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Book of Abstracts

Contents

The HIE-ISOLDE Project . . . 1

Recent results on transfer reactions using the MINIBALL/T-REX set up . . . 1

Beta delayed fission studies of the neutron deficient Tl and Fr nuclei. . . . 1

Measurements of octupole collectivity in 220,222Rn and 222,224Ra using Coulomb excitation . . . 2

Transfer reactions with T-REX for 11Be . . . 3

The new physics possibilities with HIE-ISOLDE . . . 3

The impact of the development of the Resonance Ionization Laser Ion Source (RILIS) on nuclear astrophysics at ISOLDE. . . . 3

Beam Dynamics and Beam Characteristics of the HIE-ISOLDE Linac . . . 4

Neutrino-mass oriented spectrometry at ISOLTRAP . . . 4

Measurements of competing structures in neutron-deficient Pb isotopes by employing Coulomb excitation . . . 5

Safety at ISOLDE . . . 6

The CRIS experiment: progress and highlights from 2010 . . . 6

Possibilities provided by ISOLDE for tracer diffusion experiments . . . 6

Experiments with stored highly-charged ions at ISOLDE: TSR@HIE-ISOLDE proposal . 7

The sign of the electric field gradient of wide bandgap semi-conductors measured with β-γ angular correlation . . . 8

Nuclear structure studies of the neutron-rich rubidium isotopes using Coulomb excitation 8

Single-particle states in 79Zn and the N=50 shell gap near 78Ni . . . 9

Perturbed Angular Correlations studies of Hg coordination mechanisms on functionalized magnetic nanoparticles . . . 10

Implementation of a MR-ToF isobar separator at ISOLTRAP and first online results . . . 11

Laplace Deep Level Spectroscopy … a new tool for semiconductor research at ISOLDE . 11

HELIOS: a new approach to studying transfer reactions in inverse kinematics . . . 12

Magnetic dipole moment of the Coulomb excited 2+1 state in 138Xe - final report from IS415 and future of the Transient Field technique at REX-ISOLDE 13

First combined DSAM and Coulomb excitation experiment at REX-ISOLDE - measuring the sign of the spectroscopic quadrupole moment of the 2+1 state in neutron-rich 140Ba 13

Recent developments and results of WITCH 14

Simulations of transfer reactions at HIE-ISOLDE 14

Direct identification of interstitial Mn in Ga1−xMnxAs and evidence of its high thermal stability 15

Study of single particle structure of 35Si 15

The new fast tape station at ISOLDE 16

Radiation protection and radiation safety issues for HIE-ISOLDE. FLUKA calculations. . 16

Target and Ion Source development at CERN-ISOLDE 17

ISOLDE RILIS: from proof of principle to a standard versatile technique. 17

Reactions induced by 11Be beam at Rex-Isolde 17

Research and development activities for the HIE-ISOLDE linac 18

Recent results from the HRIBF 18

The Radioactive Ion Beam Factory: recent results, present status and perspectives 19

Inorganic Nanoparticles as Functional Building Units for Composite Particles 19

Frequency-Comb Based Optical Isotope Shift Measurement of Be-12 19

Introduction 20

Plasma ion source development for molecular radioactive ion beams 20

Present and future at GANIL 21

Total Absorption Spectroscopy at Isolde; Past, Present and Future 21

Collinear laser spectroscopy at ISOLDE and recent results. 21

Recent results using radiotracer PL at ISOLDE 22

Recent Mossbauer results using 119In 22

Beta-NMR as a novel technique using radioactive beams for biophysical studies 23

Overview of first ATLAS results with LHC 2010 data and prospects for 2011 23

HIE-ISOLDE Technical Session / 0

The HIE-ISOLDE Project

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The HIE-ISOLDE project will be an important upgrade of the existing ISOLDE radioactive ion-beam facility at CERN. The present energy of 3MeV/u for post-accelerated radionuclides will be boosted to up to 10MeV/u which will allow experiments to address many more exotic nuclides using, e.g., Coulomb excitation and nucleon transfer. A R&D program on the superconducting linear accelerator is ongoing and cavity manufacturing with prototype and sputtering tests is in an advanced state. Besides the energy upgrade, the beam quality has already been improved and the beam intensity is supposed to be increased in the near future. An overview of the HIE-ISOLDE project and the present status will be given.

Medium Mass Nuclei / 1

Recent results on transfer reactions using the MINIBALL/T-REX set up

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In the last few years the investigation of one- and two-neutron transfer reactions has become a new versatile tool to study the structure of exotic nuclei at REX-SOLDE.
So far, we have investigated the (d,p) and (t,p) reaction in inverse kinematics on several nuclei with masses up to A = 80.
The powerful combination of the MINIBALL spectrometer and the T-REX Si detector array enables the coincident detection of gamma-rays and light nuclei allowing to determine excitation energies, spin assignments, and spectroscopic strengths for states in the final nucleus.
The status of the set-up, selected results from several experimental campaigns, and an outlook to the opportunities at HIE-ISOLDE will be presented.

Heavy Mass Nuclei / 2

Beta delayed fission studies of the neutron deficient Tl and Fr nuclei.

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The beta delayed fission (βDF) (EC/β +) is a rare nuclear process which couples fission and beta decay. In this process, a parent nucleus undergoes beta decay, possibly populating high-lying states in the daughter nucleus, close to the top of the fission barrier, thus allowing the fission of the daughter to

be competitive with other decay modes.
This process is expected to occur in the heavy nuclei in the actinide region (N/Z ˜ 1.5-1.6) due to their small fission barrier, but it is also likely in lighter nuclei, in particular, in the neutron-deficient region from Tl to Bi. The uniqueness of βDF in the lead region lies in the possibility of reaching exotic nuclei with an unusual N/Z ratio, e.g. N/Z=1.25 for 180 Tl, which do not undergo spontaneous fission, and thus, it allows the investigation of their low-energy fission properties.
This talk presents the recent IS466 experiment at ISOLDE facility (June/July 2010) in which a search for βDF decay of isotopes 178−184 Tl and 202 Fr has been performed. A novelty and key feature of this work was the production of pure sources of Tl isotopes using resonant laser ionization (RILIS), followed by mass separation (GPS).
Preliminary evidence for βDF of 178 Tl and of 202 Fr was obtained and will be discussed in the presentation. Moreover, measurements of the isotopes 178 Tl, 180 Tl, and 181 Tl have been carried out, which will allow data on the isotope shift to be deduced.

