# International Conference on Science and Technology for FAIR in Europe 2014

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Das Wormser


# Book of Abstracts

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## Status of FAIR

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**FAIR Overview I / 165**

## Future Nuclear Physics Facilities Around the World - how we compete and how we collaborate

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Large-scale nuclear physics facilities in the world are over-viewed, following the discussions at "Nuclear Science Symposium" in May 2013 at IFNF Frascati, organized by the IUPAP Working Group 9 whose major task is to sketch a world-wide framework for the key issues in nuclear science research for the next 10 to 20 years. Up to now experimental nuclear physics has advanced based on firm international competitions and collaborations. However, as of to date nuclear physics research has advanced to a stage that requires the construction of facilities often beyond the capacity of a single nation. The price tag for an international user facility may not be as large as projected for the International Linear Collider (ILC), but the sum of the costs for the construction and running of all the existing and proposed nuclear-physics facilities is reaching the level of the ILC. This also implies that there soon will be not only budgetary limitations but also human resources shortages to launch a future facility. Clearly this fact needs to be recognized and efforts made to enhance worldwide cooperation while keeping a good balance among domestic, regional (Europe-Africa, Asia-Oceania, and North-South America), and truly international projects.

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## Machine Overview and SIS 100

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The FAIR accelerators should increase the intensity of primary proton and heavy ion beams available for the production of secondary beams by up to two orders of magnitude, relative to the existing GSI facility. In addition to the design of the synchrotron SIS100 and the storage rings, the intensity upgrade of the existing UNILAC and SIS18 plays a key role for the FAIR project. As a first success of the upgrades a new record beam intensity for intermediate charge state uranium ions has been extracted from the SIS18. The design the SIS100 has been completed and key components, like for example the dipole magnets, are presently being tested at GSI. The presentation will also briefly summarize the expected beam intensity goals for the facility and the status of the FAIR storage rings.

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## FAIR Secondary Beams

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The efficient production of Secondary Beams at the FAIR facility provides, seconding increased primary beam rates, an additional corner-stone for the envisaged performance enhancements for serving the communities. In my talk I will outline recent developments and the pathway from activities at the existing installations towards the fully-fledged facility.

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## SPARC at FAIR: Prospects for Atomic Spectroscopy

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The program of the SPARC collaboration at FAIR is a unique research program on highly-charged heavy ions that utilizes storage ring and trapping facilities. In this talk, a short overview on various current and future activities with some emphasis on laser-related work will be given, including possibilities for experiments at the High-Energy Storage Ring HESR and the Cryring facility, which offer new exciting prospects for atomic spectrosocpy.

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## High Energy Density Physics in matter generated by Heavy Ion Beam (HEDgeHOB) at the FAIR Facility

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Knowledge of basic physical properties of matter under extreme conditions of high energy density, and in particular, of the so-called warm dense matter (WDM), such as equation-of-state, static and dynamic electrical conductivity and opacity is of fundamental importance for various branches of basic and applied physics. Intense beams of energetic heavy ions provide a unique capability for the WDM research compared to traditional drivers. Using intense ion beams, one can heat macroscopic volumes of matter fairly uniformly and generate this way high-density and high-entropy states. This new approach permits to explore fascinating areas of the phase diagram that are difficult to access by other means. Various physics issues of the high-energy-density (HED) physics research with intense heavy ion that is to be carried out at FAIR is presented. In particular, a special attention is given to the emerging diagnostic technique - high energy proton microscopy (HEPM). The results of the recent experiments are presented along with new developments in target and ion-beam diagnostic instruments and methods that are essential for the future HEDgeHOB experiments at FAIR.

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## FLAIR

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## Biophysics at Biomat

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FAIR will be a unique worldwide facility for biophysics applications. With the closure of the SIS18 at GSI, there will be no facilities able to provide heavy ions at energies above 400 MeV/n in Europe. The synchrotrons used for heavy-ion therapy, currently HIT (Germany) and CNAO (Italy), are running programs in medical physics with a limited beamtime due to the priority for patients' treatment and QA. The European Space Agency (ESA) used SIS18 at GSI for the European Space Radiation Health Program in the past 5 years. The use of very heavy ions (up to Fe or Ni) at very high energy (>1 GeV/n) makes FAIR a unique facility for space radiation research. The 1-year mission on the International Space station (starting in 2015) and the exploration programs (including Mars base) makes the problem of the exposure to galactic cosmic radiation particularly relevant. Radiation is a potential showstopper for exploration, and both NASA and ESA are investing large resources for reducing risk uncertainties and developing effective countermeasures. A large fraction of the equivalent dose in deep space comes from ions with energies 1-10 GeV/n, but the biological effects of these ions are largely unknown. The response of human tissues to Fe-ions at energies > 1 GeV/n will be the day-1 Biophysics experiment at FAIR. Biomedical research will also be extended to FAIR. One of the main problems in particle therapy is range uncertainty. The Bragg peak is potentially able to deliver a very high dose in a small tumor volume close to organs at risk, but this high precision makes particle therapy much more sensitive to uncertainties in target positioning, motion, and beam delivery than X-rays. FAIR can help solving projects with pilot projects on particle radiography (using 4-5 GeV protons) and radioactive ions (useful for PET imaging). A large International community, with interests in particle therapy and space radiation protection, will exploit the FAIR facility for solving these biomedical problems in the future years.

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# CBM

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The Compressed Baryonic Matter (CBM) experiment is 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 proton and heavy-ion beams in the energy range from 2A GeV to 45A GeV. Key aspects are the study of the equation-of-state of strongly interacting matter at high densities and the search for phase transitions and exotic (quasi) bound states. The CBM detector concept is unique by providing sufficient bandwidth to measure rare probes like multi-strange anti-baryons, di-leptons and charmed particles in conjunction with bulk observables in a large acceptance. The physics program and the status of the experiment will be discussed.

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# Hades at FAIR

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The HADES spectrometer [1] designed to measure e+e- pairs (dielectrons) in the SIS/BEVALAC energy regime is currently being operated at GSI Darmstadt and is foreseen as one of the first experiments at the future FAIR facility. One of the main objectives of the experimental approach is to systematically explore electromagnetic emissivity of compressed baryonic matter formed in the course of heavy ion collisions and to ultimately assess in-medium hadron properties. For this purpose a dedicated programme focusing on systematic investigation of dielectron production in nucleon-nucleon, proton-nucleus and heavy ion reactions has been conducted. A comparison of the nucleon-nucleon data to the one obtained in more complex systems allows for the isolation of in-medium effects [2][3]. Furthermore, as the spectrometer features excellent particle identification capabilities, the investigations have been extended to strangeness production, which in this energy regime is confined to the high density zone of the collision. In particular, appealing new results on hadrons containing two strange quarks (\phi, \varXi(1321)) [4][5] have been obtained. In this contribution, an overview of recent results as well as of future perspectives, in particular with the focus on the HADES at FAIR project, will be given.

[1] G. Agakishiev et al. Eur.Phys.J.A41:243-277,2009. [2] G. Agakishiev et al. Phys.Rev. C84 (2011) 014902 [3] G. Agakishiev et al. Phys.Lett.B690:118-122,2010 [4] G. Agakishiev et al. Phys.Rev.C80:025209,2009. [5] G. Agakishiev et al. Phys.Rev.Lett.103:132301,2009.

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# NUSTAR activities at FAIR

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The upcoming FAIR facility in Darmstadt, Germany, will produce intense high- energy beams of exotic nuclei which will be used to explore the properties of new regions of the chart of nuclides of key importance for the investigation of nuclear structure and reactions, and nuclear astrophysics. Several experiments have been planned with the aim of addressing the scientific challenges. These experiments use a variety of techniques to answer the fundamental questions in the field. They are brought together in the NUSTAR (NUclear STructure Astrophysics and Reactions) collaboration which maximizes the synergy amongst the sub-collaborations performing various experiments. With more than 800 scientists from more than 180 institutes located in 38 countries, the collaboration is well advanced and ready with the state-of-the-art instrumentation to start the measurements in the next few years. The physics case and challenges for all the NUSTAR experiments will be briefly discussed in this presentation.

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# Using Antiprotons for High Precision Studies of Hadrons

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Recently, after decades of slow progress, numerous facilities worldwide have observed a large number of new hadronic states, some of them with very unusual properties. This includes clear evidence for the existence of exotic hadronic states, i.e. states that can not be reduced to either a simple meson or baryon description. Despite this great advance, the nature of many of these states remains debated. One potentially decisive approach to determine the nature of some of these states is to perform high precision measurements of their lineshape. Such lineshape measurements will be performed using the high intensity, phase space cooled antiproton beam of the High Energy Storage Ring at FAIR. By exploiting kinematic constraints that are available in both resonance and threshold scans, well over an order of magnitude higher precision results will be obtained compared to other facilities. These measurements will be performed by the PANDA experiment, which is a multipurpose detector for a wide range of final states from antiproton annihilation reactions in the charm quark mass range. In addition to precision measurements of exotic hadronic states, PANDA has a fascinating program ranging from (but not limited to) time-like studies of nucleon structure, spectroscopy of open charm mesons, as well multi-strange and charm baryons, to the in-medium properties of charm mesons and spectroscopy of (double)-Lambda hypernuclei. This talk will present the physics reach of PANDA and the status for the detector construction.

