. As a result, they obtained the mass of the deuteron as 2.013553212535(17) atomic units, with the number in parentheses indicating the uncertainty of the last digits. The mass of the hydrogen molecular ion HD^+ , determined by the same method, is 3.021378241561(61) atomic units.

The new value for the mass of the deuteron is the most accurate ever measured, but is significantly smaller than the tabulated reference value. “To validate our result, we calculated the mass of HD^+ with this value and with the masses of the proton and the electron previously measured by us, as well as the known binding energy. The result is



LIONTRAP Penning-trap system

Hunt for excited nuclear state

Measurements in thorium-229 take a step towards the direct laser excitation of an atomic nucleus in this unique isotope.

Nuclear clocks could make our time measurement even more accurate than atomic clocks. The key to this lies in thorium-229, an atomic nucleus whose lowest excited state has very low energy. A research team from the Kirchhoff Institute for Physics at the University of Heidelberg, TU Wien, Johannes Guten-

berg University Mainz (JGU), the Helmholtz Institute Mainz (HIM), and GSI has now succeeded in measuring this low energy. Using an extremely accurate detector, it was possible to detect the tiny temperature increase due to the energy released during the de-excitation of the atomic nucleus. This brings the realization of a nuclear clock a big step closer.

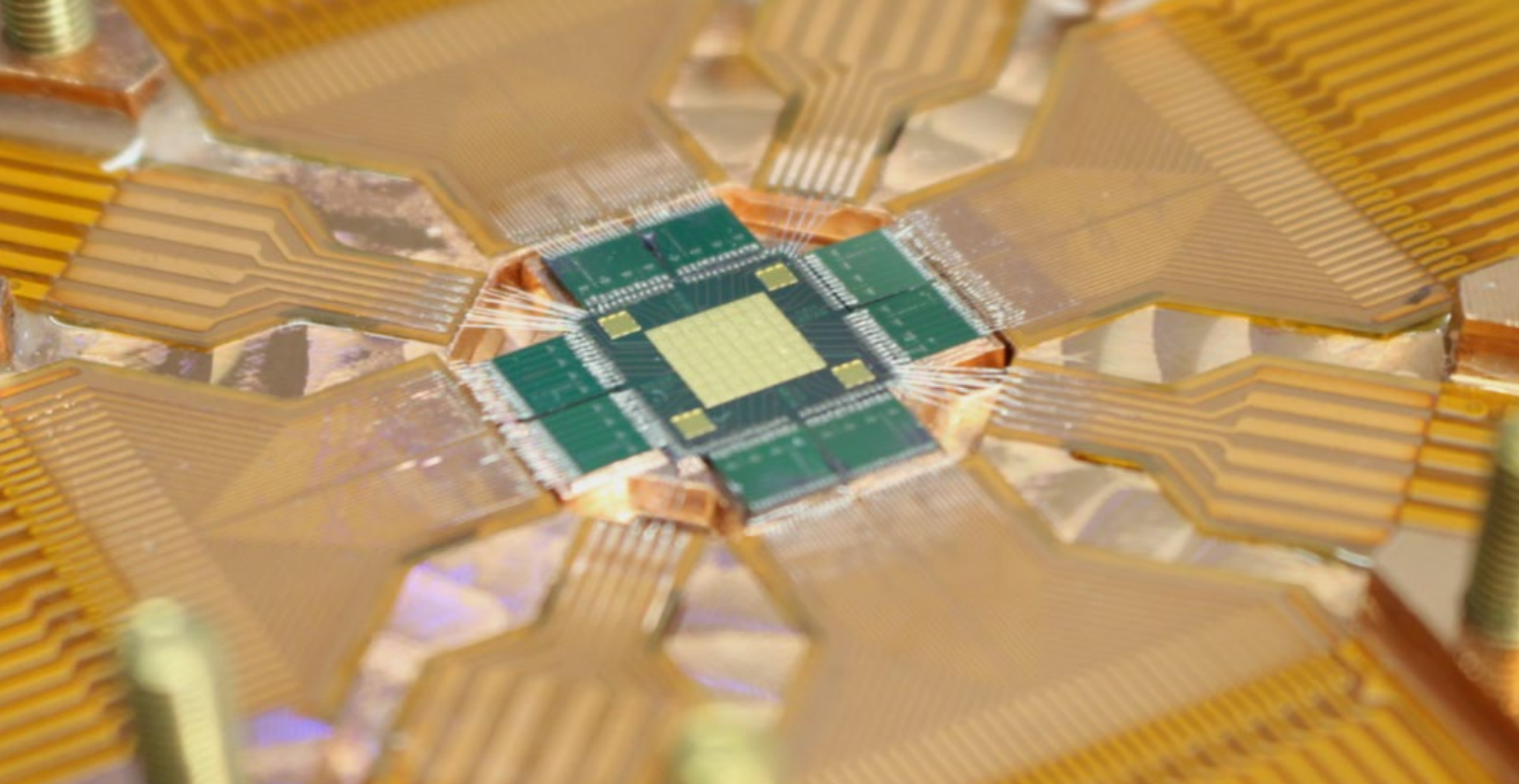
New perspectives for constructing an atomic clock

In radioactive decay, atomic nuclei spontaneously rearrange, eject some part of their building blocks, and transform into a nucleus of a different atom. In this process, the new “daughter

atom” usually has internally stored energy that is released in the form of gamma rays. The energies of these rays are characteristic for each type of nucleus — just like fingerprints. Researchers learn a lot about atomic nuclei by characterizing these gamma-ray fingerprints.

Back in 1976, L. A. Kroger and C. W. Reich investigated the decay of uranium-233, which is an artificial nucleus of uranium that decays to thorium-229 by emitting an alpha-particle; this is immediately followed by the emission of characteristic gamma-rays that occur in distinct and generally well-understood patterns. Kroger and Reich, however, registered an anomaly: one gamma-ray that was predicted by all nuclear theories was missing in the measured signals. The best explanation was that the internal energy stored in the lowest nuclear excitation of thorium-229 was too low

to be observed by the detectors. Over the following decades, many attempts were made to observe this low-energy gamma-ray without success, constraining it to ever-lower energies. Nowadays, we know that the lowest excited-energy state of the thorium-229 nucleus, called an isomer state, is located at the lowest known energy among all nuclei, at an energy that is orders of magnitudes lower than usual excitation energies. Consequently, the energy of the associated gamma-ray is so low that it is placed in the ultraviolet region of the electromagnetic spectrum rather than in the typical gamma-ray region. This leads to the unique situation that the opposite process of the de-excitation by the emission of this “ultraviolet gamma-ray”, namely the excitation of the lower state is possible by shining ultraviolet light onto the nucleus. It is the only nuclear system that could be excited with “table-top” laser light. This opens up exciting prospects, including the construction of a “nuclear” clock, in which time is measured by oscillations of the nucleus between these two states. The precision of such a clock is predicted to be better than that of the best current atomic clocks, which rely on



Microcalorimeter chip similar to the one used in the experiment. Each individual microcalorimeter (middle) measures 0.5 x 0.5 square millimeters.

oscillations between states in the electron shell, which is more susceptible to external perturbations than the 10,000 times smaller nucleus.

