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Book of Abstracts

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Hot and Dense Matter / **3**

High Energy Density Physics Research at FAIR: The HEDgeHOB Collaboration

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High Energy Density Physics (HEDP) spans over wide areas of basic and applied physics including astrophysics, planetary sciences, geophysics, inertial fusion and many others. Over the past decade, extensive theoretical work [1-8] that included sophisticated 2D and 3D numerical simulations as well as analytic modeling, has shown that due to volumetric energy deposition in matter, an intense heavy ion beam is a very efficient and novel tool to study the HEDP. Construction of the Facility for Antiprotons and Ion Research (FAIR) will allow the scientists to access unexplored regions of the HEDM parameter space. So far, four different experimental schemes have been proposed as a result of the theoretical work to study various type of problems in HEDP. One scheme named HIHEX (Heavy Ion Heating and Expansion), is suitable to study the Equation of State (EOS) of HEDM while another scheme, named, LAPLAS (Laboratory Planetary Sciences) can be used to generate physical conditions that are expected to exist in the interiors of the Giant planets in our solar system as well as the exoplanets. The third scheme involves a shockless compression (ramp type compression) of a solid material which can be used to study the material properties (yield strength and shear modulus) under dynamic conditions. The fourth scheme proposes the study of the growth of the Richtmyer-Meshkov instabilty in linear as well as non-linear regime. Theoretical work continues to explore further experiment designs to study additional problems in HEDP.

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Nuclear Structure and Reactions / **4**

Proton in-beam tests of the Lund R3B calorimeter prototype

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In-beam tests of the Lund R3B calorimeter prototype have been carried out at The Svedberg Laboratory, Uppsala, Sweden using the 179 MeV proton beam. The detector consists of a cluster of

5x3 CsI(Tl) crystals representing a section of the barrel of the calorimeter. An energy resolution of ~0.5% has been achieved and gain corrected summing has been tested. Results from the test, including multiplicity and sum spectra that show good agreement with GEANT4 simulations, will be presented.

Hadron Physics / 5

Simulations of Antihyperon-hyperon Physics for PANDA

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At high energies the strong force is well described using quarks and gluons as degrees of freedom, while at lower energies hadronic degrees of freedom are more adequate. The PANDA energy regime is in the transition region between these two descriptions. Pbarp ->YbarY is a good reaction to test models based on these two alternative viewpoints. The weak decay of the hyperons gives direct access to spin degrees of freedom in their production process, which in turn, can be related to the role of spin in the creation of strangeness (or charm in the case of charmed hyperons). Furthermore, the exclusive production of hyperons and antihyperons in pbarp collisions can also be used to study violation of CP invariance.
We present results of simulations that show that PANDA is very suitable for doing this kind of studies. If data exist for these reactions, at all, PANDA will exceed the previous measurements by orders of magnitude in statistics. Many hyperon channels for which there are no experimental data, e.g. charmed hyperons, will be accessible.

Nuclear Structure and Reactions / 6

Resonant breakup of 19-C on a proton target

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The reaction theory is a key tool to interpret experimental measurements and extract nuclear structure information. Traditional direct scattering formalisms developed to the stability line are inadequate to describe the scattering of stable from halo nuclei. With the delivery of high precision data at the future FAIR facility it is timely to have tight control of the theoretical reaction theory.

When describing the scattering of halo nuclei from a stable target it is crucial to handle its few-body character. In addition, it is necessary to treat in equal footing all opening channels (elastic, inelastic, transfer and breakup) in equal footing.

Recently a great deal of theoretical effort has being made in developing few-body multiple scattering reaction frameworks.

As a working problem example, we consider the resonant breakup scattering of ^{19}C on a proton target at 70 MeV/u that was measured and analyzed using microscopic DWBA [1]. This analysis was found to be compatible with a transition from a ground $2s_{\frac{1}{2}}$ to an excited E_x=1.46 MeV ($E_{\rm rel}$=0.9 MeV) $1d_{\frac{5}{2}}$ although a detailed reproduction of the data was not achieved. In this work we reanalyze this reaction making use of the microscopic few-body Faddeev/AGS [2,3], CDCC [4] and macroscopic DWBA collective formalisms.

We aim to pin down the relevant physics that need to be incorporated in the reaction mechanism in order to extract meaningful and accurate information from the data.

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Hot and Dense Matter / 7

The CBM experiment: its goals, status and plans

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A talk reviews the Compressed Baryonic Matter (CBM) experiment goals, informs of the current status of its preparations and, finally, concludes with the plans for the near future of the project.

Nuclear Structure and Reactions / 8

Pionic fusion study of 3N clustering in the A=6 system

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In order to provide more data on the T=1 halo state of the six-nucleon system, in particular to investigate the importance of triton-triton and triton-3He clustering, we have made an experiment studying the 3He(3He,6Li*)\pi+ reaction at CELSIUS storage ring in Uppsala.

The J\pi=0+, T=1 state at 3.56 MeV in 6Li is believed to have a similar structure as its analogue state; the two-neutron halo ground state of 6He. The formation of the specific state of 6Li in the pionic fusion of alpha particles and deuterium was studied previously [1], 1.2 and 1.9 MeV above threshold. The total cross section for the two energies was found to be 228+-6 (stat) nb and 141+-12 (stat) nb respectively.