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## Computing Challenges and Opportunities for FAIR experiments

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Computing remains a prominent and challenging element in the data processing scheme of today's design of future experiments. With the increasing complexity of heterogeneous detectors with massive amounts of electronic channels producing records of physics data, thereby, serving large and divers international scientific communities, the "big data challenge" has also become a central theme for the software and computing infrastructure for FAIR experiments. In the past decades, nuclear physics and related communities have followed and exploited the computing developments of high-energy physics (HEP) experiments. However, the ambitions of FAIR experiments, in particular with respect to the online and distributed computing demands, together with the paradigm shift in computing architectures, require a different and a more pro-active approach. In this talk, I will highlight the various computing challenges and opportunities for FAIR experiments in perspectives with the ongoing technological developments from other fields, such as HEP, astronomy, etc.

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## Results and Plans of LHCb in Charm Spectroscopy

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**Hadron Physics I / 36**

## Results and Plans Compass

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## Strangeness in Nuclear Physics

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**Heavy Ion Physics I / 38**

## Electromagetic Probes of QCD Matter in Heavy-Ion Collisions

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Photons and dileptons are pristine probes of the hot and dense medium formed in heavy-ion collisions, since, once produced, they traverse the fireball undistorted. Dilepton invariant-mass spectra are the only known observable which enable a direct access to an in-medium spectral function, in the vector channel. In the vacuum, and at low mass (M<1.5GeV), the vector spectral function is dominated by the rho(770) meson, as a massive and confined excitation of the QCD vacuum. The medium modifications of the vector spectral function are thus related to the changes in the QCD vacuum structure as the phase transition is approached and surpassed. On the other hand, at larger invariant masses (M>1.5GeV), the dilepton emissivity becomes continuum-like and its slope can serve as a thermomenter. We discuss how the temperature and in-medium spectral information can be combined to probe the QCD medium in heavy-ion collisions, how this can be utilized to interpret experimental data, and what this implies for the nature of the QCD phase transition. Effects due to baryons, which will be maximized at CBM, turn out to be of particular importance. We also discuss how the radiation of thermal photons provides complementary information on the medium's emissivity and temperature, requiring a careful consideration of blue-shift effects due to the explosively expanding fireball.

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## Probing the nuclear matter with NA61/Shine

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The study of the phase diagram of strongly interacting matter is probably the most challenging problem in the filed of heavy-ion collisions. The most prominent feature of the phase diagram is the existence of the deconfinement/chiral transition lines between hadronic and partonic phases. Modern Lattice QCD calculations advocate rapid crossover transition towards low net-baryon densities with the coincidence of deconfinement and chiral phase transition regions [1]. At higher densities, however, the deconfinement phase transition is expected to be of first order [2]. The logical consequence is the existence of a second order critical point at some intermediate values of net-baryon densities [3]. Experimentally, by changing the energy and the size of colliding nuclei one can control the net-baryon density and the temperature of the created matter. The excellent particle identification capabilities (high precision momentum and energy loss measurements) as well as its large phase-space coverage makes the NA61/SHINE experiment [4] at the CERN SPS particularly suited for these studies: (i) it probes the interesting region of the phase diagram, such that the deconfinement transition happens within the energy range of these collisions, (ii) the critical point at the location predicted by several theory groups can be probed at these energies. In this context, a survey is given of signals probing the phase structure of nuclear matter created in the interactions of heavy atomic nuclei. Seen in this light, the necessity for the differential study of event-by-event fluctuations in two dimensions is introduced and the dedicated program of the NA61/SHINE experiment is discussed. The Collaboration has already recorded p+p and 7Be+9Be runs at projectile momenta of 13A, 20A, 30A, 40A, 80A and 158A GeV/c. The results from elementary p+p reactions will serve as an important baseline for heavier systems. The energy scan of 40Ar+40Ca and p+208Pb systems will be completed in 2015. Starting from 2017 the heavier systems like 129Xe+139La and 208Pb+208Pb will be exploited. Some fluctuation measures in collected p+p reactions have already been measured and reported at several conferences [5,6]. Looking to yet another signals of fluctuations, in particular to those involving higher cumulants of the multiplicity distributions will complement these studies. For the latter a rigorous probabilistic approach has been proposed recently [7] .
[1] C. R. Allton et al., Phys. Rev. D 68, 014507 (2003). [2] K. Fukushima, J. Phys. G 35, 104020 (2008). [3] M. Stephanov, Int. J. Mod. Phys. A 20, 4387 (2005), vol. A20, p. 4387, 2005. [4] N. Abgrall et al., arXiv:1401.4699 (2014). [5] A. Rustamov, J. Phys. Conf. Ser. 426, 012027 (2013). [6] M. Mackowiak and A. Wilczek, J. Phys. Conf. Ser. 509, 012044 (2014). [7] A. Rustamov and M. I. Gorenstein, Phys. Rev. C 86, 044906 (2012).

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## Future Di-Lepton Experiments at SPS

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**Instrumentation I / 41**

## Instrumentation Atomic Physics

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## Instrumentation Plasma Physics

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## BIOMAT@APPA Cave: Beamline infrastructure and advanced instrumentation

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For experiments dedicated to biophysics and materials science (BIOMAT), the future APPA cave will provide a multi-user facility. The beamline and the experimental station have to cover very different user demands covering a broad range of beam intensities, energies and pulse structures and requiring flexible beam diagnostics and on-line monitoring of beam parameters. The target area includes settings for efficient sample exchange systems for irradiations of small (e.g., biocells) and large (e.g., satellite components) samples in air, a multi-port UHV chamber for irradiations and in-situ material analysis under high vacuum conditions, as well as special high-pressure devices to simultaneously expose samples to pressure, temperature, and energetic ions.

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## Monolithic Pixel Detectors for High-Precision Vertexing and Tracking in High-Rate Heavy-Ion Experiments

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**Hadron Physics II / 45**

## Open questions in hadron spectroscopy and dynamics

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## Open questions in hadron structure

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**Applied, Plasma and Atomic Physics I / 56**

## Solids under coupled extreme conditions: Simultaneous exposure to pressure, temperature and ion beams

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Recent advances in the design of diamond anvil cells and techniques for reaching extremely high pressures and temperatures have been combined with irradiations using swift heavy ions. These relativistic ions provide a unique opportunity to access states of matter quite far from thermodynamic equilibrium [1]. Each projectile deposits exceptional amounts of kinetic energy (GeV) within an exceedingly short interaction time (sub-fs) into nanometer-sized volumes of a material, resulting in extremely high energy densities (up to tens of eV/atom). The coupling of extreme energy deposition with high pressures and high temperatures, realized by injecting the relativistic heavy ions through a mm-thick diamond anvil of the pressure cell, dramatically alters transformation pathways and can lead to the formation of new states of matter. This innovative experimental approach allows us to probe the behavior of materials under extreme conditions, to form and stabilize novel phases in a wide range of oxides (e.g., GeO2 and Gd2Zr2O7) [2], and to manipulate the physical and chemical properties of solids at the nanoscale (e.g., CO2). A further application is to investigate the effects of radioactive decay events in compressed and heated minerals of Earth's interior, such as fission-track formation under crustal conditions and phase transitions of damaged minerals (e.g., ZrSiO4) resulting from meteorite impact [3]. This presentation describes the state-of-the-art science in this field by presenting several examples of structural modifications induced by coupled extreme conditions, as well as outlines a vision for future research at FAIR.

[1] J.M. Zhang, M. Lang, M. Toulemonde, R. Devanathan, R.C. Ewing, W.J. Weber, J. Mater. Res. 25 (2010) 1344.
[2] M. Lang, F.X. Zhang, J.M. Zhang, J.W. Wang, B. Schuster, C. Trautmann, R. Neumann, U. Becker, R.C. Ewing, Nature Materials 8 (2009) 793.
[3] M. Lang, F.X. Zhang, J. Lian, C. Trautmann, R. Neumann, R.C. Ewing, J. Synchrotron Radaition 6 (2009) 773.

**Applied, Plasma and Atomic Physics I / 48**

## Low-energy antiprotons at CERN and at FAIR

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The Antiproton Decelerator AD of CERN is currently the only facility providing beams for experiments with stopped or trapped antiprotons. An extension of the AD to lower the antiproton energy from 5 MeV to 100 keV called ELENA is under construction at CERN and should start operation in 2017, significantly increasing the number of stopped antiprotons. The physics program at CERN-AD/ELENA is focussed on precision spectroscopy and antimatter gravity experiments using cold antihydrogen. FLAIR (Facility for Low-energy Antiproton and Ion Research) was originally proposed in 2005 for FAIR but later on moved to phase 2. It consists of a magnetic storage ring called LSR which is similar to ELENA, an electrostatic Ultra-low energy Storage Ring USR decelerating until 20 keV energy, and the HITRAP facility for trapping highly charged ions and antiprotons. The lower antiproton energy and originally foreseen accumulation in a dedicated storage ring called RESR would result in a larger yield of stopped antiprotons in the full version of FLAIR. Furthermore, the storage rings of FLAIR are foreseen to provide both slow and fast extracted beam, the latter of which is not available at CERN-AD/ELENA. Thus nuclear and particle physics type experiments will only be available at FLAIR. Recently the situation has changed with the transfer of CRYRING, which was chosen by FLAIR for the LSR, from Manne Siegbahn Laboratory (Stockhom) to GSI and its installation at the current ESR storage ring of GSI. Together with the HITRAP facility already installed at ESR, a large fraction of the experiments of FLAIR with highly charged ions will be possible. If a way can be found to transport antiprotons from the production target of FAIR to the ESR, the low energy antiproton program of FLAIR could be also realized in an early stage. The potential of this facility will be reviewed in this talk.