The key problem is, though, that the energy of the isomer state is not yet known with sufficient precision to know which ultraviolet light is needed to stimulate the oscillation. A consortium of researchers from Heidelberg, Vienna, Mainz, and Darmstadt have now repeated the iconic gamma spectroscopy measurement of Kroger and Reich, but using a highly advanced state-of-the-art gamma spectrometer, designed explicitly for registering rays of such low energy.

for Physics at the University of Heidelberg developed a magnetic microcalorimeter named maXs30. This detector is cooled to minus 273 degrees Celsius and measures the minuscule temperature rise that occurs when a gamma-ray is absorbed. The temperature increase leads to a change in the detector's magnetic properties, which is then converted into an electric signal using SQUID magnetometers similar to those that are commonly used in magnetic resonance tomography. The maXs30 detector has unprecedented energy resolution and gain linearity; still, it took about twelve weeks of continuous measurement to obtain the gamma-ray spectrum with sufficient precision.

duced a special sample of uranium-233. First, they chemically removed all decay daughter products that had built up over time before the sample was used. They also removed unwanted radioisotopes, the decay of which leads to an unwanted background in the measured data. Then they designed a source geometry and sample container that led to minimum interference of the weak signals on their way from the sample to the maXs30 calorimeters. These steps were required for the success of the measurement because only one in 10,000 decay processes produces a signal that is useful for the determination of the isomer energy. The measurement produced the most precise gamma-ray spectrum of uranium-233 to thorium-229 decay to date. The team of Professor Thorsten Schumm at TU Wien, together with the Heidelberg team, employed four different schemes to derive the energy of the isomer state from this data. The most precise one yielded a value of 8.10(17) electronvolts, which corresponds to light of a wavelength of 153.1(32) nanometers, with the number in parentheses indicating the uncertainty of the last digits. This measurement paves the way for a direct laser excitation of the thorium-229 isomer. ■

Cool studies give the highest precision

For this, the research team of Professor Christian Enss and Dr. Andreas Fleischmann at the Kirchhoff Institute

To make this challenging measurement possible, the team of Professor Christoph Düllmann in Mainz and Darmstadt pro-

CERN experiment ALICE — High-precision studies of the strong force

It is the entry in a new chapter in hadron physics: In a paper published today in the journal *Nature*, the ALICE collaboration at the European Research Center CERN describes a technique that opens a door to many new high-precision studies at the Large Hadron Collider (LHC) of the dynamics of the strong force between hadrons. From the beginning, GSI has played a leading role in the construction and scientific program of ALICE, one of the largest experiments at CERN.

With the publication “Unveiling the strong interaction among hadrons at the LHC” the ALICE collaboration presents interesting new findings about hadrons and their interactions. Hadrons are composite particles made of two or three quarks bound together by the strong interaction, which is mediated by gluons. This interaction also acts between hadrons, binding nucleons (protons and neutrons) together inside atomic nuclei. One of the biggest challenges in nuclear physics today is understanding the strong interaction between hadrons with different quark content from first principles, that is, starting from the strong interaction between the hadrons’ constituent quarks and gluons.

A new chapter in hadron physics

Calculations known as lattice quantum chromodynamics (QCD) can be used to determine the interaction from first principles, but these calculations provide reliable predictions only for hadrons containing heavy quarks, such as hyperons, which have one or more strange quarks. In the past, these interactions were studied by colliding hadrons together in scattering experiments, but these experiments are difficult to perform with unstable (i.e. rapidly decaying) hadrons such as hyperons. This difficulty has so far prevented a meaningful comparison between measurements and theory for hadron-hadron interactions involving hyperons.

Enter the new study from the collaboration behind ALICE, one of the main experiments at the LHC. The study shows

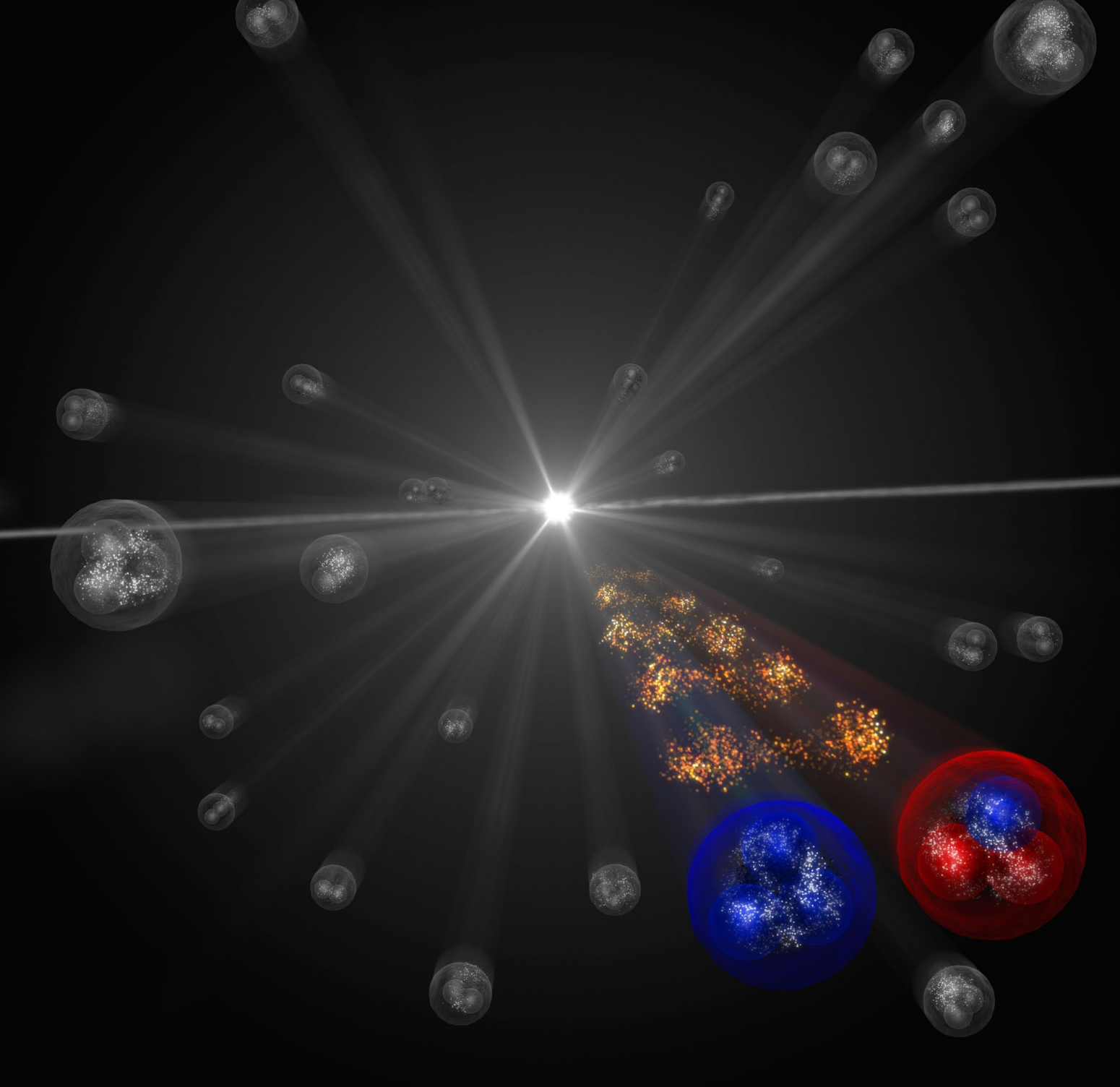
how a technique based on measuring the momentum difference between hadrons produced in proton-proton collisions at the LHC can be used to reveal the dynamics of the strong interaction between hyperons and nucleons, potentially for any pair of hadrons. The technique is called femtoscopy because it allows the investigation of spatial scales close to one-femtometer (10⁻¹⁵ meters) — about the size of a hadron and the spatial range of the strong-force action.