We have measured the cross section for the 3He(3He,6Li*)\pi+ reaction 1.2 and 1.9 MeV above threshold. The Coulomb corrected cross section is determined to be 183+-41 (stat) nb and 87+-54 (stat) nb, respectively, which is of the same order of magnitude as for the (d,4He) initial state [1]. This is an indication that 3N-3N clustering is indeed important for the description of the ground state of 6He and its analogue state in 6Li as pointed out by Arai Suzuki and Lovas [2].

Technical details of the experiment along with the results from the analysis will be presented.

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Nuclear Reactions and Astrophysics / 9

Structure and dynamics from the time-dependent Hartree-Fock model

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Within the framework of self-consistent mean-field models employing effective interactions a wide range of structure phenomena can be described, encompassing bulk properties such as masses and radii as well spectroscopy. In the absence of restrictions, such as spherical symmetry or time-reversal invariance within these models, there are additional contributions to the spin-current tensor and time-odd densities and in the mean-field that have a direct impact on deformation properties in nuclei as well as collisions between them.

Recent results from Skyrme Hartree-Fock and time-dependent Hartree-Fock calculations will be discussed, including the effects from the time-odd terms in the mean-field and the role of tensor forces in the reproduction of structure data and collisions between nuclei. These terms are shown to have non-negligible effects for describing collisions, in particular fusion.

Atomic Physics / 10

Measurement of the ground-state hyperfine splitting of antihydrogen

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The hydrogen atom is one of the most extensively studied atomic systems, and its ground state hyperfine splitting (GS-HFS) at 1.42 GHz has been measured with an extremely high precision of

10^-12. Therefore the antimatter counterpart of hydrogen, the antihydrogen atom, consisting of an antiproton and a positron, is an ideal laboratory for studying the CPT symmetry.

The ASACUSA collaboration at CERN's Antiproton Decelerator (AD) plans to measure the antihydrogen GS-HFS in an atomic beam apparatus [1,2] similar to the ones which were used in the early days of hydrogen HFS spectroscopy. The apparatus will use antihydrogen atoms produced in a superconducting cusp trap (i.e. anti-Helmholtz coils). The inhomogeneous magnetic field of such a trap will create a partially polarized beam, which will then pass through a radiofrequency resonator to flip the spin of the antihydrogen atoms. Finally a sextupole magnet analyses the spin orientation of the atoms. This atomic beam method has the advantage that antihydrogen atoms of temperatures up to 150 K can be used. Simulations showed that such an experiment is feasible if appr. 100 antihydrogen atoms per second can be produced in the ground state, and that an accuracy of appr. 10^-7 can be reached within reasonable measuring times [2].

After the first measurements at CERN, the experiments can continue at the Facility for Low-Energy Antiproton and Ion Research (FLAIR) of FAIR, possibly with improved techniques, e.g. using Ramsey's separated oscillatory field method [3].

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Hadron Physics / 11

Charmed Mesons in ep Scattering at HERA

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The production of the charmed masons in ep collisions at HERA was studied using a life time tag with the ZEUS detector at HERA. New results on D meson production at HERA have been presented. Combinatorial background to the D-meson signals is reduced by using the ZEUS microvertex detector to reconstruct displaced secondary vertices. Production cross sections are compared with the predictions of next-to-leading-order QCD, which is found to describe the data well. Measurements are extrapolated to the full kinematic phase space in order to obtain the open-charm contribution, F2cc, to the proton structure function, F2. F2cc data cover a large part of the (x,Q^2) plane accessible by inclusive F2 measurements. These data will crosscheck the gluon density. Scaling violations in F2cc is significantly larger than in F2.

Nuclear Structure and Reactions / 13

Halo nuclei breaup studies on a proton target around QFS conditions

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Halo nuclei are novel nuclear quantum systems which appear at the neutron drip line for light nuclei. They are well described by a core and one or two loosely bound valence neutrons orbiting around the core outside the range of the nuclear interaction. Therefore these structures are characterized

by low separation energies and consequently very narrow momentum distributions of the core from nucleon knockout.

15C is a one-neutron halo nucleus with a neutron separation energy of S_n=1.218 MeV. Ground state and spectroscopic information have been extracted experimentally from Coulomb dissociation studies [1], resulting in a consistent picture with a dominant (14C(0+) x 2s_{1/2}) configuration. Momentum distributions of the core extracted from single-neutron knockout reactions [2] exhibit in this case a broader width of 67 MeV/c, consistent with a larger separation energy and the same dominant configuration. However, calculations failed in reproducing the tail of the measured momentum distribution. The momentum distributions are inclusive measurements and thus it is desirable to measure also exclusive observables which incorporate more physics information.

It was shown in the work of refs. [3,4] that semi-inclusive breakup cross sections around Quasi-Free Scattering (QFS) conditions provide a very clear signature of the orbital angular momentum of the valence neutron. With increasing projectile energy the reaction formalism becomes more simplified and less terms from the Faddeev multiple scattering expansion are needed. For neutron in a S-wave the single scattering (SS) term becomes dominant as the energy increases.

