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Das Wormser



Book of Abstracts

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FAIR Overview I / 23

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.

FAIR Overview I / 24

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.

FAIR Overview II / 25

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.

FAIR Overview II / 26

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 spectroscopy.

FAIR Overview II / 27

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.

FAIR Overview III / 28

FLAIR

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FAIR Overview III / 29

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.

FAIR Overview III / 30

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.

FAIR Overview III / 31

Hades at FAIR**Author:** Jerzy Pietraszko¹¹ *GSI***Corresponding Author:** j.pietraszko@gsi.de

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 (ϕ , $\varphi(1321)$) [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.

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- [5] G. Agakishiev et al. Phys.Rev.Lett.103:132301,2009.

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NUSTAR activities at FAIR**Author:** Nasser Kalantar¹¹ *U Groningen***Corresponding Author:** n.kalantar-nayestanaki@rug.nl

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.

FAIR Overview IV / 33

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.

FAIR Overview IV / 34

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 diverse 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.

Hadron Physics I / 35

Results and Plans of LHCb in Charm Spectroscopy

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Hadron Physics I / 36

Results and Plans Compass

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Hadron Physics I / 37

Strangeness in Nuclear Physics

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Heavy Ion Physics I / 38

Electromagnetic 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 ($M < 1.5 \text{ GeV}$), 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 ($M > 1.5 \text{ GeV}$), the dilepton emissivity becomes continuum-like and its slope can serve as a thermometer. 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.

Heavy Ion Physics I / 52

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 field 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].

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Future Di-Lepton Experiments at SPS

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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.

Instrumentation I / 44

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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Hadron Physics II / 46

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.

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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 (Stockholm) 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 ($\sim 10^{16}$ V/cm) at distances from the ion of the order of the Compton wavelength ($\sim 10^{-11}$ 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 highly charged 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).

Applied, Plasma and Atomic Physics I / 50

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.

Heavy Ion Physics II / 53

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 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 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 momentum distributions 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 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 μm 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 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 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 $^{56}\text{Ni}(p,p)^{56}\text{Ni}$ in order to measure the differential cross section for elastic proton scattering and deduce the nuclear matter distribution and the radius of ^{56}Ni . Furthermore, as a feasibility study, we aimed for the investigation of the GMR of ^{58}Ni by utilizing $^{58}\text{Ni}(\alpha,\alpha')^{58}\text{Ni}$. 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 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 an 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 1 / 136

Laser cooling SIS 100 (ACC)

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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.

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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 ^{48}Ca -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 $^{48}\text{Ca}+^{243}\text{Am}$ 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 $7 \cdot 10^{18}$ ^{48}Ca 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 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 fission 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 3 / 139

WDM diagnostics (APPA)

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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 $2\text{-}3 \cdot 10^6$ particles/s/mm²) and various 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 performance during test and after irradiation with such beams will be reported.

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-m² 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/cm² and 25-kHz/cm² 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 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-Frequency 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 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 ($\sim 10^{10}$ to $\sim 10^{14} \text{ cm}^{-2}$). 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.

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[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 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 test-beam results into the CBMROOT simulation framework, feasibility studies on the measurement of di-electrons (low-mass vector mesons and J/ψ) 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 1 / 143

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

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Parallel Tier 2 / 138

PRIOR - the proton microscope for FAIR (APPA)

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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/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 PbWO₄ 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/c positrons. For calibration purposes a 150 GeV/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-2p_{3/2} 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.

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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-faceted 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.

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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.

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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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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 P_n . 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 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.

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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, planned 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 5 / 155

Neutrino Reactions in Supernova Nucleosynthesis (NUSTAR)

Author: Andreas Lohs¹¹ TU Darmstadt

We study the effect of neutrino microphysics on nucleosynthesis 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 outflow. 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 explicitly account for weak magnetism in neutrino nucleon interactions without any kinematical approximation. We find that these reactions are significant 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 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 ongoing 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 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 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.

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 $\Sigma\bar{\Sigma}$ 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 experiment and further options of this novel method will be discussed.

Parallel Tier 6 / 163

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.

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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 ± 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.

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- [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

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.

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.

Nuclear Physics I / 70

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.

Nuclear Physics I / 74

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.

Nuclear Physics I / 73

Developments in Fission

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Evening Talk / 81

Evening Talk: Novel Tests of QCD at FAIR

Co-author: Stan Brodsky¹

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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 presents the overview of such unique experiments proposed with the Super-FRS collaboration.

Nuclear Physics II / 78**First experiments with R3B****Author:** Thomas Aumann¹¹ *GSI***Corresponding Author:** t.aumann@gsi.de

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-energy branch of the Super-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 superconducting 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-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****Author:** Alison Bruce¹¹ *U Brighton*

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.

Nuclear Physics II / 127**Ring Activities: Status and first experiments****Author:** Yuri Litvinov¹¹ *GSI*

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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.

Nuclear Physics II / 128

MATS and LaSpec: Status and first experiments

Author: Daniel Rodriguez¹

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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 University [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.

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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 than 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-detectors capable of taking data at unprecedented rates. This, in turn, evokes a further paradigm change in detectors technology: high performance front end computing becomes an 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 cryomodels. 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 fragmented and 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 be 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.

Instrumentation II / 80

Closeout/Summary

210

Combination Of Message Queues And GPUs For The Event Building of the PANDA Experiment

Author: Ludovico Bianchi¹

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Poster presentation

218

Electromagnetic calorimeter for the HADES spectrometer

Author: Pablo Rodriguez Ramos¹

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Poster presentation

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Development of a compact, highly efficient heat exchanger assembly for bi-phase CO₂ Cooling of the CBM Silicon Tracker

Author: Evgeny Lavrik¹

Co-author: Jorge Sanchez Rosado²

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Poster presentation

91

Relativistic calculations of the isotope shifts in highly charged Li-like ions

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High-precision calculations of the isotope shifts in highly charged Li-like ions are performed. The mass shift contributions are calculated by merging the perturbative and large-scale configuration-interaction Dirac-Fock-Sturm (CI-DFS) methods. The field shift contributions are evaluated by the CI-DFS method including the electron-correlation, Breit, and QED corrections. The nuclear deformation and nuclear polarization corrections to the isotope shifts in Li-like neodymium, thorium, and uranium are also considered. The results of the calculations are compared with the theoretical values obtained with other methods.