Heavy Mass Nuclei / 3

Measurements of octupole collectivity in 220,222Rn and 222,224Ra using Coulomb excitation

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There is considerable theoretical and experimental evidence that atomic nuclei can assume reflection asymmetric shapes that arise from the octupole degree of freedom [1]. The associated phenomena that is observed include odd-even staggering of the positive- and negative-parity yrast bands in even-even nuclei, parity doublets in odd mass nuclei [2,3], and enhanced E1 moments due to a division of the centre of charge and centre of mass [4].
From a microscopic point of view, the wave functions of low-lying 3- octupole excitations must contain components which include the intruding unique parity state (l,j). Because of the nature of the octupole-octupole interaction in nuclei, octupole correlations are more pronounced when this intruder state comes close to the Fermi level, giving rise to [l, j; l-3, j-3] particle-hole configurations at relatively low excitation energies. The strongest correlations occur near the proton numbers Z = 34, 56 and 88 and the neutron numbers N = 34, 56, 88 and 134, where it may be possible that octupole deformation occurs in the ground state.
Indeed, at these values of Z and N, the phenomena described have been observed. However, the only observable that provides unambiguous and direct evidence for enhanced octupole correlations in the nuclei is a measure of the E3 matrix element [5,6], which gives, directly, the strength of octupole correlations in the ground state, B(E3; 0+ -> 3-).
The mass region where octupole correlations are expected to be strongest, i.e. at Z = 88 and N = 134, there is an apparent lack of spectroscopic data. Only for 226Ra, with its comparatively long half life of 1600 years, was it possible to measure the B(E3) strength using Coulomb excitation [6]. Coulomb excitation is the only way of probing this information since the 3- state is directly excited from the ground state. When nuclei are produced in excited states, the E1 decay to the 2+ sates dominates over the E3 decay.
This talk will present the current status, and the first results from the recent Coulomb excitation the post-accerated 224Ra beam at REX-ISOLDE using the MINIBALL setup.

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Light Mass Nuclei / 4

Transfer reactions with T-REX for 11Be

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Results presented for the IS430, the T-REX and the Miniball collaborations.

The aim of IS430 is to test our understanding of the halo nucleus 11Be and its structural relation to the neighbouring nuclei 10Be and 12Be through one-neutron transfer reactions. A first run in 2005 employing only charged particle detectors gave encouraging results, but showed that gamma-ray detection is needed to extract detailed information on the populated excited states in 10Be and to some extent also 12Be. The two recent runs, October 2009 and (with significantly improved statistics) September 2010, therefore employed the T-REX set-up coupled to Miniball. This presentation will focus on results from the latest run.

From the identified outgoing tritons, deuterons and protons we can extract the excitation spectra of 10Be, 11Be and 12Be. All previously known particle-bound excited states in these nuclei - except for the excited 0+ states in 10,12Be - are populated and can be identified through gamma-ray coincidences. For several of the populated states the intensity is sufficient to eventually extract the cross-section as a function of angle. The total excitation spectra and the gamma-coincident ones will be shown. Preliminary theoretical calculations for the older data will also be presented and discussed.

HIE-ISOLDE Physics / 5

The new physics possibilities with HIE-ISOLDE

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The HIE-ISOLDE project is advancing fastly (see the dedicated website http://hie-isolde.web.cern.ch/HIE-ISOLDE/). An overview will be given on the new physics possibilities emerging, mainly focussing on the energy upgrade.

Fundamental Interactions and Astrophysics / 6

The impact of the development of the Resonance Ionization Laser Ion Source (RILIS) on nuclear astrophysics at ISOLDE.

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2010 marks the 25th anniversary of the first measurement of the half-life of 130Cd at ISOLDE (1985) and the 15th anniversary of the first measurement of the decay of neutron-rich Ag isotopes (1995) ionized via Resonance Ionization Laser Ion Source (RILIS). Since that time, the nuclear decay properties of neutron-rich nuclei lying in and near the proposed path of the astrophysical r-process have been determined at ISOLDE. Elements studied using the selectivity achieved with the RILIS include Mn, Ag, Cd, In, Sn, and Sb The influence of these data on nuclear structure models will be considered, along with the impact of these measurements on the development of ideas about how and where the r-process takes place will be described. In particular, parallel developments in astronomical observations of ultra-metal-poor halo stars have combined with the nuclear physics measurements to lead to the conclusion that the formations of elements in the A = 130 mass peak and beyond seems to be a "robust primary process"that is most likely to occur in core-collapse type II supernovae.

HIE-ISOLDE Technical Session / 7

Beam Dynamics and Beam Characteristics of the HIE-ISOLDE Linac

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The upgrade of the REX-ISOLDE post-accelerator foreseen within the HIE-ISOLDE framework is presented along with a summary of the expected beam characteristics calculated using recent measurements at REX as input to end-to-end beam dynamics simulations of the linac.

Fundamental Interactions and Astrophysics / 8

Neutrino-mass oriented spectrometry at ISOLTRAP

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Precision mass measurements are performed at the mass spectrometer ISOLTRAP with a relative mass uncertainty routinely reaching 1*10ˆ-8. The time-of-flight detection technique is employed to

determine the frequency of an ion stored in a Penning trap, from which the mass can be extracted. One topic, which has been studied at ISOLTRAP recently, involves the neutrino mass determination. Neutrino-oscillation experiments are not able to measure the absolute neutrino mass, however, Penning trap mass spectrometry can provide valuable input data. Electron capture processes or neutrinoless double beta decay probe the absolute neutrino mass and can be studied in a Penning trap. The results will be presented in this contribution.

Heavy Mass Nuclei / 9

Measurements of competing structures in neutron-deficient Pb isotopes by employing Coulomb excitation

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One of the goals of modern nuclear physics research is to understand the origin of coexisting nuclear shapes and exotic excitations and their relation to the fundamental interactions between the nuclear constituents. These subjects can be investigated particularly well in the Pb isotopes close to neutron mid-shell, where a relatively small proton shell gap, together with a large valence neutron space, provides fertile ground for studies of shape transitions within a small energy range [1-5].

In alpha-decay studies, the first two excited states of the mid-shell nucleus 186Pb were observed to be 0+ states [6]. On the basis of alpha-decay hindrance factors, the second 0+ state was associated with mainly (2p − 2h) configuration, whereas the third 0+ state was associated with a (4p − 4h) configuration. Consequently, together with the spherical ground state [7], the three 0+ states with largely different structures establish a unique shape-triplet in 186Pb. Very recently, rotational bands built on these states were observed in in-beam gamma-ray measurement [8] and their collectivity confirmed in lifetime measurements [9].

In order to establish a complete picture of shape coexistence in this region, the knowledge of transition probabilities from nuclear states assigned with different shapes is essential. Transition probabilities are very sensitive to the details of a nuclear wave function and, consequently, information about nuclear shape and configuration mixing can be inferred. The main objective of IS494 experiment is to carry out the investigations of nuclear collectivity and mixing of the low-lying states in the neutron-deficient Pb nuclei, namely even-mass isotopes 188-192Pb, employing the REX-ISOLDE facility. The isotopes of interest are of particular importance as they lie in so-called transitional region, where a transition from a weaker deformed oblate structure to a strongly deformed prolate structure is proposed for the yrast states.