**Applied, Plasma and Atomic Physics I / 49**

## Testing Quantum Electrodynamics at critical background electromagnetic fields

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Quantum Electrodynamics (QED) is a well established theory and its predictions have been successfully confirmed experimentally in different regimes. However, there are still areas of QED that deserve theoretical and experimental investigation, especially when processes occur in the presence of electromagnetic background fields of the order of the so-called critical fields of QED [1]. Highly-charged ions, like lead or uranium, already provide electric fields of the order of the critical electric field of QED (˜ 10ˆ16 V/cm) at distances from the ion of the order of the Compton wavelength (˜10ˆ−11 cm). On the other hand, in view of the increasingly stronger available laser fields it is becoming feasible also to employ them to test QED under the extreme conditions supplied by ultra-intense fields [1]. In the presence of incoming particles (like electrons, positrons or photons) with energies much larger than the electron rest energy, the laser field amplitude can be effectively boosted to the critical value. Thus, the interplay between the strong field provided by a highlycharged ion and by an ultra-intense laser beam has been investigated in the process of electron-positron photo-production (Bethe-Heitler process) [2]. It has been shown that, unexpectedly, the presence of the laser field strongly suppresses the Bethe-Heitler cross section, an effect analogous to the well-known Landau-Pomeranchuk-Migdal effect.
[1] A. Di Piazza, C. Müller, K. Z. Hatsagortsyan, and C. H. Keitel, Rev. Mod. Phys. 84, 1177 (2012). [2] A. Di Piazza and A. I. Milstein, Phys. Lett. B 717, 224 (2012); ibid., Phys. Rev. A 89, 062114 (2014).

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## Atomic physics of fast ions – slow ion collisions: The FISIC Project (Spiral II)

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Knowledge of the fundamental mechanisms at stake in fast ion – slow ion collision in atomic physics can provide a real breakthrough in the understanding of energy transfers in various plasmas such as inertial confinement fusion plasmas or stellar/interstellar plasmas. Crossing two multicharged ion beams, under well controlled conditions, has always been a very challenging task, whatever the domain of physics under consideration. So far, ion-ion collisions for atomic physics have been performed mainly in the context of magnetically confined plasmas using crossed beam device in the low-energy domain where the charge transfer is the dominant process. Measurements and reliable theoretical predictions are completely lacking for fast ion-slow ion collisions, a regime in which ion stopping power is maximum, and all the primary electronic processes (electron capture, loss and excitation) reach their optimum. It corresponds to a real "terra incognita" for atomic physics. The forthcoming availability of intense and stable beams of high optical quality on French and German Large Scale Facilities (GANIL/SPIRAL2 [1] and FAIR/CRYRING [2]) opens new opportunities to probe a large variety of systems. With the FISIC project, we propose an experimental crossed-beam arrangement to measure absolute cross sections. Besides the possibility to reach the pure three-body problem (bare ion on hydrogenic target) as a benchmark, we will explore the role of additional electrons bounded to the target and/or to the projectile –one by one– to quantify the effects of closure and/or opening of different channels, the electron-electron interactions, the role of multi-electron processes and of Coulomb forces in the entrance and exit pathway of the collision. FISIC will provide a unique worldwide experimental program covering the existing gap in ion-ion collisions, which besides of fundamental interest is also of prime importance for applications. The FISIC project is supported by an international collaboration led by INSParis and involving CIMAP (Caen), HI Jena, GSI and EMMI (Darmstadt).

**Heavy Ion Physics II / 40**

## The Physics of High Baryon Density

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A Beam Energy Scan (BES) program was carried out at RHIC with the main goals to find signatures for the disappearance of the QGP, a QCD phase transition, and for a critical point. I will give an overview of various observables studied by STAR and PHENIX to identify those structures in the QCD phase diagram. Furthermore I will give an outlook on the BES phase II program which is anticipated for the years 2018-2019.

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## Dileptons in URHIC

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**Parallel Tier 1 / 135**

## Injector-upgrade for FAIR (ACC)

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An UNILAC-upgrade program will be realized until FAIR commissioning starts, providing for the high heavy ion beam currents as required for the FAIR project. A new ion source terminal and a low energy beam line are dedicated to increase the primary low charge uranium beam intensity. Additionally an injector (HSI) upgrade programme is scheduled to improve beam transmission as well as beam brilliance. The replacement of the poststripper-DTL by a new high energy linac is advised to provide a stable operation for the next decades. Recently an ALVAREZ- and an IH-type DTL-design is under investigation. Design, prototyping and testing of the key components are the next major step. FAIR commissioning has to be accomplished with the upgraded HSI, while the new poststripper will be installed after 2020. As shown in machine experiments, UNILAC can serve also as a high current FAIR proton injector for the first time. Pushing the proton intensities to the required limit a new FAIR proton linac has to be build. The recent status of the FAIR upgrade program and an outlook will be presented.

**Parallel Tier 1 / 136**

## Laser cooling SIS 100 (ACC)

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**Parallel Tier 1 / 146**

## Development and application of the RFQs for FAIR and GSI Projects (ACC)

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Almost all modern linacs include a Radio-Frequence Quadrupole (RFQ) as a dedicated section for the bunching of continuous beam and simultaneous pre-acceleration of the ions. Generally an RFQ has a strong influence on the beam quality and a performance of the whole facility. Therefore, proper design of the accelerating-focusing RFQ channel, as well as a correct beam matching to an RFQ acceptance are the key tasks for the linac development and optimization. New RFQs for the FAIR machines are recently under consideration at GSI. Also during the last years several RFQs have been designed and commissioned by GSI team in collaboration with FAIR partners. The design features of these RFQs are presented, as well as their applications for FAIR and GSI Projects, namely UNILAC upgrade, Proton Linac, CW-Linac, HITRAP Decelerator and Therapy Linac.

**Parallel Tier 1 / 143**

## Status and perspectives of Ion source developments for FAIR (ACC)

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**Parallel Tier 2 / 140**

## The quasi-free scattering program at R3B (NUSTAR)

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In this contribution I will discuss the quasi-free scattering program at R3B. A compilation of experimental results on the single-particle structure of stable and exotic nuclei probed via the quasi-free scattering reaction in inverse kinematics will be presented. The cross sections and momentumdistributions are compared to recent calculations employing the reaction model presented in Ref. [1] and, where available, to previous experimental work. Finally, the future experimental program on quasi-free scattering reactions, which is enabled through the major upgrades in the R3B apparatus and the high intensity radioactive-ion beams foreseen at FAIR, will be discussed.

[1] Aumann, T. and Bertulani, C. A. and Ryckebusch, J., Phys. Rev. C 88, 064610 (2013)

**Parallel Tier 2 / 141**

## Status of EXL (NUSTAR)

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EXL (EXotic nuclei studied in Light-ion induced reactions at the NESR storage ring) is a project within NUSTAR at FAIR. It aims for the investigation of light-ion induced direct reactions in inverse kinematics with radioactive ions cooled and stored in the future NESR (New Experimental Storage Ring). A universal detector system will be built around an internal target of the NESR in order to detect the target-like recoils. One of the key interests of EXL is the investigation of reactions at very low momentum transfers where, for example, the nuclear matter distribution, giant monopole resonances (GMR) or Gamow-Teller transitions can be studied [1]. The existing ESR (Experimental Storage Ring) at GSI, together with its internal gas-jet target, provides a unique opportunity to perform this kind of experiments on a smaller scale already today. In the last years we have developed a UHV compatible detector setup mainly based on DSSDs (Double-sided Silicon-Strip Detector) for the target-like recoils [2] and an in-ring detection system for the projectile like heavy ions. With this setup we were able to successfully investigate reactions with a stored radioactive beam for the very first time. As a part of the first EXL campaign we investigated the reaction 56Ni(p,p)56Ni in order to measure the differential cross section for elastic proton scattering and deduce the nuclear matter distribution and the radius of 56Ni. Furthermore, as a feasibility study, we aimed for the investigation of the GMR of 58Ni by utilizing 58Ni(α,α')58Ni. This contribution will present the current status of the project and preliminary results.

This work was supported by BMBF (06DA9040I and 05P12RDFN8), the European Commission within the Seventh Framework Programme through IA-ENSAR (contract no. RII3-CT-2010-262010), HIC for FAIR, GSI-RUG/KVI collaboration agreement and TU Darmstadt-GSI cooperation contract.

[1] H.H. Gutbrod et al. (Eds.), FAIR Baseline Technical Report, ISBN-3-9811298-0-6, Nov. 2006
[2] B. Streicher et al, Nucl. Instr. And Meth. A 654 (2011) 604

**Parallel Tier 2 / 142**

## Cryogenic stopping cell for the Low Energy Branch of Super FRS at FAIR (NUSTAR)

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At the Low Energy Branch (LEB) of the Super-FRS at FAIR, exotic nuclei produced by projectile fragmentation or [U+FB01]ssion will be slowed-down and thermalized using stopping cell technique.