This method has previously allowed the ALICE team to study interactions involving the Lambda (Λ) and Sigma (Σ) hyperons, which contain one strange quark plus two light quarks, as well as the Xi (Ξ) hyperon, which is composed of two strange quarks plus one light quark. In the new study, the team used the technique to uncover with high precision the interaction between a proton and the rarest of the hyperons, the Omega (Ω) hyperon, which contains three strange quarks.

“The precise determination of the strong interaction for all types of hyperons was unexpected,” says ALICE physicist Laura Fabbiotti, professor at the Technical University of Munich. “This can be explained by three factors: the fact that the LHC can produce hadrons with strange quarks in abundance, the ability of the femtoscopy technique to probe the short-range nature of the strong interaction, and the excellent capabilities of the ALICE detector to identify particles and measure their momenta.”

The nuclear physicist Professor Peter Braun-Munzinger, Scientific Director of the ExtreMe Matter Institute EMMI at GSI and longstanding chair of the collaboration board of ALICE, is significantly involved in the current investigations. He also emphasizes the importance of the now published research: “Our findings open the door to a new chapter in hadron physics, and with the factor 100 increase in statistics for the coming Run3 and Run4 at the LHC many new investigations will be possible.”

The relationship between GSI and ALICE is traditionally very close: GSI’s research department ALICE shares responsibility for the operation of ALICE’s two largest detector systems. The Time Projection Chamber (TPC) and the Transition Radiation Detector (TRD) were designed and built with significant con-



Artist's impression of the ALICE study of the interaction between the rarest of the hyperons, Omega (Ω) hyperon (left), which contains three strange quarks, and a proton (right).

tribution of GSI's ALICE department and Detector Laboratory. Currently, GSI gives an essential contribution to the ALICE upgrade program, specifically in the TPC project and in the development of the new Online-Offline (O2) software framework. To do this, GSI's ALICE department, Detector Laboratory and IT department work closely together. GSI scientists have several leading roles in data analysis and in the physics program of ALICE. GSI scientist and professor at Heidelberg University,

Silvia Masciocchi currently chairs the ALICE Collaboration Board. "Our new measurement allows for a comparison with predictions from lattice QCD calculations and provides a solid testbed for further theoretical work," says ALICE spokesperson Dr. Luciano Musa. "Data from the next LHC runs should give us access to any hadron pair". He concludes: "ALICE has opened a new avenue for nuclear physics at the LHC — one that involves all types of quarks". ■

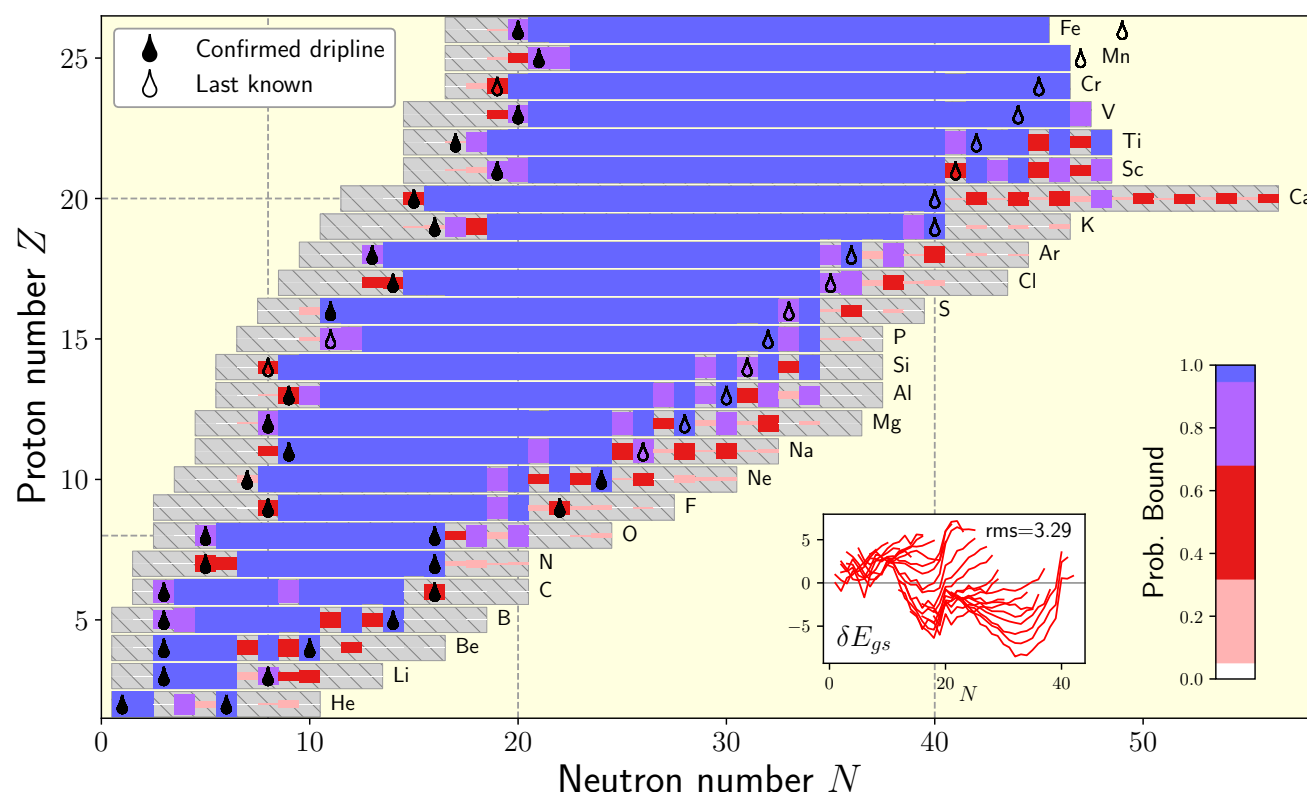
Limits of atomic nuclei predicted

Novel calculations have enabled the study of nearly 700 isotopes between helium and iron, showing which nuclei can exist and which cannot. In an article published in *Physical Review Letters*, scientists from TU Darmstadt, the University

of Washington, the Canadian laboratory TRIUMF, and the University of Mainz report how they simulated a large region of the chart of nuclides for the first time using innovative theoretical methods based on the theory of the strong interaction.