The first part of IS494 was run in August 2010, in which we collected data for 192Pb nucleus. The 192Pb nuclei were extracted from the ISOLDE UCx target and the post-accelerated beam was delivered to MINIBALL target position. At MINIBALL, the Pb nuclei were Coulomb excited in inverse kinematics using the secondary 112Cd target. MINIBALL Ge-detector array was used to detect gamma-rays de-exciting levels under investigation. Both scattered projectiles and target recoils were detected using an annular double sided silicon strip detector (CD) positioned on the beam axis after the secondary target. In this presentation, preliminary results from that experiment will be discussed.

ISOLDE Technical Session / 10

Safety at ISOLDE

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As any complex experiment, ISOLDE concentrates all type of hazards, highlighted by its radiological context link to the use of actinide targets. The future increase of energy and intensity, with the HIE-ISOLDE project, will increase or bring new hazards into the facilities as well as new safety constraints, such as ALARA procedures and Safety files for experiments, facilities or projects. This talk will give a brief overview of the safety organization at ISOLDE and will emphasis the progress being made in this area.

Heavy Mass Nuclei / 11

The CRIS experiment: progress and highlights from 2010

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Over the last two years a new experimental beam line has been designed and installed to perform collinear resonant ionization spectroscopy (CRIS) experiments at ISOLDE. The initial series of experiments will study the francium isotopes up to and including 201Fr and 218,219Fr. This work aims at answering questions on the ordering of quantum states, and effect of the 1/2+ intruder state, which is currently believed to be the ground state of 199Fr. This work will also study the edge of the region of reflection asymmetry through measurement of the moments and radii of 218,219Fr. The CRIS technique also offers the possibility of producing ultra-clean isomeric beams, which can be studied independently of the ground state or other isobars.
This presentation will present the recent progress and results from the off-line and on-line experiments performed in 2010.

Solid State II / 12

Possibilities provided by ISOLDE for tracer diffusion experiments

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Radiotracer experiments, in general, have turned out as a powerful tool for the study of diffusion phenomena in solids [1]. In this contribution, diffusion experiments have been performed using the unique abundance of radiotracers delivered by ISOLDE. In this way, it has been possible to show

that in CdTe the group I elements 67Cu, 111Ag, 193Au, and 24Na exhibit the phenomenon of uphill diffusion, i.e. they form a symmetric concentration-depth profile that is strongly peaked about the center of a typically a few 100 µm thick crystal. It turned out that this phenomenon is observed if the diffusion is performed under external Cd pressure at temperatures of about 800 K [2,3,4]. Meanwhile, the phenomenon of uphill diffusion is understandable to a large extent in the framework of a model described in [5,6]. It takes into account the charge state of all participating intrinsic and extrinsic defects moving under the influence of an internal electric field that is generated by the inhomogeneous distribution of the charged defects.
Surprisingly enough, the phenomenon of uphill diffusion is observable, too, and that at a distinctly lower sample temperature of about 550 K, if metal layers are evaporated onto the implanted surface. Uphill diffusion of 111Ag caused by evaporated metal layers has been observed for the metals Cu, Au, Ni, and Al, up to now, whereby quantitative differences show up depending on the respective metal.
In order to extend these studies, the diffusion of the magnetic species Co and Fe in CdTe has been performed. In case of the isotope 61Co implanted at ISOLDE, again unusual diffusion profiles are observed that do not correspond to the results predicted by the simple application of Fick's law; but, in this case, no uphill diffusion profile did occur. Using CdTe crystals exhibiting an initial Te excess, box-shaped Co diffusion profiles were observed upon diffusion under external Cd pressure for temperatures between 800 and 900 K. In contrast, using CdTe with Cd excess, a normal Gaussian diffusion profile was formed. Also the diffusion profile of Co is affected by a metal layer. The presence of a Cu layer evaporated onto the implanted surface of the sample significantly enhances the diffusion of Co at a temperature of 700 K as compared to diffusion under external Cd pressure or vacuum. Finally, first results of the diffusion of 59Fe in CdTe will be presented.
The range of radiotracers suited for diffusion experiments is significantly enlarged by setting up an online-diffusion chamber at ISOLDE. This chamber will enable the use of isotopes having half-lives of less than 1 h and is equipped for measuring concentration profiles up to 10 µm. In this way, it should be also possible to investigate diffusion conditions for tailoring structured impurity profiles at length scales of a few µm. This type of dopant profiles is of strong interest for technical applications, e.g. in magnetic materials or in semiconductors.

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13

Experiments with stored highly-charged ions at ISOLDE: TSR@HIE-ISOLDE proposal

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Experiments with exotic nuclei stored in a ring have shown a huge potential in the last years. Such experiments profit from high revolution frequencies of stored beams which allows to 'recycle' the exotic nuclei and from low background conditions. New experimental ideas have been proposed in addition to the well-established scientific programs on mass and half-life measurements [1]. For example, a feasibility study has been performed at the ESR of GSI where the rate of the proton induced reaction 96Ru(p,gamma)97Rh has been successfully measured in the Gamow window of the the astrophysical p-process [2]. New proposals for the ring facilities (ESR at GSI, Darmstadt and CSRe at IMP, Lanzhou) include measurements of (p,gamma) and (alpha,gamma) reactions at low energis. Other examples are the reaction studies with internal gas-jet target [3] or di-electronic recombination measurements in exotic nuclei for radii determination [4].

We propose to store HIE-ISOLDE beams in a storage ring and to perform nuclear and atomic physics experiments. A well-suited storage ring facility is the Test Storage Ring (TSR) in Heidelberg which operation will be stalled in 2013. A dedicated workshop will be held in October 2010 where the scientific program of TSR @ HIE-ISOLDE and its feasibility will be discussed.

In this contribution we propose the idea and summarize the results of the workshop.

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Solid State II / 14

The sign of the electric field gradient of wide bandgap semi-conductors measured with β-γ angular correlation

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The sign of the electric field gradient can be measured with the β-γ-perturbed angular correlation. This can help in the understanding and improvement of current models and simulations of crystal structures. In this work the wide bandgap semiconductors AlN,GaN and ZnO are investigated..
The results from the last two collections at ISOLDE are presented. 115Cd and 111Ag were implanted in 3µm thin films of GaN and AlN on sapphire substrate and in bulk ZNO. After thorough annealing we performed β-γ PAC measurements.