A novel Cryogenic stopping cell (CSC) developed for this purpose has been commissioned with U(238) projectile fragments produced at 1000 MeV/u. The spatial isotopic separation in flight was performed with the FRS applying a monoenergetic degrader. For the first time, a stopping cell was operated with exotic nuclei at cryogenic temperatures (70 to 100 K). Helium stopping gas density of up to 0.05 mg/cm3 was used, about two times higher than reached before for a stopping cell with RF ion repelling structures. An overall efficiency of up to 15 %, a combined ion survival and extraction efficiency of about 50% and extraction times of 24 ms were achieved for heavy alpha-decaying uranium fragments. Mass spectrometry with a multiple-reflection time-of-flight mass spectrometer has demonstrated the excellent cleanliness of the CSC. The results represent a milestone in the stopping-cell development around the world.

**Parallel Tier 2 / 173**

## Diamond detectors for beam monitoring, T0 determination and vertex determination for HADES and CBM experiments (CBM)

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Single-crystal Chemical Vapor Deposition (ScCVD) diamond based prototype detectors have been constructed for the high current proton, pion and heavy ion induced experiments HADES and CBM at the future FAIR facility at GSI Darmstadt. Their properties have been studied with a high current density beam (up to 2-3*10^6 particles/s/mm^2) and variouse projectile types, protons, pions and 1.25 A GeV Au ions. The detectors have been successfully tested in the HADES spectrometer showing excellent T0 determination capability, precise vertex position and radiation hardness. Details of the design, the intrinsic properties of the detectors and their pPerformance during test and after irradiation with such beams will be reported.

**Parallel Tier 2 / 137**

## Novel internal target source for future storage ring experiments (APPA)

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The introduction of cryogenically cooled, few micrometer-sized nozzle geometries and an essential modification of the experimental storage ring (ESR) target station for the first time allowed for a reliable operation using the light target gases helium and hydrogen at area densities up to values of 10^14 cm^-2 [1]. In the course of these optimization efforts, a remarkably versatile target source was established, enabling operation over the whole range of desired target gases (from H2 to Xe) and area densities (~10^10 to ~10^14 cm^-2). For future applications of the SPARC collaboration at storage rings, a completely new inlet chamber was proposed based on the experience gained during previous modification processes [2]. The much more compact chamber design will maintain the demanding storage ring vacuum requirements while enabling the operation of the target beam at an interaction length down to 1 mm. This is of paramount importance with respect to the realization of high precision experiments, e.g. by reducing the inaccuracy of the observation angle causing the relativistic Doppler broadening [3]. While being intended for the deployment at the future high energy storage ring (HESR) within the FAIR project, the new inlet chamber could also replace the current one at the ESR or serve as an internal target for CRYRING.

[1] M. Kühnel et al., NIM A, 602, 311-314 (2009) [2] N. Petridis, A. Kalinin, and R. E. Grisenti, "Technical Design Report: SPARC-Target@HESR", Stored Particles Atomic Physics Research Collaboration, 2014 [3] T. Stöhlker et al., NIM B, 205, 210-214 (2003)

**Parallel Tier 2 / 138**

## PRIOR - the proton microscope for FAIR (APPA)

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**Parallel Tier 3 / 144**

## Radiation Properties of Ions and Exotic Nuclei at Relativistic Energies (APPA)

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Owing to the recent advances in heavy-ion accelerator facilities as well as in detection techniques, new possibilities arise to study the electronic structure of simple atomic systems in strong Coulomb fields. Relativistic, quantum electrodynamics, and even nuclear effects, which are difficult to isolate in neutral atoms, often become enhanced in high-Z, few-electron ions. In order to improve our understanding of these fundamental interactions, a number of studies have been recently carried out on the characteristic photon emission from heavy ions within the framework of the Stored Particles Atomic Physics Research Collaboration (SPARC). In this contribution, we present a theoretical study of angular and polarization properties of radiative decay of heavy atomic systems with non-zero nuclear spin. In particular, we focus on the K-alpha transitions in helium-like ions following the radiative electron capture. Special attention is given to the question of how the hyperfine interaction of the nuclear magnetic moment with those of electrons affects the angular properties of the K-alpha emission for isotopes with non-zero nuclear spin. As an example, detailed computations were carried out for selected isotopes of helium-like tin, xenon, and thallium ions. A quite sizeable contribution of the hyperfine interaction upon the K-alpha angular emission is found for isotopes with nuclear spin $I = 0$, while this effect is suppressed for (most) isotopes with larger nuclear spin $I > 1/2$ [1]. From this theoretical analysis, we suggest that accurate experimental measurements of the K-alpha angular emission at ion storage rings can be utilized as an independent tool for determining the nuclear parameters, such as nuclear spin, and magnetic dipole moment, of the exotic and radioactive isotopes with $I > 0$.

**Parallel Tier 3 / 145**

## Materials behavior under extreme conditions (APPA)

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The BIOMAT beamline at FAIR will make possible materials science experiments with unprecedented heavy ion beams intensities. One of the central research directions will focus on the field of materials in high radiation fields, temperature and pressure conditions, using fast extracted, high-intensity beams. Future studies of materials behaviour in extreme environments will have a direct application to the development of accelerator components, the understanding of structural materials degradation in next generation fusion and fission reactors or the shielding of equipment and humans in deep space missions. Testing of innovative materials solutions for components for the future high–power accelerator facilities like FAIR, High Lumi-LHC, FRIB, neutrino factories and ESS, for ITER and for ESA missions in conditions of radiation, temperature and pressure reproducing operation scenarios will be possible. The availability of a high power laser at the BIOMAT beamline would make possible pump-probe experiments using laser based diagnostic, enabling online structural degradation studies during irradiation and ion-beam driven shock experiments, as well as studies on the dynamics of radiation defects on a much finer time scale, a path-breaking direction in the study of materials modification with ion beams.

**Parallel Tier 3 / 147**

## Spectroscopy of Element 115 Decay Chains at TASCA (NUSTAR)

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During the past decade, a number of correlated alpha-decay chains, which all terminate by spontaneous fission, have been observed in several independent experiments using 48Ca-induced fusion-evaporation reactions on actinide targets. These are interpreted to originate from the production of neutron-rich isotopes with proton numbers Z=113-118. In November 2012, a three-week experiment was conducted at the GSI Helmholtzzentrum für Schwerionenforschung GmbH in Darmstadt, Germany, using high-resolution alpha, electron, X-ray and gamma-ray coincidence spectroscopy to observe alpha-X-ray events to identify uniquely atomic numbers of isotopes in Z=115 decay chains, and to provide the first insight into the structure of these nuclei. The reaction 48Ca+243Am was used, with fusion-evaporation products being focused into the TASISpec set-up, which was coupled to the gas-filled separator TASCA. A beam integral of roughly 7*10^18 48Ca particles led to the observation of 30 correlated alpha decay chains with characteristics similar to those previously published. Results from the experiment will be presented.

**Parallel Tier 3 / 139**

## WDM diagnostics (APPA)

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**Parallel Tier 4 / 148**

## Development of the CBM Silicon Tracking System

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The Compressed Baryonic Matter (CBM) experiment at FAIR will explore the phase diagram of strongly interacting matter at the highest net-baryon densities in nucleus-nucleus collisions with interaction rates up to 10 MHz. As the core tracking detector of CBM the Silicon Tracking System (STS) will be installed in the gap of the 1 T super conducting dipole magnet for reconstruction of charged particle trajectories and its momenta. The requirement on momentum resolution, $\Delta$p/p = 1%, can only be achieved with an ultra-low material budget, imposing particular restrictions on the location of 2.5 million channel front-end electronics dissipating 40 KW in the fiducial volume of about 2 m3. The concept of the STS is based on a modular structure containing 300 $\mu$m thick double-sided silicon microstrip sensors read out through ultra-thin multi-line micro-cables with fast self-triggering electronics. As central building blocks the modules consisting of each a sensor, micro-cable and front-end electronics will be mounted with lightweight carbon fiber support structures onto 8 detector stations. At the station periphery infrastructure such as power and cooling lines will be placed. The status of the STS development is summarized in the presentation, including an overview on sensors, read-out electronics, prototypes, and system integration.

**Parallel Tier 4 / 149**

## High Voltage Monolithic Active Pixel Sensors for the PANDA Luminosity Detector (PANDA)

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The PANDA-Experiment will be part of the new FAIR accelerator center at Darmstadt, Germany. It is a fixed target experiment using a antiproton beam with very high resolution for precision measurements. For a variety of measurements like energy-scans the precise determination of the luminosity is needed. The luminosity detector will determine the luminosity by measuring the angular distribution of elastically scattered antiprotons very close to the beam axis (3-8 mrad). To reconstruct antiproton tracks four layers of thinned silicon sensors with smart pixel readout on chip (HV-MAPS) will be used. Those sensors are currently under development by the university of Heidelberg. In the talk the concept of the luminosity measurement is shortly introduced before a summary of the status of HV-MAPS prototypes and readout electronics is given.

**Parallel Tier 4 / 150**

## Integration of the strip detector of the PANDA Micro-Vertex-Detector (PANDA)

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PANDA is a key experiment of the future FAIR facility, under construction in Darmstadt, Germany. It will study the collisions between an antiproton beam and a fixed proton or nuclear target. The Micro Vertex Detector (MVD) is the innermost detector of the apparatus and its main task is the identification of primary and secondary vertices. The central requirements include high spatial and time resolution, trigger-less readout with high rate capability, good radiation tolerance and low material budget. To meet these requirements, the detector will be composed of four concentric barrels and six forward disks. The inner layers will be instrumented with silicon hybrid pixel detectors, while for the outer two barrels and for the outer part of the last two disks double-sided silicon microstrip detectors were chosen. In the strip part of the detector, the sensors and the readout electronics will be supported by a composite structure of carbon fiber and carbon foam, which will ensure the precise positioning of the sensitive elements while keeping the material budget low. A water-based cooling system embedded in the carbon mechanical supports will be used to remove the excess heat from the readout electronics. A flexible multilayer bus will be used to route the signals on the stave towards the DAQ system. The design of the detector, its integration concept and some relevant hardware developments will be presented. Supported by BMBF, HGS-HIRe and JCHP.