The ExtreMe Matter Institute EMMI of GSI and TU Darmstadt is also involved in the research efforts.

Atomic nuclei are held together by the strong interaction between neutrons



Global ab initio calculations from helium to iron (element He and Fe). The gray area shows all 700 calculated atomic nuclei, while the color (and height) for each isotope with neutron number N and proton number Z corresponds to the probability that it is bound (probability bound). For comparison, the experimentally known neutron and proton driplines and the most recently discovered isotope are shown with filled and empty drop-symbols, respectively.

and protons. About ten percent of all known nuclei are stable. Starting from these stable isotopes, nuclei become increasingly unstable as neutrons are added or removed, until neutrons can no longer bind to the nucleus and “drip” out. This limit of existence, the so-called neutron “dripline”, has so far been discovered experimentally only for light elements up to neon. Understanding the neutron dripline and the structure of neutron-rich nuclei also plays a key role in the research program for the future accelerator facility FAIR at GSI

ing from microscopic two- and three-body interactions, they solved the many-particle Schrödinger equation to simulate the properties of atomic nuclei from helium to iron. They accomplished this by using a new ab initio many-body method — the In-Medium Similarity Renormalization Group — combined with an extension that can handle partially filled orbitals to reliably determine all nuclei.

Starting from two- and three-nucleon interactions based on the strong inter-

determining the location of the neutron and proton driplines. Comparisons with experimental mass measurements and a statistical analysis enabled the determination of theoretical uncertainties for their predictions, such as for the separation energies of nuclei and thus also for the probability that an isotope is bound or does not exist (see figure).

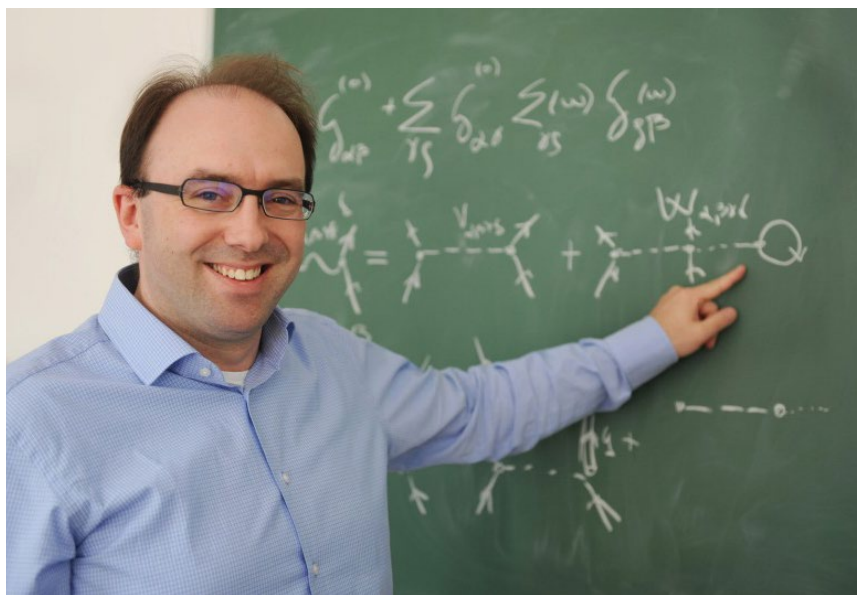
The new study is considered a milestone in understanding how the chart of nuclides and the structure of nuclei emerges from the strong interaction. This is a key question of the DFG-funded Collaborative Research Center 1245 “Nuclei: From Fundamental Interactions to Structure and Stars” at the TU Darmstadt, within which this research was conducted. Next, the scientists want to extend their calculations to heavier elements in order to advance the input for the simulation of the synthesis of heavy elements. This proceeds in neutron-rich environments in the direction of the neutron dripline and occurs in nature when neutron stars merge or in extreme supernovae. ■

Treasure trove of information about possible new isotopes

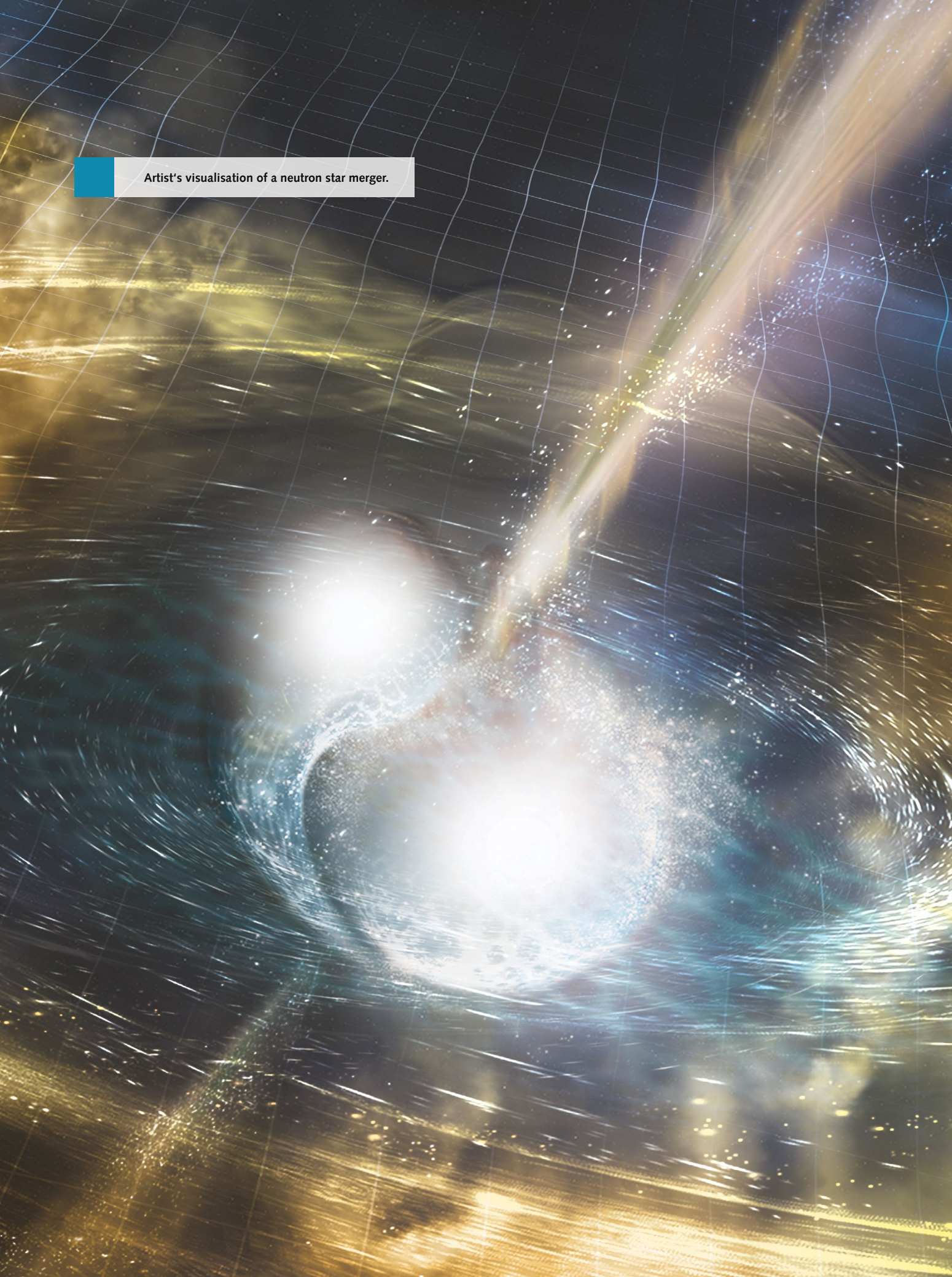
In a new study, “Ab Initio Limits of Nuclei,” published in the journal *Physical Review Letters* as an Editors’ Suggestion with an accompanying synopsis in *APS Physics*, EMMI Professor Achim Schwenk of TU Darmstadt and a Max Planck Fellow at the MPI for Nuclear Physics in Heidelberg, together with scientists from the University of Washington, TRIUMF and the University of Mainz, succeeded in calculating the limits of atomic nuclei using innovative theoretical methods up to medium-mass nuclei. The results are a treasure trove of information about possible new isotopes and provide a roadmap for nuclear physicists to verify them.