Medium Mass Nuclei / 15

Nuclear structure studies of the neutron-rich rubidium isotopes using Coulomb excitation

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We report on the first study of properties of excited states of odd-mass neutron-rich rubidium isotopes by the Coulomb excitation technique, using the Miniball array coupled to the REX-ISOLDE facility. This allowed the expected change in shape from a spherical to a deformed one at N=60 to be observed for excited states in these nuclei. These results aid the understanding of the deformation-driving role played by proton orbitals in this region. The ground states of neutron-rich nuclei in the mass 100 region undergo of a rapid change from a spherical to a deformed shape [1]. The nuclei

93–97Rb straddle this transition, which occurs at 60 neutrons [2]. The identification of the bandhead spins and the roles played by different neutron Nilsson orbitals of the Sr and Zr nuclei with N=59, 61 has an given insight into the mechanism responsible for this rapid shape change [3, 4]. The importance of the unique-parity deformation-driving downsloping νh11/2 orbitals here, which create a low-energy deformed minimum with ϵ2˜0.4, has been stated in many articles. As these orbitals are of unnatural parity they interact little with the neighboring neutron orbitals, but start to become filled around N=60. The filling of these orbitals should produce a gradual progression from a spherical shape to deformed one, which is not experimentally observed. Recently a phenomenological explanation for the rapidity of the onset of deformation has been proposed [3, 4] which invokes the importance of ν9/2[404] extruder orbital, which favors a more spherical shape. This explanation focuses only on the role played by the neutrons, however the proton-neutron interaction is known to play a major role in the onset of collectivity. More information on the deformation-driving role of the proton orbits of the region is therefore required. Furthermore, very recent mass data from ISOLTRAP at CERN-ISOLDE suggest that the Kr nuclei of this region may not undergo a rapid shape change [5]. For this reason we have chosen to study the isotopes 93–99Rb across the shape transition via Coulomb excitation. Practically no experimental information exists on the excited states of rubidium isotopes beyond A=93. The present study provides new data across the shape transition, on the spherical isotopes 93Rb and 95Rb and the well deformed nuclei 97Rb and 99Rb.
The experiment was performed using the Miniball array in Coulomb-excitation configuration. The nuclei 93,95,97,99 Rb were produced using a surface-ionization ion source and UCx target. They were subsequently post-accelerated to 2.83 MeV/u by REX-ISOLDE. Using ΔE vs. E identification one could identify that rubidium was practically the only element coming out of the ISOLDE target in this mass region. However, due to the very short half-life of some of the isotopes (e.g. T1/2 (99Rb = 50 ms) the beam composition was modified before reaching the Miniball target due to the decay in-flight and significant contamination was found.
In addition to previously known yrast levels in 93Rb and 95Rb [6] several other levels were populated by Coulomb excitation. Gamma-ray transitions in 97Rb and 99Rb were unambiguously identified providing the first information on excited states in these nuclei. The preliminary results of the experiment will be presented and compared to theoretical calculations.

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Medium Mass Nuclei / 16

Single-particle states in 79Zn and the N=50 shell gap near 78Ni

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Neutron-rich nuclei with magic numbers of neutrons and protons are reference points to map and understand the reorganization of the shell structure away from the line of beta stability. Experiment IS491 aimed at the study of single-particle properties of 79Zn, which lies only 2 protons above and 1 neutron below the Z=28 and N=50 shell closures of 78Ni. The sizes of these shell gaps, from which depends to what extent 78Ni can be considered doubly-magic, are still disputed. Shell-model calculations which take into account the effect of the tensor force predict a weakening of the N=50 shell gap near 78Ni. Recent experimental evidence [1,2] suggests instead a persistence of the gap, and in fact even an increase by 700keV in going from 81Ge to 79Zn. In this experiment, low-lying states in 79Zn were populated via the 78Zn(d,p)79Zn single-neutron transfer reaction, in inverse kinematics. Transfer reactions are the ideal tool to determine effective single particle energy, and thus determine the extent of the shell gap. In this experiment, charged particles were detected using the T-REX silicon chamber coupled to the MINIBALL detector array. Preliminary results will be presented. [1] J. Van de Walle et al., Phys. Rev. Lett. 99 (2007) 142501. [2] Hakala et al., Phys. Rev. Lett. 101 (2008) 052502. *** This work was supported by the European Union Seventh Framework Programm through ENSAR, contract no. 262010.

Solid State I / 17

Perturbed Angular Correlations studies of Hg coordination mechanisms on functionalized magnetic nanoparticles

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Water pollution by trace heavy metals (such as mercury, cadmium) is a serious environmental and public problem. The development of efficient new materials and clean-up technologies for removing those metals from water to within the legal admissible concentrations is urgent. In the last few years, a new type of eco-nanomagnets composed of amorphous SiO2 shells coating magnetite (Fe3O4) particles functionalized at the surface with dithiocarbamate (DTC) groups was developed [1], taking advantage of the high stability of the chelates formed between the DTC groups and metal ions. To improve their perfomance, the understanding of the surface coordination chemistry in these nanomaterials is crucial.

We have started a study with 119Hg isotope made on eco-nanomagnets using the perturbed angular correlation (PAC) technique to probe the coordination environment of the ions [Letter of intent I81] through the Electric Field Gradient. We present the results of experiments performed in aqueous solution containing bare and functionalized nanoparticles, of different sizes and with different uptakes

of Hg ion, to enable the determination of fractions of different local environments associated and also to conclude about the kinetics of the adsorption and desorption processes of the metal cations at the nanoparticles surfaces.

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Moments and Masses / 18

Implementation of a MR-ToF isobar separator at ISOLTRAP and first online results

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The Penning-trap mass spectrometer ISOLTRAP performs precision mass measurements at the isotope separator ISOLDE/CERN with a relative mass uncertainty routinely reaching δm/m≈1x10-8 [1]. The time-of-flight ion-cyclotron-resonance (ToF-ICR) detection technique is employed to determine the frequency of ions stored in a Penning trap, from which their mass can be extracted [2]. Nuclides with half-lives below 100ms and production yields of less than 1000 ions per second have been investigated. Masses of light systems - such as 17Ne - up to heavy ones - such as 229Rn, give insight into numerous physics topics.

As other setups are now also experiencing, ISOLTRAP is reaching a limitation with respect to the ion beam which is delivered from the on-line facility producing the short-lived nuclides of interest. In particular, due to space-charge effects only limited amounts of unwanted isobaric components can be handled by Penning traps . Thus, an isobar separator based on multi-reflection time-of-flight mass spectrometry (MR-ToF MS) has been implemented to support the isobaric contamination removal. The MR-ToF MS system consists of two ion optical mirrors between which ions are oscillating and are separated according to their different mass-over-charge ratios m/q [3]. First tests resulted in a mass resolving power of up to m/Δm ≈ 10ˆ5. The separation was demonstrated offline for the isobaric ions CO+ and N2+ and online for example at m/q=163. In combination with a Bradbury-Nielsen beamgate [4,5], a selection of the separated species can be achieved. The technical setup and recent results are presented.

