August 2020
Issue Nr. 18

FAIR GSI

target

50 years GSI

Many activities and events accompanied the year of our anniversary.

Special supplement: Corona

800 billion °C

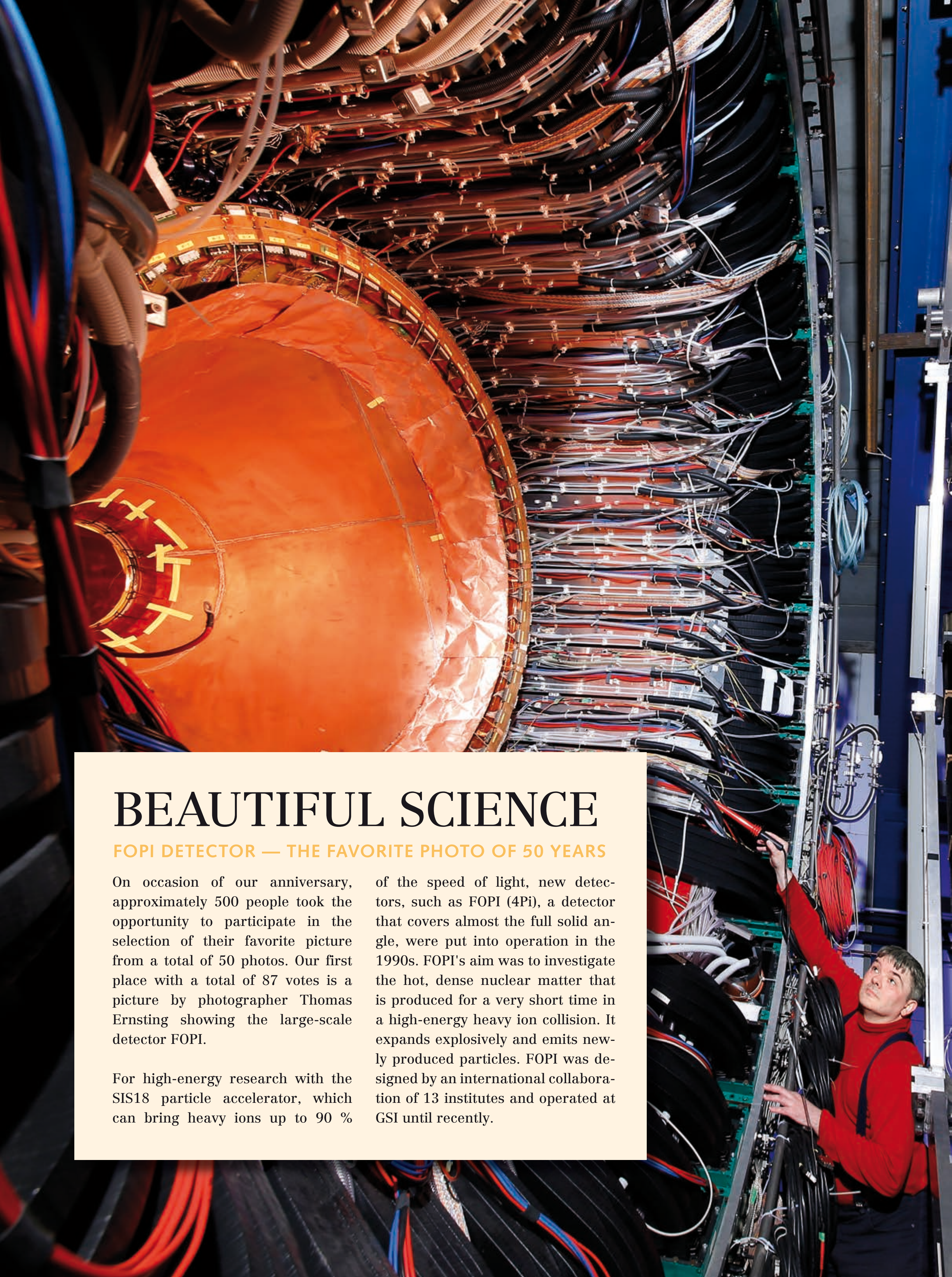
Conditions similar to neutron star mergers can be produced in particle collisions (page 36).

FAIR quadrupoles

First superconducting magnet module in new compact design delivered and in cold testing (page 12).

Historical gathering

Representatives of research institutions for superheavy elements met during conference (page 28).



BEAUTIFUL SCIENCE

FOPI DETECTOR — THE FAVORITE PHOTO OF 50 YEARS

On occasion of our anniversary, approximately 500 people took the opportunity to participate in the selection of their favorite picture from a total of 50 photos. Our first place with a total of 87 votes is a picture by photographer Thomas Ernsting showing the large-scale detector FOPI.

For high-energy research with the SIS18 particle accelerator, which can bring heavy ions up to 90 % of the speed of light, new detectors, such as FOPI (4Pi), a detector that covers almost the full solid angle, were put into operation in the 1990s. FOPI's aim was to investigate the hot, dense nuclear matter that is produced for a very short time in a high-energy heavy ion collision. It expands explosively and emits newly produced particles. FOPI was designed by an international collaboration of 13 institutes and operated at GSI until recently.

Dear readers,

We are living in very unusual times, in which the corona pandemic has impacted all areas of our lives. Of course, this is true also for our campus and our activities. Therefore, we thought it would be worth having a special supplement to this issue of the "target" magazine, dedicated to operations and research at GSI and FAIR during this time, and about our efforts to fight the pandemic. We regret we had to cancel for now the final festive event celebrating our 50th anniversary, but we are glad that we could still have many activities and events throughout last year and online. You will find more in this issue.

In addition to looking back on our history, we look to the future: to our experiments in FAIR Phase 0, to new FAIR components and to the awarding of ERC grants to our researchers. In this issue, we are particularly pleased to introduce our new Administrative Managing Director, Dr. Ulrich Breuer.

As you may have noticed, we have taken this opportunity to give our magazine a new style. In this new look, we will continue to keep you up to date about the progress achieved by our research programs and the construction of FAIR as well as current events on our campus.

I hope you enjoy reading!

Paolo Giubellino
Scientific Managing Director of FAIR and GSI
on behalf of the Management Board

50 years GSI – Five decades of cutting-edge research

The GSI Helmholtzzentrum für Schwerionenforschung is celebrating 50 years of existence — five decades of research history with outstanding scientific successes and discoveries. During this time, GSI has developed from a national research institute with worldwide collaborations into an international campus with global relevance. Now, it was the 50th anniversary of the founding day of GSI, 17 December 1969.

It was a historic day, that Wednesday 50 years ago, when Federal Science Minister Hans Leussink and Hessian Minister President Albert Osswald signed the decisive contract for the founding of GSI in Bonn. The federal government and the state of Hesse agreed to jointly build and operate a heavy ion accelerator in Darmstadt: the beginning of the Gesellschaft für Schwerionenforschung. GSI has been carrying out cutting-edge research for 50 years now, and the FAIR project is currently shaping the future. With the future accelerator center FAIR, the international dimensions of research will be significantly expanded once more. People from all over the world will be able to conduct world class research on the Darmstadt campus for decades and to explore the universe in the laboratory. Additionally, also the Helmholtz Institutes Mainz and Jena celebrated their ten year anniversary.

Many activities in the anniversary year therefore spanned from history to the future. For the anniversary day, there was the opportunity to travel back in time by photo slider on the GSI and FAIR homepage: an interactive past-today-show in which the images virtually overlap and thereby illustrate how things used to look like on campus in the past and how they look like today. The results provide exciting insights, for example into the linear accelerator,

In the selection of the favorite photos for the 50th anniversary this picture by Christian Grau made 2nd place. It was taken on occasion of the Open House in the year 2017 which was the largest event in the history of GSI and FAIR with approximately 11,000 visitors.

The main control room is the heart of the accelerator facility. The panorama shows the configuration from 1998.

the control room or the experimental halls (see also page 42).

Knowledge, passion and creativity

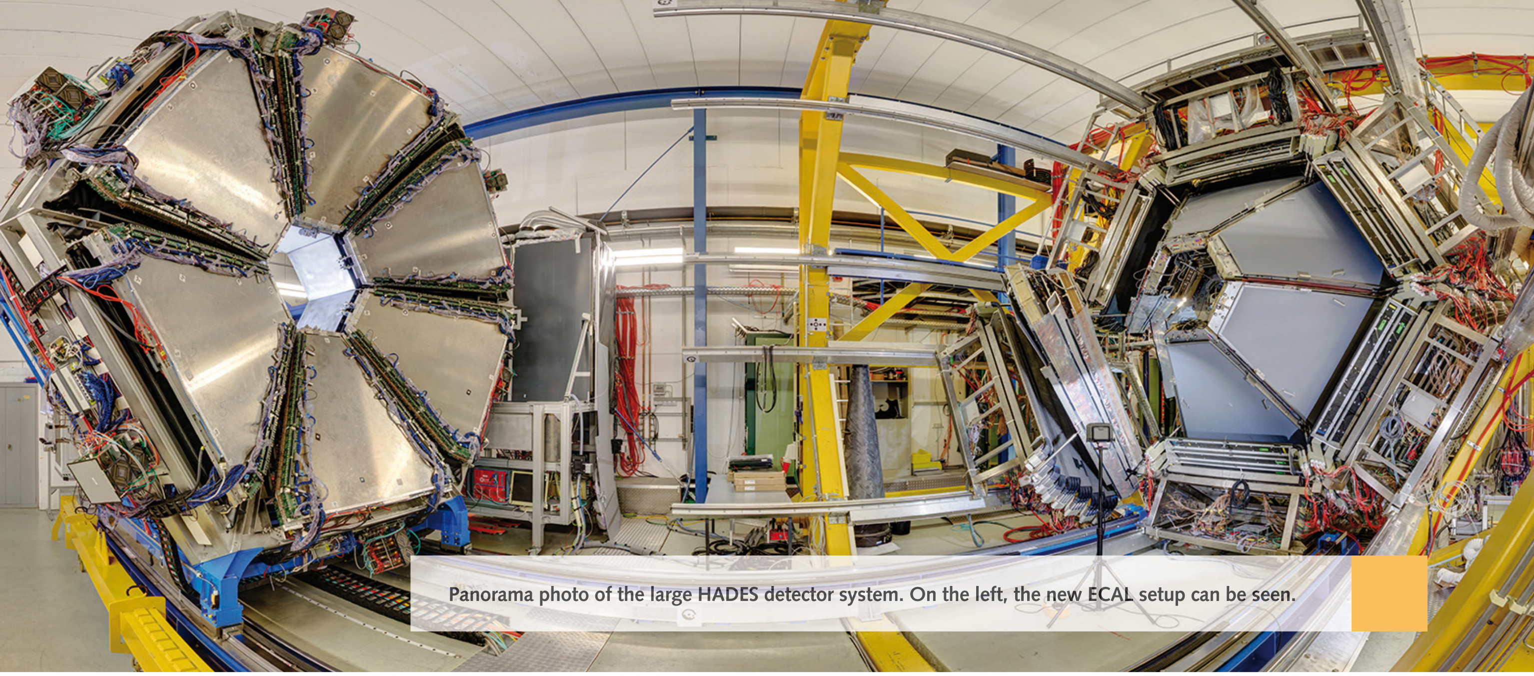
An even more detailed tour through half a century is offered by the digital GSI timeline where highlights of the GSI history are presented. Users can click their way through 50 years of GSI, and take a look into the future of FAIR. The great scientific achievements such as the discovery of six new chemical elements or the development of a new type of tumor therapy using ion beams can be found as well as the most important milestones for FAIR, from the international agreement for the worldwide unique project to the completion of the first shell constructions for the large FAIR ring accelerator.

The successes of GSI in these 50 years are based on the knowledge, passion and creativity of its staff members. Many of them have taken an active part in the anniversary year events, e.g. they chose their favorite photo in the campaign „50 years, 50 pictures“ or sent their very personal memories of their time at GSI as short stories. The most interesting anecdotes and the favorite photographic moments could be seen in a public exhibition on campus. ■

ACTIVITIES ON THE OCCASION OF THE 50TH ANNIVERSARY

- All activities: www.gsi.de/50years
- Timeline: www.gsi.de/en/zeitstrahl
- Photosilder In the past – Today: www.gsi.de/en/frueher-heute
- Favorite photo: www.gsi.de/en/lieblingsbild
- Memories: www.gsi.de/en/erinnerungen

Scan QR code to get to the overview website.



Panorama photo of the large HADES detector system. On the left, the new ECAL setup can be seen.

25 years HADES@GSI

In 1994, the international HADES collaboration, which today consists of more than 150 scientists from nine countries, became part of GSI.

The collaboration, which operates the large detector of the same name at GSI, celebrated its 25th anniversary with a special colloquium on the FAIR/GSI campus and an art exhibition in the cafeteria. In the future, HADES will become an important part of the CBM pillar at FAIR. For six years, the HADES collaboration planned the large-scale detector HADES, which was put into operation in 2001 with beams from the GSI ring accelerator SIS18. HADES stands for High Acceptance Di-Electron Spectrometer and consists of different detector systems with about 100,000 individual measuring cells as well as a superconducting magnet for deflecting charged particles. The special design of HADES makes it possible to measure particles with very high precision, and also to detect very rare particles.

During the latest data taking campaign, HADES produced up to one gigabyte of data per second. In order to find out more about the structure of neutrons and protons and thus answer the question of the origin of mass, researchers study electron-positron pairs, whose tracks have to be identified in the huge amount of data. In this way, the HADES detector system, which is as high as a house, provides researchers with exciting insights into what happens when two heavy nuclei collide at relativistic energies. In the laboratory, HADES allows them to track down the microscopic properties of extreme states of matter, e.g. as they occur inside neutron stars. Further highlights of HADES research with heavy-ion collisions are the generation of strangeness and the microscopic properties of dense nuclear matter.

Recent upgrade allows direct photon detection

Only recently, the measurement setup was significantly upgraded. The 4.5 meters high and 4.5 meters wide Electromagnetic Calorimeter (ECAL) was installed behind the previous detector in recent months. It contains 16 tons of lead glass, which will enable scientists to also directly detect photons in the future instead of using their conversion process. By measuring the photons, neutral mesons can now also be detected, and electromagnetic decays of hyperons can be investigated.

In the future, HADES will become an important part of the experimental program for the investigation of compressed nuclear matter CBM at the international accelerator facility FAIR (Facility for Antiproton and Ion Research), which is currently being built at GSI. Researchers will be able to investigate processes in neutron stars with unprecedented precision and over a very wide density range. ■

At many stations on the campus the guests could draw and paint. These included (clockwise) the experimental storage ring, the FAIR construction site, the therapy unit for tumor treatment using ions, the test facility for superconducting accelerator magnets and the largescale detector HADES. The picture was painted by Urban Sketchers participant Sandra Schwark.

Set in scene

With pencils, color palettes and other painting utensils the „Urban Sketchers Rhein-Main“ visited GSI and FAIR.

The motto of the international artist network, which is represented by regional groups all over the world, says: „We show the world, one drawing at a time" For this purpose the group members visit interesting places which they paint or draw. This time it was the world of fast ions and the universe in the lab that the „Urban Sketchers“ focused on and captured on paper.

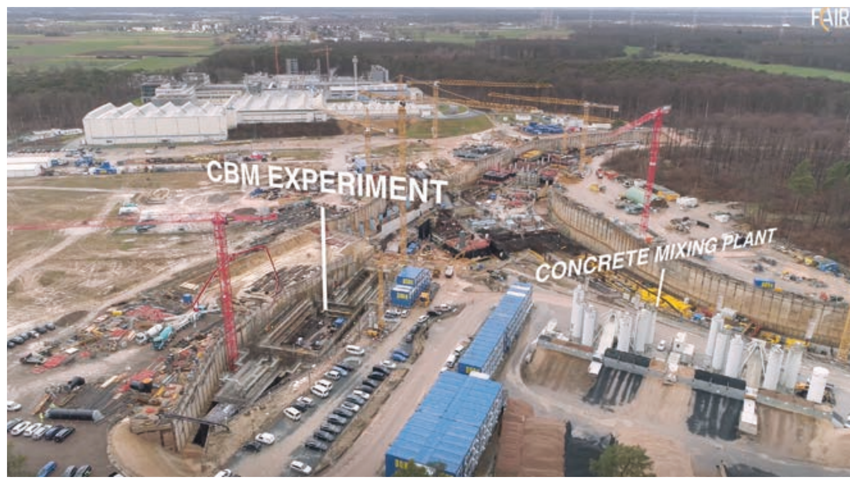
During their visit to the research campus in January 2020, Dr. Ingo Peter, head of public relations at GSI and FAIR, first gave the more than 30 artists an overview of current research projects and the international accelerator center FAIR currently under construction at GSI. Afterwards, there was time for exciting discoveries and hunting for motifs around the existing accelerator facilities, experimental setups, high-tech components and the platform, which provides a wide view of the mega construction site for FAIR and the large ring accelerator, the heart of the future facility.