In this contribution we review the curent experimental status for QFS experiments and present the expected outcome from the breakup of 15C on a proton target at QFS conditions to be measured at the R3B experimental setup.

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FAIR general and accelerator design / 15

Current Status of FAIR

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This presentation outlines the current status of the Facility for Antiproton and Ion Research (FAIR). It is expected that the actual construction of the facility will commence in 2010 as the project has raised more than one billion euro in funding. The sequence and scope of the construction will be described. Also the physics program of FAIR, based on the acquired funding, will be presented.

Atomic Physics / 17

Calculations of antihydrogen formation and collisions

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Cold antihydrogen atoms can be used for precision tests of fundamental matter-antimatter symmetries, such as the CPT theorem. Cold antihydrogen was first produced in 2002 by

the ATHENA experiment [1] and the ATRAP experiment [2]. In both experiments, as well as the more recent ALPHA experiment, antiatoms are formed by mixing antiprotons and positrons trapped in a nested Penning trap. A lot of theoretical activity has been directed at understanding the basic physics of the formation process, and explanation of experimental observations [3]. In particular, it has been pointed out that because the antiprotons are repeatedly leaving and re-entering the positron plasma, the positron-antiproton system never reaches a steady-state situation [4].

I will give a brief overview of the experiments, and present some results from simulation of antihydrogen formation from antiprotons injected into a positron plasma. Antihydrogen is formed into highly excited Rydberg states. At low temperatures the dominating process is the three-body reaction
p^- + e^+ + e^+ -> (p^- e^+) + e^+.

Formation is however not a one-step process, but in order for the antiatom to gain enough binding energy to survive to the detector a sequence of collisions is needed. Most of the time this leads to re-ionization, but occasionally the antiatoms stabilizes. The dependence of the formation rate on the temperature, density and geometry of the positron plasma will be discussed and compared to experimental results. In order to make trappable antihydrogen the formation process should be optimized to give large binding energies and low kinetic energies of the antiatoms.

I will also present theoretical results for antihydrogen colliding with simple atoms at low temperatures. In particular I will discuss the role of the strong nuclear force in atomantiatom collisions, leading e.g. to annihilation. I will also discuss rearrangement reactions, such as positronium formation.

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Nuclear Structure and Reactions / 18

Transfer reactions using a 11Be beam at ISOLDE

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The inversion of states is known to happen both in 11Be and 12Be. This indicates a breaking of the N = 8 magic number in 12Be. The breaking has been studied in several different theoretical approaches. One of them [1] describes 12Be as a three particle cluster of 10Be and two neutrons, in analogy to 11Be, which can be described by a 10Be core with an orbiting neutron. The cluster model describes the bound states in 12Be as single particle excitations of the two neutrons. A low lying 0- state has also been proposed. The state should be a bound state close to the known 1- state. The small difference in excitation energies between the 1- and the 1- could be the reason why the 0- state has not yet been observed.

The bound states in 12Be as well as in 11Be and 10Be have been studied with a transfer reaction using a low energy 11Be beam. A transfer reaction favours single particle excitations and is therefore ideal for a study of the cluster model. Experimentally determined cross sections are compared to optical model calculations in order to determine spectroscopic factors. The experiment was peroformed at the REX-ISOLDE facility at CERN in 2005 and again in october 2009. The experiment in 2005 was performed using two double sided silicon strip detectors for particle detection. Detection of gammas were included in the 2009 experiment through the MINIBALL setup. The MINIBALL consists of 144 germanium segments placed on 8 clusters. Results from the experiment in 2005 will be presented as well as preliminary results from the 2009 experiment.

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Nuclear Reactions and Astrophysics / 19

A complete kinematics approach to study multi-particle final state reactions

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Many-particle final state reactions can provide information on the structure of excited nuclear states and their decay mechanism. Progress in detector technology is making it possible to measure such many-particle final states in complete kinematics thereby opening up new possibilities for data analysis. Reaction channels indistinguishable to the incomplete measurement can be separated allowing for new interesting physics cases to be studied.
As an example, I will demonstrate how information on the structure and decay mechanism of excited states of C12 can be extracted from complete kinematics data on the reactions B10(He3,paaa) and B11(He3,daaa). Notably, we have been able to identify new gamma transitions between unbound states in C12 through use of the missing-energy method.
Similar studies with radioactive beams have, so far, been impractical mainly because of insufficient beam intensites, but should become possible at the new RIB facilities.

Nuclear Structure and Ground-State Properties / 20

Precision laser spectroscopy of light exotic isotopes

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Newly developed techniques for laser spectroscopy of very light isotopes and progress in atomic theory calculations of few-electron systems has allowed the determination of nuclear charge radii of helium, lithium and beryllium isotopes during the last years. These techniques had to provide high accuracy but at the same time sufficient efficiency to study very exotic nuclei that are produced only in minute ammounts. In this talk, I will shortly summarize the results from these techniques concerning the ground state properties of helium and lithium isotopes. Moreover, the latest measurements on beryllium isotopes are presented and the conclusions on the nuclear structure of the isotopes Be-7,9,10 and the one-neutron halo isotope Be-11 will be discussed.