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Solid State I / 19

Laplace Deep Level Spectroscopy … a new tool for semiconductor research at ISOLDE

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A comprehensive understanding of impurities and lattice defects has been central to the development of semiconductor devices. The electronic properties of these impurities depend on the chemical species, the site of the impurity in the lattice and its possible complexing with other impurities and lattice defects such as vacancies. A very important tool in the study of defects and impurities is Deep Level Transient Spectroscopy (DLTS). This has been used since 1990 at ISOLDE in a number of innovative experiments where species have been implanted which undergo nuclear transmutations.

Unfortunately conventional DLTS provides a spectrum of the carrier emission from the defect with rather low resolution. The end result is that very little physical information can be derived from DLTS and this has proved to be a major problem in many applications and has limited the scope of its use at ISOLDE. However over the last decade a major advance in DLTS has been achieved which removes all the instrumental broadening from the measurement resulting in an order of magnitude improvement in energy resolution. This is generally referred to as Laplace DLTS or LDLTS (see www.laplacedlts.eu). The new technique moves DLTS from being a fingerprinting tool to the realm of an important probe of defect physics. During the summer of 2010 a LDLTS system was commissioned at ISOLDE and has been tested with an implant of 195Hg > 195Au > 195Pt. After annealing and diffusion this implant gave a volume concentration of ˜10ˆ12 cm-3 which is very typical of the levels of interest in semiconductor devices.

In the talk LDLTS spectra taken at ISOLDE will be presented and examples shown of how the technique can be used to probe the electronic properties of defects and their local environment in the lattice. Finally some problems will be outlined to which the installation could be applied.

Summary:

An outline of the capabilities of a new installation at ISOLDE of high resolution deep level transient spectroscopy for semiconductor research will be given in this presentation.

HIE-ISOLDE Physics / 20

HELIOS: a new approach to studying transfer reactions in inverse kinematics

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The new helical-orbit spectrometer, HELIOS [1,2], at Argonne National Laboratory (ANL) provides a way of studying transfer reactions in inverse kinematics that circumvents the problems traditionally associated with this reaction mode: low resolution brought on by the rapidly changing laboratory energy with angle, and a kinematic compression at forward c.m. angles. This is achieved by transporting outgoing ions in the strong, homogeneous magnetic field of a solenoid, where the ions execute helical orbits before returning to the magnetic axis. The field disperses ions according to their energy, angle of emission, and charge-to-mass ratio giving rise to the particle's cyclotron period which provides particle identification. Along the axis, surrounding it, is an array of position-sensitive Si detectors used to measure energy, position, and time of flight. This detector array can be coupled with recoil detection to provide a full kinematic description of the reaction. To date, the device has been used to study reactions with light radioactive beams of 12B [3] and 15C [4], through to medium and heavy stable beams of 86Kr and 130,136Xe, respectively. The potential of such a device for exploitation with radioactive beam programmes, for example CARIBU at ANL [5], and around the world, is demonstrated.

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Moments and Masses / **21**

Magnetic dipole moment of the Coulomb excited 2+1 state in 138Xe - final report from IS415 and future of the Transient Field technique at REX-ISOLDE

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The isospin structure of nuclear excited states would preferably be investigated by observables which are most sensitive to it, e.g. nuclear magnetic moments. IS415 has started as one of the first attempts to measure the magnetic dipole moments of short-lived excited nuclear states at radioactive ion-beam facilities. We will report on the result obtained from this experimental campaign on the g(2+1) factor in unstable neutron rich 138Xe using Coulomb excitation and the low-velocity Transient Field technique. The impact of the experimental result will be discussed with respect to the observed reduction in the electrical quadrupole transitions probability in its isotone 136Te [1] where shell model calculations using realistic effective interactions have failed to describe the experimental behaviour [1]. On the other hand QRPA calculations could trace the origin of the observed trend to the reduction of the neutron pairing gap above N = 82 [2]. Future applications of the technique will be presented as well as an outlook for HIE-ISOLDE.
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Moments and Masses / **22**

First combined DSAM and Coulomb excitation experiment at REX-ISOLDE - measuring the sign of the spectroscopic quadrupole moment of the 2+1 state in neutron-rich 140Ba

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The importance of precise lifetime information has recently been demonstrated in experiments at REX-ISOLDE and MINIBALL using the sensitivity of the Coulex yields to the nuclear reorientation effect in order to determine the sign of the spectroscopic quadrupole moment of the 2+1 state in 70Se [1,2]. Therefore we have utilized a new combined technique of lifetime measurement using the Doppler-Shift-Attenuation-Method (DSAM) and analysis of Coulex yields for the measurement of the spectroscopic quadrupole moment of the 2+1 state in unstable neutron-rich 140Ba. On the basis of the new lifetime of tau = =12.5(6)ps it was possible to fix the sign of the spectroscopic quadrupole moment to be negative - equivalent to an oblate deformation. Furthermore the experiment was used to test the feasibility of ''Recoil-in-vacuum" studies at REX-ISOLDE and MINIBALL for the measurement of magnetic dipole moments, as recently described in [3,4]. An upper limit for the absolute value of the g(2+1)-factor in 140Ba could be obtained.

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Fundamental Interactions and Astrophysics / 23

Recent developments and results of WITCH

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The WITCH set-up (Weak Interaction Trap for Charged Particles) that was installed at ISOLDE/CERN combines a double Penning trap system to store radioactive ions and a retardation spectrometer to probe the energy of the daughter recoil ions [1]. The primary aim is to search for scalar and/or tensor interactions in nuclear beta decay by precisely determining the beta-neutrino angular correlation coefficient a. This can be extracted from the measured energy spectrum of the recoiling nuclei after beta decay in the WITCH set-up.
In the last years the set-up was upgraded (better vacuum, buffer gas purification, electro-polished electrodes, compensation magnet) and further optimized to allow for measurements with the mirror nucleus 35Ar. A first such measurement was already performed last year and allowed the investigation of systematic and unwanted effects in the system, which were compared with simulations and countermeasures were implemented in the WITCH system. The aims of this years campaigns are a calibration of our set-up with an electron capture nucleus and a complete recoil spectrum of 35Ar.

