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FACILITY FOR ANTIPROTON AND ION RESEARCH

An international science centre in Europe for studying the
building blocks of matter and the evolution of the Universe



www.fair-center.org

A new facility for fundamental science

An international research laboratory is being built to explore the nature of matter in the Universe

The experiments

Basic science

Experiments studying exotic particles will explore fundamental processes which are thought to have happened in the early phases and still happen in the ongoing evolution of the Universe. These processes produced the basic constituents of matter and overall structure we see now.

- A range of experiments will be possible in which different forms of matter are compressed. The experiments will simulate conditions in the early Universe, in ultra-dense stars and at the cores of giant planets like Jupiter.
- Antiproton beams will create exotic particles to enable the study of the strong force. They will probe how the strong force accounts for the mass of everyday nuclear particles – protons and neutrons (nucleons).
- Beams of heavy ions such as uranium will be used to generate rare atomic nuclei that live for only fractions of a second, but which played a key role in the formation of elements in stars.
- FAIR will explore, in a unique way, the properties of fundamental particles and how they combine into more complex forms of matter under a wide range of astrophysical conditions. The experiments will be truly complementary to those carried out at other international high-energy facilities.

Over the past century, scientists have built up a deep understanding of the subatomic constituents of matter in the Universe and the fundamental forces binding them. More recently, they have developed compelling theories of how those building blocks came into being. Nevertheless, there are still significant gaps in our knowledge of the nature and evolution of matter on both a cosmic and a microscopic scale – and there are many questions to explore, for example:

- How did matter in the early Universe evolve and why does it look the way it does today?
- How does matter behave across the wide range of temperatures and pressures found in the past and present Universe?
- How does the strong force work, which binds the particles comprising atomic nuclei – and where do their masses come from?
- Where do the atomic elements come from?
- How does the electromagnetic force work, which binds atoms and molecules under extreme conditions?

A world vision

To answer these fascinating and crucial questions, a major new international laboratory, the Facility for Antiproton and Ion Research, FAIR, is being constructed in Darmstadt, Germany. This is a highly sophisticated accelerator complex which will provide high-energy, precisely-tailored beams of antiprotons (the 'antimatter' versions of protons with opposite electric charge) and many kinds of ions (atoms with most of their electrons stripped away) – *at unprecedented quality and intensities*. These charged particle beams will then be accelerated and employed to create new, often highly exotic particles in a series of parallel experimental programmes.

Applied science

The scientific knowledge and technology acquired will also have wider economic and social benefits, and will underpin a variety of applications. For example, an understanding of phenomena induced by fast-moving heavy ions is important in several areas:

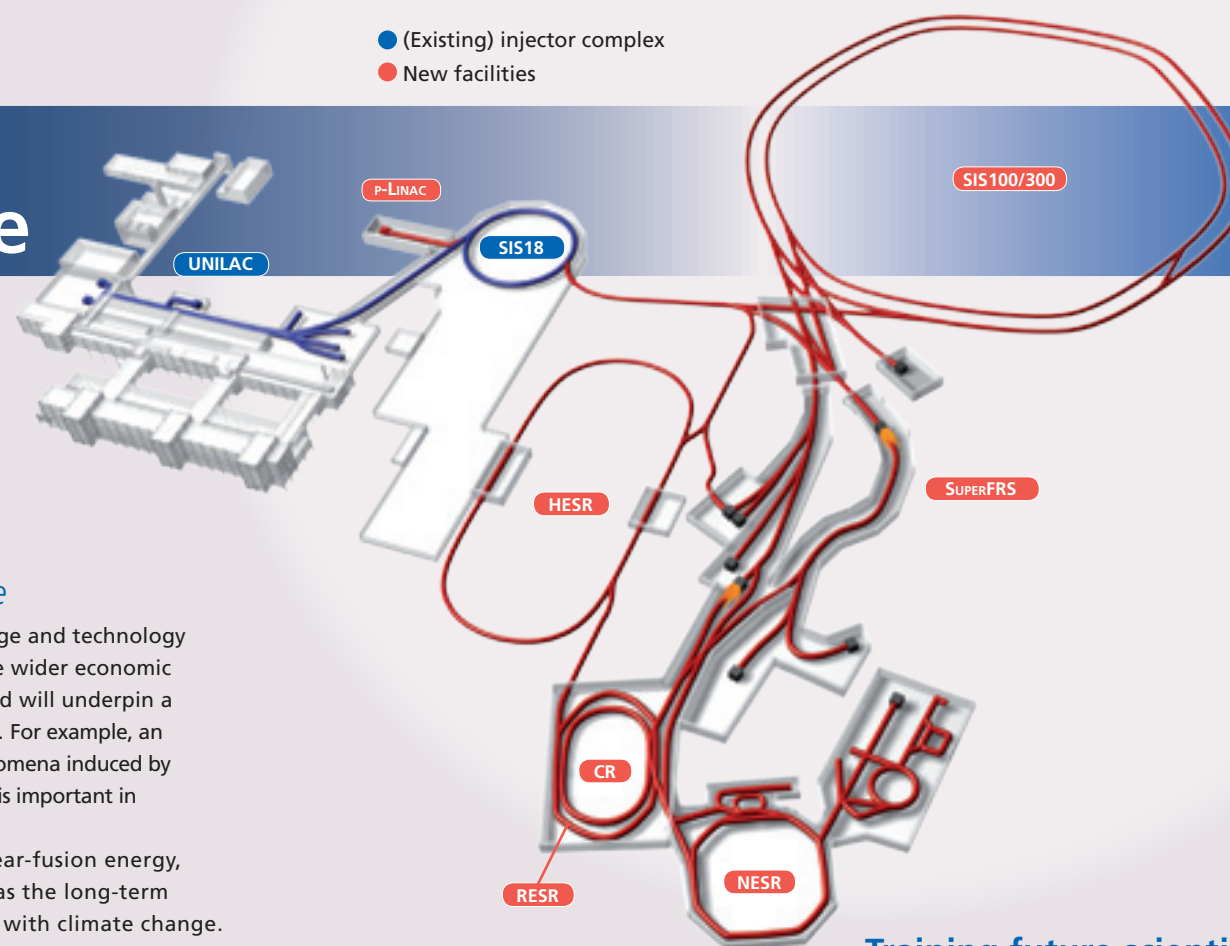
- In developing nuclear-fusion energy, regarded by many as the long-term solution to dealing with climate change. Experiments will use intense pulsed ion beams, combined with a laser, to explore a technology called inertial confinement fusion.
- In studies of the high-radiation conditions found in space, which must be taken into account in future manned space missions.
- In industrial applications of plasmas for processing materials.
- In new techniques for cancer therapy.