Nuclear Structure and Reactions / 22

Convergence properties of density-matrix expansions

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One of the current projects at the Department of Physics in the University of Jyväskylä is to explore more general forms of the Skyrme energy-density functional (EDF). The aim is to find new phenomenological terms which are sensitive to experimental data.

In this context we have extended the Skyrme functional by including terms which contain higher orders of derivatives allowing for a better description of the long range part of the nuclear force. This was done by employing an expansion in derivatives in a spherical-tensor formalism [1] motivated by ideas of the density-matrix expansion (DME). If the expansion coefficients are treated as free parameters the resulting functionals gets different number of free parameters depending on the order in derivatives and assumed symmetries. The usual Skyrme EDF is obtained as a second order expansion while we keep terms up to the sixth order.

The resulting self-consistent mean-field equations as well as the linear-response equations can be derived straightforwardly in a systematic way and solved using computer codes [2].

This formalism and code are used to evaluate different expansions of the non-local density. As an example the Hartree-Fock energy from the Gogny force is considered and the exact energy is compared with the energy obtained when using DMEs. Starting from a force in this way, all the free parameters in the functional can be derived so that the total energy becomes a functional of the local density and its derivatives which is much faster to use than the full exchange term. A new DME method is also presented which is more accurate than previous versions.

Methods based on the DME constitute a natural first step towards obtaining an ab-initio universal energy density functional which is able to give accurate and reliable descriptions of low-energy observables for the medium-to-heavy exotic nuclei studied at the new experimental facilities. This work constitutes the first test of convergence properties of different DMEs which are considered up to the sixth order.

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FAIR general and accelerator design / 23

The FAIR storage ring complex to deliver intense high-quality secondary beams for experiments

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The FAIR project aims at producing very dense secondary beams of rare isotopes and antiprotons. The concept reposes on two pillars: the production of high-intensity high-energy primary beams (all ions from protons up to bare Uranium) and the implementation of dedicated beam cooling techniques to compress the secondary beams. Versatile parallel operation of the accelerator facility with different beams and experiments is foreseen. The FAIR storage ring complex plays the central role

in the preparation of and experiments with secondary beams. It comprises three storage rings with a magnetic rigidity of 13 Tm (CR, RESR, NESR), the HESR ring with a magnetic rigidity of 50Tm and the rings of the low-energy experimental facility FLAIR.

After a short overview of the FAIR accelerator facility, the specific functions, the various concepts and design issues of the storage rings will be summarised, focussing on the 13 Tm storage rings. Emphasis will be given to the expected machine performance with respect to the requirements of the experimental communities.

Nuclear Structure and Reactions / **24**

Present and future of HISPEC/DESPEC

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The HISPEC (High-resolution in-flight spectroscopy) and DESPEC (Decay spectroscopy) projects are part of the core experimental facility at FAIR. They are aimed at nuclear structure and reaction studies, using high-resolution gamma-ray spectroscopy as their main tool. HISPEC/DESPEC will get information on the force acting between the nucleons inside the nucleus, with special emphasis on systems with exotic proton-to-neutron ratios: both proton rich and neutron rich nuclei. In extreme neutron-rich nuclei radical changes in their structure are expected with the possible disappearance of the classical shell gaps and magic numbers and the appearance of new ones. They are also highly relevant for nuclear astrophysics, especially on the nucleosynthesis of elements heavier than iron. HISPEC/DESPEC will use radioactive beams delivered by to the Low Energy Branch (LEB) of the Super Fragment Separator with energies of 3-150 MeV/u for reaction studies or stopped and implanted beam species for decay studies. The project focuses on those aspects of nuclear investigations with rare isotope beams which can be uniquely addressed with high-resolution setups. Experiments using the same techniques were successfully performed at the for-runner RISING project at the existing GSI. Some HISPEC and DESPEC detectors are already in the production phase, with the first commissioning experiments taking place in 2010. A range of experiments are planned for 2010 onwards employing devices such as the European Germanium tracking array AGATA for gamma-ray detection, and the LYCCA (Lund-York-Cologne Calorimeter) array for the identification of reaction products.
The physics case of HISPEC/DESPEC, the experimental setup, the opportunities opened are discussed.

Nuclear Structure and Ground-State Properties / **25**

The Fidipro Deformed QRPA project: past, present and future

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QRPA calculations give important information about excited state properties of nuclei. The Fidipro nuclear theory group at the

Dept. of Physics, University of Jyväskylä, has been developing advanced QRPA solvers based on Energy Density Functionals since 2008. Our goal is to produce fully self-consistent (ground state and QRPA with the same Energy Density Functional (EDF)) QRPA solvers both for axial and triaxial nuclei to the public domain. The solvers use iterative diagonalization methods generalized to handle the RPA eigenproblem [1].

The codes in development are HOSPHE-QRPA, whose HF version [2] has been published and QRPA enhanced version of HFODD [3]. Our iterative solution method has been shown to be stable, fast and resource efficient, and thus it is a good choice for more demanding QRPA calculations.

The next step in the QRPA project is to demonstrate the feasibility of iterative Arnoldi method when pairing is included and when the QRPA dimensions become very large, as with deformed nuclei.
Our final goal is to be able to make accurate iterative QRPA calculations across the whole nuclear chart using either standard Skyrme or generalized EDFs.