The „Urban Sketchers“ were offered numerous outstanding motifs, from the big picture to the aesthetic high-tech detail. At the end of their visit, the group had a wide range of artworks in front of them — extraordinary, precisely observed and realized with very individual handwritings. As stated in the Manifesto of the „Sketchers“, the illustrators, whether professional artists or enthusiastic amateurs, publish their drawings and information about their activities online via blogs and social media channels. ■

Gallery:
www.gsi.de/en/usk
Scan QR-Code to open website.

GSI and FAIR invite to a virtual visit

One of our priorities at GSI and FAIR has always been to provide the public with exciting insights into our research facilities, programs and results, and demonstrating the progress made on the construction of FAIR. However, the new situation created by the spread of the corona virus requires new approaches also here. Public guided tours on the campus and to the visitor platform at the construction site cannot be offered at present. Therefore, GSI and FAIR have arranged a digital offer, which gives all interested people the opportunity to continue visiting us virtually and interactively.



Visit the large construction site of FAIR via drone flight.

Visitors can fly over the FAIR construction site by drone flight, get to know its extraordinary dimensions and, for the first time, even dive into the large ring tunnel that will form the heart of the future accelerator center. In addition, a long-term drone lapse video was created using a new filming technique that shows the development of an entire year: With the help of GPS, several videos were superimposed, so that one can see the construction grow as if from one piece right before the eyes of the viewer, making the progress particularly tangible.

The main task of GSI and FAIR is to carry out cutting-edge research and to use the accelerator facilities to gain new insights into the structure of matter and the evolution of the universe. A science film shows how scientists from all over the world can explore the universe in our laboratory.

If you want to take a virtual walk through the research facilities of GSI and FAIR and to stand directly next to the particle accelerators and detectors, it is best to get out your mobile phone to watch our 360° video in an optimized way. The exciting video was produced for the planetarium show „Dimensions - Once upon reality“ at the Bochum Planetarium.

On all these digital and virtual routes, our guests are therefore still welcome to visit our research facilities and take a look at the FAIR construction site. Furthermore, GSI and FAIR of course offer the possibility to keep up to date and to stay in contact with us online on our homepage and on our social media channels. ■

VIRTUAL VISIT AT FAIR AND GSI

- Overview in our press release: www.gsi.de/virtueller-besuch
- Flight over FAIR construction site: youtu.be/U6WuXJ5lj6E
- FAIR site drone lapse video: youtu.be/nS9yLm6PsZY
- FAIR science film: youtu.be/N48YCJli1lo
- 360° video: youtu.be/rKVeJM5Roq8
- GSI and FAIR in social media: www.gsi.de/social-media

Scan QR code for overview website.

International Year of the P

One of the highlights of the International Year of the Periodic Table was the closing ceremony in Tokyo.

CLOSING CEREMONY WITH GSI PARTICIPATION TAKES PLACE IN JAPAN

It was the culmination of an extraordinary anniversary year: the closing ceremony of the International Year of the Periodic Table proclaimed by the United Nations, recently held in Tokyo. 2019 marks the 150th anniversary of the discovery of the periodic table. GSI was also represented at the festive event in Japan. With its decades of successful research and the discovery of six new chemical elements, GSI contributed significantly to the updating of the periodic table.

GSI as an institute of element discoverers has played a major role in the further development of the periodic table: In experiments at the GSI accelerator facility, research groups led by Professor Peter Armbruster, Professor Gottfried Münzenberg and Professor Sigurd Hofmann succeeded in discovering the six elements 107 to 112. Furthermore, under group leadership of Dr. Matthias Schädel, the first chemical classifications of some of these elements were carried out. GSI also succeeded in producing elements 113 to 117 and thus confirming initial discoveries from Japan and Russia.

One highlight of the closing ceremony in Tokyo focused on the topic „Creation of superheavy elements". Scientists who produced and discovered superheavy elements appeared on stage to celebrate the completion of the seventh row of the periodic table. GSI was represented by Dr. Alexander Yakushev for element 107 (bohrium), Professor Christoph Düllmann for element 108 (hassium), Professor Michael Block for element 109 (meitnerium), Professor Karlheinz Langanke for element 110 (darmstadtium), Dr. Dieter Ackermann for element 111 (roentgenium), and Dr. Jadambaa Khuyagbaatar for element 112 (copernicium). In addition, speeches were given by prominent scientists from the laboratories that contributed largely to the discoveries. Research Director Professor Karlheinz Langanke presented GSI and FAIR.

eriodic Table 2019

Ceremonial opening (from left): Professor Paolo Giubellino, Scientific Managing Director of FAIR and GSI, Jochen Partsch, Lord Mayor of Darmstadt, Professor Sigurd Hofmann, head of the discovery team of element darmstadtium, Professor Gottfried Münzenberg, member of the discovery team, as well as Jörg Blaurock, Technical Managing Director of FAIR and GSI.

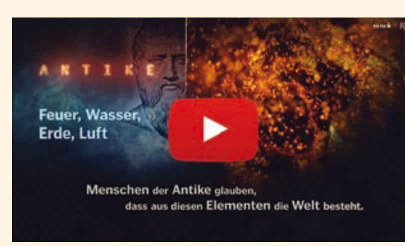
PHOTOPOINT FOR THE ANNIVERSARY: 25 YEARS AGO THE CHEMICAL ELEMENT DARMSTADTIUM WAS DISCOVERED

It was one of the greatest successes in fundamental research at GSI and at a moment that became a landmark in the history of the city of Darmstadt: that November 9, 1994, at 4:39 p.m., when for the first time the chemical element 110 was produced in the GSI particle accelerator. Today, it is named after its place of discovery „darmstadtium" and Darmstadt is the only German city eternalized in the periodic table of the elements. In addition, the element gave its name to the science and congress center „darmstadtium". GSI and the congress center remembered the discovery 25 years ago with a specially designed photopoint in the foyer of the „darmstadtium", which has been opened on the occasion of the anniversary. The new photopoint symbolizes cutting-edge research, which is world-leading and at the same time rooted in the region, and, as a further piece of the mosaic, sharpens the profile of Darmstadt as a city of science. The Scientific Managing Director of GSI and FAIR, Professor Paolo Giubellino, and the Lord Mayor of Darmstadt, Jochen Partsch, jointly opened the event. Professor Sigurd Hofmann, head of the discovery team of the element darmstadtium, gave a review of the history of the production of element 110. The anniversary of the darmstadtium's first production also coincided with the International Year of the Periodic Table proclaimed by the United Nations. ■

VIDEO: THE HISTORY OF ELEMENT DISCOVERY

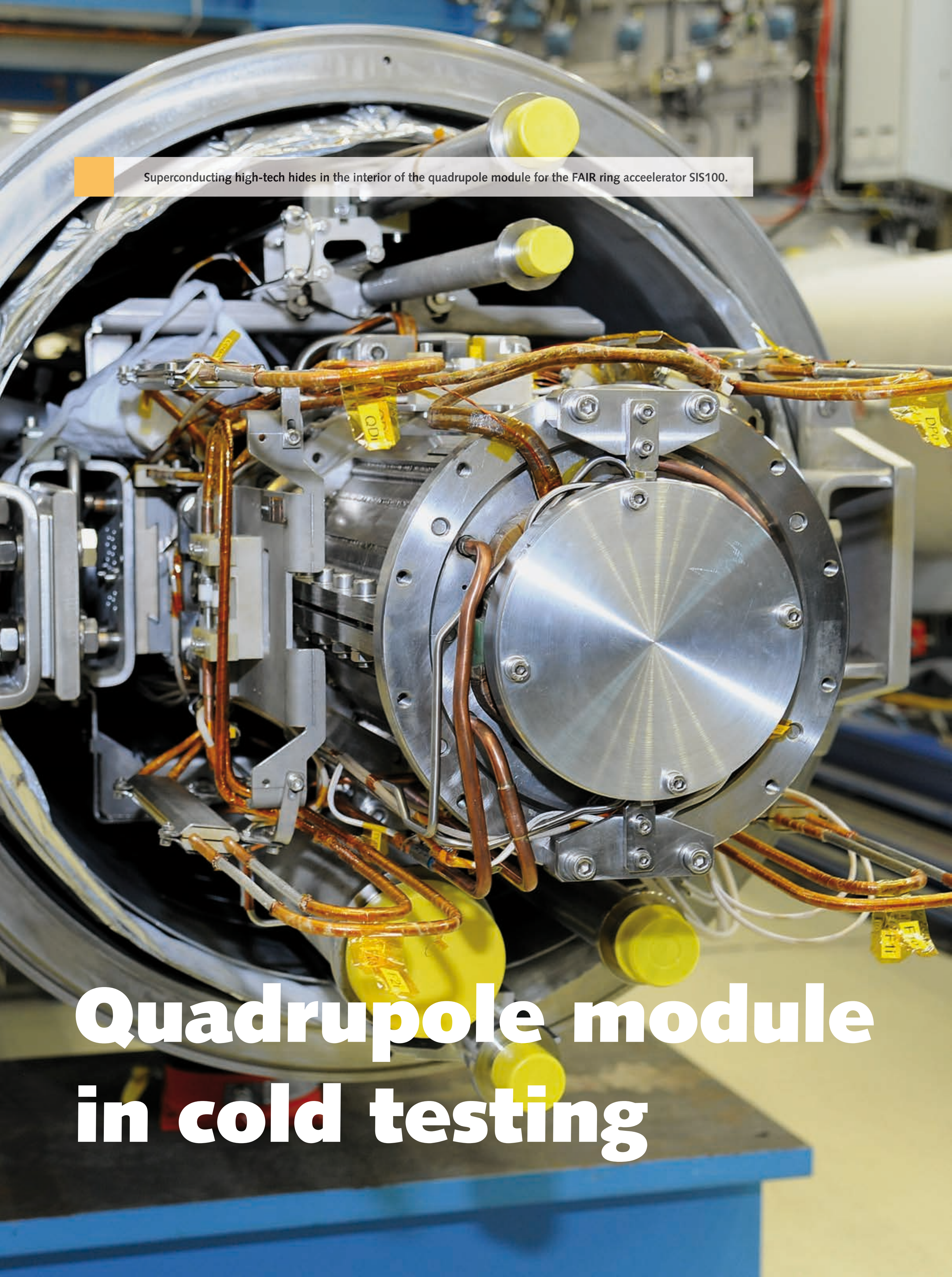
In the year 1869, the Russian chemist Dmitri Mendeleev published an order for the chemical elements which has been retained to this day: the periodic table of elements. According to IUPAC (International Union of Pure and Applied Chemistry), the periodic table is one of the most outstanding achievements of science, containing the essence of chemistry, physics and biology. It is a unique tool that has enabled scientists to predict the structure and properties of matter on Earth and throughout the universe. How was it created, and do we already know all the elements that exist in the universe?

An animated film by GSI and FAIR summarizes the history of the discovery of the elements: from the Ancient World to the creation of new elements at particle accelerator facilities such as GSI and FAIR. Experiments at the GSI accelerator facility in Darmstadt enabled scientists to discover six new elements, amongst them the elements darmstadtium and hassium, in honor of the city and the land of the laboratory. ■



Link: *youtu.be/-Cp5UJIjyoM*

Scan QR code to see YouTube video.



Superconducting high-tech hides in the interior of the quadrupole module for the FAIR ring acceelerator SIS100.

Quadrupole module in cold testing

Novel construction enables compact design

The technology behind the FAIR project is unique and customized in many areas. In the large ring accelerator SIS100, the heart of the future accelerator center FAIR, various sophisticated magnets and entire magnet systems will ensure that the ion beam is precisely guided and focused. The quadrupole modules also belong to them. The first of Series (FoS) has now been completed and delivered to GSI. Before shipment to Darmstadt, the module passed successfully an extensive test program (FAT, Factory Acceptance Test) under room temperature conditions at the manufacturer Bilfinger Noell in Würzburg.

The quadrupole doublet module consists of two superconducting quadrupole units manufactured by the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, and several cryogenic components provided by GSI (such as beam position monitors, ion catcher and thin wall quadrupole chambers). Beside of the integration of the quadrupole module, Bilfinger Noell is also in charge of the manufacturing of the cryostat vessel, the common girder, the thermal shield and other parts.

Before integrating the components, the cold mass — i.e. the part of the magnets to be cooled — needs to be assembled and installed on two common girders. The high-precision positioning of the cold mass required for this is accomplished with special suspension rods, similar to that of the dipole magnets. Overall, the high degree of integration is one of the major challenges of the SIS100 quadrupole modules. The integration of two quadrupole units in one cryostat is a design that deviates from other accelerator facilities.

The advantage of this novel design is that it enables a compact design of the FAIR ring accelerator SIS100, also allows the application of innovative technologies such as cryogenic ion catchers and provides ion-optical advantages. Since this technology has not been realized elsewhere before, the first cold test of the delivered module at its final operating temperature of -270 degrees was a particularly exciting moment for the project team and of great importance for the SIS100 project.

The first cold test was conducted at GSI Series Test Facility for superconducting accelerator magnets (STF). The result: The common girder showed a linear shrinkage but no significant lateral movement of the position of the quadrupole units. The experimental verification of this expected behaviour of the girder at thermal cycling was an important step for the whole SIS100 project. In the coming weeks and months, the module will be evaluated carefully. This will include high-voltage insulation tests and geometrical measurements, investigations on the thermo-mechanical stress and power tests with the main- and correction magnets.

The test program will be accompanied by experts from the Italian National Nuclear Physics Institute (INFN, Istituto Nazionale di Fisica Nucleare). Further tests, the SATs (Site Acceptance Tests) of the entire series of quadrupole modules, will be conducted at the facility in Salerno, Italy, later. In the second half of 2019, various contractual agreements were concluded with the INFN and the University of Salerno. ■

On the hook: With a crane the quadrupole module is carefully lifted to its place.

Prestigious European research grant awarded

„ERC Advanced Grant“ goes to GSI physicists Marco Durante and Gabriel Martínez-Pinedo as well as NUSTAR scientist Beatriz Jurado.

The renowned prize awarded by the European Research Council (ERC) underlines the outstanding quality of scientific research at GSI and FAIR. The grants are funding and acknowledgment in equal measure: They are awarded exclusively on the basis of the scientific excellence of the projects submitted and are aimed at established researchers from all disciplines whose highly innovative projects go considerably beyond the current state of the art and open up new areas of research. They are endowed with a maximum of 2.5 million euros each over a period of five years.

In his new project entitled „Biomedical Applications of Radioactive ion Beams (BARB)“, Marco Durante intends to further develop tumor treatment with charged particle therapy. “Particle therapy is rapidly growing and is potentially the most effective and precise radiotherapy technique. However, range uncertainty and poor image guidance limit its applications. Improving accuracy is the key to broadening the applicability of particle therapy“, explained Marco Durante. This could also allow better treatment of smaller metastases or tumors close to critical structures, and to small targets in non-cancer diseases, such as ventricular ablations in cardiac arrhythmia.

Marco Durante is Head of the GSI Biophysics Research Department and professor at the TU Darmstadt Department of Physics, Institute of Condensed Matter of Physics. He is an internationally recognized expert in the fields of radiation biology and medical physics, especially for therapy with heavy ions and radioprotection in space. He made important scientific progress in the field of biodosimetry of charged particles, optimization of particle therapy, and shielding of heavy ions in space. Marco Durante studied physics and got his PhD at the University Federico II in Italy. His post doc positions took him to the NASA Johnson Space Center in Texas and to the National Institute of Radiological Sciences in Japan. During his studies, he specialized in charged particle therapy, cosmic radiation, radiation cytogenetics and radiation biophysics.