The accelerator complex

In 2006, a large international research community – 2500 scientists and engineers from 44 countries – compiled the *FAIR Baseline Technical Report* detailing the layout and components of the accelerator system needed, and the types of experiments to be carried out. A key feature is a highly sophisticated and cost-effective accelerator layout that will allow the parallel and versatile production of an unprecedented range of particle beams.

The heart of FAIR comprises two large accelerator rings (a double synchrotron) to accelerate ions – from hydrogen ions (protons) to those of the heaviest naturally occurring element, uranium.

- (Existing) injector complex
- New facilities



The high-energy proton and ion beams will be used to create secondary beams of antiprotons and also of stable and unstable (radioactive) ions. The secondary beams may either be used directly or diverted to a complex arrangement of further rings for groundbreaking experiments.

The operation of the sophisticated accelerator complex will allow the simultaneous execution of several experiments from different research programmes.

New technology challenges

The demanding experiments to be carried out at FAIR require considerable technological innovation:

- New superconducting magnet designs to steer highest possible intensities of particles;
- Novel methods of accurately controlling the beam energies;
- Large detectors to trace the variety of particles generated in experiments.
- The extremely high data rate will require new hard- and software solutions such as Grid-type technologies for processing, accessing and storing the results.

Training future scientists and engineers

The innovative programmes at FAIR will provide the very best young scientists and engineers worldwide with unparalleled opportunities to participate in experiments which exploit cutting-edge technology, and which will make major discoveries. Working on FAIR experiments will give them a wide variety of transferrable, interdisciplinary skills. In this way, FAIR will contribute to creating a truly global scientific workforce.

Bringing together scientific communities

FAIR will be a multidisciplinary research centre, and has been included in the ESFRI Road Map (European Strategy Forum on Research Infrastructures), reinforcing the project's unique role as a world-class scientific facility. Member states will benefit enormously from the collaborative and creative spirit engendered through the internationally-conceived research programmes. There will also be built-in opportunities to contribute to and profit from new technologies.

International ownership

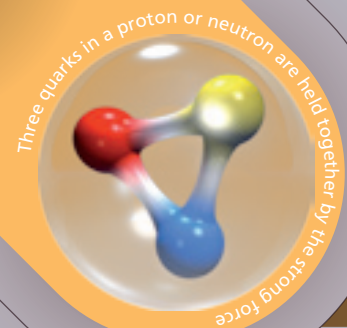
FAIR was approved by a German Scientific Advisory Committee in 2003. The German Federal Government, together with the State of Hessen, will provide up to threequarters of more than 1 billion € required for construction, with the remainder being funded internationally. Fourteen countries – Austria, China, Finland, France, Germany, Greece, India, Italy, Poland, Romania, Russia, Spain, Sweden and the UK – have signed a Memorandum of Understanding; Slovenia made a declaration for their contribution end of 2007. The countries will contribute both in kind, by supplying facility components, and in cash.

For the past 6 years, an International Steering Committee (ISC), composed of representatives of the signatory countries, has provided strategic guidance and political decision-making to the project. It is supported by working groups covering scientific and technical, and administrative and financial issues. Once negotiations are completed, signatory States will become formal shareholders of FAIR GmbH and the ISC will be superseded by a governing Council.

Schedule

- Project start – **2007**
- First stage ready for experiments – **2016**
- Entire facility completed – **2018**
- Number of scientists to work at FAIR – **3000**
- Operation costs – **120 M€/year**





BASIC SCIENCE AT FAIR

Structure of matter & the evolution of the Cosmos

Why does matter look and behave the way it does?

All of the matter we can see around us – people, the Earth, the planets, stars and galaxies – are made up of atomic nuclei. These in turn consist of combinations of positively charged protons and neutral neutrons. The number of protons in a nucleus characterises a particular element in the Periodic Table, while the number of neutrons indicates a particular isotope of an element. The lightest atom, hydrogen, has a nucleus of just one proton while its heavier isotope deuterium has an additional neutron. The heaviest stable atom naturally found on Earth is uranium-238 with 92 protons and 146 neutrons.

The origin of elements

Up to 7000 types of nuclei are possible although most of them are rather unstable, especially those with high proportions of either protons or neutrons. Nevertheless, their complex and sometimes unusual structures can show fascinating behaviour, which throws light on how the forces that hold nuclei together work.

Although existing for only a fleeting moment, some of these rare isotopes play a critical role in the nuclear reactions that build up the elements in stars. While the lighter elements are formed during a star's lifetime, the heavier elements beyond iron in the Periodic Table are thought to be created mostly in the death-throes of supermassive stars when they explode as supernovae. The elements are then spread as dust across interstellar space and eventually become the building blocks for the next generation of stars, planets – and life.

One way to test these ideas is to make and study unstable isotopes in the laboratory. FAIR will uniquely produce beams of as yet unknown heavy nuclei, measuring their masses, modes of decay and other properties.

What holds nuclei together?

Protons and neutrons themselves are made up of elementary particles called up quarks and down quarks; and generally all particles composed of quarks are called hadrons. There are four other kinds of quarks – strange, charm, top and bottom – which can form more exotic kinds of hadrons. Quarks are always tightly bound together by the so-called strong force via particles called gluons which also interact with each other.