**Parallel Tier 4 / 151**

## Development of the Time-Of-Flight System of the CBM Experiment (CBM)

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The main goal of CBM is the investigation of the phase diagram of strongly interacting matter in the region of the highest baryon densities. In order to measure the necessary observables with unprecedented precision an excellent particle identification is required. The key element providing hadron identification at incident energies between 2 and 35~AGeV is a 120~m^2 large Time-of-Flight (ToF) wall composed of Multi-gap Resistive Plate Chambers (MRPC). The most demanding challenge, however, is the enormous incident particle fluxes between 100~Hz/cm^2 and 25~kHz/cm^2 generated at the highest interaction rates that CBM is designed for (10~MHz). In this contribution we will present various MRPC prototypes developed by the CBM-Tof group. In particular the rate capability of ceramic MRPCs and low resistive glass MRPCs for the high rate region as well as float glass MRPCs for the lower rate region will be discussed. The current conceptual design of the ToF-wall which is based on a modular structure composed of modules containing the MRPC counters will be presented.

**Parallel Tier 4 / 152**

## The RICH detector of the CBM experiment and its physics potential

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The Compressed Baryonic Matter (CBM) experiment at the future FAIR facility will investigate high baryon density matter at moderate temperatures in A+A collisions from 4-35 AGeV beam energy. One of the key observables of the CBM physics program is electromagnetic radiation from the early fireball carrying undistorted information on its conditions to the detector. This includes detailed investigations of low-mass vector mesons in their di-electron channel. In CBM, electrons will be identified with a RICH detector complemented by several layers of TRD. Aiming at a stable, robust and fast gaseous detector and relying to a large extent on components from industry, the RICH concept foresees a 1.7 m long CO2-radiator, a plane of 40 × 40 cm2 trapezoidal spherical mirrors with a curvature radius of 3 m and Multi-Anode PhotoMultiplier Tubes (MAPMTs) as photo-detectors. This concept is the outcome of a series of detector simulations, feasibility studies, R&D activities on individual components, and of beam tests with a real size prototype. A Technical Design Report of the RICH detector has been accepted by FAIR. In this presentation, the RICH concept and R&D results will be discussed. Based on realistic detector descriptions implemented from the testbeam results into the CBMROOT simulation framework, feasibility studies on the measurement of di-electrons (low-mass vector mesons and J/psi) have been performed and will be presented.Results show, that both observables will be accessible with very good signal-to-background ratios and efficiencies. using a self-triggering readout electronics. Results of the feasibility studies and of the detector development will be presented and discussed.

**Parallel Tier 4 / 153**

## Performance of Prototypes for the PANDA Barrel EMC (PANDA)

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The PANDA experiment will be part of the future Facility for Antiproton and Ion Research (FAIR) and aims at the study of strong interaction within the charm sector via antiproton proton collisions up to antiproton momenta of 15 GeV/\textit{c}. Reflecting the variety of the physics program the PANDA detector is designed as a multi-purpose detector able to perform tracking, calorimetry and particle identification with nearly complete coverage of the solid angle and, adhering to fixed target kinematics, is comprised of a Target and Forward Spectrometer. The Electromagnetic Calorimeter (EMC) contained inside the Target Spectrometer is based on cooled $PbWO_4$ scintillator crystals. In order to ensure an excellent performance throughout the large dynamic range of photon/electron energies reaching from a few MeV up to 15 GeV an extensive prototyping phase is mandatory. This contribution describes the measured response of the EMC barrel part prototype PROTO60 at the largest design energy to secondary beams provided by SPS at CERN. In addition to PROTO60 a tracking station comprised of prototypes for the PANDA Micro Vertex Detector was deployed, providing precise position information of the 15 GeV/\textit{c} positrons. For calibration purposes a 150 GeV/\textit{c} muon beam and cosmic radiation, in combination with estimations from GEANT4 simulations were used. The obtained performance concerning energy, position and time information is presented. An outlook on the final barrel EMC design and the next generation prototype PROTO120 will be provided.

**Applied, Plasma and Atomic Physics II and Heavy Ion Physics III / 54**

## Resonant coherent excitation of heavy ions in a crystal at relativistic energies

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As a unique approach to investigate the dynamical response of atomic systems, our group has been involved in the selective excitation of the heavy atomic ions in the x-ray energy domain making use of a thin single crystal. The relativistic ions are guided in the silicon single crystal, and excited by a temporally oscillating strong Coulomb field arising from the periodical atomic arrangement. This process is called resonant coherent excitation (RCE).
One remarkable outcome of these experiments is the high-resolution spectroscopy that can be achieved in the measurements of the transition energies. Because the frequency can be controlled by changing the relative angle between the ion velocity and crystallographic orientation, resonant fluorescence spectroscopy is performed by observing the x-ray fluorescence as a function of the incident angle. Recently, we have demonstrated this promising scheme for resonant fluorescence spectroscopy of the 2s-2p3/2 transition (4.5eV) in 191.68 MeV/u Li-like U89+ ions using RCE at GSI.
Now as the Day-1 Physics with the SPARC project, we aim to excite 1s electron to the 2p state of H-like U91+ available from the coming SIS100/300. In addition, the RCE technique will contribute to the project of the high-energy ion storage ring as an excellent non-destructive diagnostics device to measure stored heavy ions in the ring.

**Applied, Plasma and Atomic Physics II and Heavy Ion Physics III / 47**

## Plasma Physics at FAIR in an international context

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In this talk I will discuss potential plasma physics experiments at the FAIR facility with an emphasis on high energy density physics and warm dense matter. I will discuss some of the plasma physics carried out at other facilities with the aim of showing how the unique features of the FAIR facility will enable it to compete on an international stage.

**Applied, Plasma and Atomic Physics II and Heavy Ion Physics III / 55**

## First plasma physics experiments

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The upcoming Facility for Antiproton and Ion Research (FAIR), currently under construction at the Helmholtz Center for Heavy-Ion Research GSI (Darmstadt, Germany), will offer heavy ion beams at unprecedented intensities. One of the research pillars within the multi-facetted scientific program at FAIR is the area of dense plasmas. A variety of schemes has been proposed to generate matter at High Energy Density conditions using the intense heavy-ion pulses delivered by the FAIR accelerator complex. This promises novel and unique approaches for accurate studies of matter under extreme conditions. Alternatively, FAIR proton beams can be used to radiograph large, dense plasmas. Already the parameters of the early ion beams expected when FAIR will go into operation will enable first experiments demonstrating these exciting experimental possibilities.

**Applied, Plasma and Atomic Physics II and Heavy Ion Physics III / 124**

## First experiments with CBM

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The first experiments with CBM are focused on the exploration of strongly interacting matter at neutron star core densities as it will be produced in collisions between very heavy nuclei at SIS100 energies. In particular, we will study the equation-of-state of nuclear matter up to the highest baryon densities, and search for transitions to quarkyonic or quark matter. Very promising diagnostic probes are particles with (multiple) strangeness and lepton pairs. Most of these particles will be studied for the first time at SIS100 energies. To perform these measurements, the start version of the CBM experiment will be equipped with detectors to identify both hadrons and leptons over the full SIS100 energy range .

**Hadron Physics III / 64**

## Status and Plans of JLAB-12

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Jefferson Lab is a fundamental research laboratory located in Newport News (Virginia-USA). Its primary mission is to explore the fundamental nature of confined states of quarks and gluons, including the nucleons that comprise the mass of the visible universe. It consists of a high-intensity electron accelerator based on continuous wave superconducting radio frequency technology and a sophisticated array of particle detectors. The design features and excellent performance of the accelerator made it possible to plan an upgrade in energy from 6 to 12 GeV without substantially altering the construction scheme of the accelerator. The program includes the construction of major new experimental facilities for the existing three halls, A, B, C and the construction of the new experimental hall D. The project will be completed by the year 2013 and the commissioning of the experimental halls will be extended until the end of 2015. The research program that has motivated the upgrade in energy to 12 GeV includes: the study of the nucleon "tomography" through the study of generalized parton distribution functions (GPDS) and transverse momentum dependent parton distribution functions (TMDs), the study of exotics and hybrid mesons to explore the nature of the quarks confinement, precision test of the Standard Model through parity-violating electron scattering experiments. In this presentation the Status and Plans of JLAB-12 will be given.

**Hadron Physics III / 65**

## Status and Plans for hadron structure and spectroscopy at B-Factories and BES3

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For selected examples of open charm and charmonium production, the expected reach of BESIII and Belle II will be compared to the expected reach of Panda. Systematic effects such as background, vertex resolution and fixed target vs. collider mode will be addressed.

**Hadron Physics III / 67**

## Physics prospects for first experiments at PANDA

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The PANDA experiment is one of the major projects in preparation at the upcoming FAIR facility. It will study interactions between antiprotons and protons or nuclei in the momentum range from 1.5 to 15 GeV/c. The PANDA scientific program will address a wide range of topics, all aiming at improving our understanding of the strong interaction and hadron structure using a general purpose spectrometer that will collect high quality and high statistics data in the fields of: hadron spectroscopy, hypernuclear physics, electromagnetic processes. This paper will describe some of the physics topics that will be addressed at the beginning of the experimental activity.