The new idea is to use the same beam for treatment and for imaging during treatment. Radioactive ion beams are the ideal tool, but their intensity is not yet sufficient for therapeutic applications. Only cutting-edge facilities such as FAIR and the „FAIR Phase 0“ experimental program underway at GSI/FAIR can generate such intense beams. Marco Durante explained: “With FAIR-phase-0 high-intensity beams of short-lived isotopes of carbon and oxygen nuclei will be used to enable simultaneous treatment and visualization. This can significantly reduce the range uncertainty and further advance the applicability of particle therapy.” The beam will be visualized in the target position using an innovative Gamma-PET detector that will be built by Prof. Katia Parodi at LMU Munich, partner and beneficiary of the BARB project. “BARB is an experiment showing the enormous potential of FAIR. It is indeed a collaboration between the APPA and NUSTAR pillars of the FAIR project”, said Marco Durante.

Gabriel Martínez-Pinedo is Head of the GSI Theory Research Department, professor at the Theory Center of the Institute for Nuclear Physics (Department of physics, TU Darmstadt) and principal investigator of the SFB 1245 “Nuclei: From Fundamental Interactions to Structure and Stars”. He is recognized internationally as an expert in the field of the nucleosynthesis of chemical elements in stars. He was a co-leader of the international collaboration that predicted in 2010 that the synthesis of heavy elements in a neutron star merger leads to a characteristic electromagnetic signal named kilonova. In 2017, space and ground observatories were actually able to detect the predicted electromagnetic signal after the merger of two neutron stars. Gabriel Martínez-Pinedo studied physics and received his PhD from the Autonomous University of Madrid. He specialized in nuclear structure as well as nuclear astrophysics. As a postdoc, he gained experience at the California Institute of Technology in the USA, followed by research stays of several years at the Aarhus University in Denmark and the University of Basel in Switzerland.

In his new project, entitled „Probing r-process nucleosynthesis through its electromagnetic signatures (KILONOVA)“ Gabriel Martínez-Pinedo will further develop these approaches. He explained: „The project aims to answer one of the fundamental questions in physics: How and where are the heavy elements from iron to uranium made by the r-process?”

The confirmation of the theoretical predictions on the origin of heavy elements through the observation of

Outstanding quality of research at GSI and FAIR: In the photo from left Professor Gabriel Martínez-Pinedo, the Scientific Managing Director of GSI and FAIR, Professor Paolo Giubellino and Professor Marco Durante — photographed with appropriate safety distance for coronavirus protection.

gravitational waves of a neutron star merger in combination with characteristic electromagnetic signals in 2017 had provided the sensational first direct indication that r-process elements are produced during neutron star mergers. "Additional events are expected to be detected in the following years. To fully exploit such opportunities it is fundamental to combine an improved description of the exotic neutron-rich nuclei involved in the r-process with sophisticated astrophysical simulations to provide accurate prediction of r-process nucleosynthesis yields and their electromagnetic signals", explained Gabriel Martínez-Pinedo. These predictions could then be confronted with observations. "Together with the unique experimental capabilities of the GSI/FAIR facility, it constitutes a unique opportunity to advance our understanding of r-process nucleosynthesis."

The Scientific Managing Director of GSI and FAIR, Professor Paolo Giubellino emphasized: „It is a fantastic achievement. I am extremely pleased about the recognition of these outstanding scientists who, with their innovative projects and their commitment, are tackling important challenges in nuclear physics and medical physics. The grants demonstrate the outstanding quality of scientific research at GSI and FAIR. They go to two of our flagship fields: nuclear astrophysics and biomedical applications of nuclear physics. In addition, the grants underline the outstanding research perspectives opened by our FAIR phase-0 program. With FAIR, we will be able to further expand the prospects of such groundbreaking research and enable important pioneering achievements."

GSI and FAIR are also thrilled about the award of another ERC Advanced Grant to Professor Beatriz Jurado from the Centre Etudes Nucléaires de Bordeaux Gradignan (CENBG), part of the French National Centre for Scientific Research CNRS. The experimental part of Beatriz Jurado´s project will be realized at the accelerator facility on the GSI/FAIR campus as part of FAIR Phase 0, using the storage rings ESR and CRYRING.

In her EU-funded project entitled "Nuclear rEaCTions At storage Rings (NECTAR)" she wants to further advance the measuring capabilities in nuclear physics research. Her goal is to develop a new methodology to indirectly infer neutron-induced cross sections of unstable nuclei. These cross sections are essential for nuclear astrophysics, since most of the heavy elements in the Universe are produced by neutron-induced reactions in stars, and also for applications in nuclear technology. Her work is an experimental specification of the project of Gabriel Martínez-Pinedo.

Beatriz Jurado has been closely associated with GSI and FAIR for a long time through her nuclear physics research. Her main research areas are low-energy nuclear physics, nuclear reactions and fission. Already her doctoral thesis, which she defended at the University of Santiago de Compostela, was realized at the GSI's fragment separator FRS. She is also involved in the NUSTAR collaboration, one of the four major research pillars of FAIR, as a member of the Resource Board and was, among other things, a guest at GSI as "Visiting Professor" of the ExtreMe Matter Institute EMMI.

Ready for transport: At the Indian production company the converters stand by to be delivered to FAIR and GSI in Darmstadt.

Power for FAIR magnets: India supplies converters

Highest quality for research is the principle at FAIR. The beam transport guided by magnetic fields is one of the main contributions.

To supply the magnets with power, ultra-stable high-power converters are needed. These high-tech components come from India and are an important contribution to the FAIR project. On the occasion of the completion of the first batch of power converters, Jörg Blaurock, Technical Managing Director of GSI and FAIR, visited India with a delegation.

India, one of the founding members and shareholders of FAIR GmbH, is participating in the FAIR project with numerous in-kind contributions to the accelerator and several experiments. These include the most modern ultra-stable high-power converters (USHPC) for the FAIR magnets. They are being manufactured by the Electronics Corporation of India Limited (ECIL) in association with Bose Institute of Kolkata with design assistance provided by the Raja Ramanna Centre for Advanced Technology (RRCAT), Bhabha Atomic Research Centre (BARC) and Variable Energy Cyclotron Centre (VECC).

In a festive act at the ECIL site in Hyderabad, the first batch of 67 power converters was put on the road to shipment to Germany in the presence of the GSI and FAIR delegations. Jörg Blaurock and ECIL Managing Director Sanjay Chaubey, spoke of an important moment. „This is a special highlight of a ten-year journey in close cooperation with various institutions. We started from scratch and delivered what the nation has expected us to," said Sanjay Chaubey. Jörg Blaurock stressed: „ECIL is an important and reliable partner for us. We have a very successful cooperation. India is making a valuable contribution to the FAIR project with its in-kind deliveries".

In India and on the GSI and FAIR campus, in advance prototypes and first series specimens of the power converters had already successfully undergone extensive quality and performance tests. ECIL will produce a total of about 700 converters for the magnets of the large FAIR ring accelerator SIS100, the High-Energy Beam Transport HEBT and the Superconducting Fragment Separator Super-FRS.

New Administrative Managing Director

Science manager and physicist Dr. Ulrich Breuer has taken over the position of the Administrative Managing Director of GSI and FAIR in March 2020.

Dr. Ulrich Breuer previously worked as Administrative Director at the Helmholtz-Zentrum Dresden-Rossendorf (HZDR). Together with the Scientific Managing Director Professor Paolo Giubellino and the Technical Managing Director Jörg Blaurock, Dr. Ulrich Breuer will constitute the joint management team of GSI and FAIR. He succeeds Ursula Weyrich, who has changed to the German Cancer Research Center (DKFZ) in Heidelberg as Administrative Director.

"GSI has been a synonym for cutting-edge research with worldwide reputation for decades, and with the future accelerator center FAIR, the international dimensions of research will be expanded in a future-oriented manner. I am looking forward to this responsible task and the opportunity to foster this development", said Dr. Ulrich Breuer. "I am very grateful for the trust placed in me." He names as the most important goals a solid financial and personnel planning as well as the effective support of science with customized infrastructural and administrative conditions.

His two management colleagues, Professor Paolo Giubellino and Jörg Blaurock, are also looking forward to future cooperation in the management team and emphasized: "Dr. Breuer knows the profession very well and for a long time. He brings with him a broad knowledge of science management as well as of the administrative leadership of large research institutions." The aim is to conduct top-level research at the existing facility and to realize the future accelerator facility FAIR in international cooperation. "The decision in favor of Dr. Breuer is an excellent choice. With his many years of experience we will continue to successfully shape the future of GSI and FAIR together."

Dr. Ulrich Breuer studied physics and received his doctorate at the Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen. His professional career began in 1991 at the Forschungszentrum Jülich. There he first worked as assistant to the Chairman of the Board of Directors and then in leading positions for many years.

In 2005, he changed to the Hahn-Meitner-Institut Berlin as Administrative Director, where he accompanied the merger with the Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung (BESSY) and the foundation of the Helmholtz-Zentrum Berlin. He operated as its Administrative Director from 2009 to 2011. From 2012 to 2017, he worked as Vice President Economics and Finance of the Karlsruher Institut für Technologie (KIT). Subsequently he held the position of the Administrative Director at the Helmholtz-Zentrum Dresden-Rossendorf.

Until the end of June 2020, Dr. Breuer will continue in his current position at the HZDR in addition to his functions at GSI and FAIR. ■

Dr. Ulrich Breuer changes from HZDR to GSI and FAIR.

Contract awarding for shell constructions on the southern FAIR construction site

Another important stage in the FAIR mega project is starting. While the shell construction in the construction area north is progressing continuously, a first major package has now been awarded for the southern construction site — a next decisive step in the realization.

This major contract in a three-digit million euro range was awarded to the consortium of the companies Züblin and Strabag in Germany. The construction work include the shell constructions for six buildings and a unique experimental facility — the Superconducting Fragment Separator (Super FRS).

Following the construction work already underway in the northern area for the future experiment CBM, one of the four central pillars of the FAIR research program, the construction of a further decisive research area with outstanding discovery potential for science is being started now. The Super FRS will focus on research topics concerning the nuclear structure and interactions of extremely rare, exotic particles. These new isotopes will be produced with highest intensities, separated at the Super FRS and will be made available for world unique experiments to study cosmic matter in the laboratory.

In order to realize this outstanding research infrastructure, the award package also includes the shell construction for further experimental and supply buildings as well as for transfer lines for the beams. The Technical Managing Director of GSI and FAIR, Jörg Blaurock, emphasized: "With the current contract, we are implementing a further building block of our award strategy, which is customized for the mega-project FAIR, in accordance with our planning. Now the second large construction area in the south of the FAIR site and further parts of the high-tech production are moving into focus on our way to the realization of FAIR. We will also continue with our already established integrated overall planning in close cooperation with our partners in planning and execution."

Simultaneously and closely coordinated with the progress on the construction site, the development and production of the corresponding high-tech components continues, items which are required in particular for the Super FRS. For example, these include special high-performance power converters and superconducting magnet units that later will be used in the Super FRS for beam correction to achieve a high-precision particle beam. ■

The development is progressing: On the right side the northern part of the construction field with the tunnel for the large ring accelerator SIS100, in the background on the left side the existing GSI buildings, in front of it a part of the southern construction field, which is now being further developed.

Visit to the test facility for superconducting magnets.

Visit from the European Parliament

Members of "Renew Europe Group", the third largest political group within the European Parliament, were guests at GSI and FAIR last year.

The members and their staff and consultants were informed about current research, infrastructures and the future accelerator center FAIR, which is currently under construction at GSI. The international guests were welcomed by Professor Paolo Giubellino, Scientific Managing Director of GSI and FAIR, and Jörg Blaurock, Technical Managing Director of GSI and FAIR.

The visit was part of a closed meeting of "Renew Europe" in Frankfurt, during which information tours to international top locations were also undertaken. On the GSI and FAIR campus, the more than 100 European political visitors gained insights into the scientific successes and current status of the FAIR project, one of the largest construction projects for cutting-edge research worldwide and at the same time a strong pillar of the German and European research landscape in global competition. The FAIR and GSI management provided background information and offered a compact overview of science, structural and technical progress, and the development at the site in the heart of the Rhine-Main region.

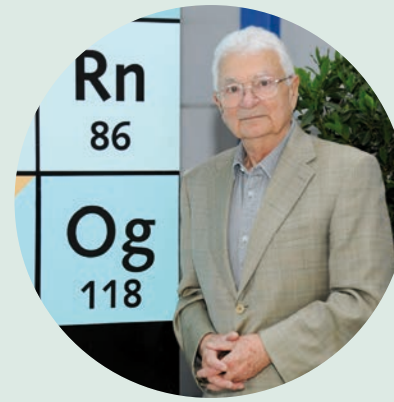
Information about high-tech components

The program for the guests also included a visit to the GSI campus and the FAIR construction site. They visited the test facility for superconducting accelerator magnets (Series Test Facility, STF), where high-tech components for FAIR are examined. During a tour of the FAIR site, they were also able to take a close view on the ongoing work on the 20-hectare site, from the completed shell construction of the tunnel segments for the large ring accelerator SIS100 up to the excavation pit for the first of the future large-scale experiments.

The "Renew Europe" group is one of the political groups of the European Parliament. It unites several liberal and centrist parties, including from the German-speaking countries amongst others the FDP with five deputies and the Freie Wähler with two deputies.

Professor Yuri Oganessian (87),

Scientific Leader of the Flerov Laboratory of Nuclear Reactions in Dubna, Russia, is the only living person a chemical element is named after: element 118, oganesson.



Professor Oganessian, you have a long history with GSI. How did it start?

My first visit to GSI was in January 1970 with Professor Rudolph Bock, one of GSI's founding fathers. By the time, only the excavation works for the buildings had been made. On the day before I spoke in Heidelberg for a scientific colloquium. Already at that time, there were plans to produce super heavy elements and to hunt for the mysterious island of stability. In 1974 we started our experiments in Dubna. While my boss, Georgy Flerov, was on vacation in summer, I had the beam time to check the idea about fusion of the massive nuclei and to make experiments. When producing fermium isotopes in fusion of the lead and argon nuclei, we observed many more events than we had expected. It was the first experimental indication of a new method for synthesis of heavy nuclei, later named as "cold fusion". These data were very important also for the German colleagues intending to synthesize new elements. At this time a close collaboration between JINR and GSI started. Afterwards visits to Dubna and Darmstadt became frequent, sometimes once per week at times. I would like to note that the progress at GSI with the new UNILAC accelerator and the SHIP separator was really big.

That was the time of the Cold War? How did scientific collaboration work between the Soviet Bloc and the Western world?

It always felt strange to me to make something interesting and then keep it a secret. Professional communication between the scientists is important, independent of political systems. Others help to improve and not to make the same mistakes twice. Political tensions don't make life easy, but scientific interest is something different than political interest. Indeed, we worked together with West Germany as well as with East Germany. Both sides wanted to collaborate. Dubna was a really wonderful field not only for communication, but also for cooperation. In those times the nation was divided, and science was a bridge. We sat together, had dinner together, on the level of direct human contact. JINR was an exception, a unique scientific center in its internationality in Russia. Flerov once said: "The best experiment is JINR itself." This gave us an advantage in experience of worldwide cooperation after the end of the Cold War.

Why did you choose physics as a profession? Was it always your passion? And how did your interest in the superheavy elements start?

As a school boy my preference was architecture. My father was a civil engineer. But as I was a good student I was chosen to take a test for physics and math. I passed it without difficulty in the first examination, so this was where I had to go. I started to study in 1950 when I was 17 years old. Afterwards I was attracted by Flerov. He discovered spontaneous fission together with Professor Konstantin Petrzhak. Flerov was a well-known scientists following the Soviet atomic bomb project. After two years of work in Flerov's group I was, at 24 years old, chosen by my colleagues to replace an older colleague and be the head of the accelerator group. That was a huge mission.

Do you have any advice for young scientists?

It seems to me they do not need any advice. They have to choose their path themselves. They have the right. Maybe they should make mistakes to find the right way. Don't worry, go ahead! If you take a wrong way, you can go back. Believe that you can pass difficulties, believe in yourself and do what seems valuable to you.

Element 118, oganesson, is named after you, and there's a stamp with your picture on it. How did that happen?