Antiproton experiments will search for unusual hadrons containing both, strange and charm quarks, and even particles made of just gluons (glueballs), which will act as sensitive probes of the theory of the strong force (quantum chromodynamics, QCD).

Further studies of the decays of these

composite particles will also tell us about events in the early Universe that led to the array of particles and fundamental forces existing now. For example, the mirror-image, antimatter versions of particles – with opposite charge and spin (or handedness) were created in - hitherto assumed - equal amounts with ordinary matter. However, they may have behaved slightly differently, explaining why there is little antimatter left in the Universe today.

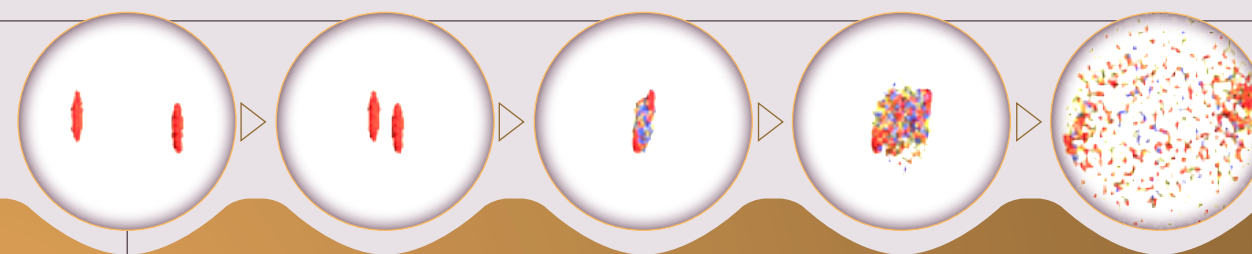
Other aspects of quark behaviour, which kicked in as the early Universe cooled, may account for the bizarre fact that the proton is 50 times heavier than the combined mass of its constituent quarks and gluons. Antiproton experiments will be able to test these ideas.

The high-pressure Universe

Fractions of a second after the Big Bang, the Universe was so hot and dense that quarks and gluons existed as a soup of unconfined particles – a 'quark-gluon plasma'. Quarks then irrevocably lost their freedom, becoming bound into protons and neutrons. Collisions between beams of heavy ions such as uranium nuclei will allow researchers to recreate these conditions in the laboratory and investigate the dramatic explosive processes involved.

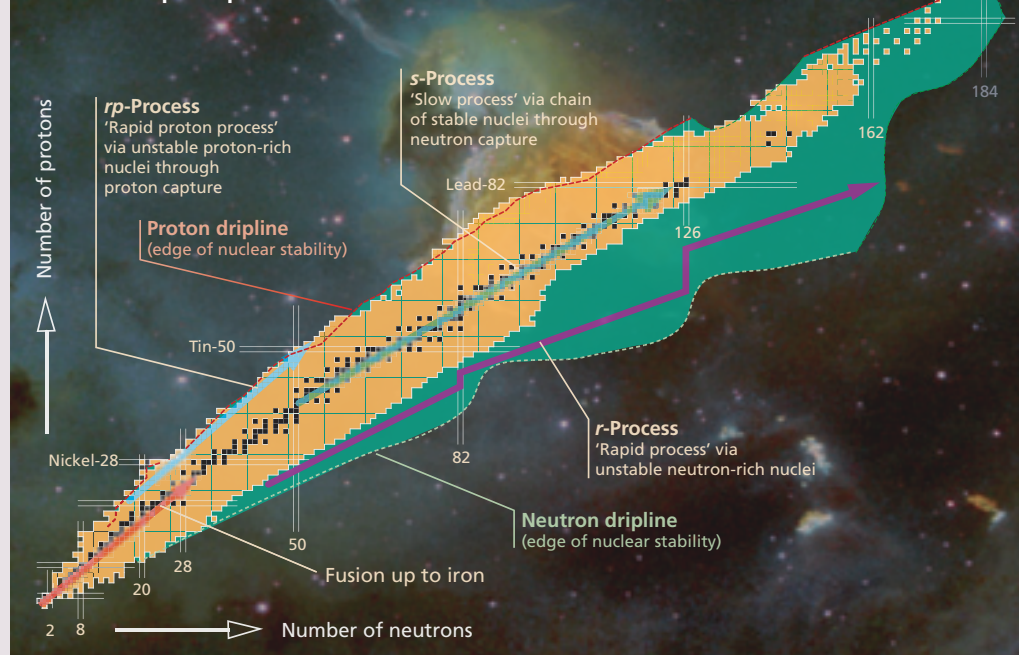
A range of such experiments will explore the behaviour of hadrons under extremes of pressure – as is found in the collapsed stellar cores left behind by supernova explosions where the nuclei have 'dissolved' into neutrons and other hadrons.

Experiments bombarding a variety of solid materials with intense pulses of heavy ions and laser beams will investigate matter at medium pressures and temperatures when it is still too hot and dense to form atoms. The nuclei and electrons then exist as a charged gas, called plasma. These conditions exist in the centres of stars and in giant gas planets like Jupiter where – at its core – the



The high-energy collision of two uranium nuclei produces dense nuclear matter, which immediately decays into a variety of new hadronic particles (H. Weber / J. W. Goethe University, Frankfurt)

The landscape of possible nuclei



hydrogen has been compressed by gravity into a solid, metal-like state.

In this way, FAIR will be able to develop a complete picture (a phase diagram) of the behaviour of matter across extremes of temperatures, densities and pressures. This will comprise the densest and hottest conditions that existed in the very early Universe and extend down to the cool, less dense environment of neutron stars, brown dwarfs (stars not large enough to have started nuclear burning) and large planets.