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The CBM MUCH Detector

Author: Anna Senger¹

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Poster presentation

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Development of prototype components for the Silicon Tracking System of the CBM experiment at FAIR

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The detector module is the building block of the CBM Silicon Tracking System. It comprises of double-sided silicon microstrip sensors, ultra-thin read-out cables and novel front-end electronics. Various types of modules will be employed in the proposed detector system, differing in sensor size and cable length according to the position. We report on the development of these module components. The silicon micro-strip sensors have a CBM specific layout. The performance of recent full-size prototypes will be presented. The cables are stacks of two low-mass signal layers, based on fine-pitch aluminum lines, and spacers. They bridge the distance between the sensors and the read-out electronics. The electronics comprises self-triggering ASICs. The integration of sensors, read-out cables and electronics into detector modules has been realized. We summarize the construction and performance of recent prototypes at in-beam test conducted at Juelich with the proton beam of 2.4 GeV.

Invited Talk (yes/no)?:

no

93

Silicon microcalorimeters for high-precision X-ray spectroscopy of highly-charged heavy ions

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High-precision X-ray spectroscopy in highly-charged heavy ions provides a sensitive test of quantum electrodynamics in very strong Coulomb fields, and is, therefore, an established subject within the program of SPARC. To improve the precision of such experiments, the new detector concept of silicon microcalorimeters, which detect the temperature change of an absorber after an incoming photon has deposited its energy as heat, is now exploited.

The development of silicon microcalorimeters for hard X-rays has been pursued by GSI and the collaborating groups for more than two decades, and the successful application at the ESR storage ring has been demonstrated in the recent past. With arrays of silicon thermometers and X-ray absorbers made of high-Z material, a relative energy resolution of about 1 per mille is obtained in the energy regime of 50–100 keV.

The contribution will discuss the detection principle and achieved performance as well as the technical challenges for applications at FAIR. An overview of potential applications, i.e. Lamb shift measurements, spectroscopy of inner-shell transitions or the determination of nuclear charge radii, will be discussed.

Invited Talk (yes/no)?:

no

Nucleon Resonances for Nuclear Structure Research

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Nucleon Resonances for Nuclear Structure Research

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Nucleon resonances are known to play a significant role in nuclear systems matter and finite nuclei. Besides giving access to sub-nucleonic degrees of freedom, they are playing an indirect, but prominent role in nuclear structure physics, e.g. for nuclear binding energies through induced three-body interactions. Thereby, the virtual excitation of the Delta-resonance is the most important single contribution. In a recent experiment at the FRS@GSI the excitation of nucleon resonances was measured using secondary beams of short-lived exotic nuclei impinging on stable targets. Heavy ion charge exchange reactions were used to excite charge exchange states in the quasi-elastic and the resonance regions. Both (p,n) and (n,p)-type reactions were observed. The data clearly resolve the spectral distributions of nuclear and nucleon charge exchange excitations, considerably better than the previous pioneering experiments e.g. at DIOGENE@SATURNE. In both charge exchange channels the Delta resonance is clearly visible, well separated from the quasi-elastic spectral component. Indications for the excitation of higher resonances are seen. The data show that the FRS@GSI is an ideal, if not unique instrument to investigate the excitation mechanisms and production probability of nucleon resonances in cold nuclear matter at normal density and variable charge asymmetry. Even better conditions will be encountered in the future at the Super-FRS once the FAIR facility comes in operation. With the then available equipment investigations of the mesonic decay of resonances in either the target or the projectile nucleus will be possible, thus allowing to studying very explicitly self-energy effects of resonances in exotic matter. The excitation of nucleonic resonances in charge exchange reactions is described RPA theory. Corresponding response functions are obtained both for the projectile and target nuclei. Medium effects on the Delta and Roper excitations are taken into account by means of their corresponding self-energies. Response functions are calculated by state-of-the-art nuclear structure input. The reaction process by itself is described within a formalism using the same basic tensorial structures as familiar from leptonic processes as charge exchange neutrino scattering. A covariant formulation is used taking care of neutral and charge current processes. Initial and final state interactions between the reacting ions are taken into account in impulse approximation with NN T-matrix interactions and eikonal theory. Cross sections are calculated in a distorted wave eikonal approximation. The excitation of the Delta and the Roper resonance, both in the projectile and target nuclei are considered.

Particle flow and the reaction plane reconstruction with the CBM experiment

Author: Vasily Mikhaylov^{None}

Poster presentation

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Overview of the STS-XYTER – a dedicated front-end chip for the CBM Silicon Tracking System

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The STS-XYTER is a 128-channel charge-sensitive front-end chip, designed specifically for the Silicon Tracking System of the CBM experiment. The chip features a self-triggering architecture, which enables it to measure the signal amplitude and the time of arrival in each input channel autonomously, as soon as the signal in the given channel exceeds a predefined threshold. The design time resolution is about 10 ns, the dynamic range is 15 fC, and the amplitude is digitized with an integrated 5-bit flash ADC. Two shapers with distinct rise times are used to achieve low rate of noise hits in combination with the good time resolution, and low power consumption (6 mW/channel). The back end of the current version of the STS-XYTER is capable of transmitting the information of up to about $3 \cdot 10^7$ hits/s over four 500Mbps LVDS links. The characterization of chips samples is ongoing. An overview of the chip architecture as well as the operation principle will be given.

