**FAIR - An International Facility for Antiproton and Ion Research**

FAIR is a new, unique international accelerator facility for the research with antiprotons and ions. It is ready to be built within the coming years near Darmstadt in Hesse, Germany. The major part of the budget will be provided by the Federal Republic of Germany, together with the State of Hesse. Other fractions will be funded by international partners from Europe and overseas.

The new facility, where various physics programs can be operated in parallel, will offer outstanding research opportunities and discovery potential for about 3000 scientists from about **50 countries**. In the course of the coming decades the experiments will reveal consolidated findings about so far unknown states of matter and still missing information about the evolution of the Universe 13.8 billion years ago.

# CBM - The Compressed Baryonic Matter experiment





The Compressed Baryonic Matter (CBM) experiment will be one of the major scientific pillars of the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt. The goal of the CBM research program is to explore the QCD phase diagram in the region of high baryon densities using high-energy nucleus-nucleus collisions. This includes the study of the equation-of-state of nuclear matter at high densities, and the search for the deconfinement and chiral phase transitions. The CBM detector is designed to measure both bulk observables with large acceptance and rare diagnostic probes such as charmed particles and vector mesons decaying into lepton pairs.

# FLAIR - Facility for Low-Energy Antiproton and Ion Research

* high-brightness high-intensity low-energy antiproton beams
* **cooled** beams down to **300 keV** in LSR
* **electrostatic** storage ring (USR): atomic collision experiments with internal targets, deceleration to **20 keV**
* HITRAP for efficient deceleration of antiprotons from 4 MeV to **rest** and extraction from a cooler trap at **keV** energies
* **slow** and **fast** extraction from LSR and USR
* rings will also be used for **highly charged ions**, (low-energy cave AP, HITRAP)
[***SPARC collaboration***](http://www.gsi.de/en/work/forschung/appa_pni_gesundheit/atomic_physics/research/ap_und_fair/sparc.htm)

**HEDgeHOB - High Energy Density Matter generated by Heavy Ion Beams**

In the environment that we are used to, matter occurs predominantly in the solid, liquid or gaseous phase. However in the universe at large, the situation is quite different. Most of the matter in the universe exists as Dark Matter or as Dark Energy and we know very little about it yet. The small fraction of visible matter exists predominantly either as hot dense plasma in the interior of stars or in stellar atmospheres, or as hot plasma of very low density in interstellar space. Therefore plasma is viewed as the fourth state of matter, following the idea that as heat is added to a solid, it undergoes a phase transition to a liquid. If more heat is added the phase transition to a gas occurs. The addition of still more energy leads to a regime, where the thermal energy of the atoms or molecules forming the gas is so large, that the electrostatic forces which ordinarily bind the electrons to the atomic nucleus are overcome. The system then consists of a mixture of electrically charged particles like ions and electrons and neutral particles as well. In this situation, the long-range Coulomb force is the factor that determines the statistical properties of the sample. Plasmas occur naturally only as a transient phenomenon in lightning or in the aurora. The practical application of man made plasmas is very extensive and ranges from material modification, surface cleaning, and micro fabrication of electronic components to the future prospects of energy production in fusion plasmas.

Only very little is known about the bulk properties of matter in high energy density states. It is therefore an interesting field with promising applications to astrophysics, plasma physics and material sciences. As soon as we will be able to investigate high energy density samples under reproducible conditions in the laboratory with high repetition rate, we can expect a rapid progress in this field. Traditional methods to generate high energy density states are based on dynamic shock compression. Chemical explosions, high current Z-pinches, high power lasers and in a few cases even nuclear explosions were used to expose matter to high pressure up to the Gbar regime. As a consequence the investigated sample undergoes a number of phase transitions during the experiment.

Intense heavy ion beams open a new pathway to address this research experimentally. The unique energy deposition characteristics of heavy ion beams assure that macroscopic volumes are heated fast and in a very homogeneous way, such that temperature gradients as well as density gradients are very low compared to other methods.

Already today GSI accelerators deliver the most intense heavy ion beam for plasma physics experiments. The beam parameters of the new FAIR facility outnumber the current status in many respects: it is not only the absolute number of particles per bunch that will increase by about 3 orders of magnitude, but also the beam power will increase by a factor of 3000 due to pulse compression down to 50 ns (see Tab. 1). The specific energy deposition will increase from 1 kJ/g, which is a typical value for current experiments, to abot 600 kJ/g. This opens the possibility to reach out into currently inaccessible parameter regimes for high energy density (HED) states of matter, which is synonymously also called the regime of Warm Dense Matter (WDM).

**PANDA - Antiproton Annihilation at Darmstadt**

The PANDA Experiment will be one of the key experiments at the Facility for Antiproton and Ion Research (FAIR) which is under construction and currently being built on the area of the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt, Germany.

The central part of FAIR is a synchrotron complex providing intense pulsed ion beams (from p to U). Antiprotons produced by a primary proton beam will then be filled into the High Energy Storage Ring (HESR) which collide with the fixed target inside the PANDA Detector.

The PANDA Collaboration with more than 450 scientist from 17 countries intends to do basic research on various topics around the weak and strong forces, exotic states of matter and the structure of hadrons.

In order to gather all the necessary information from the antiproton-proton collisions a versatile detector will be build being able to provide precise trajectory reconstruction, energy and momentum measurements and very efficient identification of charged particles.

**NUSTAR - Nuclear Structure, Astrophysics and Reactions**

The NUSTAR collaboration is devoted to the study of NUclear STructure, Astrophysics, and Reactions. More than 700 scientists from more than 170 participating institutes worldwide form the NUSTAR community. They all concentrate on the development and realization of new instrumentation and methods for future experiments at the upcoming FAIR facility. The research interest of the NUSTAR collaboration is focused on the use of beams of radioactive species separated and identified by the Superconducting FRagment Separator (Super-FRS), which is the central element of all NUSTAR experiments. This web page gives an overview of the NUSTAR@FAIR project. The current experimental program of NUSTAR at GSI Darmstadt and further information can be found here.

**SPARC - Stored Particles Atomic Research Collaboration**

The new facility at GSI has key features that offer a range of new opportunities in atomic physics and related fields. First, high-charge state ions moving at velocities close to the speed of light generate electric and magnetic fields of exceptional strength. Second, at those relativistic velocities, the energies of optical transitions, such as for lasers, are boosted to the x-ray region. The strong fields carried by heavy, highly-charged ions are their outstanding attributes for atomic and applied physics research. Together with anticipated high beam intensities a range of important experiments is envisioned.

 In relativistic, high-Z ion-atom collisions, extremely intense photon fields arise due to both, the high nuclear charges and the extremely high velocities. This will even lead to the creation of real particle-antiparticle pairs (e.g. e+-e).
 For the heaviest ions, Quantum ElectroDynamics (QED), the Standard Model of electromagnetism and a basis of modern physics, will be probed near the critical field limit associated with the extreme conditions of high charge states and high velocities. The fields present in highly relativistic collisions are strong enough to produce real e+-e- pairs directly out of the vacuum. Precision studies of QED in bound states will be possible through the large Doppler shifts of highly relativistic ions which generate extreme energy shifts for photons in the ion rest frame. As a consequence, even the heaviest few-electron ions can now be studied in precision QED experiments by using state of the art laser systems. The Doppler effect will also be used for the first time for laser cooling of heavy, highly-charged ions, promising beams at relativistic energies and brilliances that are suited for unique precision studies in atomic and nuclear physics. Moreover, the interaction of relativistic, highly-charged heavy ions with matter provides new possibilities in applications, in particular in material modifications and tests as well as in biophysics and space research.