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HIE-ISOLDE Physics / 24

Simulations of transfer reactions at HIE-ISOLDE

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The planned High Intensity and Energy (HIE) upgrade of the radioactive beam facility ISOLDE will enable post-acceleration of radioactive beams up to an energy of about 10 MeV/u, thus opening the door to nuclear reaction studies. In the case of transfer reactions in inverse kinematics a recoil separator is often well suited to tell recoils and beam apart and to select the exit channel. A set of nuclear transfer reactions in inverse kinematics have been simulated using realistic parameters for HIE-ISOLDE and their cross sections calculated. Two different types of spectrometer designs are being considered for HIE-ISOLDE, namely a recoil mass separator or a ray-tracing type of spectrometer. The performance of the two types of spectrometer designs is compared and their scientific possibilities and limitations discussed based on the simulation results and expected yields.

Solid State I / 25

Direct identification of interstitial Mn in Ga1−xMnxAs and evidence of its high thermal stability

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The lattice location of Mn in GaAs has been intensively studied in recent years due to its crucial role on the magnetic properties of Ga1−xMnxAs, one of the most studied dilute magnetic semiconductors. Maximum Curie temperatures (TC) are usually achieved after low temperature annealing (˜200ºC), which is generally attributed to out-diffusion of interstitial Mn (MnI). However, despite major developments in film quality, the TC of Ga1−xMnxAs remains below room temperature even at very high Mn concentrations.
We report on the study of the lattice location of Mn in Ga1−xMnxAs by means of electron emission channeling from the decay of implanted 56Mn produced at ISOLDE/CERN. In addition to Ga1−xMnxAs thin films with x = 0.01 and x = 0.05, we have studied intrinsic GaAs, p+-GaAs and n+-GaAs. We locate the majority of the implanted Mn atoms in substitutional Ga sites and a significant fraction in tetrahedral interstitial sites with As nearest neighbors. Contrary to the general belief that interstitial Mn out-diffuses at ~200ºC [1], we give evidence of its high thermal stability up to 400ºC. Showing that MnI is immobile up to temperatures where phase segregation is known to occur, we discuss strategies and prospects for achieving room temperature ferromagnetism in Ga1−xMnxAs.

Light Mass Nuclei / 26

Study of single particle structure of 35Si

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We report on an experimental study which investigated a shell structure in the neutron-rich N=20 region. A lot of experimental works have been made to pin down the nuclear structure around 32Mg, and the results are consistently interpreted that the magic number N=20 disappears in this region. In the framework of shell model, such a shell evolution may be attributed to the variation of the energies of single particle states (SPS) depending on the isospin. However, the single particle structures around the 32Mg have not yet been well investigated experimentally.
We studied isobaric analog resonances (IARs) of 35Si, which is located in the vicinity of 32Mg, by proton resonance elastic scattering on 34Si in inverse kinematics. Assuming an isospin symmetry of nuclear forces, the single particle configuration of IARs are the same as those for the corresponding parent SPSs in 35Si. The spectroscopic information on the IARs can be extracted by R-matrix analysis on the excitation function of the proton elastic scattering [1,2].
A 34Si beam was produced by a 400˜pnA 40Ar beam of 63˜MeV/nucleon and separated with the fragment separator RIPS in the RIKEN Nishina Center. The energy of the beam was degraded to around 5 MeV/nucleon by a thick carbon plate of 90˜mg/cm2 thickness. The beam bombarded on a polyethylene target of 10.9˜mg/cm2 thickness. The recoil proton energy around 12˜MeV was measured by three layers of silicon detectors. Several resonances have been clearly observed in the obtained proton excitation function.
We will present the detailed experimental setup and the preliminary result on the SPS of 35Si.

ISOLDE Technical Session / 27

The new fast tape station at ISOLDE

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We present the latest results from the new fast tape-station installed at Isolde. With a transport time of 200ms and the ability to make in-beam measurements, we are able to make accurate yield and release measurements of very short-lived isotopes, down to half-lives of just a few milliseconds.

HIE-ISOLDE Technical Session / 28

Radiation protection and radiation safety issues for HIE-ISOLDE. FLUKA calculations.

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The production of radioactive ion beams (RIB) is worldwide a scientific topic of great interest. Continuous and significant improvements of the particle accelerator and targets technologies opens new potentialities for the production of RIBs and their use for fundamental and applied science, with increasing intensities and new types of beams available to perform measurements.

The High Intensity and Energy ISOLDE (HIE-ISOLDE) project is an upgrade of the existing ISOLDE facility, art CERN. The foreseen higher nominal intensity and power of the primary beam is expected to increase the energy and the intensity of the produced RIBs. The ISOLDE facility uses the proton beam from the PSB with an energy of 1.4 GeV and an intensity up to 2 µA. After upgrade (final stage) the HIE-ISOLDE facility is supposed to run at energy up to 2 GeV and an intensity up to 4 µA. The upgrade imposes constrains to the existing experimental and supply areas. Taking in to account the new beam power and beam intensities a new assessment of the existing radioprotection

and radiation safety issues. Special attention must be devoted to the shielding of the beam dump and experimental areas. The diversification of the types of targets which can be used for irradiation dictates the need to pay special attention to the shielding issues in case of heavy targets due to high-energy secondary particles produced during irradiation.
On this work the FLUKA particle transport code was used to perform the simulation of the dose distribution, of the energy deposition and particle fluxes on the facility taking in to account the variation of the primary beam power and intensity, and to assess the shielding configuration of the new facility.

ISOLDE Technical Session / 29

Target and Ion Source development at CERN-ISOLDE

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The presentation will report on the new beams made available in 2010 at ISOLDE. It will also provide some feedback on how the beams were produced this year, and some options for future improvements. Some of the highlights are the unexpected Fe beam produced with a VADIS ion source and a submicron target, the delivered neutron rich Au beams, and the replacement of the traditional MK3 FEBIAD on molten lead target units. The recent progresses on the use of (n,X) reactions for beam production will finally be presented, along with possible lines of research for improvement of the neutron converter.

ISOLDE Technical Session / 30

ISOLDE RILIS: from proof of principle to a standard versatile technique.

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The high efficiency and selectivity of laser ionization in a hot cavity has been proven at ISOLDE off-line mass separator in 1989. Following the first on-line demonstration of laser-ionized Yb radioactive isotopes at ISOLDE-3, the technique has served for a great number of ISOLDE experiments. Today, the laser ion source named RILIS is one of principal ion sources used at ISOLDE and other ISOL-facilities in the world.
At ISOLDE beams of 26 different elements were produced using high repetition dye lasers. Until 2008 the dye lasers were pumped by copper vapor lasers. Following a plan for upgrade of the laser setup, a new 100W Nd:YAG laser as well as new dye lasers have been installed at RILIS. This resulted in a noticeable improvement in the production of ion beams. In particular, the beam stability increased and higher isotopic yields have been observed.
In 2010 a fully solid state laser system based on 10 kHz repetition rate Ti:Sapphire lasers has been built at CERN to compliment the dye laser system. Its implementation at RILIS is planned for 2011. Due to that the range of elements accessible with RILIS will be extended. A faster switch from one to another element could be achieved using the duo-laser system of RILIS.