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Nuclear Structure and Reactions / 26

Structure and reactions of few-nucleon systems

Author: Giuseppina Orlandini[1]

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The talk will deal with an overview of the most recent developments in few-body physics regarding both nuclear structure and reactions. I will concentrate on ab-initio approaches, shortly describing the methods, some of their recent applications, and the perspectives of the field in view of the upcoming FAIR program.

Atomic Physics / 30

Precision electron collision spectroscopy of highly charged ions

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Collisions between highly charged ions and electrons in merged electron beams have been introduced as a precision tool for determining atomic properties, applying ion storage rings both at lower and at high ion beam energy. Photorecombination in these collisions can be resonant, as the incident electron is captured in a bound quantum state while the target - a few-electron highly charged ion - is excited. Hence, the resonances probe the excitations of few-electron ions with high energy resolution. In precision electron collision spectroscopy at ion storage rings, resonance energies in the total photorecombination cross section (dielectronic recombination) are measured by precisely varying the electron impact energy. At lower ion energies, in the storage ring TSR, Heidelberg, resonances at collision energies down to less than 10 meV were resolved for medium-heavy ions, finding the 2s-2p excitation energies in Li-like scandium (Z=21) at the highest absolute precision so far realized for this transition in any highly charged ion. Moreover, the hyperfine splitting of the electron recombination resonances is resolved for this nucleus. While TSR obtained highest resolution using a photocathode electron source, the ESR at GSI has addressed much heavier Li-like systems with a similar technique, extracting nuclear charge radii from dielectronic recombination energies of three-electron Nd ions (Z=60) and very recently obtaining data of this type even for Li-like uranium nuclides. The technique and the results will be reviewed. Also the perspective of using systems with a larger electron number as precision probes for ionic-core or even nuclear excitations will be discussed. In recent studies at TSR, the use of the technique also for Be-like and B-like ions was investigated (Z=32 and 26, respectively). With a precise theoretical understanding, suitable low-energy photorecombination resonances would become available for a wider range of elements than for Li-like ions, while the challenges for atomic structure calculations increase.

Atomic Physics / 31

SPARC – Environment for Atomic Collision Physics at FAIR

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The new facility at GSI (FAIR) will have key features that offer a range of new research opportunities, among others, in atomic physics and related fields. In recent years, SPARC (Stored Particles Atomic Physics Research Collaboration) is grown up to more than 300 physicists from all over the world. The lecture will give a survey of selected atomic physics topics which form a motivation of the SPARC activities concerning future collision experiments at FAIR.
One of the actual frontiers in atomic physics is the study of matter exposed to extremely strong electromagnetic fields. In particular, highly charged ions form unique laboratories where such conditions are largely fulfilled. These species can be stored in form of intense beams and used in collision experiments. For such investigations, precise spectroscopy of photons emitted in collisions of heavy ions with atoms is required. This emission gives details of the specific electronic transition mechanisms operating in strong fields as well as information on electronic structure of the exotic atomic systems (e.g. H- and He-like uranium). Accurate measurements of electron binding energies are very well suited to deduce characteristic quantum electrodynamics (QED) phenomena in strong fields. QED, the basis and cornerstone of all present field theories, is the best confirmed theory in physics, however, precise tests in the strong-field limit are still pending. Moreover, details concerning photoionization of very heavy atoms can be revealed in such experiments when observing radiative electron capture (REC). Here, angular distribution of REC photons sensitively proves the rigorous relativistic treatment of the process, even at relatively low ion velocities.
In addition, in the discussed slow ion-atom collisions the electronic clouds of the collision partners adjust their motion to the Coulomb field of the nuclei and form molecular orbitals (MO's). Electron vacancy production in such collisions was commonly discussed as a manifestation of mechanisms transporting electrons out of these transiently formed MO's. Vacancies produced in the quasi-molecular levels may become inner-shell vacancies in one of the collision partners and finally decay via characteristic x-ray emission. First fingerprints of this scenario were observed as early as 1965. Over the years many intriguing details in the inner-shell ionization data have been discussed

and explained within the MO picture. Simultaneously, probing of extremely strong fields via the innermost molecular levels (e.g. 1sσ or 2sσ) of the exotic quasi-atoms with the united charge Z » 100, revealed many puzzles which couldn't be solved with the available generation of accelerators. In particular, the very fundamental question whether the 1sσ-level becomes a resonance in the negative energy continuum remained without answer. An implication of the molecular model is possibility of observing x-rays in a form of continua (MO x-ray radiation) created during collisions. These continua have been observed for the first time in 1972, followed by basic proofs of their quasi-molecular origin. Molecular x-ray radiation has been studied extensively over next two decades. Many aspects concerning production mechanisms, angular distribution, impact parameter dependencies or energy distribution of MO x-ray radiation have been successfully investigated. However, one of the main goals, estimation of the electron binding energies in the vicinity of the united atom limit for Z » 100, is still open for further experiments.
Many of the research topics mentioned – from collision dynamics to spectroscopy – that were started successfully at GSI, will be expanded into new regimes and under much better and advanced experimental conditions at FAIR. The new facility ensures that the unprecedented feasibilities concerning beam energy, intensity, experimental tools can be reached. In particular, an option for merged or crossed beams would provide possibilities to study electron binding energies in supercritical electromagnetic fields using quasi-molecular radiation.