Invited Talk (yes/no)?:

no

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Study of compression modes of ^{56}Ni using an active target

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Compression modes, i.e., Isoscalar Giant Monopole Resonance (ISGMR) and Isoscalar Giant Dipole Resonance (ISGDR) can be studied in exotic nuclei using inelastic scattering in inverse kinematics. Since the spin and isospin of an alpha particle are both equal to zero, the most favourable process to study the isoscalar $L=0$ (GMR) and $L=1$ (GDR) modes is the inelastic alpha particle scattering. However, performing experiments with exotic beam is still a challenge, as beams of exotic nuclei have relatively low intensities. Hence to get a reasonable yield, a thick target is needed which in turn degrades the energy resolution. Therefore, a good alternative is to use an active-target, such as time-charge-projection-chamber (TCPC) MAYA at GANIL, in which the target can itself be used for detection and its thickness can be increased without a severe loss of energy resolution. Very low energy (\sim sub MeV) particle detection is also possible because MAYA has a low detection threshold. In the present experiment, inelastic scattering of secondary ^{56}Ni beam at energy of 50 MeV/u with the helium gas took place inside the target/detector volume. The tracks of the low-energy recoil alpha particles have been measured in the detector volume yielding their scattering angles, ranges and energies. Furthermore, we have measured the decay protons and alpha particles from the giant resonance region in ^{56}Ni using the forward-angle Si/CsI telescope, in coincidence with inelastically scattered alpha particles in MAYA. In this way we can study the macroscopic as well as microscopic

properties of the ISGMR and ISGDR of ^{56}Ni . Results obtained so far for the elastic and inelastic scattering will be discussed in this poster.

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Calculations of pair-creation probabilities in low-energy heavy-ion collisions

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The supercritical effects of QED have not yet been studied in experiments. The supercritical fields cause the instability of the vacuum, which can decay spontaneously via creation of electron-positron pairs [1]. Such strong fields can be achieved in low-energy heavy-ion collisions. At the future FAIR facility it will be possible to produce sufficient amount of heavy ions of required energies [2].

Investigation of supercritical effects requires the proper theoretical methods for treatment of heavy-ion collisions. In this work we present a many-electron method which takes into account the dynamics of occupied negative-energy states. The approach is based on propagation of all initial states via numerical solving of time-dependent Dirac equation using the monopole approximation. The amplitudes of the various processes are obtained with the second quantization technique [1, 3]. Employing the developed method the systematic calculations of pair-creation probabilities have been performed for subcritical and supercritical heavy-ion collisions.

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85

Isotope shifts of the g-factor of high-Z Li-like ions

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Co-authors: Andrey Volotka²; Dmitry Glazov¹; Guenter Plunien²; Ilya Tupitsyn¹

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Relativistic calculations of the nuclear recoil and nuclear size contributions to the g-factors of highly charged lithiumlike ions are performed. The nuclear recoil effect is calculated within the rigorous QED approach. As the result, the most accurate theoretical predictions for the corresponding isotope shifts are obtained.

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Charmonium ground state studies via e^+e^- annihilations

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Charmonium spectroscopy is an ideal tool to systematically study the strong interaction between the fundamental building blocks of matter, quarks and gluons. From a theoretical and experimental point of view, charmonium is considered as one of the most controllable two-quark systems. Hence, precision measurements of the properties of charmonia allow a thorough study of the non-perturbative features of the strong interaction, such as confinement and the dynamic generation of the mass of hadrons. Although all predicted charmonium states below the open-charm-production threshold have been observed experimentally, our knowledge is surprisingly sparse on the spin singlet S-wave states, including the charmonium ground state, the η_c . Even for the basic properties of this state, the mass and width, large discrepancies between various experiments have been observed. Intriguingly, BESIII recently observed an interference between various hadronic decays of the η_c and a non-resonant background in radiative magnetic dipole transitions. Although, such an interference partially explains the discrepancies observed earlier, its origin remains a puzzle. In this work, we study the η_c line shape using world's largest data sample of $\Psi(3686)$ events which is collected in e^+e^- annihilations with the BESIII detector at the BEPCII storage ring in Beijing, China, with the aim to shed light on this puzzle.

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Quality assurance for the CBM Silicon Tracking System

Author: Anton Lymanets¹

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Poster presentation

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Observation of coherence in radiative recombination

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The process of radiative recombination (RR) was studied in the regime of hard x-rays. In the experiment the relativistic electrons recombined into the $2p_{3/2}$ excited state of hydrogenlike uranium ions and the RR x-rays and the subsequently emitted characteristic x-rays were detected in coincidence. In this new type of experiment the reaction plane is defined by the incoming (unpolarized) electron and the emitted RR x-ray propagation directions, and, most importantly, the formed excited state becomes a coherent superposition of the magnetic substates. Here the electron propagation direction in the ion rest-frame is taken as the quantization axis. As the result of the coherence the state

attains a new alignment axis, which is confined to the reaction plane and forms a finite angle γ with respect to the collision axis. The alignment angle γ can be measured via the angular distribution of the characteristic Ly α 1 x-rays.

The results show the dominance of the relativistic effects and indicate the generation of the strong magnetic fields during the recombination process. The technique of the photon-photon coincidences was extended, for the first time, to the domain of hard x-rays and heavy ions. This is a qualitative improvement from the previous experiments, and it has a high potential for studies of alignment and polarization phenomena in atomic collisions. Moreover, by this technique we are able to manipulate and monitor the alignment and coherence of the excited states in heavy highly charged ions.

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Development of novel Compton polarimeters and imagers

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To study fundamental processes in atomic collisions and perform polarisation diagnostics of hot fusion and astrophysical plasmas we develop a broad range of polarisation sensitive x-ray and gamma-rays detectors. Two detectors are based on Silicon PIN diodes and Silicon Drift Detectors and dedicated to the energy range of 10-30 keV. This is the lowest energy range that was accessed by the Compton and Rayleigh polarimeters. For the energy range of 30 keV - 2 MeV we use a segmented planar germanium detector. It employs a novel technique of Pulse Shape Analysis of the detector signals for a 3D sensitivity to the positions of the x-ray interactions. With this detector we for the first time employed the techniques of Compton Imaging and background reduction in a physics experiment. It also achieved the polarisation resolution of 0.3 deg which is the record for Compton polarimetry. To improve this further we develop a high resolution polarimeter that is based on a rotationally symmetric annular planar segmented germanium detector.