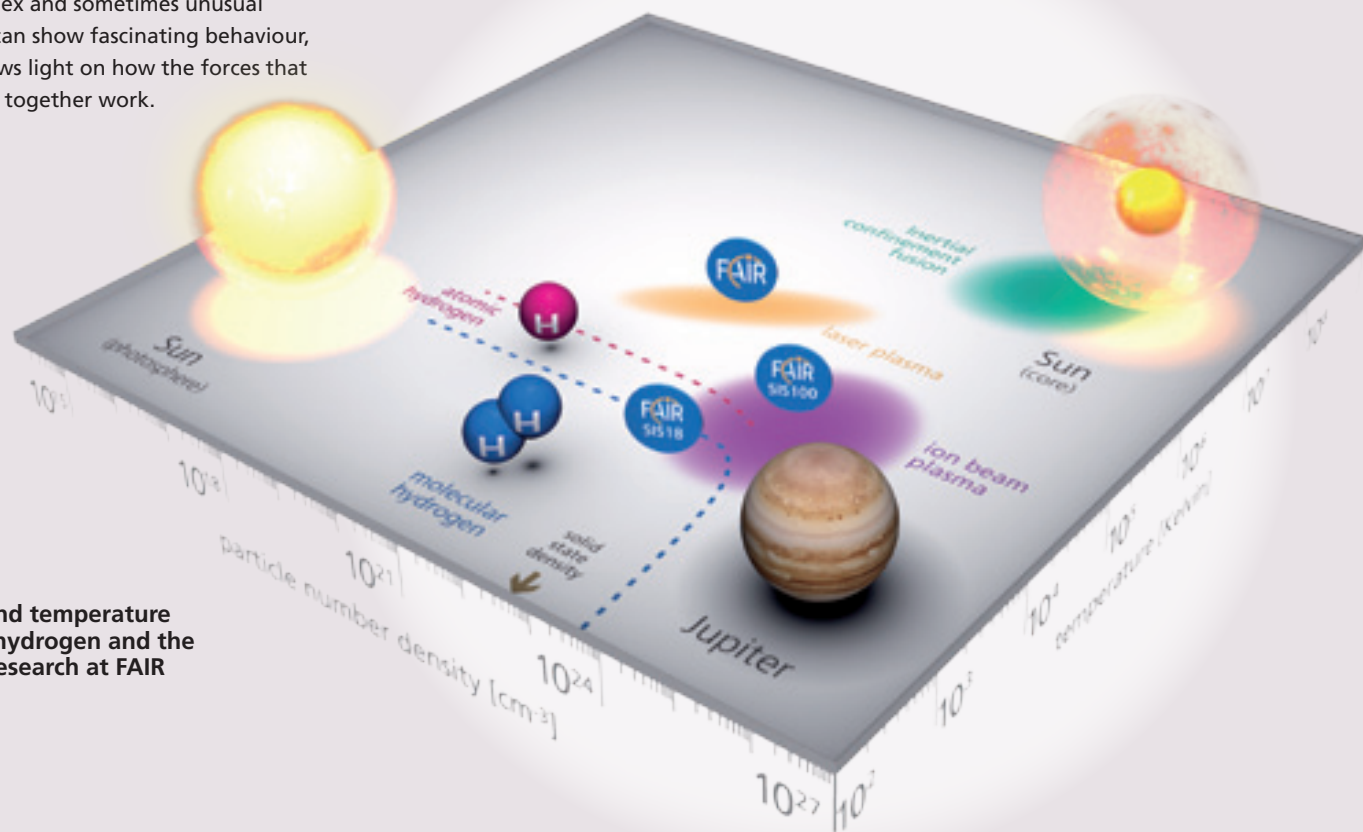
Naked ions and antimatter

Charged particles such as nuclei and electrons feel the electromagnetic interaction – the force that holds them together in atoms, and is responsible for chemistry and for life. Highly-charged heavy ions that have been stripped of practically all their electrons offer the possibility of testing the theory describing the interaction (quantum electrodynamics, QED) at very high electromagnetic fields. Ions will be slowed down and caught in special 'traps' for precision study.

The unique properties of very slow antiprotons offer opportunities to study QED through interactions with atoms and molecules. Antiprotons can also be combined with positrons to create antihydrogen, the only atom of antimatter ever made. Antihydrogen is the mirror version of normal hydrogen. It provides a precise probe of the fundamental symmetries of particles and forces – thus giving a deeper understanding of Nature.

FAIR's scientific programme will thus contribute to our basic understanding of matter in all its forms under a wide range of conditions. It will also illuminate how matter evolved on a cosmic scale from the beginning of time, through the nuclear cores of stars, to the levels of atomic complexity seen in our Solar System.

Density and temperature states of hydrogen and the areas of research at FAIR





THE PROPOSALS

The FAIR accelerator complex

The facility has been designed to accommodate as many experiments as possible in the most efficient and cost-effective way, taking advantage of a series of novel technologies



The Universal Linear Accelerator (UNILAC) at GSI

The FAIR Facility consists of a carefully designed configuration of interlinked machines for accelerating and storing high-quality particle beams, and creating new particles by colliding or bombarding the beams on targets for a wide range of experiments. The experimental accelerators are equipped with state-of-the-art detectors and various instrument set-ups to measure the characteristics of new, exotic particles that may exist for only a brief time.

Concept and layout

The facility is centred around two large accelerator rings (SIS100 and SIS300), 1100 metres in circumference and built one above the other in a subterranean tunnel. These machines, called synchrotrons, utilise a combination of electric and magnetic fields to accelerate and bend the path of charged particles so that they gain energy while circulating around the rings. Accelerators, UNILAC and SIS18, will pre-accelerate the ions before they are injected into the first ring SIS100. A new proton linear accelerator will be built to inject high intensity proton beams.