The new study is not the first attempt to theoretically explore the extremely neutron-rich region of the nuclear landscape. Previous studies used density functional theory to predict bound isotopes between helium and the heavy elements. Professor Schwenk and colleagues, on the other hand, explored the chart of nuclides for the first time based on ab initio nuclear theory. Start-

ing from microscopic two- and three-body interactions, the researchers calculated the ground-state energies of nearly 700 isotopes. The results are consistent with previous measurements and serve as the basis for



EMMI Professor Achim Schwenk of TU Darmstadt, together with scientists from the University of Washington, TRIUMF and the University of Mainz, succeeded in calculating the boundaries of atomic nuclei up to intermediate-weight nuclei using theoretical methods.

An artist's visualization of a neutron star merger. Two bright, glowing spheres of blue and white light are shown in the process of colliding. The impact creates a massive, turbulent cloud of blue and white gas and dust, with bright yellow and orange light emanating from the center. The background is a dark, deep blue space filled with a grid of thin, glowing blue lines, suggesting a warped gravitational field or spacetime curvature. The overall scene is dynamic and energetic, capturing the moment of cosmic collision.

Artist's visualisation of a neutron star merger.

Black hole — yes or no?

New computer simulations promise insights into the outcome of neutron star collisions.

A new study lead by GSI scientists and international colleagues investigates black-hole formation in neutron star mergers. Computer simulations show that the properties of dense nuclear matter play a crucial role, which directly links the astrophysical merger event to heavy-ion collision experiments at GSI and FAIR. These properties will be studied more precisely at the future FAIR facility. The results have now been published in *Physical Review Letters*. With the award of the 2020 Nobel Prize in Physics for the theoretical description of black holes and for the discovery of a supermassive object at the center of our galaxy the topic currently also receives a lot of attention.

But under which conditions does a black hole actually form? This is the central question of a study lead by GSI within

an international collaboration. Using computer simulations, the scientists focus on a particular process to form black holes, namely the merging of two neutron stars.

Mass is the critical parameter

Neutron stars consist of highly compressed dense matter. The mass of one and a half solar masses is squeezed to the size of just a few kilometers. This corresponds to similar or even higher densities than in the interior of atomic nuclei. If two neutron stars merge, the

matter is additionally compressed during the collision. This brings the merger remnant on the brink to collapse to a black hole. Black holes are the most compact objects in the universe, even light cannot escape, so these objects cannot be observed directly.

“The critical parameter is the total mass of the neutron stars. If it exceeds a certain threshold the collapse to a black hole is inevitable,” summarizes Dr. Andreas Bauswein from the GSI Theory department. However, the exact threshold mass depends on the properties of highly dense nuclear matter. In detail these properties of high-density matter are still not completely understood, which is why research labs like GSI collide atomic nuclei — like a neutron star merger but on a much smaller scale. In fact, the heavy-ion collisions lead to very similar

conditions as mergers of neutron stars. Based on theoretical developments and physical heavy-ion experiments, it is possible to compute certain models of neutron star matter, so-called equations of state.

Employing numerous of these equations of state, the new study calculated the threshold mass for black-hole formation. If neutron star matter or nuclear matter, respectively, is easily compressible — if the equation of state is „soft“ — already the merger of a relatively light neutron stars leads to the formation of a black hole. If nuclear matter is „stiffer“ and less compressible, the remnant is stabilized against the so-called gravitational collapse and a massive rotating neutron star remnant forms from the collision. Hence, the threshold mass for collapse itself informs about properties of high-density matter. The new study revealed furthermore that the threshold to collapse may even clarify whether during

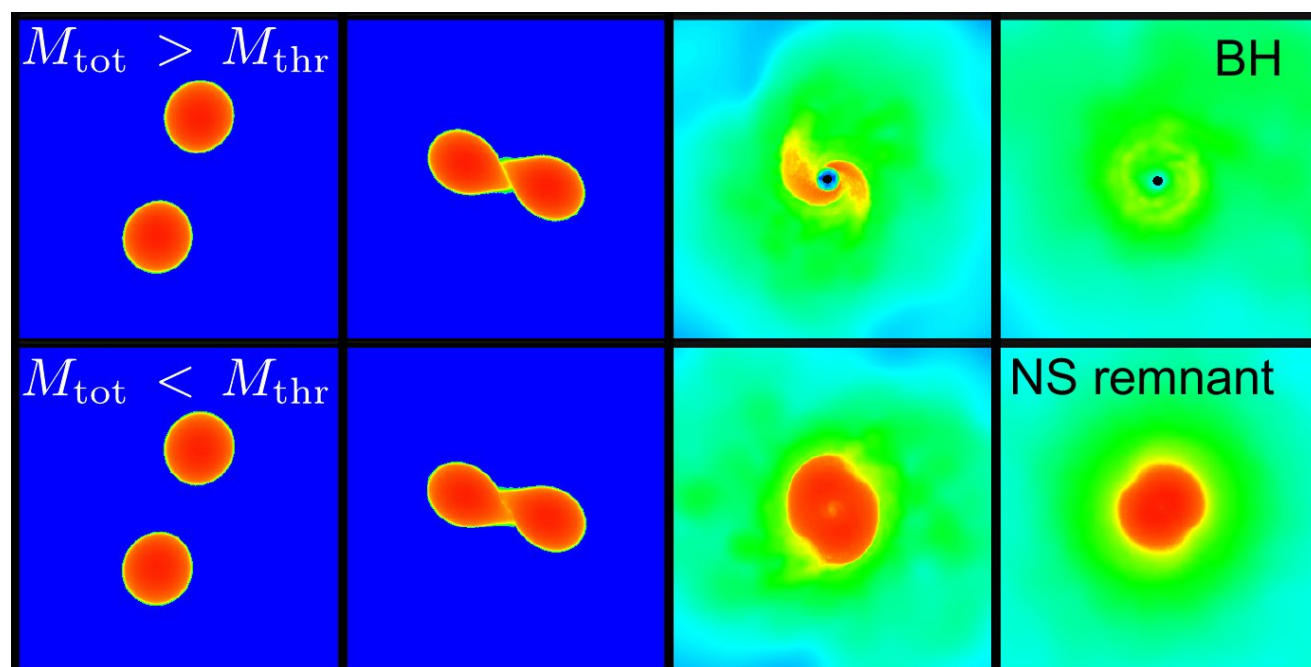
the collision nucleon dissolve into their constituents, the quarks.