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Thermal Simulations For the Super-FRS Slit System

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X- and Y \times position slit systems will be used as collimator for stopping the unwanted charge states of primary beam and fragments produced at the reaction target of the in-flight Superconducting Fragment Separator (Super-FRS) at the FAIR facility, GSI. In the case of the most frequently used fission reaction of ²³⁸U beam at 1.5 GeV/u on ¹²C target (2.5 g/cm²), the most abundant charge states of ²³⁸U fragments produced at the target are 92+, 91+ and 90+ ions. Among these fragments, 90+U fragments with 2.7% emission probability from the target may reach the PPF2 X-slits with an energy of about 1.3 GeV/u with a maximum power of 500 W. This value represents an upper limit, because the intensity will be lower for lower charge states produced, and at the other slit positions. A block of high-density material with 96% of Tungsten, 3% of Nickel and 1% of Iron, named as DENSIMET@185 has been proposed to be used as a slit in Super-FRS pre and main separator areas. Thermal simulations are carried out to estimate the maximum and minimum temperature values

on the slits and -on the apparatus in the neighbourhood of the slits. Several cooling methods have been simulated on a block of DENSIMET with a proposed dimensions 200 mm X 180 mm X 250 mm, and which will be used in the pre-separator area of Super-FRS beam line. The present results from the thermal simulations suggest a new way of cooling technique to lower the temperature of the block by substantial amounts without any water cooling during experiments at Super-FRS beam lines.

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Laser cooling of ion beams - from ESR and CSRe to HIAF and FAIR

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We present recent results from laser cooling and preparatorial experiments at ESR and CSRe. One of the first steps towards laser cooling of highly charged ions at high beam energies will be the development and testing of laser systems with large frequency range to address the initially broad momentum spread of ion beams injected into a storage ring. For Li-like and Na-like heavy ions transition life times are short, demanding high laser intensities for saturation of the cooling transition. We show how a combination of scanning cw and pulsed lasers can be used for efficient cooling and how advanced optical detection techniques can complement standard beam diagnostics.

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CBMTRD: Chamber Prototype and Readout Developments

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Poster Abstract:

The Compressed Baryonic Matter (CBM) experiment is one of the major experiments which is planned for the Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany. The goal of the CBM research program is to explore the QCD phase diagram in the region of high baryon densities using high energy nucleus-nucleus collisions. In the CBM experiment, high interaction rates will be measured. For this purpose, a special detector design is required to be fast enough to digest these extreme rates.

The Transition Radiation Detector (TRD) is being designed to identify electrons and positrons with $p > 1.5$ GeV/c, emerging from these collisions. This will allow the measurement of J/Ψ and low mass vector mesons in A+A and P+A collisions with the CBM experiment. In Frankfurt, a Multi Wire Proportional Chamber (MWPC) prototype with high signal collection speed is designed and developed, that will be able to cope with the high hit rates anticipated in the CBM.

The poster will demonstrate TRD prototype designs as well as electronic readout chain applied to accumulate the data from the planned test beam campaign at the CERN-SPS in Geneva, Switzerland.

Keywords: CBM; TRD

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The Micro Vertex Detector of the Compressed Baryonic Matter Experiment at FAIR.

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The Compressed Baryonic Matter Experiment (CBM) is one of the core experiments of the future FAIR facility at Darmstadt/Germany. The fixed-target experiment will explore the phase diagram of strongly interacting matter in the regime of highest net baryon densities with numerous probes, among them open charm. Open charm reconstruction requires a vacuum compatible Micro Vertex Detector (MVD) with unprecedented properties. Its sensor technology has to feature a spatial resolution of $< 5\mu\text{m}$, a non-ionizing radiation tolerance of $> 10^{13}$ neq/cm², an ionizing radiation tolerance of 3 Mrad and a readout time of few 10 μs /frame. Thinned Monolithic Active Pixels Sensors, developed at IPHC Strasbourg, are promising candidates, if integrated in an ultra-thin detector, employing high-performance materials such as thermal CVD-Diamond. After the prototyping phase, we focused on finalizing the MVD layout and studying its performance. We are also progressing with an upgrade of the read-out chain and addressing the pre-integrations activities. The above mentioned activities are the subject of this contribution.

Invited Talk (yes/no)?:

NO

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Feasibility studies for the open-charm production in proton-antiproton reactions for the PANDA experiment

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The PANDA experiment is one of the pillars of the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany. The PANDA physics program is focused on answering fundamental questions related to Quantum Chromodynamics (QCD), mostly in the non-perturbative energy

regime. Spectroscopy exploiting D-mesons and Λ_c -baryons that are composed of a heavy charm valence quark and one or two light valence quarks is an integral part of the PANDA physics program. Such systems can systematically provide information on various key features of QCD, such as heavy-quark symmetry, chiral symmetry breaking, and the nature of exotic states. In this work, the experimental feasibility of studying the production mechanisms of associative open-charm hadrons in antiproton-proton annihilations is investigated using Monte Carlo simulations. We present results obtained for the channels $p^- + p \rightarrow D^0 D^{\bar{0}}$ and $p^- + p \rightarrow \Lambda^+ c \Lambda^- c$, highlighting the detector performances (efficiencies and resolutions) and the statistical significance that can be achieved with the foreseen luminosities.

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A flexible COME & KISS QDC for PMT and MAPD readout

Author: Adrian Rost¹

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Poster presentation

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A NEW PROTOTYPE WITH ALTERNATING WIRES FOR THE CBM-TRD

Author: Susanne Gläsel¹

Co-authors: Andreas Arend¹; Christoph Blume¹; Ernst Hellbär¹; Florian Roether¹; Pascal Dillenseger¹; Werner Amend¹

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The CBM (Compressed Baryonic Matter) at FAIR will be dedicated to the exploration of the QCD phase diagram in the region of high net-baryon densities. The CBM Transition-Radiation Detector (TRD) has to deliver a good tracking and electron identification performance at high interaction rates. A thin Multi-Wire Proportional Chamber without drift volume delivers the required high rate capabilities.

One key challenge is to achieve stability of the gas gain. To reduce its sensitivity to cathode deformations, an alternating wire structure, as proposed for the ALICE VHMPID (Nucl. Instrum. Meth. A698 (2013) 11-18), is exploited: Field wires are introduced between the sense wires to improve the field line geometry and its stability.

