ISOLDE Workshop and Users meeting 2007/2008

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Book of Abstracts

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Nuclear Physics III / 0

Sub-Barrier Coulomb Excitation of 110Sn and First Results on 108,106Sn

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The advent of radioactive ion beams (RIBs) places exotic nuclei within reach of experimental study. In particular, RIBs enables a new investigation of the low energy structure of isotopes in the vicinity of the doubly magic 100Sn nucleus. We present here the first results from a series of measurements of the reduced transition probability - the B(E2) value - for the neutron deficient Sn-isototpes 110,108,106Sn [1]. All three experiments were performed using sub-barrier Coulomb excitation at 2.8 MeV/u at REX-ISOLDE with the MINIBALL germanium detector array. This technique provides a measurement accuracy of ˜10%. The B(E2) value can presently difficult to obtain using any other method, due to a high lying 6+ isomer present in the neutron-defiecient even Sn isotopes.
Doubly-magic nuclei are of significant theoretical importance, since they provide a good testing ground for shell-model calculations. The Sn isotopic chain comprises nuclei between neutron numbers N=82 and N=50. Therefore it provides a unique opportunity to study the shell structure evolution as a function of the neutron degree of freedom. The spectroscopy of the low lying states in the even Sn isotopes have been explained within the generalized seniority scheme [2]. Large scale shell model calculations using a model space confining the neutrons to the $gdsh$ orbitals support this picture [3]. Our recent experiments together with results from refs. [3,4] indicate a deviation from theoretical predictions manifested in a stronger than expected collectivity towards the proton dripline. This might imply that further core-polarization effects and a refined effective interaction are needed. One perhaps important effect recently discussed in refs. [5,6,7] is that of an enhanced attractive neutron-proton interaction in spin- isospin-flip vertices contained in the monopole part of the tensor force. Hence, with a decrease of neutrons in the orbital 0g7/2, the proton 0g9/2 becomes less bound, implying an increased core-excitation probability. Thus, this effect could compete with a reduction of the B(E2) values originating in the decrease in neutron number. We will present the latest results and data analysis from 110,108,106Sn, and where they stand in comparison with present theoretical models.

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[5] T. Otsuka et al., Phys. Rev. Lett. 87, 082502 (2001).
[6] T. Otsuka et al., Phys. Rev. Lett. 95, 232502 (2005).
[7] B. L. Cohen et al., Phys. Rev. 127, 597 (1962).

Nuclear Physics III / 1

Shape coexistence in n-rich Strontium isotope at REX+ Miniball

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The nuclei in the mass region A =100 around Sr and Zr show a dramatic change of the nuclear ground-state shape from near spherical for N <=58 to strongly deformed for N> = 60. Theoretical calculations predict the coexistence of slightly oblate and strongly prolate deformed configurations in the transitional region. However, excited rotational structures based on the highly deformed configuration, which becomes the ground state at N = 60, are not firmly established in the lighter isotopes, and the earlier interpretation of a very abrupt change of shape has been challenged by recent experimental results in favor of a rather gradual change. The low spins electromagnetic properties of the neutron-rich 96Sr were studied by low-energy Coulomb excitation using the REX-ISOLDE facility and the MINIBALL detector array. The experiment was performed in June 2007 using a molecular extracttion and for the first time at the new position of the Miniball array. Preliminary results will be presented.

Nuclear Physics II / **2**

IS456 - Ground and isomer state properties of the neutron-deficient polonium isotopes using the ISOLDE RILIS

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For many years, the RILIS has provided very clean beams for ISOLDE. It is now also a tool used for precision measurement of nuclear ground and isomer state properties. Combining the laser spectroscopy technique in the ion source itself with the high sensitivity and precision of nuclear spectroscopy, it is possible to extract optical spectra for very exotic nuclei as was demonstrated with the lead and bismuth studies at the RILIS. This last summer, a similar study was performed on the neutron-deficient 193–200,202,204Po isotopes using recently developped laser ionized beams of polonium. In this presentation, we shall report on the achievements of experiment IS456 as well as on the challenges of the analysis of such data. The first insight on the nuclear properties will be discussed.