Hadron Physics / 32

What are Hadrons Made of?

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When quarks were first discovered, it was widely considered that the age-old quest for finding the basic constituents of matter was finally over. All matter is comprised of hadrons & point-like leptons, and the hadrons, in turn, are made of quarks: three quarks form a baryon and a quark-antiquark pair forms a meson. However, developments during the intervening forty years indicate that Nature is probably not so simple. On the theoretical side, the emergence of QCD has led to expectations for the existence of hadrons formed from more complicated arrangements of quarks, antiquarks & (now) gluons. On the experimental side, a number of new meson states have been found – the "XYZ mesons" – that do not neatly fit into the simple quark-antiquark picture of the original quark model. Intriguingly, it seems that for at least some of the newly observed mesons, an identification with any the theoretically predicted new types of particles is problematic. In this talk I will review the current experimental situation and suggest strategies for experimentation at FAIR, BES-III & a Super-B factory that might help clarify the situation.

Nuclear Reactions and Astrophysics / 35

Reaction measurements on and with radioactive isotopes for nuclear astrophysics

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After an introduction to several astrophysical sites, recent experiments will be discussed contributing to the needs for nuclear reaction rates under the respective conditions. The experiments discussed cover a broad range of stellar sites - from p-process to s-process and experimental techniques - from experiments using radioactive samples to measurements with radioactive ion beams.

Nuclear Structure and Reactions / 36

Breakup reaction study of drip-line nuclei at the new-generation RI-Beam facility RIBF

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Recent experimental results using the breakup reactions at the new-generation RI-beam facility, RIBF, at RIKEN, will be presented. After briefly introducing the facility and showing some of the other highlights of the experiments at RIBF facility, we focus more on the breakup experiments. We measured the inclusive Coulomb and nuclear breakup of neutron drip line nuclei 22C and 31Ne[1]. Enhanced cross sections have been observed for these nuclei to exhibit the halo nature of these nuclei. This is the finding that the halo structure is found near and inside the island of inversion region for the first time. Near-future projects and experimens at RIBF are also discussed in this presentation.

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Nuclear Structure and Ground-State Properties / 37

Frontiers in nuclear structure theory from a FAIR perspective

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Understanding nuclei is a quantum many-body problem of incredible richness and diversity and studies of nuclei address some of the great challenges that are common throughout modern science. Nuclear structure research strives to build a unified and comprehensive microscopic framework in which bulk nuclear properties, nuclear excitations, and nuclear reactions can all be described. A new and exciting focus in this endeavor lies in the description of exotic and short lived nuclei. The extreme proton-to-neutron asymmetry of these nuclei isolates and amplifies important features of nuclear many-body open quantum systems.

In this talk, theoretical advances in rare isotope research will be reviewed in the context of the main scientific questions. Particular attention will bo given to the progress in theoretical studies of nuclei due to the advent of terascale computing platforms.

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Nuclear spectroscopy with fast exotic beams

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The often surprising properties of neutron-rich nuclei have prompted extensive experimental and theoretical studies aimed at identifying the driving forces behind the dramatic changes encountered in the exotic regime. In-beam nuclear spectroscopy with fast beams and thick reaction targets – where °-ray spectroscopy is used to tag the final state – provides information on the single-particle structure as well as on collective degrees of freedom in nuclei that are accessible for experiments at beam rates of only a few ions/s.
Recent results from nuclear spectroscopy experiments that utilize the interplay of nuclear-structure effects and reaction mechanisms performed at the National Superconducting Cyclotron Laboratory at Michigan State University will be presented.

Nuclear Structure and Ground-State Properties / 39

Mass measurements and laser spectroscopy with radioactive beams - a FAIR perspective

Author: Ari Jokinen[1]

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Advances in the production and manipulation of radioactive isotopes together with new innovations in optical spectroscopy and ion trap technique have resulted in a great progress in understanding of ground-state properties. The recent achievements pave the way for a study of ground-state properties of the most exotic nuclei, achievable only with the next generation facilities, like FAIR. In this presentation, examples of modern techniques and related scientific results will be given and an outlook for the research of ground-state properties at FAIR with MATS (Precision Measurements of very short-lived nuclei using an Advanced Trapping System for highly-charged ions) and LaSpec (Laser Spectroscopy of short-lived nuclei) will be discussed.

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Nuclear structure studies at FAIRs ring branch

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The ring branch at FAIR will consist of three different storage rings that are used to pepare circulating rare ion beams with suitably selectable parameters
in few seconds time scale. This, together with the increased secondary beam
intensities from FAIRs synchrotron and the Super Fragment Separator, leads to unprecedented conditions for physics experiments in storage rings. Several experimental facilities that are foreseen to be installed in the New Experimental Storage Ring will be presented & motivated with their associated physics programme. The performance and opportunities of in-ring experiments will be opposed to "conventional" experimental techniques and discussed.