Lab measurements of the anode current and of the energy resolution were performed with an iron-55 source. The results clearly indicate a superior performance for the new prototype: Gain variations can be reduced from up to 60 % (standard prototype) to below 15 % (new prototype).

Supported by BMBF and the Helmholtz International Centre HICforFAIR.

Invited Talk (yes/no)?:

no

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Relativistic calculations of pair creation probabilities in low-energy heavy-ion collisions

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Co-authors: Guenter Plunien²; Ilya Tupitsyn¹; Vladimir Shabaev¹; Yury Kozhedub¹

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Collisions of highly charged ions allow to study relativistic and quantum electrodynamic effects. If the total charge of the colliding nuclei is larger than $Z_c = 173$, the ground state of the combined quasi-molecular system should dive into the negative-energy Dirac continuum. Investigation of the processes accompanying such collisions can gain insight into the detection of the diving phenomenon. Relativistic calculations of the differential electron-positron pair creation probabilities in the collision of two uranium nuclei at the energy close to the Coulomb barrier are performed. Two methods of differential probability evaluation are compared. One of them uses an exact wave function of continuum, while another one uses a wave function of discretized continuum in a finite basis.

Invited Talk (yes/no)?:

no

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A Luminosity Detector for PANDA

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The detector of the PANDA experiment at FAIR is optimized for hadron spectroscopy especially in the charm sector. Main topics of the PANDA physics program are the search for new and predicted states and the precise measurement of the line shape of new and already discovered resonances, e.g. the X(3872). This will be done by using the energy scan method for measuring the line shape very precisely and by the determination of the quantum numbers. Crucial for these measurements is the precise determination of the luminosity at each energy point for normalization of the data taken. For the measurement of the luminosity, elastically scattered antiprotons at extreme forward angles will be used in the angular range of 3.5 to 8 mrad. The very precise determination of the scattering angles of the antiprotons and the separation of the scattered antiprotons from inelastic background reactions are only two of the challenges of this detector system. The luminosity detector will use 4 planes of HV-MAPS (High Voltage Monolithic Active Pixel Sensors) for the reconstruction of the tracks. The active area of the detector extends from 3.5 to 10 cm from the beam axis. The whole detector system will be operated in vacuum in order to reduce the systematic uncertainty due to multiple scattering. The design of the PANDA luminosity detector will be presented.

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TRIGA-SPEC - a development platform for MATS and LASPEC

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The TRIGA-SPEC experiment [1] at the research reactor TRIGA Mainz consists of a Penning trap experiment (TRIGA-TRAP) for mass measurement and a collinear laser spectroscopy setup (TRIGA-LASER). These setups are the prototypes for the MATS- and the LASPEC-Experiments at FAIR [2]. It is used for technical developments to improve the sensitivity and accuracy of the techniques. Additionally the reactor will provide also short-lived isotopes produced by neutron-induced fission of ²³⁵U, ²³⁹Pu or ²⁴⁹Cf in a target chamber that is located close to the reactor core. The fission products are transported to the on-line surface ionization source, where they are ionized.

The ions are accelerated to 30 keV and mass separated in a dipole magnet. To increase the detection efficiency of both experimental branches, radiofrequency-quadrupole (RFQ) is included in the common beamline to cool and bunch the ions. The energy spread and temporal width of the bunches has been characterized and optimized by time resolved collinear laser spectroscopy in the optical detection chamber of the TRIGA-LASER setup. That became possible due to the development of a new time-resolved data acquisition system and has been used to improve the RFQ settings, leading to a better adaption of the bunch properties to the respective experiment. This is very important for the injection into the Penning trap system (TRIGA-TRAP) for precision mass spectrometry as well as for collinear laser spectroscopy (TRIGA-LASER).

The setup as well as the latest developments and results at TRIGA-SPEC are presented.

[1] J. Ketelaer et al., Nucl. Instr. Meth. A 594, 162 (2008)

[2] D. Rodriguez et al., Eur. Phys. J. Special Topics 183, 1-123 (2010)

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Invited Talk (yes/no)?:

no

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Status and improvements of the LASPEC-prototype TRIGA-LASER

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The TRIGA-LASER setup is the prototype of the LASPEC experiment at the future FAIR facility, where collinear laser spectroscopy will be applied to extract nuclear charge radii, spins and nuclear moments of short-lived radioactive isotopes produced by the Super-FRS [1]. Since it is being developed as part of the TRIGA-SPEC experiment [2] at the research reactor TRIGA Mainz, it will be supplied with short-lived radioactive isotopes which are produced by neutron-induced fission of ²³⁵U, ²³⁹Pu or ²⁴⁹Cf inside the reactor and ionized in an online ion source.

Collinear laser spectroscopy is strongly facilitated by an RFQ cooler and buncher: Restricting the photon detection to times when an ion bunch arrives at the detection region reduces the laser-induced background by four to five orders of magnitude [3]. As a first test of the newly developed FPGA-based time-resolved data acquisition [4] and the TRIGA-SPEC RFQ, the hyperfine structure of ⁴³Ca⁺ was recorded with cooled and bunched ions. This brings the TRIGA-LASER experiment very close to the spectroscopy of radioactive ions produced by the online ion source.

Spectroscopy was carried out on stable calcium ions using an offline ion source installed directly at the TRIGA-LASER beamline. These measurements of the D1 and the D2 line of Ca⁺ ions supported by the frequency comb allowed us to considerably improve the accuracy of the isotope shift in the D2 line compared to literature.

The improvement of the data acquisition and the measurements of the calcium-D2-line will be presented.

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[2] J. Ketelaer et al., *Nucl. Instr. Meth. A* 594, 162 (2008)

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This work was supported by the Helmholtz Association, HIC for FAIR, PRISMA cluster of excellence and the Bundesministerium für Forschung und Lehre.