Nuclear Physics III / **3**

Coulomb excitation on the 184,186,188Hg nuclei

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We report on a Coulomb excitation experiment at 'safe' energies on the even-even neutron-deficient 184,186,188Hg isotopes at the REX-ISOLDE radioactive beam facility. For the first time a Coulomb excitation experiment using post-accelerated radioactive ion beams was performed in the heavy mass region. Apart from the first 2+ to the 0+ ground state transition, also Coulex towards the second 2+ and the 4+ state was observed and gamma-rays from the different decay paths were detected in the Miniball gamma-spectrometer. From the intensity of these gamma-rays the matrix elements connecting the different states in the different bands will be deduced for these nuclei. The obtained results should lead to a better understanding of the shape coexistence in this mass region of the nuclear chart.

HIE-ISOLDE / 4

ISOLDE news

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I shall review briefly recent (and foreseen) administrative changes at CERN that are relevant for the ISOLDE users, including registration of users and safety courses.

HIE-ISOLDE / 5

Spin determination and nuclear moment measurements of 71Cu and 72Cu

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As part of the IS439 experiment the COLLAPS collaboration has recently measured the hyperfine structure of 71,72Cu. From this work we are able to unambiguously assign the spin of 72Cu and extract the magnetic and quadrupole moments for both isotopes. This work is part of the ongoing investigation of the evolution of nuclear structure with neutron excess in the copper isotope chain. A central motivation of the original proposal was to measure the spin/parity of 72Cu, and thus resolve the inconsistency between recent results from in-source spectroscopy and beta-decay studies [1,2]. This experiment uses high-resolution laser spectroscopy, which can unambiguously measure the nuclear spin and provide model-independent measurements of the nuclear moments. The interpretation of these recent measurements in conjunction with the hyperfine structure measurements from 2006 will be presented and discussed.

[1] J.-C. Thomas et al., Phys. Rev. C 74, 054309 (2006).
[2] U. Koster, Private Communication, 2005.

Technical Developments / 6

Hydrodynamics of ISOLDE liquid metal targets

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The proton beam from the CERN Proton-Synchrotron Booster (PSB) is highly pulsed. A typical 1.4 GeV PSB pulse consists of four bunches, with a maximum bunch power of 12 GW. This is more than six orders of magnitude higher than the often quoted average beam power of ˜2.7 kW. The lifetimes of early liquid metal targets exposed to the PSB beam were severely compromised through broken welds, corroded proton beam windows and flow of liquid metal into the ion source. To reduce the energy densities for liquid metal target units, the current practice is to spatially defocus the beam and to apply a time-staggered extraction mode to the PSB bunches. Hydrodynamic simulations of proton-induced transient effects such as splashing were carried out and showed that the 10 us bunch spacing which matches the target relaxation time leads to constructive interference of proton-induced pressure waves. Measurements of the release of 84Kr from a Pb target and 111Cd from a Sn target confirm the dependence of release on bunch spacing. Small changes in the PSB bunch spacing can significantly reduce pressure amplitudes and may be a solution to further improve ISOLDE liquid metal target release and yield properties by increasing the practical limit of 8e12 protons per pulse whilst ensuring target lifetimes remain unaffected. With the ongoing design phase and planned construction of the CERN accelerator complex upgrade, this study introduces some of the engineering tools which will be required in the development of the new target and ion source units compatible with the proton beam characteristics.

Summary:

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Technical Developments / 7

Selective contaminant adsorption for RIB purification at ISOLDE

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Target and ion source units have been recently developed at CERN-ISOLDE with the aim of delivering isobarically clean beams of short lived neutron-rich Cd and Zn. Chemical selectivity is achieved by specific interaction of the contaminant with a catching material inserted in the transfer line [1, 2]: a quartz insert allowed the retention and the decay of alkali contaminants by controlling its temperature. The temperature dependence showed to originate from a longer effusion time, and higher decay, of the impurities by selective adsorption onto the quartz. The design of this transfer lines is presented. Alkali suppression factors are deduced from 80Rb, 8Li, 46K and 126,142Cs yield measurements. The enthalpy of adsorption for Rb and Cs is calculated from 80Rb and 126Cs suppression factors.