Course set for the future

“We are very excited about these results because we expect that future observations can reveal the threshold mass,” adds Professor Nikolaos Stergioulas of the department of physics of the Aristotle University Thessaloniki in Greece. Just a few years ago a neutron star merger was observed for the first time by measuring gravitational waves from the collision. Telescopes also found the “electromagnetic counterpart” and detected light from the merger event. If a black hole is directly formed during the collision, the optical emission

of the merger is pretty dim. Thus, the observational data indicates if a black hole was created. At the same time the gravitational-wave signal carries information about the total mass of the system. The more massive the stars the stronger is the gravitational-wave signal, which thus allows determining the threshold mass.

While gravitational-wave detectors and telescopes wait for the next neutron star mergers, the course is being set in Darmstadt for knowledge that is even more detailed. The new accelerator facility FAIR, currently under construction at GSI, will create conditions, which are even more similar to those in neutron star mergers. Finally, only the combination of astronomical observations, computer simulations and heavy-ion experiments can settle the questions about the fundamental building blocks of matter and their properties, and, by this, they will also clarify how the collapse to a black hole occurs. ■



The upper and lower series of pictures each show a simulation of a neutron star merger. In the scenario shown in the upper panels the star collapses after the merger and forms a black hole (BH), whereas the scenario displayed in the lower row leads to an at least temporarily stable star (NS remnant).

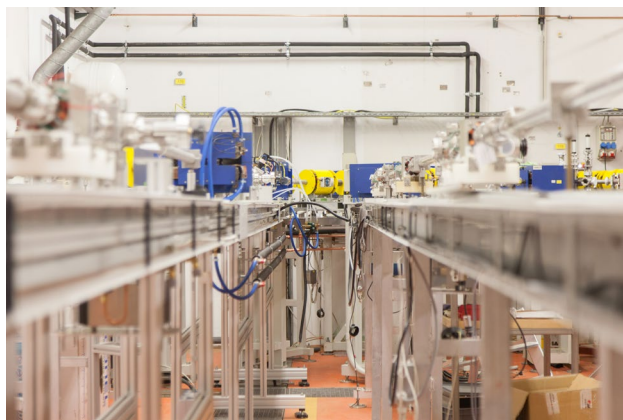
Cluster project ELEMENTS

The Hessian state government is supporting cutting-edge research in Hesse with almost 40 million euros over a period of four years in the funding line "Cluster Projects" launched by the state from April 2021. One of the funded projects is ELEMENTS. The project combines the strong research forces of several international leading institutions and is being funded with 7.9 million euros until 2025. Besides Goethe University Frankfurt and TU Darmstadt, which are equally leading the project, the University of Gießen and GSI are also involved. This collaboration will allow the researchers to combine their outstanding expertise in gravitational physics and in the physics of nuclear reactions, as well as to make synergistic use of the accelerator facilities in Darmstadt — the FAIR facility at GSI and the TU's electron accelerator S-DALINAC at the Institute of Nuclear Physics.

The cluster project ELEMENTS (Exploring the Universe from microscopic to macroscopic scales) will study neutron stars, the barely visible little brothers of black holes. They are formed after a star has burned out when it was not massive enough to be compressed into a black hole by its own gravitational pressure after its end. Neutron star mergers are visible in the sky as extremely light-intense processes, kilonovae, where the heaviest chemical elements are produced through nuclear reactions under extreme conditions. The ELEMENTS project investigates the dynamics in the fusion of two neutron stars and in this context also examines the gravitational field, nuclear matter and — the main topic of the physicists

at GSI/FAIR and the TU Darmstadt — the heavy chemical elements that are created in the process.

"I am delighted with this decision of the State of Hesse," said the Scientific Managing Director of GSI and FAIR, Professor Paolo Giubellino. "In the State of Hesse we understand how to bring together the right people and the right topics. We provide research structures at international top level. That enables us to achieve a leading standing in important future research fields. The current research program at GSI and FAIR offers excellent opportunities, and in the coming years the FAIR accelerator center will open up further innovative potential." ■



View along the beamline of the electron accelerator S-DALINAC.

IMPRINT

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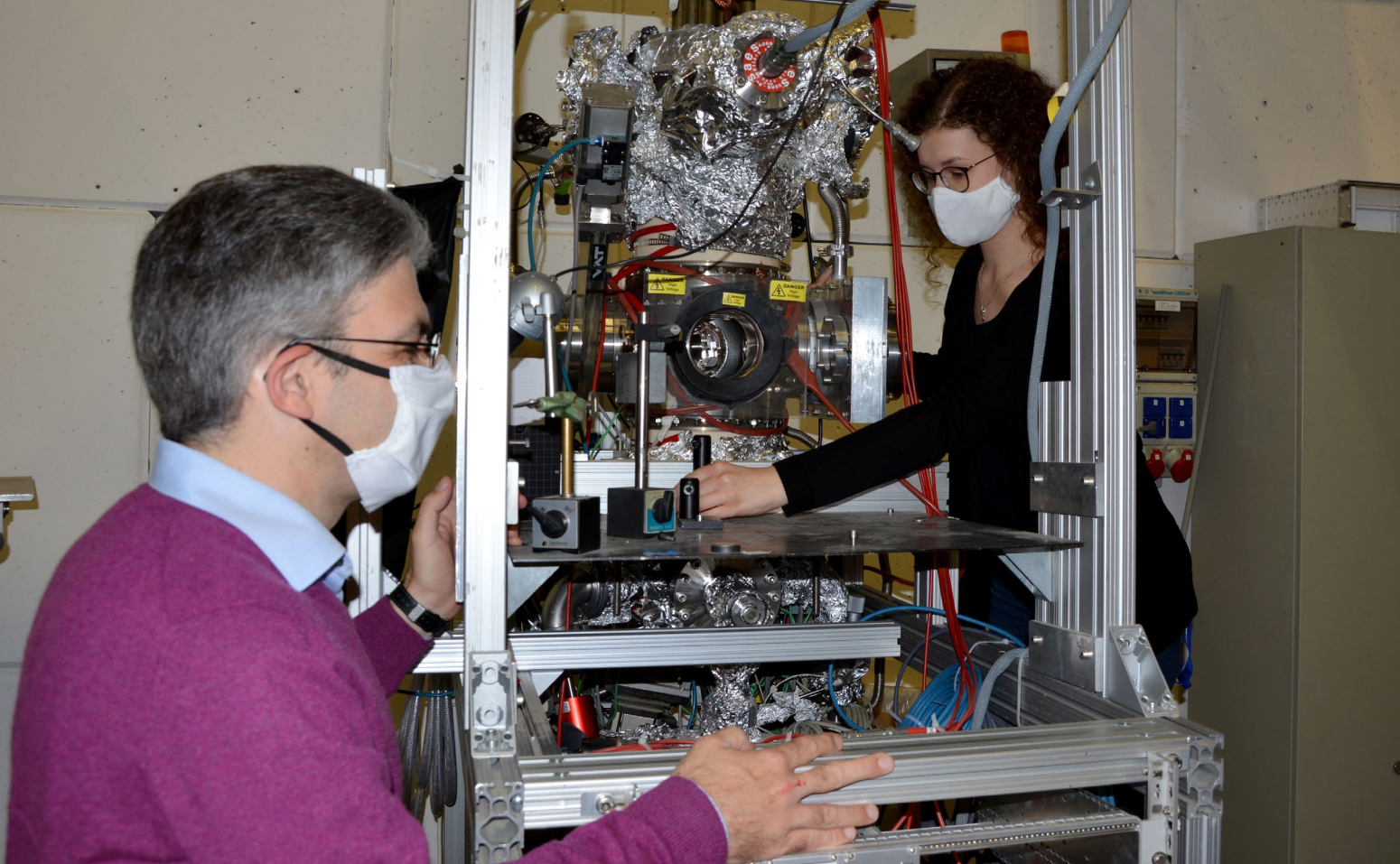
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GSI operates a unique accelerator facility. Researchers from around the world use it for experiments on the building blocks of matter and the evolution of the universe. Currently the accelerator facility FAIR is being built in international cooperation.