Invited Talk (yes/no)?:

no

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Simulation of the PANDA Lambda disks

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The main physics motivation of PANDA is to explore the non-perturbative regime of QCD and to study hadronic states. In this context, here is a possibility to include hyperon studies in the PANDA physics program. Hyperons travel a large distance before they decay into other particles. In order

to increase the acceptance to measure these particles, there is a concept to include an additional “Lambda Disk” detector. The Micro Vertex Detector (MVD) is the innermost tracking detector of PANDA. It consists of four barrel layers and six forward disk layers. It is made up of two types of silicon sensors – silicon hybrid pixels and double sided silicon strips. The last layer of the MVD forward disk is situated at 23 cm downstream of the interaction point and the first layer of GEM tracking station is located 110 cm downstream from the interaction point. Hence, there is a large region, close to the beam pipe, without tracking information. Therefore, it is proposed to place two additional disks known as the Lambda disks in this region. The detector will enhance the reconstruction probability for hyperons. As a starting geometry, the Lambda disks have been proposed to contain only double sided silicon sensors elements and not any pixel sensors. At present, we are involved in simulation studies of the Lambda disks detector with the reaction $p\bar{p} \rightarrow \Lambda \bar{\Lambda}$ to calculate the reconstruction efficiency and resolution for this channel. This channel provides essential input in understanding the vertex reconstruction of hyperon pairs. We have also started to study with the reactions $p\bar{p} \rightarrow D^+ D^-$ and $p\bar{p} \rightarrow J/\psi \pi^+ \pi^-$ to see how the reconstruction performance of these channels is affected with and without the Lambda disks. In this presentation we will report about the reconstruction efficiency of lambda and lambda bar particles with and without the Lambda disks. In addition, a simulation study of detector coverage and material budget with the Lambda disks essential for the development of the detector will be presented.

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Parity nonconservation effect in the resonance elastic electron scattering on heavy He-like ions

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We investigate the parity nonconservation effect in the elastic scattering of polarized electrons by heavy He-like ions, being initially in the ground state. The enhancement of the parity violation is achieved by tuning the energy of the incident electron in resonance with quasidegenerate doubly-excited states of the corresponding Li-like ion. Two possible scenarios are considered. In the first scenario, the polarization of the outgoing electron is assumed to be detected, while in the second one it remains unobserved. The feasibility of the experimental study of the proposed process is discussed.

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Ionization probabilities in highly charged ions exposed to strong laser fields

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Nowadays, laser technologies are rapidly developed. For instance, there is PHELIX facility (The Petawatt High-Energy Laser for Heavy Ion EXperiments) [1] at GSI (Darmstadt). This facility allows us to obtain extremely intense laser fields. Highly charged ions are the ones of the most interesting objects that can be experimentally studied with such strong fields. FAIR will provide a unique opportunity to carry out ionization experiments with highly charged hydrogenlike ions (up to uranium) exposed to strong laser fields from PHELIX facility for testing QED effects in extremely intense fields. The theoretical description of the process under consideration is needed for such experiments at FAIR.

In present work the time-dependent Dirac equation for a highly charged hydrogenlike ion in presence of a strong laser field was solved numerically. The interaction with the intense electromagnetic pulse was considered within the dipole approximation in the length gauge. At the first stage the stationary problem in the Coulomb potential of the nucleus was solved with the dual kinetic-balance (DKB) approach [2], in which the basis functions are constructed from B-splines. The DKB approach provides a solution of the stationary radial Dirac equation. A significant advantage of this approach is the absence of spurious states. At the second stage the time-dependent problem for a hydrogenlike ion in presence of a strong electromagnetic field was solved. The time-dependent Dirac wave function was expanded in terms of the stationary Dirac equation solutions. The expansion coefficients were found employing the Crank-Nicolson propagation scheme [3].

Relativistic calculations of the excitation and ionization probabilities in highly charged ions exposed to strong laser fields were performed. Also convergence properties of the excitation and ionization probability values with respect to different basis set parameters used in the calculations were studied.

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Relativistic calculations of critical distances for homonuclear quasi-molecules

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The ground-state energies of one-electron homonuclear quasi-molecules for the nuclear charge number in the range $Z = 1 - 100$ at the “chemical” distances $R = 2/Z$ (in a.u.) are calculated. The calculations are performed for both point- and extended-charge nucleus cases using the Dirac-Fock-Sturm approach with the basis functions constructed from the one-center Dirac-Sturm orbitals. The critical distances R_{cr} , at which the ground-state level reaches the edge of the negative-energy Dirac continuum, are calculated for homonuclear quasi-molecules in the range: $85 \leq Z \leq 100$.

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Calculation of the binding energies of berylliumlike ions

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In this work the calculations of the binding energies of four-electron (berylliumlike) ions are performed for the wide range of the nuclear charge values $Z = 18 - 96$.

The calculations incorporate the first two orders of the rigorous QED perturbation theory. The third and higher orders of the interelectronic interaction are calculated within the Breit approximation by means of the configuration-interaction Dirac-Fock-Sturm method. In addition, the effects of nuclear recoil and nuclear polarization are taken into account.

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Charge states distribution for Bi²⁶⁺ and Au²⁶⁺ after a plasma stripper

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This plasma stripper experiment is performed at Z6 area of GSI. We adapt the two ion species of Bi and Au with both the initial charge state of 26+. These 3.6 MeV/u projectiles with a frequency of 36 MHz penetrate the hydrogen plasma produced in the inductively coupled plasma device. The both 3.6 MeV/u Bi²⁶⁺ and Au²⁶⁺ with a frequency of 36 MHz are adopted as the projectiles. Taking advantage of a dipole, the emergent projectiles with the different charge state are separated on a Scintillator. The emitting photons from this Scintillator are captured by an ICCD camera. Under the assumption of proportionality relationship, the charge states distribution of projectiles after the plasma are obtained.

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Studies of the coherence in two-step radiative recombination of highly charged heavy ions

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Radiative recombination (RR) is one of the basic processes that occurs in laboratory plasma, in collisions of heavy ions with electrons at ion storage rings and EBIT. During the last decades RR of highly charged heavy ions remains the subject of intense theoretical and experimental research (see Ref.[1] and references therein). Radiative recombination is a time-reversed photoionization, hence it allows to study this fundamental electron-photon interaction in large-energy and strong-field regime, which is not accessible in the direct channel. Moreover, the RR is very sensitive to the spin, relativistic and QED effects in the structure and dynamics of heavy atomic systems.