[1] E. Bouquerel et al., 'Purification of a Zn Radioactive Ion Beam by alkali suppression in a quartz line target prototype', European Phys. Journal A (in press).

[2] –K.L. Kratz et al., 'The Beta-decay half-life of 13048Cd82 and its importance for astrophysical r-process scenarios', Z. Phys. A325 (1986) 489.

Nuclear Physics I / 8

The d(30Mg, 31Mg)p transfer reaction at REX-ISOLDE: Results from IS454

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Thirty years after the discovery of the "island of inversion" [1] the borders of the island are still not well determined and in particular the evolution of the single-particle structure is not well investigated.

Transfer reactions yield important spectroscopic information, i.e. spin and parity assignments as well as spectroscopic factors, complementary to the information obtained in Coulomb excitation [2].

In order to study transfer reactions in inverse kinematics at REX-ISOLDE with MINIBALL a new setup was built covering a large solid angle. This new setup overcomes the limitations of previous transfer experiments performed at REX-ISOLDE [3].

In the first experiment the nucleus ^{31}Mg which is right on the edge of the "island of inversion" was studied via the d(^{30}Mg, ^{31}Mg)p reaction.

First results of this beamtime which took place at the end of October this year will be shown as well as future plans for transfer experiments at REX-ISOLDE.

[1] C. Thibault et al., Phys. Rev. C 12, 644 (1975)

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[3] M. Pantea, PhD Thesis, TU Darmstadt, Germany (2005)

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Nuclear Physics II / **9**

Breakup of the 18.2 MeV state in 11Be: New decay modes.

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The ^{11}Li β-decay offers a unique window to understand the nuclear structure far beyond the valley of stability. The β-delayed charged particle emission of ^{11}Li has been the subject of several previous studies [1-4]. The established channels involve the emission α particles (2α+3n), ^{6}He (^{6}He+α+n), tritons (^{8}Li+t), deuterons (^{9}Li+d) and the emission of 1n and 2n feeding the ground states of ^{10}Be and ^{9}Be respectively. The two channels involving α particles were previously studied in a ^{11}Li β-decay coincidence experiment by Langevin et al.[4]. The coincidence charged particle spectrum was explained as due to the breakup of two states in ^{11}Be at 10.6 and 18.2 MeV excitation energy. The breakup of the latter was assumed to ocur by the three body channel nα^{6}He and the 5-body 3n2α. However, a recent ^{11}Li β-decay experiment performed by our collaboration [7] observed structures in the coincidence scatter plot interpreted as the sequential break-up of ^{11}Be through intermediate ^{A}He resonances.

In this work we present the first results of a new ^{11}Li β-decay experiment we performed at ISOLDE to clarify our previous interpretation [7]. The experimental set-up, consisting of 3 DSSSD's, was optimized for maximum solid angle coverage while having good spatial resolution. This improvements allowed us to record five times as many statistics as in the previous experiment, and to obtain direct evidence of sequential three-body, nα^{6}He, break-up of ^{11}Be through the ground state of ^{7}He. Moreover, by reconstructing the neutron energy using energy and momentum conservation, we have identified two new states in ^{11}Be decaying through this new ^{7}He channel at 15.25, 16.18 MeV on top a previously known state at 18.0 MeV.

1] M. Langevin et al., Phys Lett. B146 (1984) 176.

[2] M. Langevin et al., Nucl. Phys. A366 (1981) 449.

[3] I. Mukha et al., Phys. Lett. B367 (1996) 65.

[4] M.J.G. Borge et al., Nucl. Phys. A613 (1997) 199.