Light Mass Nuclei / 31

Reactions induced by 11Be beam at Rex-Isolde

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Elastic scattering and reaction mechanisms around the barrier, in reaction induced by halo nuclei, has been the object of many publications in the last years (see e.g. [1-3] and ref. therein). In collisions induced by halo nuclei, direct reactions, as for instance transfer or break-up, may be favored owing to the low binding energy, the extended tail of the matter distribution and the large Q-value for selected transfer channels. Moreover, the effects of the coupling to the continuum on the fusion cross-section are not fully understood. Experimentally, almost all elastic scattering and reaction mechanism studies around the barrier with halo nuclei have been performed with 2n halo nucleus 6He and only few experiments have been performed with 1n halo 11Be [4,5].
I will present new results obtained at Rex-Isolde and LNS Catania concerning different reaction channels for the collisions 9,10,11Be+64Zn at energy close to the Coulomb barrier. The analysis of elastic scattering shows a damped elastic angular distribution for the collision induced by the 11Be halo nucleus when compared to the ones induced by 9,10Be. Correspondingly, the total reaction cross-section extracted for 11Be+64Zn is more than a factor of two larger than for the other two systems. It will be shown that such an enhancement of the total reaction cross-section with 11Be is due to the presence of strong transfer/break-up channels.

HIE-ISOLDE Technical Session / 32

Research and development activities for the HIE-ISOLDE linac

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The talk will illustrate the research and development activities within the HIE-ISOLDE project, mostly focusing on the cavity development and report on the preliminary results of the cold RF tests.

Medium Mass Nuclei / 33

Recent results from the HRIBF

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The development of fission fragment and proton-rich beams1 at the Holifield Radioactive Ion Beam Facility (HRIBF)2, along with the availability of batch mode beams of 7,10Be and 26Al, has led to unique research of nuclear structure close to the shell closures, and reactions of relevance to nuclear astrophysics. Additionally, recent access to intense low-energy beams directly from the RIB platform at the LERIBS3 beam line has already led to high statistics decay spectroscopy in the region close to 78Ni.
I will present the recently published4 results of a neutron transfer experiment on a reaccelerated beam of 132Sn. The purity of the states populated in 133Sn reflects the doubly-magic nature of 132Sn. Comparisons will be drawn with the benchmark doubly-magic nucleus 208Pb.
Other recent results from the HRIBF will be highlighted.

Light Mass Nuclei / 34

The Radioactive Ion Beam Factory: recent results, present status and perspectives

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The current status of the Radioactive Ion Beam Factory at the RIKEN Nishina Center will be presented. The facility is based on a new heavy-ion accelerator complex which can deliver very intense beams of nearly all elements, including Uranium, to the new two-stage in-flight fragment separator BigRIPS, to produce high-energy radioactive ion beams, which can be used at several experimental target stations.

The facility is operational since 2007 and the high performance and the potential of this new facility has been demonstrated by a series of recent experiments, including the discovery of over 40 new isotopes using in-flight fission of a 345 MeV/u Uranium beam (0.2 pnA), and experiments shedding new light the island of inversion near the neutron-rich Ne, Na isotopes. The later experiments utilized a very high-intensity 48Ca beam of nearly 100 pnA at 354 MeV/u.

In addition to an overview of the upcoming physics program (mainly in-beam gamma-ray spectroscopy), I will shortly introduce the major experimental devices that are now in operation (ZeroDegree spectrometer , high-resolution spectrometer SHARAQ, DALI2 gamma-ray spectrometer), that are under construction (electron-RI scattering system SCRIT, large acceptance spectrometer SAMURAI), as well as future devices (Rare RI storage ring, RF ion-guide gas-catcher system SLOWRI, next generation high-resolution gamma-ray spectrometer SHOGUN).

Solid State I / 35

Inorganic Nanoparticles as Functional Building Units for Composite Particles

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Inorganic nanoparticles have been investigated as components in various functional materials and devices for diverse applications. These nanomaterials can be prepared as pure phases or as multiphase materials which in turn are used as fillers in polymer matrices in order to fabricate nanocomposites.
In this communication chemical aspects that have been particularly relevant in our research on nanoengineering composite particles will be presented and discussed. A particular emphasis will be made on the use of chemical strategies well known within the inorganic chemistry field in order to produce a variety of nanocomposite particles. Illustrative examples comprising the chemical synthesis of photoluminescent nanosilicas, plasmonic metal nanoparticles and superparamagnetic iron oxide nanophases will be presented. All these nanoparticles can be used as starting materials to produce polymer composites in the form of colloidal stable aqueous emulsions or in bulk form. In this regards, it will be shown that the surface functionalization of the nanoparticles is of paramount relevance considering the type of polymers used and also the polymerization route employed. Finally, the challenges and potential applications of materials emerging from this nanocomposite science will be put in perspective.

Light Mass Nuclei / 36

Frequency-Comb Based Optical Isotope Shift Measurement of Be-12

Authors: Andreas Krieger[1]; Christopher Geppert[1]

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Charge radii measurements of the lightest elements are benchmark tests for nuclear structure calculations. In this part of the nuclear chart, ab-initio models that treat the nuclei as consisting of individual nucleons which interact via nucleon-nucleon and three-nucleon forces are available. Moreover, the appearance of the so-called halo nuclei, having an extended nuclear matter distribution due to weakly bound nucleons, makes this region particularly interesting.
After the successful isotope shift measurements of Be-7,9,10,11 in 2008, we could now extend the measurements to the isotope Be-12 and cope with the low production rates using optical detection combined with the ion-photon coincidence technique. This isotope is interesting because Be-11 is the prototype of a one-neutron halo nucleus and also Be-14 is known to have halo character, whereas the information about the structure of Be-12 is still vague. First results of the charge radius measurement from the recent beam time at COLLAPS will be presented. Besides the isotope shift measurement of Be-12, several systematic effects were tested during the beamtime, e.g. ion beam deceleration or acceleration by the resonant laser light. High accuracy atomic structure calculations allow us to extract a preliminary nuclear charge radius from the measured optical isotope shift very accurately.

37

Introduction

Author: Yorick Blumenfeld[1]

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Welcome the participants and give some information on the implementation of the ENSAR contract at CERN/ISOLDE.