The stamp is from Armenia, where I originally come from. A good friend of mine from Armenia was a diplomat. His son is a journalist. He had the idea about the stamp and made it happen. When elements are named, there is no general rule, but mainly tradition. They can be named after planets, countries, cities or people. A name in honor of a scientists is a tribute and a memory of their great contribution to science, even if they did not deal with the synthesis of elements. But there are also people who synthesize elements. These discoverers decide on the name of their element. Many scientists with great contributions are involved in the synthesis of a superheavy element. Therefore, the name of the element is proposed on behalf of all the authors of the discovery. In two cases, it was done in honor of living persons. In my case, the proposal was made by the authors of two collaborating groups from the Flerov Laboratory in Dubna and the Livermore National Laboratory in USA. As they told me it was also supported by our collaborators from Oak Ridge National Laboratory and Vanderbilt University — the co-authors of our previous discovery of element 117.

You're over 80 years old and still an active researcher. Do you ever think about retiring?

It seems that I still have the resource to work in science. Unfortunately, my wife has passed away, so I live alone. My children have moved to the USA. Of course I visit them and my grandchildren often, but after a week I want to go back. Science is still my great interest. It's my job as long as they will have me. ■

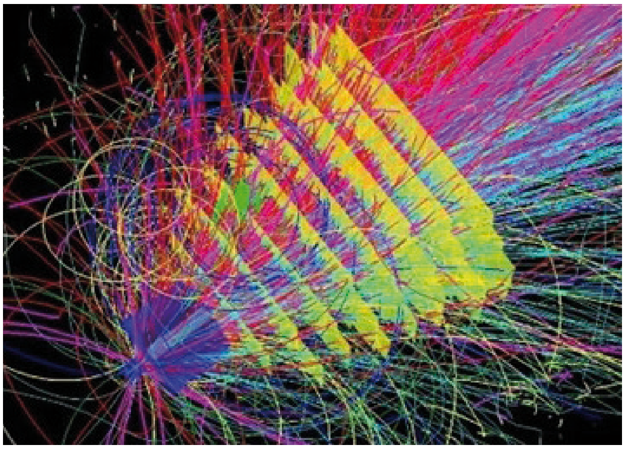
CREMLINplus: three million euros for FAIR

The European Commission is providing 25 million euros for scientific cooperation between European research infrastructures - in particular the projects of the European Strategy Forum for Research Infrastructures (ESFRI) and the mega science projects in Russia. The long-term cooperation of the GSI Helmholtzzentrum für Schwerionenforschung with the Joint Institute for Nuclear Research (JINR) in Dubna in the large-scale projects of FAIR (Facility for Antiproton and Ion Research) and NICA (Nuclotron-based Ion Collider facility) also benefits from this EU funding.

As part of the new EU project CREMLINplus (Connecting Russian and European Measures for Large-scale Research Infrastructures - plus), FAIR GmbH is receiving three million euros in funding for cooperation between the FAIR experiment CBM (Compressed Baryonic Matter) and the experiments on the future NICA collider at JINR.

CREMLINplus will provide additional funding of 2.6 million euros over a period of four years for further eleven institutes of the CBM collaboration from seven countries.

The joint development of silicon track detectors, the design of ultra-fast, self-triggered data acquisition systems, the development of software packages for online event selection and data analysis, as well as the construction of target chambers, extremely thin beam pipes and calorimeters for event characterization will be supported. In another work package,



Simulation of particle traces in the CBM experiment.

the next generation of ultra-thin silicon pixel sensors (MAPS - Monolithic Active Pixel Sensors) is being developed under the direction of the GSI detector laboratory. These silicon pixel detectors make it possible to measure the experiment traces locally with higher accuracy. Very good spatial resolution is required for identification, especially for special particles seldom produced in collisions.

GSI and FAIR can contribute their competence and many years of experience in the fields of detector technologies, front-end electronics, data acquisition as well as simulations and data analysis. ■

View inside the storage ring CRYRING.

Funding for CRYRING research

Federal Ministry of Education and Research supports project to investigate properties of magnetic materials.

The research is concerned with the properties of magnetic materials and tailor-made changes to new materials: Two teams of female physicists from the University of Duisburg-Essen (UDE) will receive a total of 2.8 million euros for a period of three years. They are developing new instruments for experiments on particle accelerators. One project will be implemented at the CRYRING ion storage ring at the GSI and FAIR campus in Darmstadt.

Tailor-made changes to new materials

At CRYRING, which will also be part of the future accelerator facility FAIR, the researchers under the direction of Professor Marika Schleberger are investigating solids using ion beams. In order to do this, a measuring station on the 17-meter-diameter ring, in which the ions fly from low speeds to a quarter of the speed of light, is being equipped with novel instruments. They are being specially developed by the project partners of the UDE and the University of Gießen. The researchers want to analyze the particles that are released during bombardment with ions in order to answer key questions: How to achieve customized changes in new materials using the targeted removal of individual atoms? In which subunits do biomolecules break under particle bombardment, and can one control this process? How can detection sensitivity be further increased?

The CRYRING is a contribution from Sweden to FAIR, which was transported from Stockholm to GSI. It was initially set up in cooperation with GSI for experiments and machine tests on the existing GSI accelerator facility. The system is planned for long-term use in atomic research with slow antiprotons at the FAIR facility.

Another project, under the direction of Dr. Katharina Ollefs deals with novel, energy-efficient cooling using magnetic materials. Both joint projects are funded by the Federal Ministry of Education and Research with 1.4 million euros each for a period of three years. ■

Groundbreaking in Jena

The structural extension of the Helmholtz Institute Jena (HI Jena) has begun, the groundbreaking ceremony has taken place last year.

The new building, which will be erected in the immediate vicinity of the existing institute building, will create additional office, seminar and laboratory space. The groundbreaking ceremony is also an important starting signal for further fostering the successful growth of the Helmholtz Institute Jena, a branch of GSI located on the campus of the Friedrich Schiller University (FSU) Jena.

After the welcome address by the Director of the Helmholtz Institute Jena, Professor Thomas Stöhlker, the Minister for Economy, Science and Digital Society of the State of Thuringia, Wolfgang Tiefensee, and the Minister for Infrastructure and Agriculture, Birgit Keller, passed on their greetings. On behalf of GSI spoke Research Director Professor Karlheinz Langanke, and Professor Georg Pohnert, Vice President of Research, spoke on behalf of the Friedrich Schiller University Jena.

The Thuringian Ministry of Infrastructure had announced an architectural competition for the new research building. The winner was a regional office: The jury unanimously selected the design of the "Osterwold°Schmidt EXP!ANDER Architekten" office in Weimar, which had submitted the plans jointly with Impuls Landschaftsarchitektur Jena. The four-storey, cube-shaped building with a floor area of around 240 square meters connects to the target laboratory in the basement. As link to the existing institute building, an interlocking gate is planned.

From left Professor Georg Pohnert, Vice President of Research of the Friedrich Schiller University Jena, the Minister for Economy, Science and Digital Society of the State of Thuringia, Wolfgang Tiefensee, the Minister for Infrastructure and Agriculture, Birgit Keller, the Research Director of GSI and FAIR, Professor Karlheinz Langanke and the Director of the Helmholtz Institute Jena, Professor Thomas Stöhlker.

The construction period for the new building, which will be erected on a slope on a federal state property within the university site, will be approximately two years. The state of Thuringia is financing the construction project and has scheduled eight million euros for it in its state budget.

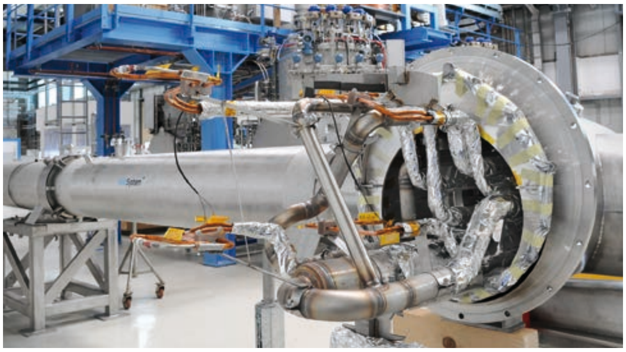
With the additional institute building, the infrastructural conditions for cutting-edge research, which has been carried out at the HI-Jena since the institute was founded ten years ago, will be further improved. The institute's research activities focus on the physics occurring at the border between conventional particle-acceleration technology and the fast-evolving field of laser-induced particle acceleration. The HI Jena offers outstanding research in the field of coupling of intense photon fields and the supporting development of appropriate instrumentation. In addition, the Helmholtz Institute Jena will further expand and strengthen the close connection between the university and the large-scale research facility GSI with the international accelerator center FAIR, which is currently being built here.

Around 100 employees and associated scientists in ten working groups are currently working at the HI Jena. There is also an own research school ("Research School of Advanced Photon Science") with around 60 doctoral students. ■

COMpact

SERIES PRODUCTION: CRYO BYPASS LINE FOR FAIR RING ACCELERATOR

Extreme cold in one area, warm room temperature right next to it — the sophisticated cryotechnology for the large FAIR ring accelerator SIS100 is a major challenge. An important element in achieving the best possible technical solutions for cooling SIS100 is now going into series production: the so-called bypass lines, a Polish contribution to the FAIR facility. Last year a delegation of GSI and FAIR, visited the Wrocław University for Science and Technology (WUST) in Poland. The delegation met with representatives of the Polish FAIR shareholder, the University of Wroclaw, as well as the top management of the executing Wroclaw company Kriosystem. The meeting marked the start of the important phase of series production of bypass lines for the SIS100. The bypass lines ensure the transport of the cryogenic agent (liquid helium, LHe) past warmer accelerator components. In this way, they constantly guarantee the cold of -268.6 °C required for the operation of the superconducting magnets in the entire ring system. According to a design of WUST University, Kriosystem has already manufactured and delivered the first of a series of bypass lines, which was successfully tested and accepted at GSI in Darmstadt. With the signed manufacturing contract between the provider WUST and the company Kriosystem, the series production of 27 such bypass lines will now be launched. ■


Testing of cryo bypass on the FAIR and GSI campus.

POSITIVE TRADE FAIR BALANCE: FAIR PROJECT PRESENTED AT EXPO REAL

The current construction planning and the next steps towards the realization of the mega construction project FAIR were the focus of this year's trade fair presentation at Expo Real in Munich. The result of the participation in the internationally renowned real estate trade fair was again very positive. The worldwide unique building project for science could be presented to the industrial sector with a lot of exciting news and was met with great interest. Potential contractors and bidding syndicates for the upcoming work on the FAIR construction site actively took advantage of opportunities to hold direct and comprehensive talks about the construction plans for FAIR and find out about possible participation.


FAIR presented itself at the Darmstadt booth of the Expo Real.

In-depth talks at the trade fair stand, a whole series of very focused one-on-one discussions and the acquisition of new contacts with experts contributed to the fact that participation in the 2019 trade fair can be regarded as a success. The presence of many relevant players from the construction sector on the days of the fair also provided an excellent opportunity to further enhance the FAIR project profile in the construction industry. The expert discussions confirmed once again that a custom-made megaproject such as FAIR can be very attractive for a construction company's portfolio due to its unique selling points.

The proven partnership with the science city of Darmstadt was continued this year. The FAIR project had its presentation at the Darmstadt stand, which was featured as part of the Frankfurt Rhine-Main metropolitan area. With around 45,000 visitors and exhibitors from more than 40 countries, the Expo Real trade fair is one of Europe's most important get-togethers for the real estate, construction, and location marketing sectors. ■

SUMMER STUDENT PROGRAM AT GSI AND FAIR

Participants of the Summer Student Program 2019.

37 Students from 19 countries participated in the Summer Student Program of GSI and FAIR in 2019. They spent eight weeks on campus, getting to know the experiments and research areas of GSI and FAIR and experiencing everyday work at an international accelerator laboratory. Each summer student worked in a research group on a small scientific or technical project from ongoing research operations. Every year, except 2020, where it had to be cancelled because of the corona pandemic, the Summer Student Program offers participants an insight into research at a particle accelerator facility. Many students return to Darmstadt after the Summer Student Program for a master's or doctoral thesis at GSI and FAIR. ■

SATURDAY MORNING PHYSICS: MORE THAN 200 HIGH-SCHOOL STUDENTS

Over 200 participants attended Saturday Morning Physics.

More than 200 high-school students from all over the state of Hesse, participating in the "Saturday Morning Physics" series of lectures, took the opportunity to gain exciting insights into current physical research at FAIR and GSI. During tours of the research facilities, the participants explored the accelerators and experiments on the GSI and FAIR campus and learned about the construction of the international accelerator facility FAIR."Saturday Morning Physics" is a project of the physics department of the TU Darmstadt. The series of lectures is held annually and aims to increase the interest of young people in physics. The visit to FAIR and GSI takes place as an excursion within the series. ■

SCIENTIFIC COOPERATION WITH UNIVERSITY OF SALERNO TO BE INTENSIFIED

From left: Professor Salvatore De Pasquale, Professor Paolo Giubellino, Professor Vincenzo Loia und Professor Luca Lista.

Perspectives and opportunities for future cooperation with the University of Salerno were the focus of a visit by Professor Paolo Giubellino, Scientific Director of FAIR and GSI. The aim is to intensify the scientific exchange between researchers. In order to promote scientific and technological cooperation between GSI/FAIR, the University of Salerno (UNISA) and the department of physics, a "Memorandum of Understanding" (MoU) has now been concluded. This collaboration will start soon with activities at the University of Salerno in the framework of cryogenic testing of superconducting magnet modules for SIS100, the large FAIR ring accelerator currently under construction. In this framework mutual exchange of researchers and students is foreseen to improve the mutual knowledge in the field of cryogenic facilities devoted to superconducting magnets for particle accelerators. ■

This artist's impression shows two tiny but very dense neutron stars at the point at which they merge and explode as a kilonova.

ALCHEMY OF MERGING NEUTRON STARS

For the first time, astronomers have identified a chemical element that was freshly formed by the merging of two neutron stars. The underlying mechanism, called the r-process – also known as rapid neutron capture – is considered to be the origin of large quantities of elements heavier than iron. This discovery sheds new light on the mystery of the environments in which this r-process takes place. The team of astronomers, also including scientists of FAIR and GSI, has now unequivocally demonstrated that the fusion of two neutron stars creates the conditions for this process and acts as a reactor in which new elements are bred.

Progress in understanding the synthesis of heavy elements

The origin of heavy elements such as gold, lead and uranium has not yet been fully clarified. The lightest elements – hydrogen and helium – were already formed in significant quantities with the Big Bang. Nuclear fusion in the cores of stars is also a well-established source of atoms in the mass range from helium to iron.

For the production of heavier atoms, scientists suspect a process that attaches free neutrons to already existing building blocks. The fast variant of this mechanism is the so-called r-process (r stands for rapid) or fast neutron capture. At present, research is being carried out to determine which objects might be sites where this reaction takes place. Possible candidates so far are a rare type of supernova explosions and the merging of dense stellar remnants like binary neutron stars.

An international group of astronomers with substantial participation of Camilla Juul Hansen from the Max Planck Institute for Astronomy (MPIA) in Heidelberg has now discovered the signature of the element strontium, which was formed by the r-process during an explosive fusion of two neutron stars. With on average 88 nucleons, of which 38 are protons, it is heavier than iron. Professor Almudena Arcones and Privatdozent Andreas Bauswein were also involved in the publication in the scientific journal Nature. In addition to their activities in the research department for theoretical physics at FAIR and GSI, they are also active at the Technical University of Darmstadt and at the University of Heidelberg, both partner universities of FAIR and GSI. They provided valuable estimates for the publication. The process and characteristics of the r-process are among the important research questions to be investigated at the future FAIR accelerator facility currently under construction in Darmstadt.