[5] M. Madurga et al., in preparation

Technical Developments / **10**

Towards High Intensity Energy ISOLDE: extrapolation of yields for accelerated isotopes at REX-ISOLDE

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Since the first year of operation, REX-ISOLDE has been delivering numerous post-accelerated radioactive beams [1,2]. An update of the ISOLDE database 3 is being done, including REX efficiencies for more than 50 isotopes corresponding to more than 15 elements. Based on this data the yields of post-accelerated beams was extrapolated for the upgrade of the ISOLDE facility, the so-called High Intensity Energy ISOLDE project.
A method will be demonstrated to predict yields for post accelerated isotopes at HIE-ISOLDE starting from the existing low energy ISOLDE yield database. The REX post acceleration system has the potential to transport and accelerate most of the 700+ radioisotopes from 65 elements of ISOLDE's repertoire thanks to the generic approach used for charge breeding and acceleration.
[1]: J. Cederkall et al., nucl. Phys. A746 (2004) 17c-21c
[2]: D. Voulot et. al. Nucl. Instrum. and Meth. A, proceeding of the EMIS 2007 conference, to be published

HIE-ISOLDE / 11

Transfer reactions with HIE-ISOLDE

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The evolution of the shell structure far from stability shows striking effects, due to changes in the underlying interaction. Spin-orbit and proton-neutron interactions, pairing, the vicinity of the continuum, induce effects that translate in observables such as the migration of single-particle levels, reduced or disappearing shell gaps, deformation. Precise spectroscopic information has been so far mainly provided by decay studies; with the development of intense and pure post-accelerated beams of unstable ions, however, the use of reaction methods has also become possible.

Transfer reactions, thanks to their selectivity, are a particularly valuable tool, as they can give access to the most complete information about the structure of the populated levels. They have been used extensively for the investigation of the structure of stable nuclei; with radioactive nuclei, the experimental conditions set severe requirements on the quality of the ion beams and the detection setup.

HIE ISOLDE will provide an important opportunity to apply transfer reaction methods in regions of the chart of nuclei which are not accessible at other facilities. One-nucleon transfers can be used to study the single-particle states in the vicinity of a closed shell nucleus, or their evolution along a series of isotopes between closed shells. We will present some concrete examples for the N=16, 20, 28 and Z=28 regions, discussing the feasibility of measurements utilizing the present detection arrays and possible upgrades.

Nuclear Physics I / 12

First proof of shape coexistence at the borderline of the 'Island of Inversion': Identification of the second 0+ state in 30Mg and measurement of its electric monopole strength

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The 1789˜keV level in 30Mg was unambiguously identified as the second excited 0+ state by measuring its E0 transition to the ground state via conversion electron spectroscopy. This
level corresponds to the strongly deformed intruder 0+ state, thus proving for the first time shape coexistence in this nucleus at the borderline of the ‘Island of Inversion’ around N ˜20. The matrix element
rhoˆ2(E0,0+_2 -> 0+_1) = 3.6(7) E-3 allows to deduce
the squared mixing amplitude aˆ2 between the unperturbed lowest two 0+ states, indicating a rather weak coupling between the spherical and deformed configurations.
One week of beamtime was dedicated for the conversion electron measurement in 30Mg following the beta decay of 30Na which took place in August 2007 at ISOLDE.

Solid State Physics / 13

Lattice location of implanted ions and characterization of implantation-induced damage in Ge

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Due to its high mobility of charge carriers, Ge is seen as an important material in future semiconductor technology. Despite the fact that this elemental semiconductor is known for a long time, the knowledge about the lattice location of impurities, the induced structural and electrical damage of Ge after ion implantation is relatively scarce.

Here we present a study of the lattice location of several impurities after ion implantation, in correlation to the structural and electrical implantation-induced damage. The lattice location of several elements (i.e. Na, Fe, Cu, In, Ag, Sn and Er) was examined in detail with the emission channeling (EC) technique using radioactive isotopes produced at ISOLDE.

The EC-experiments clearly indicate that for most of the investigated elements, the substitutional (S) Ge-position is not the overall preferred lattice site, even after annealing up to 500℃. With the exception of Er, no elements occupy the tetrahedral (T) lattice site. However, a somewhat striking result is that next to the S-site, other ‘more exotic’lattice sites such as the bond-centered (BC), split

(SP) and anti-bond-centered (AB) site get occupied by some of the implanted ions, before and even after annealing.