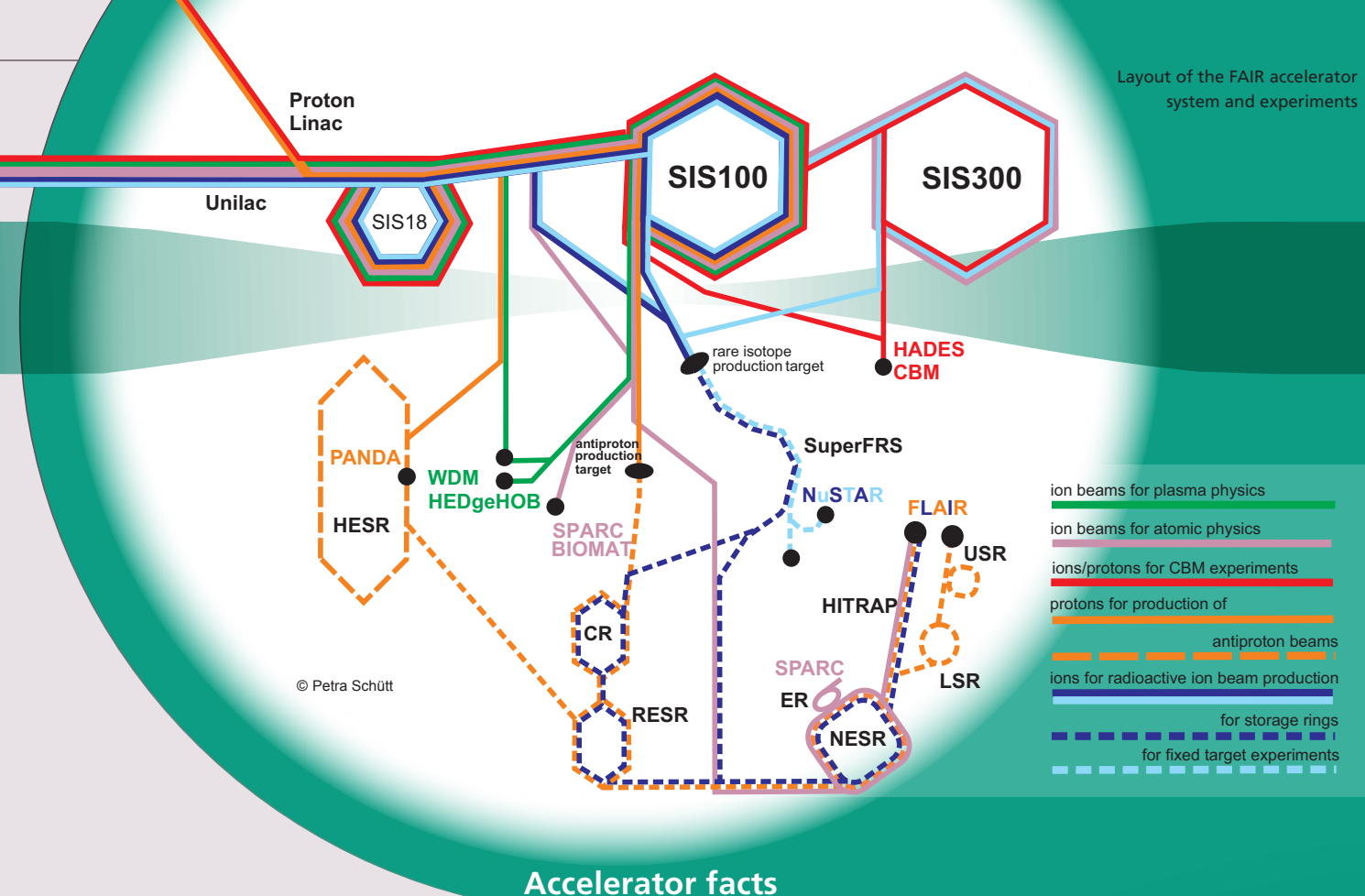
The goal of SIS100 is to generate intense pulses of ions for the conversion to secondary beams of rare nuclei and also for the conversion of proton beams into antiprotons. Accelerated uranium ions stripped off their electrons are also fed into SIS300 where their energy is increased 15-fold for experiments involving collisions between heavy nuclei.

Collector, storage and cooling rings

Coupled to the SIS100/300 rings is a complex system of further rings into which the beams are guided, and then accelerated, stored and refined for specific experiments. The operation of FAIR will be uniquely versatile in that up to five research programmes with five different particle beams can be carried out at the same time. This will be achieved by coordinating beam operation in both the synchrotrons and adjacent storage and accelerator rings. In this way, each experiment can make maximum use of the highest available beam intensity.

The technical challenges

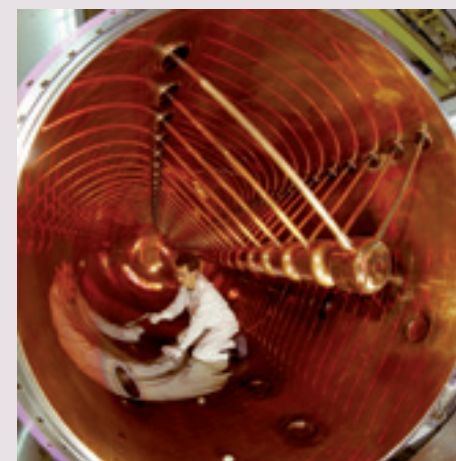
- **The intensity challenge**
Fast cycling SIS100/300 magnets will push present limitations of technology in superconductivity and compact, powerful radiofrequency devices will produce very short, intense pulses of particles.
- **The radiation challenge**
The intense particle beams will necessitate the development of new types of carefully selected materials and new designs for the accelerator and detector components to withstand the radiation generated inside them.
- **The acceleration challenge**
Sophisticated devices to generate high gradient, variable radiofrequency fields at extremely high power are needed for the rapid acceleration of the very heavy uranium-238 ions (which will have lost 28 electrons, U^{28+}).
- **The ultra-high vacuum challenge**
Novel materials and accelerator concepts will ensure ultra-high vacuum (10^{-12} mbar) conditions in the presence of intense ion beams in the accelerator vacuum tubes.