ISOLDE Technical Session / 38

Plasma ion source development for molecular radioactive ion beams

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Increased ionization efficiencies for light noble gases and molecules are still required for new physics experiments, in present facilities like ISOLDE and for future installations such as EURISOL. In order to improve these beams, two new plasma ion sources are implemented on to the ISOLDE target ion source base.
The first one is a COMIC-type ion source operating at 2.45 GHz and equipped with a fully quartz coated plasma chamber. The beam current stability is typically better than 1 % and beams are easily reproducible. The highest efficiency achieved so far for xenon is about 15 %. However, the main goal is to produce molecular beam including radioactive carbon (as CO+ or CO2+), in which case the efficiency was measured to be about 0.2 %.

The second project develops radiation hard Helicon-type ion source operating at 10 ⋯100 MHz. The first plasma ignition tests have been performed and different antenna geometries have been tested. The next step is to implement the system on a full target and ion source unit compatible with the ISOLDE front-end and perform studies at the offline separator.
First online tests online are foreseen during 2011.

Fundamental Interactions and Astrophysics / 39

Present and future at GANIL

Author: Heloise Goutte[1]

[1] *GANIL*

In this talk I will present some recent experimental and theoretical results obtained at GANIL. Then I will detail the SPIRAL2 project, and the theoretical developments that have been undertaken recently to describe nuclear structure properties of exotic nuclei and nuclear reactions.

Heavy Mass Nuclei / 40

Total Absorption Spectroscopy at Isolde; Past, Present and Future

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Total Absorption Spectroscopy (TAS) is an essential technique to measure beta decay BGT distributions free of systematic errors ("Pandemonium Problem").The TAS spectrometer "Lucrecia", the largest TAS spectrometer presently operating, was installed at ISOLDE with this purpose. The scientific programme so far has been focused on the investigation of ground states nuclear shapes. They are deduced from the comparison between the experimental BGT and theoretical calculations assuming different deformations for the parent state. It started in the mass region A≈70 (Refs. 1 and 2) and it continues today with studies in the A≈190 region. Some preliminary results will be presented on nuclei 78Sr, 76Rb, 78Rb, 188, 190 and 192Pb. In the next future we plan to continue this experimental programme in the A≈190 region (Ref. 3), with the studies of 182,184,186Hg and 186Pb. Furthermore we plan to initiate a research programme in the region "below"132Sn, and to study the possibility of contributing to the geo-neutrino studies (Ref. 4). These ideas will be briefly presented.

Moments and Masses / 41

Collinear laser spectroscopy at ISOLDE and recent results.

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Thirty years of collinear laser spectroscopy at ISOLDE have yielded a large number of nuclear spins, magnetic moments, electric quadrupole moments and mean square charge radii. The experiments

were not just collecting nuclear data, but continuously improving the method by combining it with different detection techniques. Thus the measurements became increasingly sensitive and accurate, coping with very low yields of short-lived nuclei. This gave access to particularly interesting regions of nuclei far from stability.
Several experiments carried out over the past years, could be completed in 2010. Isotope shift measurements in magnesium yield the charge radii over the complete neutron sd-shell, from 21Mg to 32Mg which is situated well in the centre of the "island of inversion". Most sensitive measurements were performed using optical polarization and beta-asymmetry detection of which previous outstanding results include the unexpected spins and magnetic moments of 31Mg and 33Mg.
Using absolute wavelength measurement and simultaneously taking spectra with collinear and anticollinear laser beams it was possible to overcome the accuracy limitation for very light elements arising from the huge Doppler shifts and to measure charge radii of the beryllium isotopes. The measurements, performed on 7-11Be in 2008, were now completed with a very sensitive measurement on 12Be using ion-photon coincidence for background reduction.
With the installation of ISCOOL, it had become possible to extract the beams in short bunches, thus allowing the background of fluorescence detection from scattered laser light to be reduced substantially. This was exploited for high resolution measurements on neutron-rich copper isotopes up to 75Cu, and recently on neutron-deficient isotopes down to 58Cu.

Solid State II / **42**

Recent results using radiotracer PL at ISOLDE

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The results of photoluminescence (PL) studies on ZnO implanted with radioactive As ⟶ Ge and Ga ⟶ Ge isotopes are described. In both cases, identical PL effects are observed, indicating that identical daughter Ge defects are created. We conclude, on the basis of the well-established result that Ga occupies Zn sites, that implanted As also occupies Zn sites in ZnO. This finding corroborates results from electron channeling measurements by Wahl et al [Physica B 404, 4803(2009)]. Preliminary indications from this work and allied studies of stable isotopes are that both Ge and Si act as weak binding centres for excitons in ZnO.

Solid State II / **43**

Recent Mossbauer results using 119In

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119Sn Mössbauer spectroscopy utilizing implantation of 119In (T½=2.4 min) has been performed at ISOLDE for the first time in over two decades. Development(s) in data aqusition and analysis techniques allow us to obtain more information from these experiments than was possible in the past.

New findings in group IV semiconductors and oxides (ZnO, MgO and Al2O3) will be presented and discussed.

Solid State II / 44

Beta-NMR as a novel technique using radioactive beams for bio-physical studies

Authors: Alexander Gottberg[1]; Monica Stachura[1]

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Beta-NMR is a technique which has been successfully applied at ISOLDE in solid state and nuclear physics for several decades [Arn87, Cho03, Kee08]. Due to physical-technical boundaries this technique has never been applied to soft matter investigation, although it holds great promise for numerous applications.

Beta-NMR is based on the implantation of a radioactive ion beam carrying a polarized nuclear spin; hence it requires vacuum conditions to maintain the ion beam, its energy, charge and polarization. By use of a sophisticated instrumentation we are able to maintain a liquid target of controlled temperature and pH, in order to simulate the physical conditions of chemical processes in nature. We then pump from around 5 mbar in the liquid sample surrounding down to 10-6 mbar in the beam line on a distance as short as 40 cm. Thus we achieve radioactive beam transmissions of approx. 25% at 30 keV. Higher transmissions can be expected at 60 keV, usually provided from ISOLDE.
This fulfils the conditions to make the beta-NMR technique available for life science aspects.

Thanks to the COLLAPS collaboration, the bio-beta-NMR project (I88) will take advantage of an already existing online setup at ISOLDE to carry out the world's first beta-NMR measurements on a liquid aqueous sample. Later experiments on metal ion containing complexes and subsequently on metal ion binding proteins are planed.

General Interest Talk / 45

Overview of first ATLAS results with LHC 2010 data and prospects for 2011

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This presentation will cover some highlights of the first physics results obtained with the ATLAS detector during the LHC operation in 2010 with proton-proton collisions at 7 TeV centre-of-mass energy and during the recently completed first heavy-ion operation with lead-lead ions colliding at 2.76 TeV per nucleon. The first Standard Model measurements will be covered as well as first results from searches for new phenomena. Prospects for 2011 will also be covered with some emphasis on the search for the Higgs boson.