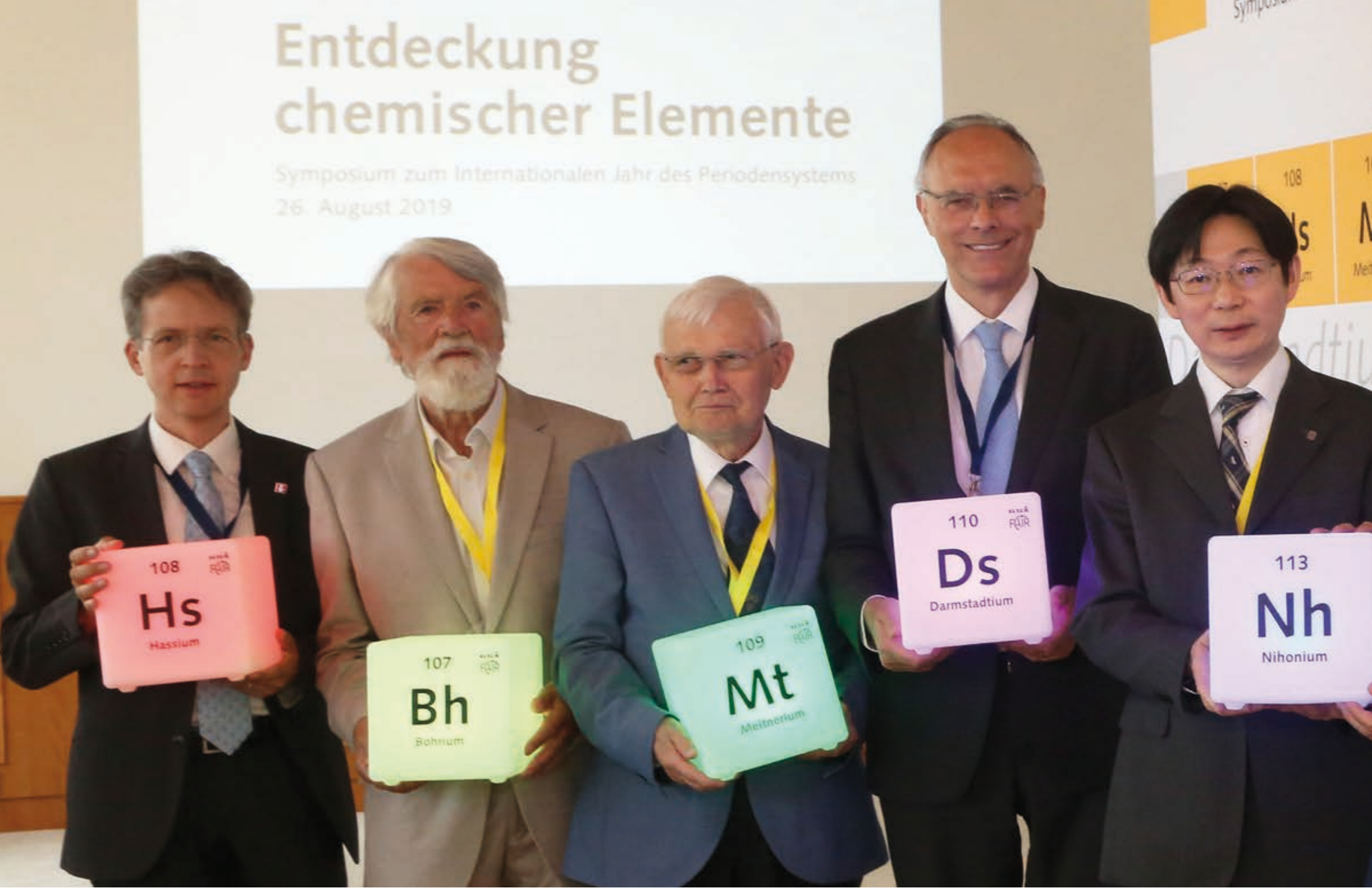
The explosive merger produced a raging expansion shell moving with 20% to 30% of the speed of light. It consists of newly formed matter, of which strontium alone amounts to about five Earth masses (1 Earth mass = 6·1024 kg). Thus, for the first time, the researchers provide clear evidence that such a collision provides the conditions for the r-process in which heavy elements form. Besides, this is the first empirical confirmation that neutron stars consist of neutrons.

The r-process is truly rapid. Per second, more than 10^{22} neutrons flow through an area of one square centimetre. The beta decay transforms some of the accumulated neutrons into protons, emitting one electron and one antineutrino each. The special aspect about this mechanism is that the neutrons combine to form large compounds faster than the newly formed conglomerates break up again. In this way, even heavy elements can grow from individual neutrons within less than a second.

Using the Very Large Telescope (VLT) of the European Southern Observatory (ESO), scientists obtained spectra following the spectacular discovery of the gravitational wave signal GW170817 in August 2017. In addition to a gamma-ray burst, the kilonova AT2017gfo, an afterglow in visible light due to radioactive processes, which faded within a few days after an initial sharp increase in brightness, occurred at the same location. The first analysis of the spectra in 2017 by another group of researchers did not yield a clear result about the composition of the reaction products.

Dr. Hansen and her colleagues based their re-evaluation on creating synthetic spectra and modelling the observed spectra, which were recorded over four days at intervals of one day each. The spectra indicate an object with an initial temperature of about 3700 K (approx. 3400 °C), which faded and cooled in the following days. The brightness deficits at wavelengths of 350 and 850 nm are conspicuous. These are like fingerprints of the element that absorbs light at these parts of the spectrum.

Taking into account the blue shift of these absorption lines caused by the Doppler effect the expansion following the merger event produces, the research group calculated spectra of a large number of atoms using three increasingly complex methods. Since these methods all yielded consistent results, the final conclusion is robust. It turned out that only strontium generated by the r-process is able to explain the positions and strength of the absorption features in the spectra. ■



HISTORICAL GATHERING

INTERNATIONAL MEETING OF THE DISCOVERERS OF CHEMICAL ELEMENTS

As part of the International Year of the Periodic Table 2019, the Conference on the Chemistry and Physics of Heavy Elements (TAN) taking place in Wilhelmshaven, Germany, last year brought together the discoverers of new chemical elements in a unique historical gathering.

Researchers from Germany, Russia and Japan, who have added new elements to the periodic table in recent years, met at the international congress. The organizers of this year's TAN conference were GSI, the Johannes Gutenberg University and the Helmholtz Institute Mainz.

There are currently 118 elements listed in the periodic table. 92 of them occur naturally on Earth. The search for further new elements is conducted using particle accelerators. To produce elements, researchers collide an ion beam consisting of atomic nuclei of one element with

From left: Professor Christoph E. Düllmann; Professor Peter Armbruster, Professor Gottfried Münzenberg, Professor Paolo Giubellino, Dr. Kouji Morimoto, Professor Hideto En'yo, Professor Sergey N. Dmitriev, Professor Yuri Oganessian, Professor Michael Block

a material sample of another element. In the fusion of the atomic nuclei of both elements a new, heavy element can be produced. The recognition and inclusion of a new element in the periodic table takes place as soon as the discovery has been confirmed. Heavy elements produced in this way are unstable, i.e. they decay within a short time. Unresolved research questions in this field include, for example, how heavy elements are formed, whether heavier elements can have longer lifetimes again due to their special nuclear configuration (known as the island of stability) and which chemical and physical properties the heavy elements have.

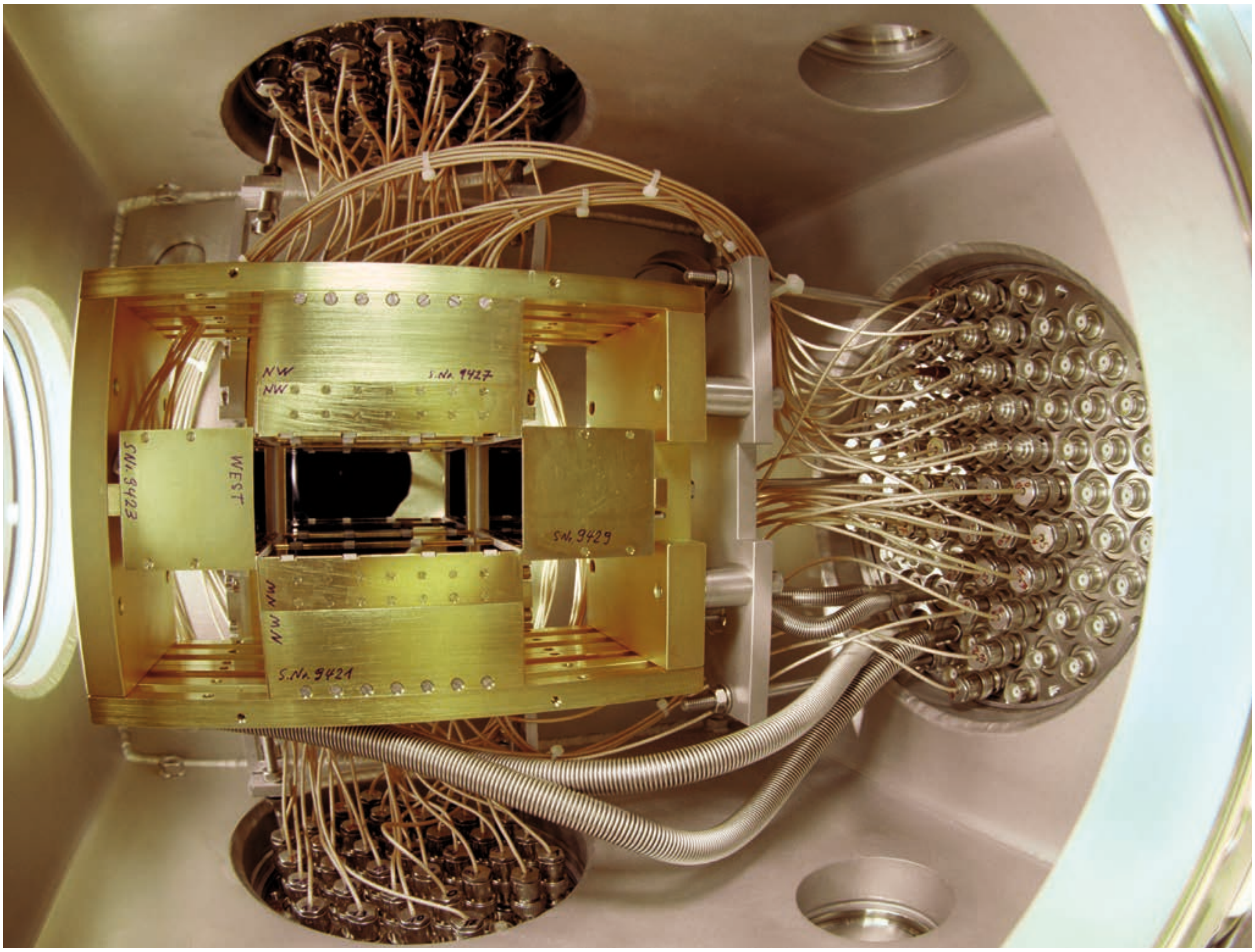
Professors Peter Armbruster and Gottfried Münzenberg, who held leading positions in the production of elements 107 to 112 (bohrium, hassium, meitnerium, darmstadtium, roentgenium and copernicium) at GSI during their active research careers, were present at the conference. Professor Yuri Oganessian was also on site. He is an element discoverer from Russia and currently the only living person an element is named after: element 118, oganesson. He was head of the discovery team of Elements 114 to 118 (flerovium, moscovium, livermorium, tennessine and oganesson) at the Flerov Laboratory of the Joint Institute for Nuclear Research, JINR in Dubna, Russia. Dr. Kouji Morimoto from Japan of the RIKEN Nishina Center for Accelerator-Based Science, who was a member of the element 113 discovery team, attended as well. The current heads of GSI, the Flerov Laboratory and the RIKEN Nishina Center, where the respective elements were discovered, also participated in the conference.

"Research on the heavy elements is an incredibly exciting field, there are many unanswered questions," explained Professor Paolo Giubellino, Scientific Managing Director of GSI and FAIR. "Where do the elements come from? How are they produced in explosions of stars and other stellar events? We would like to elicit answers to these questions from the cosmos with the help of our accelerator facilities. The investigation of the heaviest elements will continue to play a very important role in the future of our laboratory. The FAIR facility, which is currently being built at GSI in Darmstadt in international cooperation, offers new opportunities to bring the universe into the laboratory."

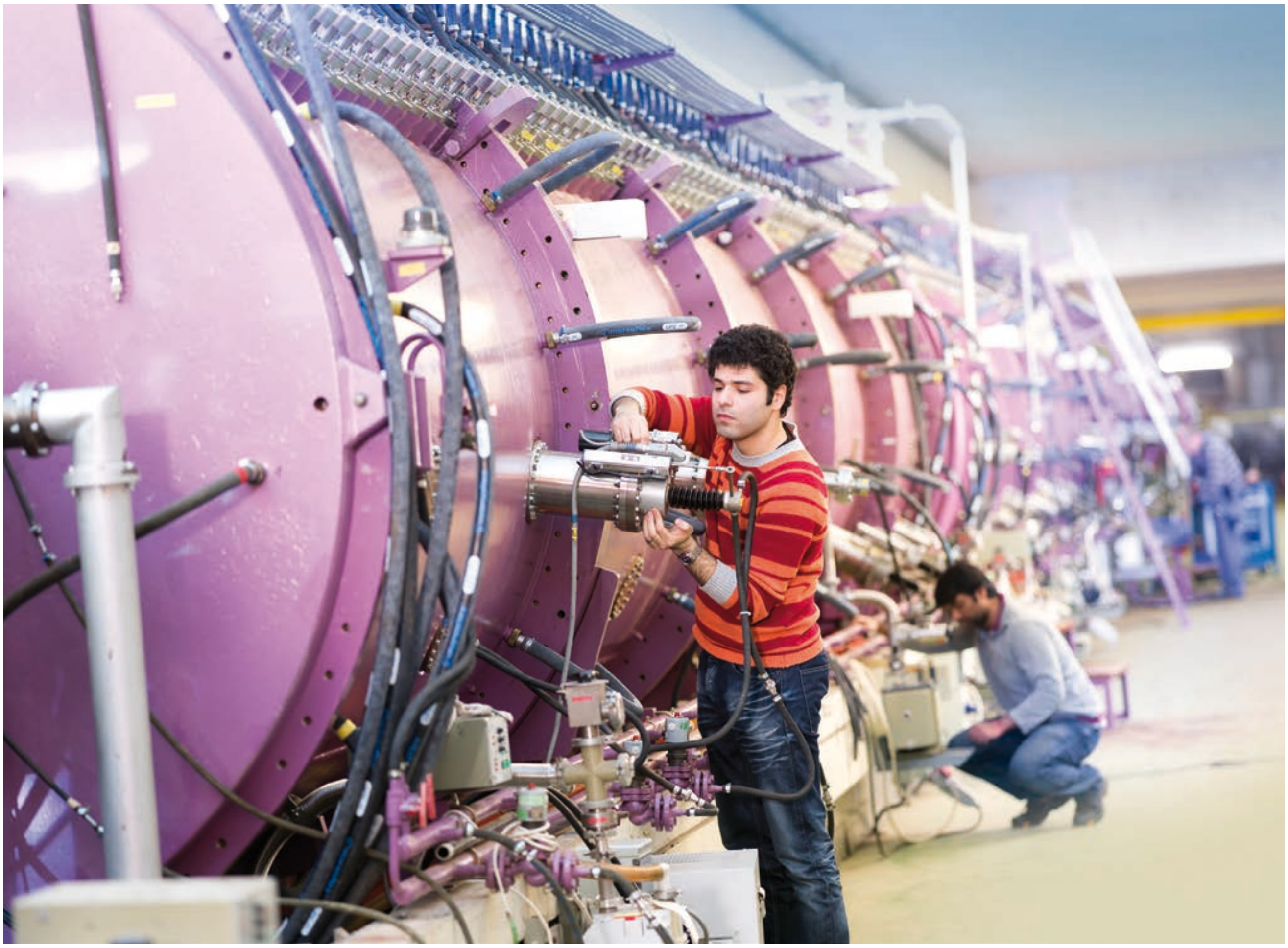
Professor Sergey Dmitriev, Director of the Flerov Laboratory of Nuclear Reactions (FLNR) said at the congress: "Priority experiments on the synthesis of new superheavy elements — flerovium (114), moscovium (115), livermorium (116), tennessine (117), oganesson (118) — were carried out at the FLNR using the U400 accelerator. Further progress required the construction of a superheavy-element factory at FLNR whose key facility is the DC280 cyclotron with the ion beam intensity an order of magnitude higher than that achieved to date. The commissioning of the factory will allow experiments on the synthesis of the elements 119 and 120 and will significantly expand the work on the study of nuclear and chemical properties of superheavy elements."

In Japan, the search for new elements also continues: "Since December 2018, we run '119th element search' experiment using one of the five cyclotrons in the RIKEN RI Beam Factory. At the end of 2019, our linear accelerator will be equipped with newly-built super conducting cavities and ready to synthesize new elements with higher beam intensity. We will run both experiments in parallel as long as resource permits. We will continue these experiments until somebody, hopefully RIKEN, finds the 119th element," Hideto En'yo, head of the RIKEN Nishina Center, described the current research goals.