Layout of the FAIR accelerator system and experiments

Accelerator facts

- Double synchrotron SIS100/300 – circumference 1100 metres
- 500 billion uranium ions per pulse for SIS100 at 1 GeV per nucleon (uranium ions contain 238 nucleons!), and 40 thousand billion protons at 29 GeV – compressed to short bunch lengths of tens of nanoseconds
- Will deliver 100 billion heavy ions a second
- Antiproton beams will be available at energies of 1 to 15 GeV (One GeV, or gigaelectronvolt, is a billion electronvolts)



Inside the UNILAC showing the central beam pipe



Electron cooler at GSI

Preparing the beams

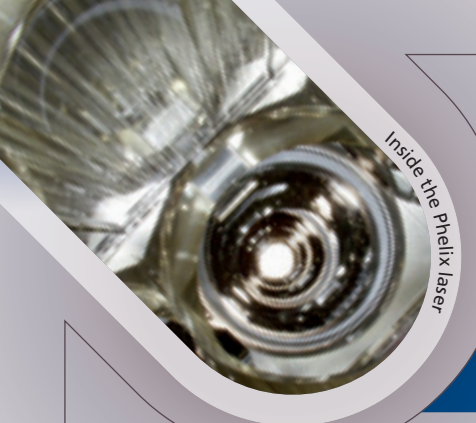
An important requirement for precision experiments is that the secondary beams acquire a well-defined energy with all the particles travelling in the same direction and speed – so-called beam cooling.

FAIR will employ two kinds of cooling:

- Electron cooling, in which the ions are coerced into slowing down to the same speed by periodically being jostled by a parallel beam of electrons of precisely defined velocity;
- Stochastic cooling, in which a probe samples the speed of the ions utilizing pulses of electromagnetic energy for correction, are successively adjusting the particle speed until it is uniform.

The beams are cooled and modified for experiments in four further rings:

- **The Collector Ring (CR)** in which secondary ion beams and antiprotons undergo stochastic cooling. At the same time, the masses of short-lived nuclei can be measured;
- **The Recycled Experimental Storage Ring (RESR)** in which antiprotons are accumulated to produce more intense beams after they have been cooled in the CR. Short-lived nuclei are also decelerated;
- **The New Experimental Storage Ring (NESR)** for experiments with exotic ions and antiprotons. The NESR is equipped with electron and stochastic cooling for a variety of experiments including very low-energy experiments;
- **The High-Energy Storage Ring (HESR)** in which antiproton beams are prepared at energies up to 14.5 GeV using electron and stochastic cooling for experiments.



THE EXPERIMENTS

An international research programme

About 3000 researchers from around the world will carry out experiments which aim to understand the fundamental structure of matter and how the Universe evolved from its primordial state into what we see today

Working in international collaborations, scientists will explore exotic forms of matter – from particles that have not existed naturally for billions of years to unusual nuclei that survive only briefly in the dense hearts of exploding stars. Experiments will also use the ion beams generated to investigate the application of new technologies.



NuSTAR Collaboration

Nuclear Structure, Astrophysics and Reactions with Rare Isotope Beams – NuSTAR

One of the main objectives of FAIR is to create secondary beams of highly unstable nuclei for probing nuclear structure and the origin of the elements in the Universe. These are produced by passing the primary heavy-ion beam through a target. The ions break up into other nuclei which are immediately separated in a magnetic separator – the SuperFRS. The process delivers beams of all kinds of isotopes down to the shortest-lived, in high purity, with a wide range of energies, and in timed pulses tailored for experiments. For the first time, the heaviest unstable nuclei will be produced in large enough quantities for precision studies.

They are then directed to three experimental areas:

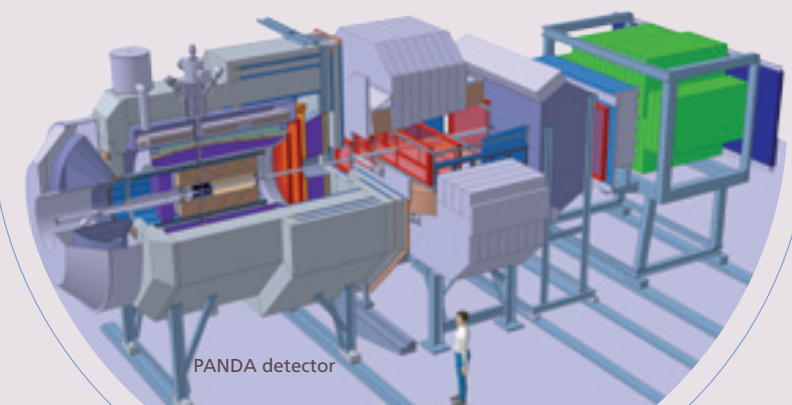
- The high-energy branch where reactions of high-energy heavy nuclei relevant to astrophysical processes will be investigated;
- The low-energy branch where properties of nuclei such as decay modes and energy levels can be explored using low-energy beams;
- The ring branch where exotic nuclei are collected, cooled and stored in the FAIR ring system (CR-RESR-NESR). There, experiments will measure the masses and lifetimes of unknown nuclei or probe their structure using an electron or antiproton beam.



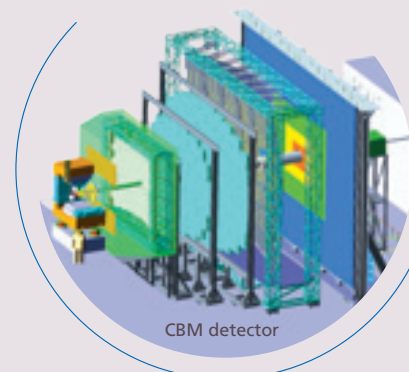
PANDA Collaboration

AntiProton ANnihilation at DArmstadt – PANDA

Antiproton beams of unprecedented intensity and quality will be produced at FAIR. They are made by bombarding a target with protons, cooled in the two cooler rings (CR and RESR) and then stored in the High Energy Storage Ring (HESR). There, they interact with a proton target (hydrogen) to produce a variety of composite particles containing strange and charm quarks. In particular, one particle consisting of a charm quark and antiquark – charmonium – will probe aspects of the strong force not investigated before. The interaction region is enclosed by the multipurpose PANDA detector. This is composed of layers of different kinds of detecting devices to track the paths and measure the energies of particles produced by the antiproton-target collisions.