**Radioactive Isotope Beam Facilities / 237**

## Posterprize ceremony

**Radioactive Isotope Beam Facilities / 60**

## FRIB Status and Scientific Program

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This talk will review the current status of the FRIB project, its planned capabilities, and provide a broad outline of the scientific program. FRIB will be based on a superconducting LINAC that will be able to deliver 400kW beam power of at least 200 MeV/u ions for all stable isotopes. The accelerator and facilities are upgradeable to 400 MeV/u by addition of cryomodules into unused space. The facility will have capabilities for stopping and reaccelerating ions to a few MeV/u for astrophysical studies and Coulomb-barrier experiments. A review of the planned experimental equipment required for the scientific program will also be presented.

**Radioactive Isotope Beam Facilities / 61**

## RIKEN RI Beam Factory (RIBF): Status and Plans

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[1] *RIKEN*

The RI Beam Factory (RIBF) [1] at RIKEN, which became operational in March 2007, is one of the next-generation in-flight rare isotope (RI) beam facilities. At RIBF the BigRIPS in-flight separator [2] has been used to produce a variety of RI beams by using in-flight fission as well as projectile fragmentation. Its major features are two-stage structure, large ion-optical acceptances, and excellent performance in particle identification. Efficient RI-beam production has been made possible by these features of the BigRIPS separator, allowing us to significantly expand the region of accessible exotic nuclei.
Secondary reaction studies and decay studies on rare isotopes have been extensively performed using the following major research instruments at RIKEN RIBF: 1) BigRIPS in-flight separator: RI-beam production and also used as a spectrometer. 2) ZeroDegree spectrometer: a forward spectrometer fixed at 0 degrees 3) SAMURAI spectrometer: large acceptances and kinematically complete measurement 4) SHARAQ spectrometer and dispersion-matching beam line for high-resolution measurement 5) SLOWRI & PALIS gas catchers: combination of in-flight and ISOL schemes **6) Rare RI ring: isochronous ring for TOF mass measurement** 7) SCRIT (Self-Confining RI target) for electron-RI scattering ** 8) Gamma-ray array detectors for in-beam gamma ray measurement such as DALI2 9) Decay station using Ge array detectors such as EURICA 10) Others In my talk the overview and status of the RIBF facility will be presented. The intensity-upgrade plans for the RIBF accelerators will be also outlined.

- kubo@ribf.riken.jp ** Under development [1] Y. Yano: Nucl. Instr. and Meth. B 261 (2007) 1009; H. Okuno et al.: Prog. Theor. Exp. Phys. 03C002 (2012). [2] T. Kubo: Nucl. Instr. and Meth. B 204 (2003) 97 ; T. Kubo et al.: IEEE Trans. Appl., Supercond., 17 (2007) 1069 ; T. Kubo et al.: Prog. Theor. Exp. Phys. 03C003 (2012), doi: 10.1093/ptep/pts064.

**Radioactive Isotope Beam Facilities / 62**

## Spiral II: Status and plans

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**Parallel Tier 5 / 154**

## β-decay half-lives and β-delayed neutron emission measurements for very exotic nuclei beyond N=126 relevant in the freeze-out of the r-process

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This contribution reports on the status of the data analysis of the experiment performed at the GSI-FRS facility (Germany), where very exotic nuclei, beyond N=126, were produced and isotopes of Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn and Fr were precisely identified using tracking detectors with the method of time-of-flight. Thanks to the detection system which comprised two detection systems, a Double-sided Silicon Strip Detector and a high efficiency Neutron detector were used to determine the decay properties of the implanted isotopes of Hg, Tl and Pb via implant-beta-neutron correlations. Around 14 isotopic species were implanted with enough statistics to determine their half-life. Some of them are expected to be neutron emitters, in such cases it has been possible to obtain the β-delayed neutron emission branching ratios Pn. The relevance of these data and the role of this kind of measurements in nuclear structure and r-process nucleosynthesis will be discussed.

**Parallel Tier 5 / 155**

## Neutrino Reactions in Supernova Nucleosynthesis (NUSTAR)

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We study the effect of neutrino microphysics on nucleoysnthesis in core-collapse supernovae. In particular, we show how neutrinos connect the nuclear physics of the core of a protoneutron star to the nucleosynthesis in the low density neutrino driven wind. We find that a consistent implementation of neutrino interactions with the underlying equation of state leads to a neutronrich matter out flow. The neutron richness of the outflow is directly related to the nuclear symmetry energy. The nucleosynthesis in the ejecta can reproduce the weak r-process pattern that is observed in metal poor stars. We also investigate the impact of additional opacity sources relevant for electron antineutrinos and muon neutrinos. These include inverse neutron decay and charged-current reactions for muon neutrinos. Our calculations explicitely account for weak magnetism in neutrino nucleon interactions without any kinematical approximation. We find that these reactions are signicant contributions to total neutrino opacities and should therefore be implemented in future core-collapse supernova simulations. Andreas Lohs is a member of

H-QM Helmholtz graduate school and supported by GSI and HIC for FAIR. This work is partly supported by Deutsche Forschungsgemeinschaft through contract SFB 634.

**Parallel Tier 5 / 156**

## Dilepton production in pion-nucleon and pion-nucleus reactions (CBM)

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We calculate electron-positron pair production in pion-nucleon and pion-nucleus collisions. Parameters of the model are fitted to pion photoproduction data. We use these cross sections in a transport model to study π-nucleus reactions. We investigate especially what is the effect of the interference between the ρ and ω mesons on the dilepton spectra. . We suggest a way how experimentally the decoherence can be measured in the medium, comparing π-N, π-light nucleus and π-heavy nucleus. These results are meant to give predictions for the planned experiments at the HADES spectrometer in GSI, Darmstadt. These reactions may be studied in JPARC, too.

**Parallel Tier 5 / 158**

## Strange baryons and antibaryons in nuclei: unique opportunities for PANDA@FAIR (PANDA)

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PANDA is a key experiment of the FAIR facility in Darmstadt. It will study fundamental questions of hadron physics and QCD by exploring interactions between an antiproton beam and a fixed proton or nuclear target. Because of the relative large production cross section of hyperon-antihyperon pairs in antiproton-nucleus collisions PANDA is a unique factory for hyperon-antihyperon pair production. This feature makes PANDA an ideal instrument to study hyperons and antihyperons in nuclear medium. The exclusive production of hyperon-antihyperon pairs close to their respective production threshold offers a unique opportunity to study the nuclear potential antihyperons in nuclei quantitatively. In the case of Lambda-\bar{Lambda} and Sigma - \bar{Lambda} production in antiproton-neon collisions around 1 GeV incident energy, calculations using the Gießen BUU transport model indicate a strong sensitivity of transverse momentum correlations on the depth of the \bar{Lambda} potential in nuclei. The expected sensitivity of the PANDA experimen and further options of this novel method will be discussed.

**Parallel Tier 5 / 172**

## SU(3) flavour symmetry in the charmed baryon sector from the lattice

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Recently many new charmonium states were discovered but also mesons and baryons with open charm, the latter in particular at the LHC. The spectroscopy and decays of some of these particles should also be relevant for the PANDA experiment. We present results on the spectrum of charmed baryons with and without strangeness as well as of charmonium states. The spectra were obtained in lattice simulations with $n_f = 2 + 1$ sea quark flavours, keeping the sum of light quark and strange quark masses $2m_{ud} + m_s$ constant. Extrapolations towards the physical point

are then made in terms of the SU(3) symmetry breaking parameter in the different relevant representations.

**Parallel Tier 6 / 159**

## On-line Event reconstruction in the CBM experiment (CBM)

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The CBM experiment is an experiment being prepared to operate at the future FAIR facility. Its main focus is the measurement of very rare probes, which requires interaction rates of up to 10 MHz. Together with the high multiplicity of charged tracks produced in heavy-ion collisions, this leads to huge data rates of up to 1 TB/s. Most trigger signatures are complex (short-lived particles, e.g. open charm decays) and require information from several detector sub-systems. First Level Event Selection (FLES) in the CBM experiment will be performed on-line on a dedicated processor farm. This requires the development of fast and precise reconstruction algorithms suitable for on-line data processing. The algorithms have to be intrinsically local and parallel and thus require a fundamental redesign of traditional approaches to event data processing in order to use the full potential of modern many-core CPU/Phi/GPU architectures. Thus, algorithms of the package are based on the Cellular Automaton and Kalman filter methods and implemented in single precision and massively parallelized.

**Parallel Tier 6 / 160**

## FPGA Helix tracking for PANDA (PANDA)

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The PANDA detector is a general-purpose detector for physics with high luminosity cooled antiproton beams, planed to operate at the FAIR facility in Darmstadt, Germany. The central detector includes a silicon Micro Vertex Detector (MVD) and a Straw Tube Tracker (STT). Without any hardware trigger, large amounts of raw data are streaming into the data acquisition system. The data reduction task is performed in the online system by reconstruction algorithms programmed in VHDL (Very High Speed Integrated Circuit Hardware Description Language) on FPGAs (Field Programmable Gate Arrays) as first level and on a farm of GPUs or PCs as a second level. One important part in the system is the online track reconstruction. In this presentation, an online tracking finding algorithm for helix track reconstruction in the solenoidal field is shown. A performance study using C++ and the status of the VHDL implementation will be presented.