FAIR UND GSI IN SOCIAL MEDIA





Doctoral student Jessica Warbinek (right) together with her supervisor, Professor Michael Block working on the optimization of a vacuum chamber, which she will subsequently use for her work during the upcoming experimental phase at GSI.

EU-funded PhD network for research on radioactive elements

Nuclear and atomic physicists and nuclear chemists of Mainz University and GSI are closely involved in the EU Innovative Training Network on Laser Ionization and Spectroscopy of Actinide Elements.

In the context of an international network funded by the European Union, scientists at Johannes Gutenberg University Mainz (JGU) and GSI are participating in the education of young postgraduate students in the fields of nuclear and atomic physics and nuclear chemistry. The goal of this Innovative Training Network (ITN) on Laser Ionization and Spectroscopy of Actinide Elements (LISA) is to decipher the

structure of actinides, i.e. the heavy, mostly short-lived elements at the bottom of the periodic table, and thus put in place the prerequisite for their future use in biomedical physics, in nuclear applications, and for environmental monitoring. Members of the consortium are some of the world's leading experts in fundamental atomic and nuclear physics and nuclear chemistry. The EU is supporting the

LISA project for a period of four years with a total funding worth 4 million Euros.

LISA is coordinated by the CERN research center. As for Mainz University, Professor Christoph Düllmann and Professor Klaus Wendt are involved as is Professor Michael Block at GSI. "Of the 15 early-stage researchers being funded, six are expected to obtain their doctorates at JGU. We thus play a significant role within the new LISA network," said Professor Klaus Wendt. "Thanks to the highly effective collaboration between our nuclear chemistry and physics disciplines here at JGU with the Helmholtz Institute Mainz in the field of actinide research we are also expecting interesting and important results here." Wendt himself will supervise three doctoral students. This is the second time he has become involved in an EU training network.

International participation

In addition to the universities in Mainz, Hanover, Jena, Gothenburg in Sweden, and Leuven in Belgium, major research institutions such as CERN, GSI, the heavy ion accelerator Grand Accélérateur National d'Ions Lourds (GANIL) in France, and the accelerator facility in Jyväskylä in Finland are also participating in the ITN. There are also two commercial partners based in Kassel and Glasgow. Moreover, there are twelve other partner organizations from Canada all the way to Japan, who can contact the doctoral students for scientific exchange.

In the initial phase, Professor Christoph Düllmann's group at the JGU Department of Chemistry is to chemically purify exotic actinide isotopes that are available in sufficient quantities and are adequately stable. "We will develop techniques to then convert them to a form optimized for the intended experiments within the LISA network in Jyväskylä and at GANIL, also in Mainz and at GSI," explained Düllmann, head of the joint Superheavy Element Chemistry Group of JGU, GSI, and the Helmholtz Institute Mainz (HIM).

At GSI, Professor Michael Block's group will be employing laser spectroscopy to study the heaviest actinides. These can only be produced artificially and are generally very short-lived. With the help of lasers, the optical excitation of ener-

gy levels in the elements' atomic shells will be measured in detail in order to determine their atomic and nuclear properties. "The ITN is an optimal research environment for doctoral candidates to systematically and comprehensively study these exotic actinides," said Block. The first candidate has already started her work at GSI this summer.

Uranium and plutonium are probably the best known actinides, but curium, einsteinium, fermium, and mendelevium also belong to this group of radioactive elements. They all are usually extremely unstable and at present can only be produced synthetically in research reactors or particle accelerators. Due to their short-lived nature, they still provide science with major puzzles. Researching them should therefore improve our understanding of their atomic and nuclear properties. Building on this, the LISA network intends to develop new laser technologies to be able to create and investigate actinides for the development of innovative applications. LISA will promote the coherent and symbiotic collaboration between the participants, which is intended to continue after the end of the project.

Due to the ongoing coronavirus crisis, the doctoral students from abroad will not yet be able to begin their research in Germany. It is expected that one doctoral student from Poland and another doctoral student from Mexico, as well as candidates from Canada, UK, and the USA, will be supervised in Mainz. The team is currently planning an academic training session for all 15 doctoral students and other guests in Mainz in the fall of 2021. ■

Lanthanoide		Actinoide	
57	La	89	Ac
58	Ce	90	Th
59	Pr	91	Pa
60	Nd	92	U
61	Pm	93	Np

Actinides are radioactive metals with atomic numbers 89 to 103 in the periodic table.

Dual study

Top-level research at world class is only possible with powerful IT. With the Green IT Cube, GSI/FAIR has therefore built one of the most energy-efficient high-performance data centers worldwide. In order to attract qualified new personnel and at the same time to advance the development of modern IT, GSI offers a dual study program of computer science in cooperation with the University of Applied Sciences Darmstadt. The 22-year-old Jannika Fücksle is one of the students. Currently she is in the fifth semester.



Mrs. Fücksle, you are studying in a dual study program of computer science at the University of Applied Sciences Darmstadt in cooperation with GSI. What are you currently working on?

Since October 1, 2020, I am doing my so-called practical semester at GSI, which means I am working on a specific and exciting IT project. In total it is my fifth semester and I have already spent an internship semester at GSI before. Furthermore I will spend my last semester for my final thesis at GSI again.