We investigate the radiative recombination of the relativistic electron with bare heavy ion into the $2p_{3/2}$ excited state of H-like ion and its subsequent Lyman- α_1 ($2p_{3/2} \rightarrow 1s_{1/2}$) decay. We consider the scenario where RR photon and subsequently emitted characteristic photon are detected in coincidence. In this case the axial symmetry of the RR-populated $2p_{3/2}$ state is removed and the magnetic sublevels of the highly charged ion are populated coherently [2]. In our previous work [3] we found a rather strong correlation between the polarization states and emission patterns of the recombination and decay photons in the process under consideration. In the present work we have employed the density matrix approach and relativistic Dirac's theory for description of the coherence between the magnetic substates of the highly charged heavy ion.

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High precision calculations of the hyperfine structure in Li-like bismuth

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Investigations of the hyperfine splitting (HFS) in highly charged ions can provide tests of quantum electrodynamics (QED) in the strongest electromagnetic field presently available. The simultaneous study of the HFS in H- and Li-like ions is required, since the Bohr-Weisskopf effect, dominating the theoretical uncertainty, is almost cancelled in the specific difference of the HFS values (cf. [1]). Ab-initio calculations of the screened QED corrections are needed to decrease the uncertainty of the theoretical prediction for this specific difference. Recently, the HFS in Li-like bismuth was observed in laser spectroscopy experiment at the experimental storage ring (ESR) in GSI (cf. [2]). In the present work the screened diagrams containing electric and magnetic vacuum-polarization loops have been

evaluated to all orders in αZ [3, 4, 5]. The internal-loop contributions are rigorously approached including the Uehling and the Wichmann-Kroll terms. The accuracy of the theoretical prediction for the specific difference of the hyperfine splitting values in H- and Li-like bismuth is improved.

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Disentangling PANDA's timebased data stream

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Poster presentation

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System integration of the Silicon Tracking System for the CBM experiment at FAIR

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Poster presentation

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Relativistic calculations of the isotope shifts in highly charged Li-like ions

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Poster presentation.

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Production of hypernuclei from excited nuclear residues in relativistic ion collisions: New opportunities for FAIR.

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Investigation of hypernuclei is a rapidly progressing field of nuclear physics, since they give opportunities both to improve methods of traditional nuclear studies and to open new horizons for studying particle physics and nuclear astrophysics. Within dynamical and statistical theories we study the main regularities in the production of hypernuclei emerging from the projectile and target residues in relativistic ion collisions. This process will also allow to understand the mechanisms of peripheral collisions and the properties of hyper-matter of low temperatures, including hyperon-hyperon interactions at low energies. We demonstrate that the yields of hypernuclei increase considerably at beam energies above the energy threshold for Lambda hyperons (~ 1.6 AGeV), followed by a saturation for yields of hypernuclei with increasing the beam energy up to few TeV [1]. These hypernuclei have a broad distribution in masses and isospin. They can even reach beyond the neutron and proton drip-lines since they are stable with respect to nucleon emission [2]. Weak decay of such hypernuclei may lead to formation of normal nuclei beyond the drip-lines also, thus providing a unique chance for reaching the islands of stability on the nuclear chart. The production of specific hypernuclei depend strongly on the isotopic composition of the projectile, therefore, it will be possible to obtain exotic hypernuclei that may be difficult to reach in traditional hypernuclear experiments [1]. We show also new calculations including DCM, UrQMD, and HSD transport models, the coalescence model, and the statistical model, with formation of light hypernuclei at all rapidities and large hyper-residues. The perspectives of hypernuclear studies involving these novel processes at the present accelerators are discussed.

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Recoil effect to the g factor of boronlike ions

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g factor of highly-charged ions proved to be an excellent tool for the high-precision comparison between experiment and theory. Measurements of the bound-electron g factor in light highly charged ions during the last 15 years have reached an accuracy of ppb and better [1-4]. As a spectacular result of these investigations, the most accurate value of the electron mass was obtained [5]. Experiments with heavy ions, in particular, those planned at FAIR, will give an opportunity to test quantum electrodynamics in strong electric and magnetic fields. In addition, simultaneous study of

g factors of heavy hydrogenlike and boronlike ions will allow for precise determination of the fine structure constant [6]. Currently, the g-factor measurements for boronlike argon are performed at GSI (ARTEMIS experiment) [7]. At present, the accuracy of the corresponding theoretical value is at the ppm level [8] and its improvement is in demand.

We present the evaluation of the nuclear recoil effect to the g factor of boronlike ions in the ground $P_{1/2}$ state and in the first excited $P_{3/2}$ state in the medium-Z region. Recoil correction is calculated to first order in the electron-to-nucleus mass ratio, and to zeroth and first orders in $1/Z$. The leading-order relativistic corrections are taken into account to zeroth order in $1/Z$ according to the formulae obtained in Ref. [9]. The first-order contribution in $1/Z$ is considered within the nonrelativistic theory. The results allow us to improve accuracy of the recoil correction to the g factor of boronlike ions for $P_{1/2}$ and $P_{3/2}$ states.

The work was supported by the SAEC “Rosatom”, the Helmholtz Association, RFBR (grants 13-02-00630 and 14-02-31316), Saint-Petersburg State University (grants 11.0.15.2010 and 11.42.1225.2014), and DFG (grant VO 1707/1-2).

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The Micro Vertex Detector project in the PANDA experiment

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The fixed target experiment PANDA will use cooled antiproton beams of unprecedented quality that will be available at the Facility for Antiproton and Ion Research (FAIR) in Darmstadt.

PANDA includes the Micro Vertex Detector (MVD) [1], as innermost tracker, and in particular it will allow the secondary vertices of short-lived particles to be detected. Due to the forward boost of the particles produced by antiprotons with momenta up to 15 GeV/c the MVD layout is asymmetric with four barrels surrounding the interaction point and six disks in the forward direction. The inner layers are composed of hybrid epitaxial silicon pixels and the outer ones of double sided silicon strips, with about 10.3×10^6 pixels and 162×10^3 strips channels.