**Parallel Tier 6 / 161**

## FPGA based read-out systems (CBM)

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The central part of many state-of-the-art data acquisition systems is formed by programmable logic devices (FPGA). During the recent upgrade of the HADES detector at GSI, a huge set of dedicated electronics and software has been developed and validated in experiment. Several FAIR experiments already profited from these developments in the past years. I will present

this framework and on-going extension work to cope with new requirements with respect to the planned high-rate experiments at FAIR. Special emphasis will be put on synergies between different groups at FAIR and other institutions world-wide.

**Parallel Tier 6 / 162**

## Frontend Electronics for high-precision single photo-electron timing (PANDA)

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High-precision single photon timing with resolutions well below 100 ps is becoming increasingly important. It enables new detector designs, like the Time-of-Propagation DIRC of Belle II, or the TORCH upgrade for LHCb, and to improve existing designs, e.g. allow chromatic corrections in DIRCs. These applications have in common a high channel density, limited available space and low power consumption. We report on Frontend Electronics developed for the PANDA Barrel DIRC. The customised design utilises high-bandwidth pre-amplifiers and fast discriminators providing LVDS output signals which can be directly fed into the TRBv3 readout using FPGA-TDCs with a precision better than 20ps RMS. The discriminators also provide Time-over-Threshold (ToT) information which can be used for walk corrections thus improving the obtainable timing resolution. Two types of cards, optimised for reading out 64-channel Photonis Planacon MCP-PMTs, were tested: one based on the NINO ASIC and the other, called PADIWA, on FPGA-based discriminators. Both types feature 16 channels per card, thus requiring four cards to read out one 64-channel MCP-PMT. Power consumption for the complete readout of one Planacon MCP-PMT is approx. 10W for the NINO FEE and approx. 5W for the PADIWA FEE. The timing performance of the cards was tested with a fast laser system and also in a test experiment at the MAMI accelerator in Mainz using a small DIRC prototype to image Cherenkov patterns. In both cases, using the ToT information, a timing resolution of better than 100ps was found for the complete readout chain.

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## R&D for the PANDA Barrel DIRC (PANDA)

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The PANDA detector requires excellent particle identification (PID) for the full solid angle and a wide momentum range. In the barrel region of the detector the hadron PID will be performed by a DIRC counter. The successful BABAR DIRC inspired the baseline design of the PANDA Barrel DIRC, which was further advanced by such modifications as fast photon timing and focusing optics. Narrow long radiator bars and an oil-filled expansion volume are at the core of the baseline design. Detailed simulations have shown that the PID performance of this design meets the PANDA PID requirement. However, in order to reduce the detector cost and optimize the performance, a number of alternative design elements and parameters have been studied. The most significant design alternative is the use of wide radiator plates instead of narrow bars. This option would reduce the number of radiator pieces to be polished, and thus result in significant fabrication cost savings. Other important design options include the use of individual compact prism-shaped expansion volumes and an advanced focusing system. The extensive R&D program includes the detailed PANDA Barrel DIRC simulation and testing of the increasingly complex prototypes in particle beams. The simulation studies and results of the test beam campaigns will be discussed in this contribution.

**Parallel Tier 6 / 164**

# Particle therapy for non-cancer diseases (APPA)

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Cardiac arrhythmias, like atrial fibrillation, are often treated by radiofrequency catheter ablation. Thereby scar tissue is created to isolate the heart's conduction system from anatomical areas containing misled electrical signals, which generate and sustain the irregular heartbeat. Catheter ablation procedures have a varying success rate and can lead to severe side effects or even death [1]. Recently, animal studies showed that a non-invasive ablation with photons is feasible [2, 3]. Based on the experiences gained in cancer treatment, even more promising results are expected for the creation of cardiac lesions with ions [4]. In order to investigate the feasibility of carbon ion radio-surgery on cardiac target volumes an animal study was conducted at GSI. Heartbeat gated computed tomography (CT) scans of eighteen pigs were acquired. Three different cardiac volumes were investigated: the atrioventricular node (AVN), the pulmonary vein (PV) and a region in the left ventricles (LV). The PV and LV were targeted with 40 Gy single fraction doses in three and four pigs, respectively. The AVN irradiation was designed as a dose-escalation study including dose groups of 0, 25, 40 and 55 Gy. The influence of the respiratory motion was compensated by ventilating the animals, while the heartbeat influence was mitigated by the use of multiple irradiations with a reduced dose deposition (rescanning). The dose depositions in the organs at risk (OAR) were examined. The heartbeat motion influence on the target volumes was small ($< 5$ mm) but required compensation. Safety margins were used for the irradiation (ITV + isotropic 5 mm for AVN and PV and range margins of (2 mm $\pm$ 2%) for the LV). Good dose homogeneity in the target area was achieved, while the dose deposited in critical volumes (e.g. aorta, esophagus, trachea, skin) were negligible. The results, both satisfying in target coverage as well as OAR sparing, led to the application of the generated treatment plans. Final results on the formation of scar tissue are expected in the end of October. Scanned carbon ion beams have the potential to become an accurate, fast, and non-invasive treatment approach for arrhythmias.

[1] Cappato et al., Worldwide survey on the methods, efficacy and safety of catheter ablation for human atrial fibrillation, Circulation 111(9), 2005 [2] Sharma et al., Noninvasive stereotactic radiosurgery (CyberHeart) for creation of ablation lesions in the atrium, HeartRhythm 7(6), 2010 [3] Blanck et al., Dose-escalation study for cardiac radiosurgery in a porcine model, Int. J. Radiat. Oncol. Biol. Phys. 89(3), 2014 [4] Bert and Durante, Motion in radiotherapy: particle therapy, Phys. Med. Biol. 56(16), 2011

**Nuclear Physics I / 69**

# Nuclear Masses and their Importance for Nuclear Structure, Nuclear Astrophysics and Fundamental Studies

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The mass of the nucleus reflects the total energy of this many-body system and thus is a key property for a variety of nuclear structure and fundamental investigations. Modern experimental techniques, like storage ring or Penning-trap mass spectrometry, have pushed in recent years the limits of sensitivity, resolution and accuracy. This has allowed to access exotic species very far from the valley of beta-stability. This could be done due to tremendous progress in production and preparation techniques for short-lived nuclides, e.g. by new target and ion sources combinations and the development of a multi-reflection time-of-flight separator.

The use of new manipulation techniques for stored ions has improved the resolving power by almost two orders of magnitude giving access to low lying isomeric states. The mass accuracy achieved even for very short-lived species in the ms regime and below allowed, e.g., to probe the shell structures and their evolution toward the neutron dripline or to perform in some regions fine examinations of the mass surface. The latter includes many exciting results like, for instance, an

intriguing observation in the heavy mass region reflecting either a N = 134 subshell closure or an octupolar deformation, testing of isospin symmetry in mirror nuclei, behavior of proton-neutron interaction across the closed shells, sensitivity of masses to collective structure of the nucleus and many others.
In addition, with the nowadays achievable accuracy in Penning-trap mass spectrometry on short-lived exotic nuclides, precision fundamental tests can be performed, among them a test of the Standard Model, in particular with regard to the weak interaction and the unitarity of the Cabibbo–Kobayashi–Maskawa quark mixing matrix. Furthermore, accurate mass values of specific nuclides are important for nuclear astrophysics and neutrino physics as well as for the search of physics beyond the Standard Model.
In this review, recent trends in the determination of nuclear masses, their impact on nuclear structure, nuclear astrophysics and fundamental studies and the comparison to modern calculations will be presented.

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## Ab initio calculations in nuclear physics

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The description of nuclei starting from the constituent nucleons and the realistic interactions among them has been a long-standing goal in nuclear physics. In addition to the complex nature of nuclear forces with two-nucleon, three-nucleon and possibly even four-nucleon components, one faces the quantum-mechanical many-nucleon problem governed by an interplay between bound and continuum states. In recent years, significant progress has been made in ab initio nuclear structure and reaction calculations based on input from QCD employing Hamiltonians constructed within chiral effective field theory. I will discuss recent breakthroughs that allow for ab initio calculations for ground states and spectroscopy of nuclei throughout the p-, sd-, and pf-shell and beyond with two- and three-nucleon interactions. I will also present new ab initio many-body approaches capable of describing both bound and scattering states in light nuclei simultaneously and discuss results for resonances in exotic nuclei, reactions important for astrophysics and fusion research.

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## Developments in Nuclear Structure

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Far from the valley of beta stability, the nuclear shell structure undergoes important and substantial modifications. In medium-light nuclei, interesting changes have been observed such as the appearance of new magic numbers, and the development of new regions of deformation around nucleon numbers that are magic near stability. The observed changes help to shed light on specific terms of the effective nucleon-nucleon interaction and to improve our knowledge of the nuclear structure evolution towards the drip lines. In particular, it has been shown that the monopole part of the tensor force of the proton-neutron interaction gives the main contribution to the shell evolution. The possibility of having a good theoretical description of these phenomena is essential to allow a deep insight into the nuclear effective interaction, to interpret the structure of nuclei far from stability, to predict the position of the drip-lines and to understand the nucleosynthesis pathways. In the last few years, particular effort has been put on studying light and medium-mass neutron-rich nuclei where these effects manifest more dramatically. Detailed nuclear structure information is becoming available both with stable and radioactive beams nowadays and deeper insight on nuclei approaching the drip line is foreseen with the future radioactive beams facilities. The status of the present scenario and future perspectives will be discussed.