And in the times when you are not in a practical semester, what do you do? How do we have to imagine a “dual study program”?

In the dual study program I alternately spend one semester either in the company or at the university. In the company, in my case GSI, I do specific practical IT development projects, at the university it is more about the theoretical basics. The study program takes seven semesters and I finish with a bachelor degree. Afterwards, there is

also the possibility to study for a master's degree.

So you are currently in your practical semester at GSI and you have a specific project ahead of you or already started? What is your task in this semester at GSI?

GSI is strongly involved in the ALICE experiment at CERN in Geneva, both scientifically and technically. There, the JAlEn software is used to operate the globally distributed ALICE computing infrastructure. With JAlEn, data is

transferred and computational jobs are efficiently distributed across the available computational capacities in the grid to enable simulation, reconstruction and analysis of the physics data of the ALICE experiment on a large scale. To put it simply, I'm testing whether the ALICE software JAliEn could also be used later at FAIR or whether it can be adapted to be used.

Who comes up with such a project? Is there someone who supports you at GSI?

Yes, of course! I am in the IT group Distributed Computing and my supervisor is Dr. Kilian Schwarz. He thinks about suitable projects in advance, which then have to be approved by the university. Above all, the university checks whether the project is appropriate for the study program.

Now we have learned something about your practical semester at GSI. What does a semester at the university look like?

As already mentioned, I get the theoretical basics there. There are predefined modules that I have to complete and there are elective courses. Topics are for example "computer architectures", "programming, algorithms & data structures", "software engineering" or "development of web-based applications", but there are also many more. And of course I have to write exams. For each passed exam you get points, so called "Credit Points". Only if I collected enough credit points I can proceed with the next semester.

What about the exchange with other students from your semester? You meet regularly at the university, but are you completely "alone" without contact to the other students during the practical semester?

During the semesters at the university, we meet regularly in the various lectures and tutorials. The last semester was completely online because of Corona. But there is also a regular exchange during the practical semesters, even though the students in the dual study program work in many different companies.

And how does the exchange between students take place during the practical semesters?

The practical part is also supervised from the university side. There is an accompanying professor who accompanies me and four other students at other companies. We usually meet three times during a practical semester, each time at a different location. There we exchange information about our projects and thus also get to know IT tasks in other companies. By the way, this is also very interesting for our supervisors in the companies, who therefore usually participate in the meetings. This also creates an exchange of know-how between the IT departments of the cooperating companies.

What influence does Corona have on the practical semesters?

At the moment, I work mainly from home. However, if I follow the obligatory hygiene measures, I could also come to GSI if necessary.

How do students actually choose the companies where they want to spend their practical semester?

There is a long list of cooperating companies for the dual IT degree program at Darmstadt University of Applied Sciences. If you are interested, you must first apply to one of these companies. And only if you have a confirmation from the company and a valid training contract, you can enroll at the university.

That means, you have a contract with GSI?

Yes, exactly. I am employed at GSI and I also receive a salary all year round, i.e. also during the university semesters. That is of course great, but it also means that I don't have semester breaks, like students of other courses. So I work at GSI during the semester breaks "as usual" and if I want to take a holiday, I have to apply for a vacation with my supervisor, just like all other employees here.

You said there is a long list of companies where you can get a dual degree in computer science. Why did you decide for GSI of all companies?

During my school time at the Heinrich-Emanuel-Merck School we once visited GSI on a guided tour. Afterwards I was totally enthusiastic about the research at GSI and the future project FAIR. We also visited the Green IT Cube and that's when I realized how important a powerful IT is for research. That actually never let me go. I also took advanced courses in IT and chemistry. That fits GSI quite well! So the enthusiasm has never left me until today. I really wanted to go to GSI and I am glad that it worked out!

We are also glad that you are with us and when young motivated people find their way to us. Soon your studies will be over. Do you already have plans for the future?

I really enjoy working here. I find the tasks in IT exciting and they are very divers, you always have to deal with the latest technology. And being part of this unique research facility, where people from all over the world come to do research, is of course an additional motivation. So I would like to do my master studies at GSI and I could very well imagine working here permanently later on. ■



Dr. Thomas Friedrich from GSI's Biophysics department is laureate of the Hermann Holthusen Award 2020. The science prize is awarded by the German Society for Radiooncology (DEGRO).



Professor Marco Durante, head of the GSI Biophysics research department, has been awarded the prestigious Failla Award 2020 by the Radiation Research Society (RRS).



For his research at the boundary of nuclear physics and astronomy, **Professor Friedrich-Karl Thielemann** receives the Karl Schwarzschild Medal. (Interview on page 24).



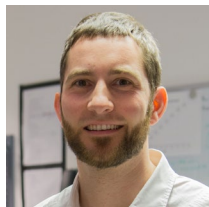
For his outstanding scientific achievements in the field of exotic nuclei the physicist **Professor Hans Geissel** received the Polish Alexander von Humboldt Award in Physics.



Dr. Uwe Niedermayer has received the Young Scientist Award for Accelerator Physics of the German Physical Society (DPG).



Professor Almudena Arcones has been elected "Fellow 2020" by the American Physical Society (APS).



The laser physicist **Dr. Jan Rothhardt** from the Helmholtz Institute Jena received the renowned Röntgen Prize of the Justus-Liebig-University Gießen.



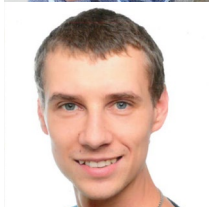
The PANDA PhD Prize 2020 was awarded to **Dr. Walter Ikegami Andersson** for his doctoral thesis at GSI, FAIR, and the University Uppsala.



Dr. Antoni Woss has been honoured with the PANDA Theory PhD Prize 2020 for his doctoral thesis at the University of Cambridge.



For their doctoral theses at GSI and FAIR, **Dr. Hanna Malygina** and **Dr. Ievgenii Kres** received the dissertation prize of the CBM collaboration for outstanding final theses in 2018 and 2019.



This year, the Christoph Schmelzer Award went to **Dr. Alina Benderer** from the German Cancer Research Center DKFZ Heidelberg and the engineer **Dr. Giorgia Meschini** from the biomedical department of the State Polytechnic University in Milan (Politecnico di Milano) in recognition of their dissertations.



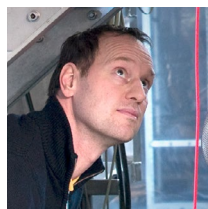
Dr. Ivan Miskun has been honored with the FAIR-GSI PhD Award 2020 donated by Pfeiffer Vacuum.



Dr. Bernhard Franzke receives the Horst Klein Award by the Frankfurt Physical Society, the Goethe University Frankfurt and the Working Group Accelerator Physics (AKBP) of the German Physical Society.



Professor Omar Azzaroni received the Georg Forster Research Award by the Alexander von Humboldt Foundation.



Dr. Danyal Winters was awarded a Fellowship of the Chinese Academy of Sciences.