PANDA features a triggerless architecture, therefore the MVD has to run with a continuous data transmission at a high interaction rate (about 10^7 interactions/s) with hits which will have precise timestamps (the experiment clock is 160 MHz). In addition, the energy loss of the particles in the sensor will be measured as well.

To cope with these requirements, custom readout chips are under development for both hybrid pixel (ToPix in 130 nm CMOS technology) and double sided silicon strip (PASTA in 110 nm CMOS technology) devices.

The powering and cooling of the readout are challenging since the MVD volume is limited by the surrounding detectors. The MVD will work at room temperature to simplify the layout which foresees the routing of cables and cooling pipes and the services in the backward region only.

The simulations show that the main component affecting the material budget of this detector is the cabling [1]. The present MVD layout foresees aluminum interconnections instead of copper in the active volume.

The support structures are made of carbon fibers and highly thermal conductive carbon foam with

embedded cooling pipes underneath the readout chips. The use of carbon paper to increase the cooling efficiency and decrease the material budget is under study.

The design of the MVD is in an advanced stage. Detector prototypes have been built and tested to validate the design of each components and the triggerless readout.

The MVD technological aspects will be reported in this talk.

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The RICH detector of the CBM experiment and its physics potential

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Poster presentation

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The CBM First Level Event Selector (FLES)

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Poster presentation.

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Constraining the symmetry energy of the nuclear matter equation of state at supra-normal densities

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Understanding the equation of state (EOS) of nuclear matter is of fundamental importance in many areas of nuclear physics and astrophysics [1]. The EOS may be divided into a symmetric matter part independent of the isospin asymmetry and an isospin term, also quoted as symmetry energy $E_{sym}(\rho)$, that enters with a factor δ^2 into the equation of state [2], where $\delta = (\rho_n - \rho_p)/\rho$, where ρ_n , ρ_p , and ρ are neutron, proton and nuclear matter densities.

The EOS of asymmetric nuclear (neutron) matter is a quantity of crucial significance in understanding the physics of isolated and binary neutron stars, type II supernovae and neutron star mergers. Experimental information about the EOS can help to provide improved predictions for neutron star observables such as stellar radii and moments of inertia, crustal vibration frequencies, and neutron

star cooling rates, which are currently being investigated with ground-based and satellite observatories.

In the laboratory, there are different means to study the nuclear matter equation of state and the density dependence of the symmetry energy in particular: nuclear masses, neutron skins, pygmy resonance, and nuclear structure at the drip line give access to nuclear matter properties at densities lower than and at saturation density ρ_0 . But heavy ion collisions provide the only way to explore densities different from the saturation density ρ_0 in the laboratory, as in the course of such a collision matter suffers compression and expansion phases. In the beam energy range of 0.1 to 2.0 A GeV nuclear matter is compressed upto three times normal nuclear matter density.

Several observables (e.g. neutron/proton ratios and elliptic flow) from collisions of radioactive and stable beams are predicted to be sensitive to the symmetry energy. The unique opportunities for such studies FAIR will offer will be discussed.

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Low-mass di-electron reconstruction at the CBM experiment

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The Compressed Baryonic Matter (CBM) experiment at the future FAIR facility is designed to investigate high baryon density matter at moderate temperatures in Au+Au collisions from 4A GeV to 35A GeV beam energies. 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 decay channel. In the presented simulation studies we investigate the feasibility to effectively reduce the combinatorial background with the currently foreseen experimental setup, which does not provide electron identification in front of the magnetic field. The strategy of the electron identification and background suppression will be discussed. Simulation results with most-up-to date realistic detector description as well as detailed background studies will be presented.

Invited Talk (yes/no)?:

no

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First steps towards atomic physics of fast ion - slow ion collisions: the FISIC project

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Radiator and detector prototype for CBM TRD design and performance

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The CBM TRD Detector - hardware and planning

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Online reconstruction of multi-strange hyperons in the CBM Experiment

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The Time-Of-Flight System of the CBM Experiment

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Radiation hydrodynamics simulations of matter at high energy density

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Concept and performance of the Silicon Tracking System for the CBM experiment at FAIR

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Measurement and DWBA analysis of the ${}^7\text{Li}({}^3\text{He},d){}^8\text{Be}$ reaction cross sections at $E({}^3\text{He}) = 20 \text{ MeV}$

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The elucidation of production and destruction processes of Lithium, Beryllium and Boron light elements both in stellar and interstellar media is of crucial interest in connection with several astrophysical problems. In addition to the rarity of Li, Be and B elements in the solar-system (the Li-Be-B problem), some of these problems are, e. g., the origin and interactions of cosmic rays, galactic chemical evolution and gamma-ray astronomy. Important efforts have been made previously in order to improve our knowledge of these problems, and the current work dealing with the ${}^7\text{Li}(p, \alpha){}^8\text{Be}$ nuclear reaction enters in this framework. This reaction indubitably contributes to the depletion of lithium in stellar interiors and, consequently, the corresponding rate needs to be determined with the highest possible precision at stellar temperatures. Several experiments have been carried out to perform direct measurements of the astrophysical $S(E)$ -factor for this reaction [1-3]. This method would yield more accurate results if the partial (reduced) widths involved in theoretical expressions to be fitted to experimental data were known with limited uncertainties. Alternatively, this goal may be more easily attained, for instance, via a DWBA theoretical analysis of angular distribution experimental data for the ${}^7\text{Li}({}^3\text{He}, d){}^8\text{Be}$ proton-transfer reaction where the $2+$ excited states of ${}^8\text{Be}$ of astrophysical interest at $E_x = 16.626 \text{ MeV}$ and 16.922 MeV are formed with high cross sections. In this work, the angular distributions for these states and the $1+$ state at 17.640 MeV produced in the later reaction have been measured at the Orsay – Institut de Physique Nucléaire tandem accelerator for $E({}^3\text{He})=20 \text{ MeV}$, using a high energy resolution position sensitive detection system on the line of the split-pole electromagnetic spectrometer. Then, the measured cross section data have been carefully analyzed within the DWBA theory, extracting relevant values of the nuclear level spectroscopic and asymptotic normalization factors that are reported and discussed here in comparison to previous ones from the literature [4, 5].

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