PANDA detector

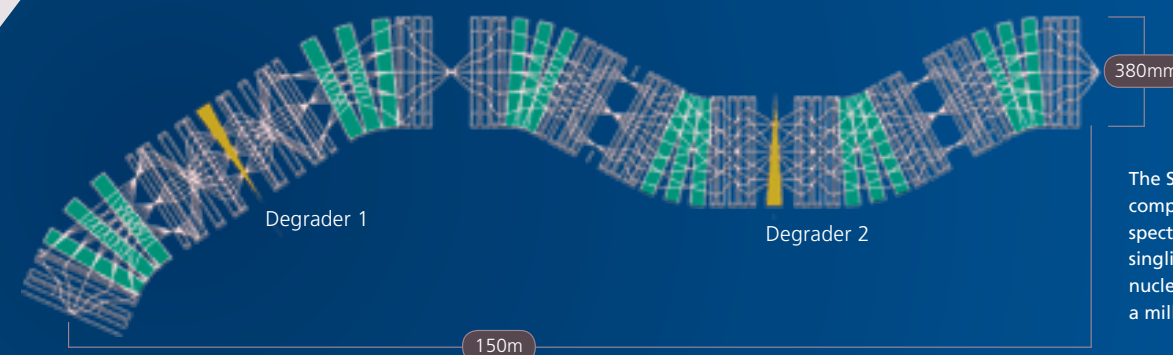


CBM detector

Compressed Baryonic Matter – CBM

High-energy collisions between heavy nuclei will be carried out at FAIR to investigate how nuclear matter behaves over a range of high pressures typically found in supernova explosions and neutron stars. At very high densities, we expect the constituents of atomic nuclei, the protons and neutrons, to ‘melt’ into a quark-gluon plasma. This phase transition to such a new state shall be observable in violent collisions between nuclei at energies provided by the FAIR accelerators. A universal detection system will identify the particles that are created in the dense reaction zone, for example, particles containing strange and charm quarks which serve as sensitive diagnostic probes. The experiments at FAIR will complement studies of the more primordial hot quark-gluon plasma state being carried out with the Large Hadron Collider (LHC) at CERN in Geneva.

SuperFRS Superconducting Fragment Separator



The SuperFRS – a highly complex magnetic spectrometer capable of singling out one specific nucleus from a swarm of a million million nuclei



HEDgeHob Collaboration

High Energy Density generated Heavy Ion-Beams – HEDgeHOB, and Warm Dense Matter – WDM

FAIR’s powerful beam pulses will enable the creation of large volumes of dense plasma with energy densities similar to those found in stars and giant planets. To achieve this, the beams can be specially ‘shaped’ to optimise heating and/or compressing of the samples by the ion beams. For example, a hollow ion beam with a ring-shaped focal area will be used to heat up the metal shell encapsulating a pellet of hydrogen or water ice so that it expands and compresses the pellet without heating it up significantly. Researchers will thus be able to study a high-density plasma but at low temperatures. The experiments will further benefit from the unique possibility to perform in situ high-energy proton radiography on dense plasmas created by the heavy ion beam and the diagnostic possibilities of a high-energy petawatt laser facility.



SPARC Collaboration

Stored Particle Atomic Physics Research Collaboration – SPARC

The physics of extremely strong electromagnetic fields is in the focus of the SPARC collaboration. For this purpose, high precision experiments on the heaviest ions will be performed in order to gain detailed insights into their electronic structure and internal dynamics. The results of these experiments allow for unique conclusions on the validity of the fundamental theory of the interaction between matter and light in the strong field limit. The experiments will take advantage of virtually all the key features of FAIR – high-intensity beams of stable and unstable ions in various charge states and at velocities ranging from zero to close to the velocity of light. In addition, the SPARC collaboration will contribute to the answer of a longstanding question, namely the understanding of the interaction of very heavy ions with various forms of matter. The experiments will comprise not only usual but also exceptional targets such as ultra-cold electrons, atoms, and molecules or clusters which can even be exposed to intense light fields produced by high-energy lasers.

Facility for Low Energy Antiproton Ion Research – FLAIR

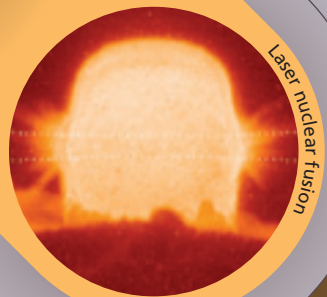
Low-energy antiprotons will be prepared in a dedicated experimental area by decelerating the antiproton beam in two consecutive storage rings. The antiprotons will then be stored and investigated in the rings and in traps, or be extracted to experimental set-ups. The research topics of the planned experiments include fundamental symmetries, interactions between matter and antimatter and the physics of antimatter atoms. With up to 100 times higher intensities, this work on antihydrogen will follow up on the ground-breaking research carried out at CERN.

High-energy irradiation facility for BIOPhysics and MATerials Research – BIOMAT

Heavy ion beams from SIS18 and SIS100 will be employed in a multi-purpose facility for studying high-energy radiation effects on biological systems and materials under a variety of conditions. BIOMAT will share the high-energy beamline and experimental area with the SPARC Collaboration.