A total of 120 researchers from 19 countries and 4 continents took part in the TAN conference. During the conference week, they discussed the current results and perspectives of research on the so-called transactinides, the namesakes of the TAN conference series. This refers to the elements starting with the atomic number 104 which follow the subgroup of actinides. They are all artificially produced and will be further investigated in the course of research on heavy elements. "We are trying to determine their chemical properties, for example" explained Professor Christoph Düllmann, co-organizer of the TAN, professor at the University of Mainz and head of the GSI and HIM research departments on the chemistry of heavy elements. "The elements are sorted into the groups of the periodic table according to their atomic number. Elements with similar chemical properties stand below each other. In the case of new artificial elements, of course a clarification is needed which proper-



Detector for the measurement of the elements discovered at GSI's SHIP experiment.

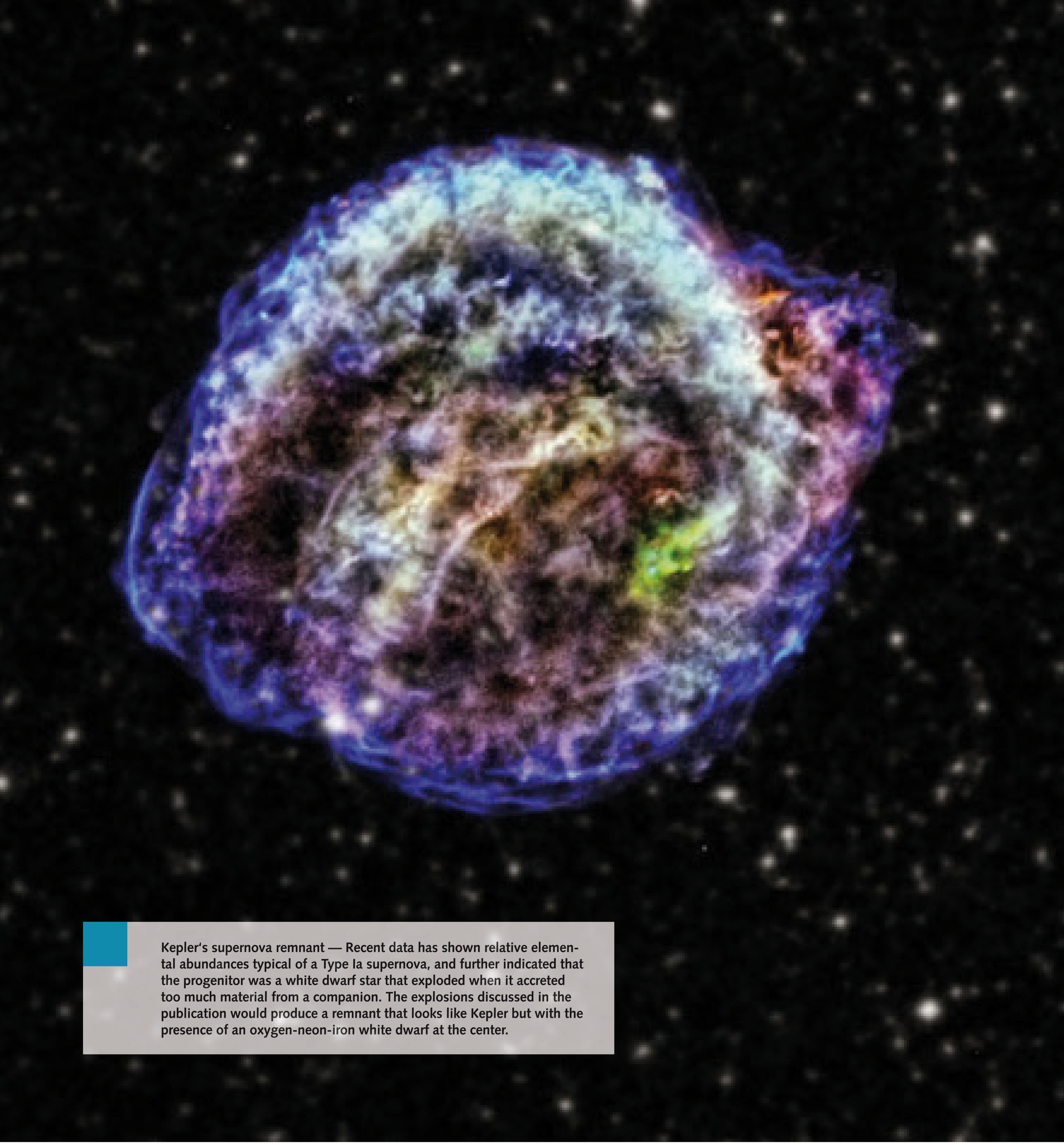

The GSI linear accelerator UNILAC was used to accelerate the ions in the production of elements 107 to 112.

ties they have, and whether they also belong to these groups, or whether the high nuclear charge in these exotic atoms causes a disruption of the electron shell and thus leads to unexpected chemical properties."

"We are also investigating the physical properties of the new elements in the same way," commented Professor Michael Block, another TAN co-organizer and professor in Mainz, who is also head of the GSI and HIM research department on the physics of heavy elements. "For example, the configuration and the energy levels of the nuclear building blocks can be determined by spectroscopic investigations, or high-precision mass measurements of the nuclei can be carried out in order to understand the behavior of the elements in detail and further improve the current nuclear models."

The TAN Conference took place in the International Year of the Periodic Table 2019 (IYPT) proclaimed by UNESCO, which celebrates the 150th anniversary of the Periodic Table. In 1869, the Russian chemist Dmitri Mendeleev introduced a system to the elements, which were previously disordered, and made predictions about missing, then unknown elements. He is thus regarded as the father of the periodic table. The conference had a local connection to the physician and chemist Lothar Meyer, who also proposed a corresponding system for the elements. He came from the neighboring village of Varel, south of Wilhelmshaven.

In addition to scientific discourse, a symposium on the occasion of the IYPT with information on the history of the periodic table and the element discoveries, as well as an outlook on the future of research on heavy elements, took place over the course of the TAN. Representatives of the international organizations IUPAC and IUPAP, responsible for naming the elements, as well as the German Physical Society and the Society of German Chemists were also present. The TAN is one of many examples of successful international cooperation in the world of research. ■



Kepler's supernova remnant — Recent data has shown relative elemental abundances typical of a Type Ia supernova, and further indicated that the progenitor was a white dwarf star that exploded when it accreted too much material from a companion. The explosions discussed in the publication would produce a remnant that looks like Kepler but with the presence of an oxygen-neon-iron white dwarf at the center.

EXPLOSION OR COLLAPSE

Experiment on beta-decay sheds light on fate of intermediate-mass stars

A NEON TRANSITION IS THE KEY PIECE

A group of scientists, among them several from GSI and from Technical University of Darmstadt, succeeded to experimentally determine characteristics of nuclear processes in matter ten million times denser and 25 times hotter than the centre of our Sun. A result of the measurement is that intermediate-mass stars are very likely to explode, and not, as assumed until now, collapse. The findings are now published in the scientific magazine Physical Review Letters. They stress the fascinating opportunities offered by future accelerator facilities like FAIR in understanding the processes defining the evolution of the Universe.

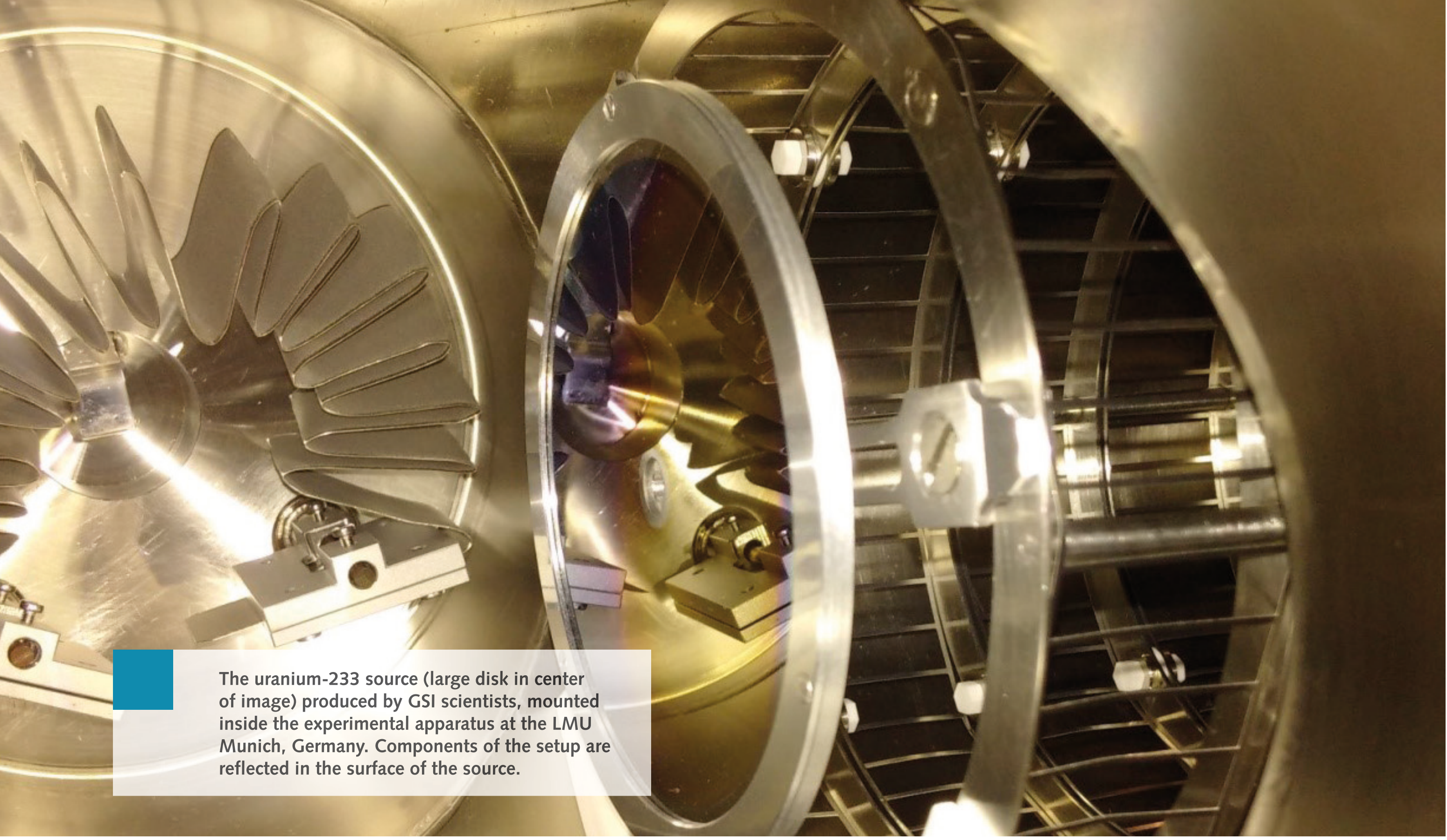
Stars have different evolutionary paths depending on their mass. Low-mass stars such as the Sun will eventually become white dwarfs. Massive stars, on the other hand, finish with a spectacular explosion known as a supernova, leaving either a neutron star or a black hole behind. The fate of both low- and high-mass stars is well understood but the situation for intermediate-mass stars, which weigh between seven and eleven times as much as the Sun, has remained unclear. This is surprising since intermediate-mass stars are prevalent in our Galaxy.

"The final fate of intermediate-mass stars depends on a tiny detail, namely, how readily the isotope neon-20 captures electrons in the stellar core. Depending on this electron capture rate, the star will be either disrupted in a thermonuclear explosion or it will collapse to form a neutron star," explains Professor Gabriel Martínez-Pinedo of GSI's research department Theory and the Institut für Kernphysik, TU Darmstadt. Professor Karlheinz Langanke, Research Director of GSI and FAIR, adds: "This work started when we realized that a strongly suppressed, and hence previously ignored and experimentally unknown, transition between the ground states of neon-20 and fluorine-20 was a key piece of information needed to determine the electron capture rate in intermediate mass stars." By a combination of precise measurements of the beta-decay of fluorine-20 and theoretical calculations, an international collaboration of physicists with participation from GSI and TU Darmstadt, has now succeeded in determining this important rate. The experiment took place under conditions far more peaceful than those found in stars, namely at the Accelerator Laboratory of the University of Jyväskylä. The measurements showed a surprisingly strong transition between the ground states of neon-20 and fluorine-20 that leads to electron capture in neon-20 occurring at lower density than previously believed. For the star, this implies that, in contrast to previous assumptions, it is more likely to be disrupted by a thermonuclear explosion than to collapse into a neutron star. "It is amazing to find out that a single transition can have such a strong impact on the evolution of a big object like a star," says Dag Fahlin Strömberg, who, as a PhD student at TU Darmstadt, was responsible for large parts of project's simulations.

Since thermonuclear explosions eject much more material than those triggered by gravitational collapse, the results have implications for galactic chemical evolution. The ejected material is rich in titanium-50, chromium-54, and iron-60. Therefore, the unusual titanium and chromium isotopic ratios found in some meteorites, and the discovery of iron-60 in deep-sea sediments could be produced by intermediate-mass stars and indicate that these have exploded in our galactic neighbourhood in the distant (billions of years) and not so distant (millions of years) past.

In the light of these new findings the most probable fate of intermediate-mass stars seems to be a thermonuclear explosion, producing a subluminous type Ia supernova and a special type of white dwarf star known as an oxygen-neon-iron white dwarf. The (non-) detection of such white dwarfs in the future would provide important insights into the explosion mechanism. Another open question is the role played by convection — the bulk movement of material in the interior of the star — in the explosion.

At existing and future accelerator centres like the international FAIR project (Facility for Antiproton and Ion Research) currently under construction at GSI, new not yet investigated isotopes and their properties can be investigated. Thus, scientists continue to bring the universe into the laboratory to answer the unsolved questions about our cosmos. ■



The uranium-233 source (large disk in center of image) produced by GSI scientists, mounted inside the experimental apparatus at the LMU Munich, Germany. Components of the setup are reflected in the surface of the source.

NUCLEAR CLOCK TRANSITION

Physicists have measured the energy associated with the decay of a metastable state of the thorium-229 nucleus. This is a significant step on the way to a nuclear clock which will be far more precise than the best of today's atomic timekeepers.

Modern atomic clocks are the most accurate measurement tools currently available. The best current instruments deviate by just one second in 30 billion years. However, even this extraordinary level of precision can be improved upon. Indeed, a clock based on an excited nuclear state of thorium-229 should make it possible to enhance timing accuracy by another order of magnitude. Now a team including members from GSI and its outpost, the Helmholtz Institute Mainz, has taken an important step towards such a clock. Indeed, the new study is featured on the title page of the leading journal Nature. In the paper, the authors report that they have succeeded in quantifying the energy released by the decay of the excited thorium-229 nucleus, which is an essential prerequisite for the realization of a thorium-based nuclear clock.

Unlike current atomic clocks, which make use of oscillations in the outer electron shells of atoms, nuclear clocks employ oscillations within the nucleus as their timekeeper. In both cases, the oscillations are the product of transitions between defined energy levels, which can be excited by laser light of a specific wavelength. Typically, the energies required to excite oscillations in the vast majority of atomic nuclei are orders of magnitude higher than those required to stimulate transitions in the orbital shells of electrons – which precludes the use of conventional lasers for this purpose. However, there is only one viable candidate for the development of a nuclear clock – the thorium-229 nucleus. Its excited state is located at an energy that is by far the lowest of any state found in the approximately 3800 currently known atomic nuclei. Irradiation with UV light, which is within the capability of lasers now available, is sufficient to populate this excited state.

However, up to now, the precise energy required to generate the excited thorium-229 has remained unknown. "To induce the nuclear transition, the wavelength of the laser light must be tuned to match the transition energy exactly. We have now succeeded in measuring this precisely for the first time," says Benedict Seiferle, lead author of the new paper.