Hadron Physics / 42

Effective Theories for Hadrons at FAIR

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After an introduction to QCD and the concept of effective theories I will present some general considerations how to decide if a given hadron has a dominant hadronic substructure (”hadron molecule”, dynamically generated state). I will select two examples, one from the sector of charmed mesons and one from the sector of light mesons, to illustrate these ideas.

Nuclear Structure and Reactions / 43

Three-body correlations as a key to the structure of light unbound nuclei

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The neutron dripline as being defined by the heaviest, proton-deficient, bound isotopes, determines the limit of nuclear stability at the neutron-rich side of the nuclear chart. Neutron or proton knockout from light dripline nuclei leads to the formation of unbound nuclear systems with extreme A/Z ratios, followed by their immediate decay. An experiment of this kind has been performed at GSI (Darmstadt). A relativistic beam consisting of the halo nuclei ^{11}Li and ^{14}Be with energies of 280 and 305 MeV/nucleon, respectively, impinged on a liquid
hydrogen target. The experimental setup, consisting of the neutron detector LAND, the dipole spectrometer ALADIN and different types of tracking detectors, allows the reconstruction of the momentum vectors of all reaction products measured in coincidence.

The properties of unbound nuclei were investigated by reconstructing the relative-energy spectra as well as by studying the energy and angular correlations between their
decay products. The relative energy spectra were reconstructed for unbound nuclei ^{9,10}He and ^{10,12,13}Li. In addition, three-body $^8\mathrm{He}+\mathrm{n}+\mathrm{n}$ and $^{11}\mathrm{Li}+\mathrm{n}+\mathrm{n}$ energy and angular correlations in ^{10}He and ^{13}Li were studied using the hyperspherical harmonics formalism, providing information about their structure. The talk is devoted to a discussion of the obtained results for these unbound isotopes and a physics interpretation of the data.

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Frontiers in hadron theory from a FAIR perspective

Hadron Physics / 49

Hadron Physics using Polarized Antiprotons

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The PAX collaboration has recently proposed to use an internal polarized hydrogen storage cell gas target in the Antiproton Decelerator ring (AD) of CERN to determine for the first time the two total spin−dependent pbar-p cross sections σ1 and σ2 at antiproton beam energies in the range from 50 to 450 MeV [1]. The data to be obtained are of interest in itself for the general theory of pbar-p interactions and will provide a first experimental characterization of the spin- dependence of the nucleon-anti-nucleon potential. Furthermore, the data are required to define the optimum parameters of a dedicated Antiproton Polarizer Ring (APR), that shall be used to feed a double−polarized asymmetric pbarp collider with polarized antiprotons. Such a machine has been recently proposed by the PAX collaboration for the new Facility for Antiproton and Ion Research (FAIR) at GSI in Darmstadt, Germany [2].
The availability of an intense beam of polarized antiprotons will provide access to a wealth of single− and double−spin observables, thereby opening a new window to QCD spin physics at FAIR. A recent measurement at COSY revealed that ep spin−flip interactions provide insufficiently small cross sections to depolarize a stored proton beam [3]. Therefore, this measurement rules out the use of polarized positrons to polarize an antiproton beam by e+pbar spin−flip interactions. The approach favored by PAX to provide a beam of polarized antiprotons is based on spin filtering, using an internal polarized hydrogen gas target — a method known to work for stored protons [4]. We are aiming to improve intensities of polarized antiproton beams by at least ten orders in magnitude compared to what has been achieved hitherto. In a first step, the equipment necessary for the experiments at AD will be commissioned and tested at COSY, which implies to carry out spin-filtering measurements with stored protons [4].
Provided antiproton beams with a polarization around 20% can be obtained with a dedicated APR, the High Energy Storage Ring for antiprotons at FAIR could be converted into a double−polarized asymmetric pbar-p collider by implementation of an additional COSY−like ring. In this setup, antiprotons of 3.5 GeV/c would collide with protons of 15 GeV/c at c.m. energies of sqrt(s)≈sqrt(200) GeV, with a luminosity in excess of 10^31 cm^−2s^−1. The PAX physics program proposed for FAIR [2] has been highly rated by various committees [5]. It includes foremost a first direct measurement of the transversity distribution of the valence quarks in the proton, and a first measurement of the moduli and the relative phase of the time−like electric and magnetic form factors GE,M of the proton.
The talk will give an overview about the status of the project.
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Hot and Dense Matter / 50

Hot and dense matter theory

Author: Laszlo P. Csernai[1]

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Ultra-relativistic heavy ion reactions provide a tool to study the collective properties of extreme states of matter, of the Quark Gluon Plasma. Collective flow dynamics is one of the most dominant observations and enables us to draw conclusions on the Equation of State, on the transport properties and of the phase structure and transitions of the matter. The collective elliptic flow scales with number of constituent quarks in the emitted particles indicating that the flow developed in the Quark Gluon Plasma phase. The subsequent hadronization is rapid, and happening together with the final freeze out of the emitted hadrons. On the other hand there are hints that hadronization goes through a Quarkyonic matter phase, where first deconfinement and then chiral symmetry ceases.