CBM Collaboration

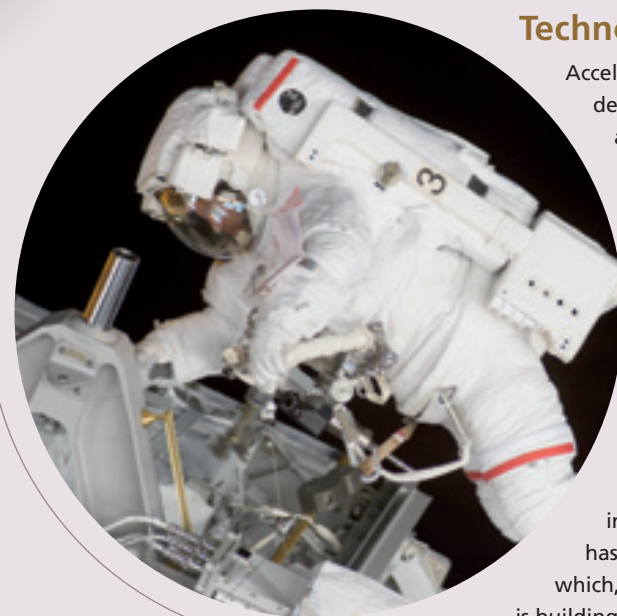


Laser nuclear fusion

INDUSTRY, TRAINING & PUBLIC OUTREACH

FAIR and society

As an international laboratory, FAIR is in a strong position to make a powerful contribution to society



•Radiation testing for space applications

When in space, spacecraft are exposed to cosmic radiation in the form of high-energy ions, which can damage a satellite's electronic hardware and therefore its operation. The radiation also poses a serious hazard to astronauts – especially over long periods of exposure, as during the proposed manned missions to Mars. So far, only limited data are available on the radiobiological effects.

A dedicated irradiation facility, BIOMAT (High-Energy Irradiation Facility for Biophysics and Materials Research), will be installed on FAIR's high-energy beamline. In a collaborative programme with the European Space Agency (ESA), heavy ion beams will be used to simulate cosmic rays in experiments testing the effectiveness of materials used in radiation shielding, and for evaluating radiation damage to living cells.

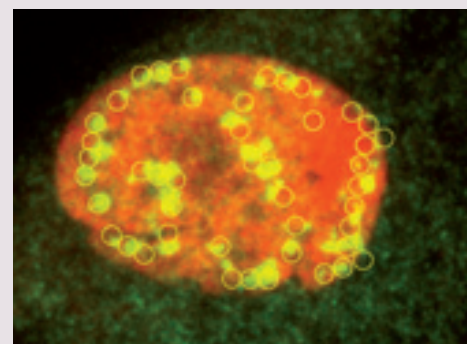
Another set of experiments carried out at high pressure will simulate radioactive decay processes in the Earth's mantle, and probe the effects of high-energy ions on materials under these extreme conditions.

Applied science

•Nuclear fusion

In the context of countering global warming, nuclear fusion (of hydrogen isotopes to give helium plus energy) is now a significant candidate for future energy generation. One approach is to fire intense beams of heavy ions at a pellet containing deuterium and tritium. The resulting compression and intense heating (inertial confinement) must be high enough to ignite the fusion reaction.

The HEDgeHOB and WDM collaborations will study the basic processes of inertial confinement fusion. They will compress and heat target-pellet components and materials using pulses of heavy ions generated by the SIS18 and the SIS100 accelerators. The PHELIX petawatt laser will diagnose the effects just nanoseconds later.



Radiation-damaged cell

Technology transfer

Accelerators, once exotic tools developed through basic science, are now used routinely in industry and medicine.

Brilliantly innovative ion-beam radiotherapy for treating difficult tumours was first developed and piloted at GSI – one of the driving forces behind FAIR. GSI built the first ion-therapy centre using three-dimensional scanning technology at the Radiological University Hospital in Heidelberg. The technology has now been licensed to Siemens which, following medical certification, is building dedicated radiotherapy facilities in Germany, and later worldwide, to treat cancer patients.

•Rapidly-cycling superconducting magnets

Many of the tough technical challenges that FAIR has to address will also result in innovative solutions that can be exploited elsewhere. Of particular interest are the rapidly-cycling superconducting magnets designed to generate the very intense ion pulses. The magnets will offer a cheaper way to achieve high-intensity particle beams in other accelerator experiments around the world. For example, the world's most powerful high-energy machine, the LHC, may be upgraded in a few years to produce even higher intensities of particle beams; FAIR's superconducting magnet technology may offer an efficient route to this goal.

Closer to everyday life, the same technology could be applied to generating alternating current for the electricity industry in a much more economical way.



GSI pioneered ion tumour therapy



•High-speed electronics

The data from FAIR will be generated at 10 times the rate expected from the LHC experiments. FAIR scientists are working on new ultra-fast electronic systems for capturing and identifying significant experimental events, which again will feed into other future high-energy projects.

•Radiation-hard chips

The electronics used to control the FAIR accelerators will have to withstand the extreme radiation environments created by the intense beams. Radiation-resistant devices will have to be developed that may find use in other fields such as nuclear power stations or in spacecraft.

world-class researchers working in a highly creative international atmosphere. Students will have the opportunity to work in all research areas, participating in instrument development during the construction phase – and in experiments right at the frontiers of discovery once FAIR is commissioned. FAIR will continue and enhance GSI's summer training programmes for students working with the research teams.

The FAIR community already comprises several hundred university research groups. However, a more ambitious mode of international collaboration is being set up. New FAIR satellite centres such as the FAIR Russia Research Centre (FRRC) have already been inaugurated in countries with a complex science-community structure, to allow broader participation in FAIR. There, students will have an opportunity to work on experimental data, while benefiting from FAIR expertise. The best students will be given grants to enable them to visit the Facility more easily.

Education

The ground-breaking work pursued at FAIR will help to stimulate young people to take up and continue with science as a career. The existing GSI 'pupils' laboratory', which gives more than 1400 school students a year the opportunity to carry out experiments relevant to high-energy and nuclear physics research, will be extended to accommodate twice as many pupils, particularly from other countries, and also across a wider age-group.

Outreach

In order to form a responsible society with a rich, knowledge-based culture, it is vital that the public understands and appreciates the exciting advances being made in fundamental science. FAIR will continue GSI's outreach activities in producing materials for the press and in organising public lectures, exhibitions and other regular events such as 'Open House', when thousands of visitors are invited in to tour the Facility.

Training top scientists

One of the key roles of FAIR will be as an incubator for the best scientists of all disciplines including physicists, chemists, materials scientists and engineers. They will be able to take advantage of tutelage from



Participants of the summer student programme at GSI