For these measurements, carried out at LMU, the authors of the study made use of the doubly charged thorium-229 cation. Sources providing this cation in the excited nuclear state were developed in Mainz. "Uranium-233 was chemically purified and subsequently deposited on titanium-covered silicon wafers using an electrochemical method. This yields homogeneous thin films. Uranium-233 undergoes alpha decay, producing thorium-229. Thorium-229 recoils from the thin film due to the energy released in the alpha decay, hence entering into a dedicated ion trap developed at LMU in which thorium-229 cations are recovered," Christoph Düllmann, chemist at GSI and HIM, describes the process. The excited state of the cation has a lifetime of hours. This is relatively long for an excited nuclear state and is crucial for the future development of the clock, but it hampers measurement of the decay energy. "This long lifetime means that decay to the ground state occurs only rarely. As measurement of this decay was the goal of our experiment, we exploited the fact that the decay occurs rapidly when the cations are given the opportunity to collect the missing electrons," says Seiferle.

FAST DECAY DUE TO ELECTRONS

To provide electrons, Seiferle and colleagues guided the ions through a layer of graphene. On its way through this layer, each ion picks up two electrons and emerges as a neutral atom on the other side. Thanks to this controlled neutralization step, the excited state then decays to the ground state within a few microseconds. The neutralized atoms expel an electron from an outer atomic shell, thus generating a positively charged thorium-229 ion. The kinetic energy of the free electron depends on the excitation energy of the nuclear state and is determined using an electron spectrometer. However, this energy is only a fraction of the energy used to generate the excited nuclear state. The rest remains in the thorium-229, which renders the interpretation of the resulting spectra complex.

The result indicates that the thorium-229 nucleus can be excited to this level by irradiation with laser light at a wavelength . Now lasers specifically designed to emit in this wavelength range can be constructed. This step will bring the first nuclear clock a great deal closer to practical realization. The researchers believe that a thorium-based nuclear clock will open up new avenues in the basic sciences, but will also find many applications, which only become possible on the basis of extremely precise measurements in the time domain.

The current results open the way for new research prospects at the FAIR accelerator facility currently being built at GSI. Professor Thomas Stöhlker, Vice Research Director and head of the Atomic Physics division at GSI, says: „This refined energy value opens up future research opportunities at the FAIR storage rings, allowing for precision studies of thorium-229 and its isomer at highest charge states via dielectronic recombination." ■

The experimental storage ring ESR at GSI allows to determine the energy with highest precision.

800 billion °C — Star collisions in the laboratory

They are among the hottest moments in cosmic events: the collisions of neutron stars in the universe, in which chemical elements are formed. With particle collisions in the accelerator scientists are able to create similar conditions at GSI and the future FAIR accelerator center. Now, an international group of researchers at the HADES collaboration has succeeded for the first time in measuring the thermal electromagnetic radiation – the so-called black-body radiation – produced in this process. This allowed them to determine the temperature at 800 billion degrees Celsius and to explore further details about building blocks of matter under such conditions. The results were recently published in the journal „Nature Physics".

The HADES detector system on the GSI and FAIR campus in Darmstadt, as tall as a house, provides researchers with exciting insights into the events of the collision of two heavy nuclei at relativistic energies and – as has now been very successfully done – allows them to track down the microscopic properties of extreme states of matter in the laboratory. The latest results of the HADES collaboration, involving more than 110 scientists from numerous countries, mark an important moment: "The reconstruction of thermal radiation from compressed matter is a milestone in the understanding of cosmic forms of matter. It not only allows to extract the temperature of the system formed in the collision but also provides deep insight into the microscopic structure of matter under such conditions," says Professor Joachim Stroth, spokesperson of the HADES collaboration, who coordinated the current analyses together with Professor Tetyana Galatyuk. Numerous other scientists from GSI and FAIR were involved in the current publication.

The Scientific Managing Director of GSI and FAIR, Professor Paolo Giubellino, whose research focus is the physics of high-energy heavy ion collisions and the matter produced in them, is already looking forward to the future and to the worldwide unique accelerator center FAIR, which is currently being built at GSI: "HADES will continue to contribute a lot to the exploration of atomic nuclei and their building blocks and will be an important part of FAIR's Compressed Baryonic Matter (CBM) experiment. Among other things, researchers there

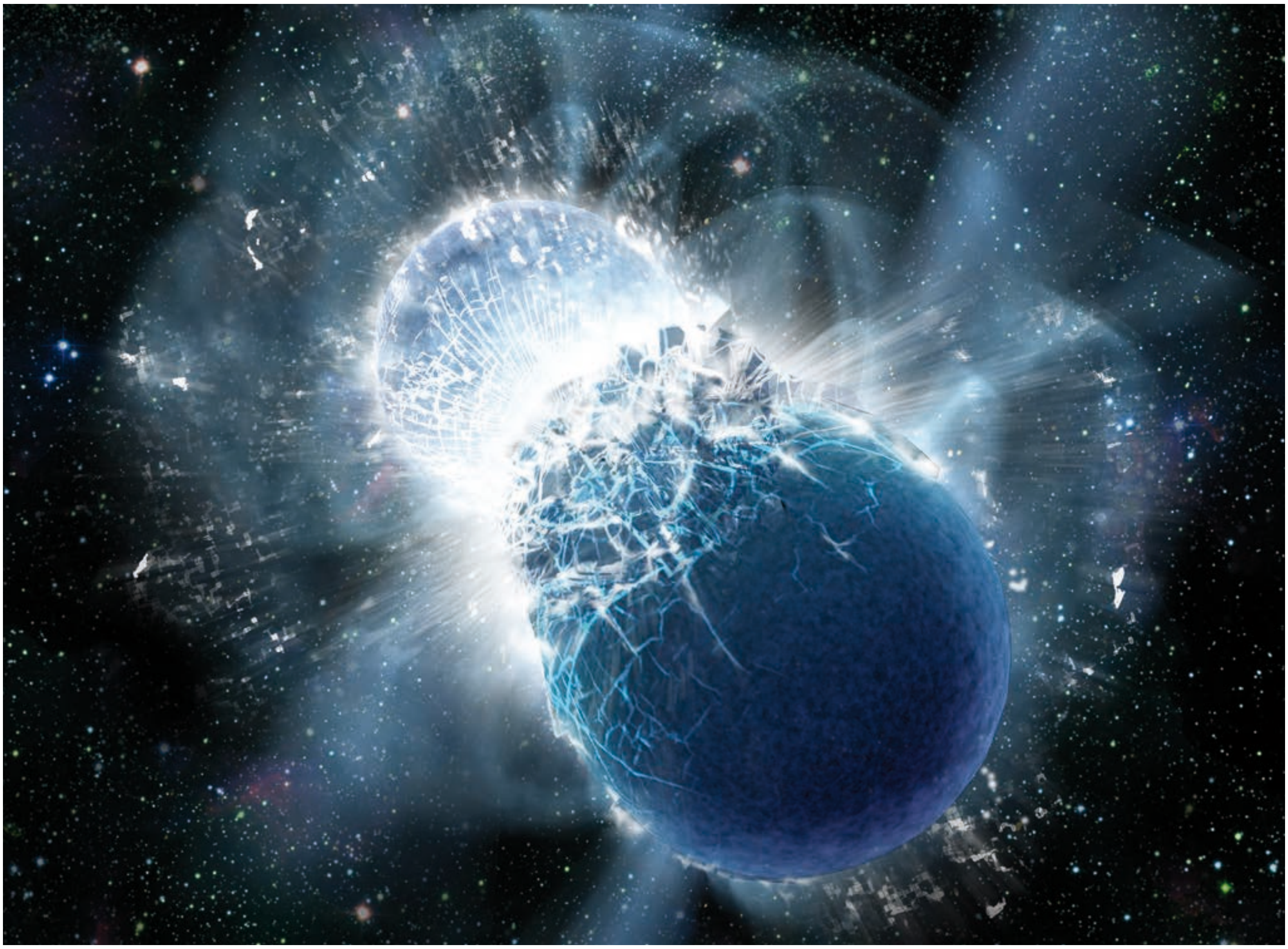
The interior of the HADES detector .

will be able to investigate processes within neutron stars with unprecedented precision and over a very wide range of densities."

The electromagnetic radiation observed by the HADES detector within the scope of the study now presented is mediated by virtual photons. They exist for an instant and soon decay into a pair of leptons (dilepton), e.g. an electron and a positron. Since leptons do not undergo strong interactions, the dense hadronic medium is nearly transparent to this radiation. Nevertheless, it is produced throughout the whole evolution of the reaction and therefore provides an ideal probe for the microscopic properties of the dense and hot medium created in the collision. From the spectral distribution of the radiation it could be deduced, that the matter must have reached temperatures in excess of 70 megaelectron volt (800 Giga Kelvin) and densities three times the nuclear saturation density.

Indeed, the densities and temperatures reached in the collision zone of such heavy-ion reactions resemble the conditions in neutron star merger processes. Since the detection of gravitational waves and electromagnetic radiation emitted from these giga novae events in a wide range of the electromagnetic spectrum, it is suggested that such merger events are the cosmic kitchens for the synthesis of heavy nuclei. An important input to respective theoretical investigations is the so-called equation of state of matter under extreme conditions. With heavy-ion reaction experiments at relativistic energies some of the relevant properties are now accessible in the laboratory.

The HADES experiment is the first to successfully reconstruct thermal electromagnetic radiation in collision of heavy-ions at energies around one gigaelectronvolt per nucleon. About three billion gold-gold collisions had to be recorded and analyzed to finally reconstruct 20,000 virtual photons via their decay into a pair of electrons and with masses larger than 200 megaelectronvolt/c^2. ■



Inside neutron star mergers, extremely high temperatures and densities are produced.

Participants of the first ESA-FAIR Summer School

First ESA-FAIR Summer School

Cosmic radiation research is the focus of this new high-quality offer for international young scientists.

Premiere of the „ESA-FAIR Radiation Summer School“: 15 young researchers from eight countries came together to work intensively on the topic of cosmic radiation. The Summer School for radiation research was jointly established by the European Space Agency ESA and FAIR.

Researching cosmic radiation and their effects on humans, electronics and materials is a decisive contribution to the future of human spaceflight, so that astronauts and satellites in space are provided with the best protection during the exploration of our solar system. Furthermore, it also contributes to detailed knowledge about the risks of radiation exposure on Earth.

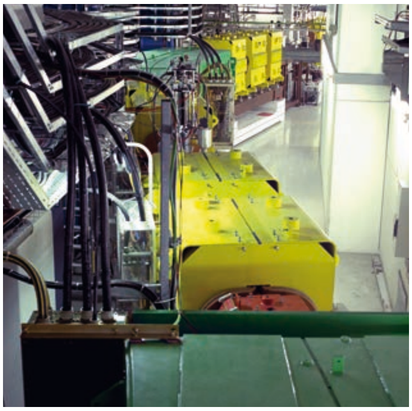
The Summer School was held at ESA´s European Space Operations Centre ESOC as well as at the GSI/FAIR campus in order to train students in basic heavy ion biophysics for space applications, e.g. space radiation detection, monitoring and protection.

The Summer School's top-class scientific program, opened by Thomas Reiter, ESA Interagency Coordinator, and Professor Paolo Giubellino, Scientific Managing Director of GSI and FAIR, included lectures from experts in the field, site visits to facilities in Darmstadt and practical training and research opportunities at GSI/FAIR. The participants commuted between the two locations ESOC and GSI/FAIR campus. Among other things, there was the opportunity to discuss the radiation risk during life and work in space with Marco Durante, head of the GSI Biophysics Department. At the GSI and FAIR accelerator facilities, the students had the opportunity to participate in experiments and learn more about the research fields of radiation biology, electronic components, materials research, shielding materials and instrument calibration. At the end of the ESA-FAIR Radiation Summer School, participants took written exams and carried out teamwork, which was evaluated and rated by the lecturers.

The establishment of the Summer School is a direct result of the close cooperation between ESA and FAIR on cosmic radiation research. The existing GSI accelerator facility is the only one in Europe that can generate all of the ion beams that occur in our solar system. The opportunities will be expanded even further by the future FAIR accelerator center: FAIR will enable researchers to conduct experiments with an even wider spectrum of particle energies and intensities.

COMpact

NEW ATOMIC NUCLEUS FOUND — FAR FROM STABILITY



The GSI Fragment Separator FRS.

Where does the world of atomic nuclei end? Scientists went further into the region of unstable elements than ever before. For the first time, an experimental collaboration has detected potassium-31 at the GSI Fragment Separator, an isotope with eight neutrons less than the stable potassium atom.

Potassium-31 lies further outside the proton dripline than has ever been observed before: It is extremely short-lived with a half-life below nanoseconds, but the sheer existence of the atomic nucleus is a new record. In physics, the proton dripline marks a boundary beyond which we find the unbound atomic nuclei. Due to the unbalanced ratio of neutrons and protons, they can hardly exist and decay very quickly. Potassium-31 is four neutrons far outside this dripline. An atomic nucleus that remote from the proton dripline has never been observed before.

Daria Kostyleva analyzed the data from the fragment separator experiment and carried out simulations for her PhD thesis. „We haven't reached the border between unbound systems and chaotic nuclear matter yet," she says. „There could be atomic nuclei that are up to seven neutrons away from the proton dripline. We want to test whether the main nuclear structure principles still apply there."

These systems could be found in the future at the new FAIR facility. The used detectors are part of the experiment program of the super fragment separator (Super-FRS) which will be operated at FAIR and is part of the large-scale experimental collaboration NUSTAR. Thanks to FAIR's much more intense particle beam and the higher energies that can be achieved, scientists expect to discover many new isotopes. ■

NASA MISSION DELIVERS BEST-EVER PULSAR MEASUREMENTS

Scientists have reached a new frontier in our understanding of pulsars, the dense, whirling remains of exploded stars, thanks to NASA's Neutron star Interior Composition Explorer (NICER). This X-ray instrument aboard the International Space Station has produced the first precise and dependable measurements of both a pulsar's size and its mass, as well as the first surface map of one of these mysterious objects. The ExtreMe Matter Institute EMMI of GSI and Technical University Darmstadt is also involved in the research efforts.

For decades, scientists have been trying to figure out exactly how pulsars work. In the simplest model, a pulsar has a powerful magnetic field shaped much like a household bar magnet. The field is so strong it rips particles from the pulsar's surface and accelerates them. Some particles follow the magnetic field and strike the opposite side, heating the surface and creating hot spots at the magnetic poles. The whole pulsar glows faintly in X-rays, but the hot spots are brighter. As the object spins, these spots sweep in and out of view like the beams of a lighthouse, producing extremely regular variations in the object's X-ray brightness. NICER measures the arrival of each X-ray from a pulsar to better than a hundred nanoseconds, a precision about 20 times greater than previously available, so scientists can take advantage of this effect for the first time.

The scientists from TU Darmstadt and EMMI have provided the expertise for understanding the impact of the NICER observations for the equation of state of dense matter. ■

NASA's Neutron star Interior Composition Explorer (NICER) is an X-ray payload aboard the International Space Station.

A NEW APPROACH TO THE HUNT FOR DARK MATTER

A study that takes a novel approach to the search for dark matter has been performed by the BASE Collaboration at the European research center CERN: For the first time the researchers are exploring how dark matter influences antimatter instead of standard matter. GSI researchers are also involved.

„To date, scientists have always conducted high-precision experiments at low energies using matter-based samples in the hope of finding a link to dark matter," explains Dr. Christian Smorra, the lead author of the study. „Now we've decided to search explicitly for interactions between dark matter and antimatter. It is generally assumed that interactions of dark matter will be symmetric for particles and antiparticles. Our study seeks to determine whether this is really the case."

The scientists are focusing their attention on one single antiproton that has been captured in a special device known as a Penning trap. The particle was produced by scientists using the Antiproton Decelerator (AD) at CERN, the world's only research institution capable of generating low-energy antiprotons.

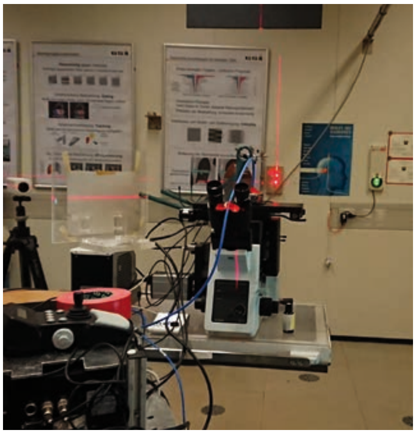
Stefan Ulmer working at the BASE experiment.