Nuclear Reactions and Astrophysics / 51

Exotic nuclear structure and reactions from an ab initio perspective

Phenomena that are difficult to describe in standard many-body methods as Hartree-Fock or the shell model are regarded as exotic, like clustering of nucleons which leads to molecule like structures, or halos formed by weakly bound nucleons. These special configurations are found as ground states and excited states whenever one is close to the energy of the corresponding breakup threshold. Thus they require Hilbert spaces that know about the continuum.

An ab initio description assumes the centers of mass and the spins of the nucleons as the degrees of freedom and as the interaction among them a realistic two- and three-body potential that reproduces phase shifts and other properties of the two- and three-nucleon system.

In the Fermionic Molecular Dynamics (FMD) approach we aim at a unified microscopic description including well bound nuclei with shell structure, nuclei featuring clustering or halos, and continuum states like resonances and scattering states. We achieve this by exploiting the versatility of Gaussian wave packets.

The same microscopic effective interaction is used for all nuclei and all states, such as well bound states, halos, cluster states like the Hoyle state in ^{12}C, or even nucleus-nucleus scattering at astrophysical energies well below the Coulomb barrier.
This effective interaction is based on the V_{UCOM} interaction derived from the realistic Argonne V18 interaction by explicitly including short-range central and tensor correlations within the Unitary Correlation Operator Method (UCOM).

Nuclear Structure and Ground-State Properties / 52

The Advanced Implantation Detector Array (AIDA)

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The objective of the DESPEC Advanced Implantation Detector Array (AIDA) project is to develop, commission and exploit a state of the art silicon detector array for decay spectroscopy experiments using the SuperFRS fragment separator at the FAIR facility. It is anticipated that AIDA will be operated in conjunction with other detection systems, such as gamma-ray and neutron detector arrays, which requires that AIDA should be very compact while still accepting all ions from the SuperFRS. To achieve these objectives AIDA will use large area double-sided silicon strip detector (DSSD) and application specific integrated circuit (ASIC) technologies. AIDA will be used for implantation-decay experiments and perform spectroscopy quality measurements of charged particle decays with energies from tens of keV to MeV. The challenge is to achieve this within microseconds of multi-GeV exotic ion implants and with an instrumentation density to match the very high degree of detector segmentation required for the observation and characterisation of long-lived decays. The current status of the AIDA project will be presented.

Atomic Physics / 53

Nuclear Effects in Atomic Lifetimes: Studied with Be-like ions at Storage Rings and EBITs

Author: Istvan Orban[1]

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Be-like ions are sources of forbidden emission lines which are relevant for the information on astrophysical plasmas. We propose to study the lifetimes of metastable states, and the influence of nuclear spin on it, in Be-like ions along the isoelectronic series, through electron-ion collision processes and through laser excitation.
The radiative decay of the 1s^2 2s2p(^3P_0) first excited state is strongly forbidden and as a consequence, this state has very long lifetime in ions along the Be-like isoelectronic sequence [1]. A nuclear spin, if present, mixes a small amount of (^1P_1) character into the 1s^2 2s2p(^3P_0) state, which opens a weak radiative decay mode of the metastable state. Thus in the presence of a nuclear spin, the lifetime becomes on the order of seconds and it is accessible for storage ring experiments [2]. Because the dielectronic recombination (DR) spectrum of the ground state and metastable ions is different, recombination measurements allow the selective access to ions in metastable and ground state.
At storage rings ions can be observed from µs to hours, and DR offers a fast and efficient way of monitoring the amount of metastable fractions and thus these lifetimes even for radioactive ion beams as they will become available in NESR of FAIR. At first, we plan to test the theoretical description of nuclear effects on the electronic structure with experimental lifetimes at stable isotopes. We expect to apply this knowledge on nuclear properties of radioactive ions at FAIR. Additionally, in the experiments, different charge breeding techniques and collision with electrons and/or high density gas jet targets could prove to be useful for populating the (^3P_0) metastable state and for production of ion beams with enhanced metastable content.
At Electron Beam Ion Traps (EBIT), laser spectroscopy of the trapped ions will provide information about level separation and lifetimes of the (^3P_j) states. Also, in Be-like ions, an exotic recombination channel proceeds through the simultaneous excitation of both 2s core electrons during the attachment of the free electron[3]. This reaction channel termed tri-electronic recombination, gives strong contributions to the recombination spectra of Be-like ions. Due to the strong correlation of the two excited electrons, this process is relevant for the description of electron-electron interaction. In case of the highly charged Be-like ions created in the EBIT, the detected photons will reveal information about the radiative stabilization paths of the triply excited states through which TR takes place. The description of the involved triply excited states is challenging for theory and the obtained experimental results will benchmark the calculations.

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Hadron Physics / 55

Nuclear systems with strangeness

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Selected topics in strangeness nuclear physics are reviewed. The discussion involves hyperon-nucleus interactions, few-body systems with hyperons, spectroscopy of Lambda hypernuclei, double- and multi-strangeness baryonic systems. We also briefly report on the study of antikaon-nucleus dynamics in the quest for kaonic nuclei.

Nuclear Structure and Ground-State Properties / 58

Welcome and opening remarks

Welcome and opening remarks by the local organizing committee.

Nuclear Structure and Ground-State Properties / 59

Nuclear reactions with radioactive beams at FAIR

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