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## Developments in Fission

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**Evening Talk / 81**

## Evening Talk: Novel Tests of QCD at FAIR

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The antiproton and heavy ion facilities at FAIR will provide ideal platforms for testing many novel aspects of Quantum Chromodynamics, the fundamental theory of hadron and nuclear physics. These include: (a) new probes of hadron and nuclear structure; (b) the breakdown of factorization theorems due to QCD lensing effects; (c) the nonuniversality of nuclear anti-shadowing; (d) the hidden-color degrees of freedom of nuclei; (e) the physics of charm and bottom production at high momentum fraction; (f) the production and decay of exotic heavy-quark hadrons; (g) higher-twist reactions such as digluon-initiated quarkonium production; and (h) color transparency and the dynamics of hard exclusive and diffractive reactions. I will also discuss recent advances in understanding color confinement and the fundamental light-front wavefunctions of hadrons in nonperturbative QCD.

**Nuclear Physics II / 77**

## First experiments with Super-FRS

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Super-FRS collaboration has been started this year that aims to identify the unique physics using Super-FRS as a separator and high-resolution spectrometer. The collaboration identified a number of experiments that should be prepared before completion of FAIR and Super-FRS. This talk present the over view of such unique experiments proposed with the Super-FRS collaboration.

**Nuclear Physics II / 78**

## First experiments with R3B

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The R3B experimental facility comprises a versatile setup for kinematical complete measurements of Reactions with Relativistic Radioactive Beams (R3B) at the FAIR facility at the high[U+2010]energy branch of the Super[U+2010]FRS. The R3B international collaboration has completed an extended R&D and prototyping phase and started construction of the final detector components. The central part, a super-conducting large-acceptance dipole magnet with high field integral, is almost completed and will be delivered to GSI and installed beginning of 2015 in the present experimental hall Cave C. The detection systems are added and integrated step-wise in Cave C and will be ready for commissioning and first experiments already in 2017 when the SIS18 will start[U+2010]up operation again. The completed and fully commissioned setup will be transferred to the FAIR experimental hall in 2019, when the construction of Super-FRS will be advanced. The combination of high-energy beams with a versatile and complete detection system for high-resolution measurements is basis for a unique physics program with radioactive beams to investigate properties and reactions of neutron-proton asymmetric nuclei, which will explore science questions related to nuclear structure, astrophysics, reactions, and nuclear matter. The presentation will give a brief overview of the R3B physics program and it's staging towards FAIR and at FAIR.

**Nuclear Physics II / 126**

## HISPEC/DESPEC: Status and first experiments

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The HISPEC/DESPEC collaboration is one of the sub-collaborations of NUSTAR and will utilise high-resolution γ-ray and neutron spectroscopy to address questions in nuclear structure, reactions and nuclear astrophysics. Experiments will use a range of detector setups to study exotic nuclei unreachable in other laboratories with the first experiments using the AIDA implantation and decay system in connection with a DESPEC Ge array (DEGAS) to measure β-decay life-times, Q values and excited states of neutron-rich nuclei. By using FATIMA (in combination with DEGAS) level lifetimes in the nanosecond regime can be accessed. Combinations of AIDA with the neutron detectors BELEN and MONSTER will give information on β-delayed neutron emission and neutron spectroscopy respectively, while the DTAS total absorption spectrometer will be used to measure the β-decay strength function. In-beam experiments will use the combined power of state-of-the-art γ-ray arrays such as AGATA combined with charged-particle detectors LYCCA (and the LEB spectrometer) to identify the secondary reaction products of interest. The status of our detector setups and the physics goals of our first experiments will be briefly discussed.

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## Ring Activities: Status and first experiments

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Cooled stored stable and exotic nuclei at highest atomic charge states offer unprecedented experimental conditions for atomic and fundamental physics as well as for nuclear structure and astrophysics research. The combination of the heavy-ion synchrotron SIS, fragment separator FRS and the cooler-storage ring ESR were for about two and a half decades a worldwide unique facility to conduct the corresponding experiments leading to many impressive results. It is therefore not surprising that the huge potential of storage-ring experiments is reflected in the FAIR facility, where the construction of several dedicated storage rings is foreseen suiting challenging experimental conditions for NuSTAR, APPA and PANDA projects. However, the modularised start version of FAIR caused severe consequences for the storage-ring based research programs. The present status, the short- and middle-term perspectives at GSI/FAIR as well as competition projects worldwide will be discussed in this contribution.

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## MATS and LaSpec: Status and first experiments

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The high production yields expected at the future Facility for Antiprotons and Ion Research (FAIR) will allow precision experiments on very exotic nuclei with the advanced trapping system MATS, for the measurements of atomic masses and nuclear-decay schemes, and with LaSpec,

for precision collinear laser spectroscopy of ions and atoms. MATS and LaSpec, designed since 2010 [1], will be located at the end of the Low Energy Branch (LEB) of the Super-FRagment Separator (Super-FRS). First-stage prototypes of both experiments have been installed at the TRIGA research reactor at Mainz Unversity [2]. In 2014, first off-line results with trans-uranium isotopes have been obtained with the MATS prototype for the first stage [3] and with praseodym and calcium at LaSpec. Both prototypes can be transferred to FAIR allowing to perform measurements in the first phase of the project, provided the LEB of the Super-FRS and the ion-catcher to thermalize the ions are in operation. In this contribution, the status of MATS and LaSpec together with potential nuclei to be studied initially at FAIR will be presented. Other on-going developments carried out within these international collaborations in order to extend the applicability of traps and lasers in subsequent phases of FAIR will be also shown.

[1] D. Rodríguez et al., Eur. Phys. J. ST 183 (2010) 1-123 [2] J. Ketelaer et al., Nucl. Instrum. Methods A 594 (2008) 162-177 [3] M. Eibach et al., Phys. Rev. C 89 (2014) 064318

**Instrumentation II / 72**

## Innovative technology for SiPM-like detectors

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Invented in Russia at the end of last century SiPMs have been significantly improved during following years. From the very beginning a SiPM demonstrated an ability to detect visible light photons from a single one to thousands and more but now this is a detector with really high photon detection efficiency which is even higher then 60%. Main figures of merit for the SiPM-like detectors - SSPM, APD-G, MPPC, SPM- are photon detection efficiency (PDE), interpixel crosstalk (XT) and dark rate. It should be noted that for significant number of applications it is not enough to have just a high PDE. It is quite important to have at the same time XT as low as possible. Crosstalk suppression is a hot technological problem for SiPM detectors now. SiPM's dark rate was considerably improved during last years of detector developments. Several years ago the average value for dark rate was at the level of 1MHz/mm2 and now advanced producers show values below 100 kHz/mm2. It looks like such trend will continue further. SiPMs started as matrixes of a p-n-junctions connected together on a common substrate and now such detectors have a name "analog" SiPM. It means that during last years a digital SiPM family have appeared where each photosensitive p-n-junction equipped by active electronic components. Such dSiPMs have an ability to access an each micropixel and in case of bad noise behavior to mask them out. In comparison to analog SiPM this kind of detectors is less sensitive to external conditions (voltage, temperature), do not require external electronics but PDE is lower and readout is slower. However, the position sensitivity of such detector is an attractive feature of a dSiPM and timing properties for large area detectors look better then for traditional analog SiPM approach.

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## Modern 3D-Detectors

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In historic perspective 3D-detectors have greatly advanced particle physics: cloud and bubble chambers, emulsion chambers, spark and streamer chambers have either led to Nobel Prize-worthy discoveries, or their invention itself was rewarded by a Nobel Prize. However, these detectors are read out visually and are thus notoriously slow. In this respect the invention of multi-wire proportional-chambers was a breakthrough (also rewarded by a Nobel Prize) and their offspring, e.g. drift and time-expansion chambers had further advanced particle science. However, modern experiments require 3D-detecors capable of taking data at unprecedented rates. This, in turn, evokes a further paradigm change in detectors technology: high performance front end computing becomes in integral part of the detector. We will present two examples of very modern, in fact,

not yet existing 3D-detectors: the proposed upgrade of the ALICE TPC and the CBM Silicon Tracking System. Both detectors are designed to record data at previously not conceivable rates and can be made working only in combination with massive online computing.

**Instrumentation II / 75**

## Superconducting magnet development for the FAIR accelerator complex

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Accelerators and Fragment Separators feeding experimental detectors of large scale scientific instruments, require magnets for the guiding their ion beams. The FAIR accelerator complex requires superconducting magnets for two machines: for SIS100 to achieve the requested high currents and SuperFRS for its large acceptance. In this contribution we summarize the most essential design aspects of the magnets for the targeted machines and the challenges in the magnet design next to the production status of the different magnets and their cryomodules. For SIS100 the first 3 m long series dipole (maximum field 1.9 T, ramp rate 4 T/s) has been built. We present its first test results obtained next to an outlook on further procurements.

**Instrumentation II / 76**

## Secondary Beam Targets at FAIR

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For the future FAIR facility two production targets are foreseen. In the SuperFRS target particles of the primary heavy ion beam will be fragmentated und selected in the succeeding fragment separator. Details of the SuperFRS have been presented in previous talks already. This talk will focus on the antiproton- or pbar-production-target. It will be bombarded by 29 GeV protons and proton-antiproton-pairs will created and separated in the pbar separator. The setup will be presented and compared with the Super FRS. Besides the technical parameters also radiation protection issues will be discussed.

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## Closeout/Summary