The scientists then stored and experimented with the antiprotons created there using the BASE Collaboration's trap system.

Using their experimental set-up, the researchers have already explored a specific frequency range but without success — no evidence pointing to the influence of dark matter has come to light to date. „But we have managed to achieve levels of sensitivity as much as five orders of magnitude greater than those employed for observations related to astrophysics. As a result, we can now redefine the upper limit for the strength of any potential interactions between dark matter and antimatter based on the levels of sensitivity we've managed to accomplish," explains Stefan Ulmer, spokesperson of the BASE Collaboration. ■

ANALYSIS OF REPAIR PROCESSES IN RADIATION-DAMAGED CELLS

These are future-oriented research results, combining most advanced physics and biology and at the same time demonstrating the great potential of the future accelerator center FAIR: Scientists at GSI have been able to observe the repair processes in human cells after radiation damage more directly and with higher resolution than ever before. For the radiation experiments at the accelerator facility on the GSI and FAIR campus in Darmstadt, high-energy ion beams, which are also characteristic of cosmic radiation in space, were used and combined with modern microscopy techniques. The investigations were carried out as part of the first stage of the FAIR experimental program, „FAIR Phase 0".



Mesurement setup for studies of cell cultures irradiated with heavy ions.

Using heavy ion beams it is possible to simultaneously generate simple and clustered DNA damage in the same cell and to investigate this damage in real time via „live cell imaging". The researchers were thus able to observe parallel how the same cell reacts to complex damages and to single damages.

The results of the measurements show differences in this damage response: The DNA repair proteins seem to be recruited faster to the clustered damage than to the individual DNA damage outside the ion track. On the other hand, the delayed repair there seems to be faster and less difficult. Thus, the results clearly demonstrate the impact of the quality of DNA lesion on the dynamics of early radiation response and repair and indicate that simple and clustered DNA damage should be treated separately when assessing radiation effects. A precise understanding of DNA repair mechanisms is of great importance, for example, for risk assessments during long-term space missions. ■

The fast and energy efficient supercomputer L-CSC uses efficient water cooling and customary GPUs.

GREEN SUPERCOMPUTER „MADE IN HESSEN“

By 2030, data centers could be responsible for 13 percent of worldwide power consumption. Already today, the waste heat from single large-scale data centers could be used to heat up to 10,000 households. An answer to this global challenge comes from Hessen, to be specific, it comes from Goethe University and GSI.

Both were recently granted a European patent for their concept for an energy-efficient cooling structure for large data centers. This patent now paves the way for the commercialization of the pioneering technology developed by Professor Volker Lindenstruth, Professor Horst Stöcker and Alexander Hauser of e3c. Together with parallel patents outside Europe, the invention can now be put to economic use throughout the world. The team has already received enquiries from various countries for the construction of such large data centres.

The data center is thus becoming an important export commodity “made in Hessen”. This success is also thanks to Innovectis, Goethe University’s own transfer agency, and its managing director Dr. Martin Raditsch, the driving force behind the invention’s commercialization, as well as the GSI departments Technology Transfer headed by Dr. Tobias Engert and Patents headed by Michael Geier. The successful commercialization of the patents is a perfect example of collaboration between a university and a major research facility in Hessen.

NDC Data Centers GmbH, a Munich-based company, has obtained the rights to market the green technology in data center construction projects around the globe and is thus also making a major contribution to the careful handling of our energy resources against the backdrop of global digitalization.

The basis for these activities is the visionary concept of a significantly optimized cooling system for large data centers with the highest possible level of energy efficiency, which was developed by Volker Lindenstruth, Professor for High-Performance Computing Architecture at Goethe University and former head of the Scientific IT Department at GSI. On the basis of his concept, large data centers and commercial IT systems can today be operated with up to 50 percent less primary energy consumption in comparison to conventional data centers.

The technology has been in use for years and is being continuously improved: The first data center of this type was Goethe University’s own, which was set up in the Infraserv industrial park. Another very large data center, the Green IT Cube, was built by the GSI Helmholtzzentrum in Darmstadt and financed from funds provided by the German federal government and the Federal State of Hessen via Helmholtz expansion investments. The concept enables the realization and particularly efficient operation of data centers for large-scale research facilities such as FAIR (Facility for Antiproton and Ion Research), which is currently being set up at GSI. Later, the Green IT Cube will be the central data center for FAIR, one of the largest projects worldwide in support of research. Moreover, the waste heat from the servers in the Green IT Cube is already being used today to heat a modern office and canteen building on the GSI campus.

Apart from the high energy savings associated with the use of this new technology, the construction of such data centers is also extraordinarily cost-efficient, thus minimizing procurement and operating costs: An expedient coupling of ecology and economy.

Lindenstruth’s supercomputers have received several awards for their energy-efficient concept in recent years. At the end of 2014, one of his computers ranked first place in the global listing of the most energy-efficient supercomputers, thanks to its greatly optimized computer architecture.

Professor Karlheinz Langanke, Research Director of GSI and FAIR, said: “The Green IT Cube high-performance computing center at the GSI Helmholtzzentrum is an outstanding example of how practical and usable know-how and developments evolve out of basic research. The Green IT Cube was developed for enormous volumes of measurement data from scientific research: It provides the highest computing capacities required and is at the same time extraordinarily energy-efficient and space-saving.” ■

COMpact

FAIR IS ELEVENTH CO-ORGANISER OF THE BIG SCIENCE BUSINESS FORUM 2020

The International Organising Committee of the Big Science Business Forum 2020 (BSBF2020) has accepted FAIR as the eleventh co-organising Big Science organisation. FAIR will send technical, scientific and administrative delegates to BSBF2020 in Granada from 6th to 9th October. BSBF2020 participants will get the chance to get in depth knowledge of FAIR's procurement plans and liaise with its technical representatives. Big Science Business Forum 2020 will be the second edition of the single one-stop shop for European companies and other stakeholders to learn about Europe's Big Science organisations' future investments and procurements worth over 38 million euros. Following the success of the first edition, which took place in 2018, the forum will again offer businesses the chance to learn about business opportunities in the coming years, within a wide range of business areas and technologies. ■

NEW INTERNATIONAL NUCLEAR ASTROPHYSICS RESEARCH NETWORK

The ExtreMe Matter Institute (EMMI) with its research groups at Technical University of Darmstadt and the GSI Helmholtzzentrum für Schwerionenforschung will participate in a new network of networks for nuclear astrophysics research. The US National Science Foundation (NSF) awarded a $2 million grant to the Joint Institute for Nuclear Astrophysics — Center for the Evolution of the Elements (JINA-CEE), led by Michigan State University (MSU), to create the new International Research Network for Nuclear Astrophysics (IReNA). IReNA is composed of seven universities as core institutions in the United States, and also includes 62 associated institutions in 17 countries. ■

LOOKING INTO THE FUTURE OF QUANTUM COMPUTING ACROSS INDUSTRIES

The first Applied Quantum Conference was hosted by a collaborative syndicate of large science-focused organizations based in Darmstadt: the Operations Centre of the European Space Agency (ESA/ESOC); GSI/FAIR; and the science and technology company Merck. Held in February 2020, it brought together very different sectors that are at the same time very similar in terms of the problems they face and are trying to solve.

The conference focus was to discuss the coming paradigm shift in quantum technology. More specifically, the event aimed to identify quantum solutions to current and future needs, connect communities and facilitate interactions to foster future productive collaborations and solutions. The conference attracted a panel of highly distinguished speakers from Merck, ESA/ESOC and GSI/FAIR. In addition, top universities presented the very latest progress from their labs, and a select group of startups and established international firms demonstrated products and results at the very cutting edge of this technology landscape.

Quantum mechanics in physics is fundamentally about how molecules, atoms, or sub-atomic particles behave. Over the years, such particles have been observed to act in ways which are highly unexpected and difficult to explain using the established laws of classical physics. As a result, there are currently close to 20 different philosophical interpretations of what quantum behavior is, all valid in their respective applications. Companies like Merck are interested in quantum behavior as it applies in an industrial context. This includes how it can be used to approach challenges in Performance Materials, Life Science and Healthcare.

"The first Applied Quantum Conference was extremely successful in bringing together experts for the application of quantum computing to many real-world challenges from different sectors. Exchanging the gained experiences showed several commonalities and unveiled the potential for common approaches to further increase the utilization of quantum computing. At GSI and the future international FAIR accelerator facility, which is currently under construction, we look forward to intensifying the existing collaboration with ESA and Merck in this and other fields," said Dr. Tobias Engert, co-organizer and head of the Technology Transfer of GSI and FAIR. ■

Overcoming traditional computational methods: quantum computing.

IMPRINT

Publisher and copyright: GSI Helmholtzzentrum für Schwerionenforschung GmbH | Facility for Antiproton and Ion Research in Europe GmbH, Planckstraße 1, 64291 Darmstadt

E-Mail: target@gsi.de

Published: August 2020

Editors: Ingo Peter (responsible), Jutta Leroudier, Berit Paflik, Carola Pomplun, Lena Weitz

Additional contributors: M. Block, C. E. Düllmann, M. Durante, T. Engert, C. Ewerz, P. Ghosh, T. Hahn, P. Spiller, J. Stroth, S. Utermann

Photos: CDC/ Alissa Eckert, MS; Dan Higgins, MAM - p. 1 b.; GSI - p. 1, 11 r., 18, 41 b.; T. Ernsting/HA Hessen Agentur - p. 2, 42; G. Otto - p. 3 r., 11 l., 12, 13, 14, 15 t., 17, 19, 20, 24 t., 25 t. r., t. l., 46 t. r., b. r., 47 t. r., m. r., b. r., 48 2nd f. l., t. m., m., b. m., t. r.; C. Grau - p. 5; A. Zschau - p. 6, 30, 40 t., 46 t. l., b. l., 47 t. l., m. l., b. l.; A. Rost - p. 7; Sandra Schwark - p. 8; L. Möller/GSI/FAIR - p. 9, 18; P. Raeder - p. 10; Private - p. 15 b., 48 t. l., 2nd f. b. l., b. l.; H. Welker - p. 16; CBM-Kollaboration - p. 21; J. Hosan - p. 22, 37; F. Ronneberger - p. 23; I. Peter - p. 24 b.; Universität Salerno - p. 25 b.;University of Warwick/M. Garlick/ESO - p. 26; B. Lübbe/Wilhelmshavener Zeitung - p. 28/29; J. Hosan/HA Hessen Agentur - p. 31, 35; X-ray: NASA/CXC/NCSU/M. Burkey et al., Optical: DSS - p. 32; L. von der Wense/LMU München - p. 34; Dana Berry, Sky Works Digital Inc - p. 38; P. Shlyaev/ESA - p. 39; NASA - p. 40 b.; M. Brice/CERN - p. 41 t.; FAIR/CDTI - p. 44 t.; NSCL - p. 44 b.; G. Altmann/Pixabay - p. 45; U. Dellmar - p. 48 b. m.; Benjamin/HD - p. 44 m. r.; UTMB Galveston - p. 44 b. r.

Layout: Bauer und Guse GmbH, C. Pomplun

Print: EK Print, In den Wingerten 25, 64291 Darmstadt

You would like to receive the target magazine regularly? The subscription is free of charge: www.gsi.de/target

GSI operates a unique large-scale accelerator. Researchers from around the world use this facility 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

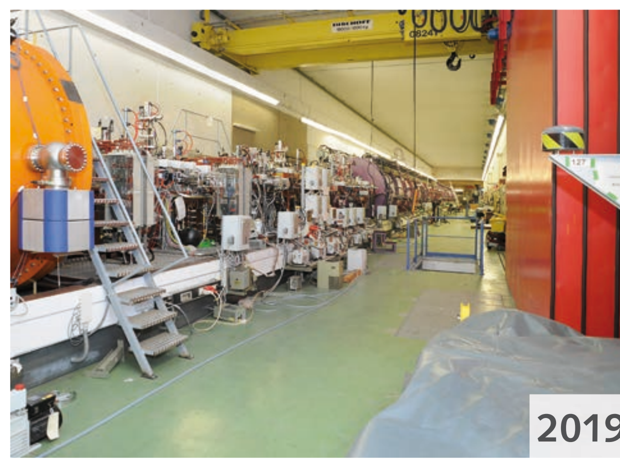
In the past — Today

Many activities in the anniversary year spanned the arc from history to the future at GSI and FAIR. Here you can see what it used to look like on campus and what had changed in comparison in the anniversary year.

The entrance area of the campus: During the construction of GSI still a building site, today completed and greened.

The main control room: The heart of the accelerator facility has been modernized and rebuilt several times.

View of the campus area: The guesthouse (back left) was completed in 1992. The office and canteen building (left) was built in 2016.



The linear accelerator UNILAC, which can bring all naturally occurring elements to speed, has been upgraded several times.

Not only the cars are newer, also the parking lot looks very different. The appearance will continue to change, a new car park is currently being built.

Further pictures of "In the past — Today" can be found on our website with an interactive photo slider allowing an overlay of the photos (scan QR code):
www.gsi.de/en/frueher-heute

The PANDA PhD Prize 2019 was awarded to **Dr. Silke Grieser** for her PhD thesis on cluster-jet targets, among others for the PANDA experiment at FAIR. The PANDA Collaboration annually honors a dissertation with the award.

Dr. Kristian König (m.) has been honored with the FAIR-GSI PhD Award 2019 for his PhD thesis on high-precision voltage measurements. The annual award is endowed with 1,000 euros by Pfeiffer Vacuum.

Professor Heinz-Jürgen Kluge, former head of the Atomic Physics division and Research Director, has been awarded the Robert Wichard-Pohl Prize 2020 by the German Physical Society (DPG) for contributions to physics with interdisciplinary significance. He received the award for his experiments and prescision measurements in atomic and nuclear physics as well as his teaching and societal commitment.

The radiation biologist **Professor Claudia Fournier** from the Biophysics Department of GSI was appointed by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) as an expert to a United Nations scientific committee meeting.

Prestigious European research grant awarded to GSI and FAIR: An „ERC Advanced Grant“ of the European Research Council (ERC) goes to the two GSI physicists **Professor Marco Durante** (r.) and **Professor Gabriel Martínez-Pinedo** (l.), as well as to the NUSTAR researcher **Professor Beatriz Jurado** (without photo). Read more on page 14.

This year, the Christoph Schmelzer Prize honored the two doctoral theses of **Dr. Sonja Schellhammer** (l.) from Helmholtz-Zentrum Dresden-Rossendorf and **Dr. Sebastian Meyer** (r.) from the Ludwig-Maximilians-University Munich. This prize is awarded annually by the Association for the Promotion of Tumor Therapy with Heavy Ions e.V. for outstanding master's and doctoral theses in the field of tumor therapy with ion beams.

The non-profit Giersch Foundation and the Helmholtz Graduate School „HGS-HIRe for FAIR“ recently awarded prizes for excellent doctoral theses and promising doctoral courses. For the fifth time, outstanding young researchers were honoured. This year, the **„Giersch Award for an Outstanding Doctoral Thesis“**, worth 6,000 euros each, was presented to six young researchers for their completed dissertations. Another 24 promising young researchers, currently in the doctoral phase at universities in the region, were awarded a **„Giersch Excellence Grant“** of 2,500 euros each

This year's FAIR-GENCO Young Scientist Award goes to **Dr. Clémentine Santamaria** from Lawrence Berkeley National Laboratory in Berkeley, USA, for her milestone achievements to answer long-standing questions of the evolution of shell structure far from stability and her striking expertise in both nuclear spectroscopy and nuclear reactions. The award is presented by the GSI Exotic Nuclei Community (GENCO) and is endowed with 1,000 Euros.

Professor Silvia Masciocchi, head of GSI's research department ALICE, has been elected as Chair of the ALICE Collaboration Board. The board is the highest body overseeing the ALICE collaboration. It considers all issues, policies, decisions and recommendations relevant to the construction, maintenance, operation and upgrading of the ALICE experiment at CERN, as well as any issues related to the analysis and publication of information or data taken during experiments with the ALICE set-up. GSI was involved in the construction and scientific program of ALICE from the start.

The head of the GSI Biophysics Research Department **Professor Marco Durante** has received the Martin Schneider Memorial Award. With this award, the University of Texas Medical Branch (UTMB) in Galveston annually honors scientists providing outstanding contributions in radiology or radiotherapy. It was the first time that the award honored a non-US scientist.