The structural quality of implanted Ge samples was also investigated by the Rutherford Backscattering/Channeling (RBS/C) technique as a function of energy, mass and fluence of implanted ions, which helped in explaining the EC results.

Technical Developments / **14**

FEBIAD ion source operation modes to tune its selectivity: physics processes, numerical simulations and experimental data.

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The FEBIAD ("Forced Electron Beam Induced Arc Discharge") ion sources are used for the production of radioactive 1+ ion beams for a wide range of chemical elements. Their small volume and high operating temperature provide good confinement times and ionization efficiencies. Nevertheless, the source lacks in selectivity, ionizing elements regardless of their ionization potential. Presently, the in-source selectivity can be tuned by making use of the different adsorption enthalpy by optimizing the operating temperature, or by creating molecular compounds of the element of interest.
Within the HIGHINT Marie Curie project, theoretical, numerical and experimental investigations are ongoing for the ion source upgrading towards higher operating pressures and, consequently, higher extracted currents.
These investigations let us also tune the selectivity of the source, by operating the source in different modes, which will favor the ionization of a specific class of elements.
When creating a good plasma confinement, the ionization of a gas with a lower ionization potential than the buffer gas should be favored, to the detriment of its residence time.
By using a weak plasma confinement, the ionization selectivity should be increased for elements having different volatilities.
The theoretical model of this approach and the ongoing simulations are presented, as well as some concrete on-line results such as the Chlorine suppression for Argon ionization.

Technical Developments / **15**

ECR charge breeding at ISOLDE

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At ISOLDE, CERN, an online test bench is dedicated to radioactive ion charge breeding with the Daresbury Phoenix booster.
Two succesful experiments have concluded the program of investigation of the performances of the booster undertaken in the frame of the IS397 proposal. The first one consisted in the trapping and charge breeding of 61Fe daughter nuclides from the beta decay of 61Mn. As a metallic element, Fe is a

beam difficult to produce at ISOLDE. The second one consisted in the injection of a "cocktail" beam of isobars providing new information on the processes involved in the capture of the 1+ beam.

Nuclear Physics III / 16

Local Probe Studies on Highly Distorted Rare-Earth Manganites

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The perovskite manganites of the family RMnO3 (R=Eu, Gd, Ho, Y, Er and Lu) show different competing orders, e.g. orbital, magnetic, and dielectric, that lead to intriguing properties as colossal magnetoresistance and multiferroic behaviour.
Looking forward to investigate locally the interplay between structural, electric and magnetic degrees of freedom, samples have been synthesized via sol-gel methods and studied with the Perturbed Angular Correlation (PAC) technique.
In this first work we have limited the use of PAC to measure the Electric Field Gradient (EFG) / Magnetic Hyperfine Field (MHF) in a series of samples with different rare-earths (R), aiming to find a correlation between these local parameters and the ionic radius of the R element.
At ISOLDE small pellets were implanted with 111mCd and subsequently annealed to remove implantation defects. The PAC measurements have been performed from 10K up to 473K for the same samples. These results are compared with the ones previously obtained for other perovskite manganites like LaMnO3, PrMnO3 and CaMnO3. Complementary information is obtained through X-ray diffraction data and SQUID measurements on the same samples. The unit-cell parameters, the bond distances and angles are also factors that can be related to the effects under study, and their revision is also proposed in order to complete the microscopic characterization of these compounds.

Solid State Physics / 17

First results from electron emission channeling on-line experiments

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This talk reports on the results from the first electron emission channeling on-line run of the EC-SLI collaboration, which took place during this year's Mn beam time in June. Using our new on-line setup which is equipped with a position-sensitive Si pad detector with fast readout system and which was mounted on the LA2 beam line, two isotopes were successfully used for beta- emission channeling experiments for the first time: 56Mn (2.58 h) and 61Co. While 56Mn was available directly, 61Co was obtained by means of implanting the short-lived precursor isotope 61Mn and exploiting the decay chain 61Mn (4.6 s)->61Fe (6 min) ->61Co (1.6 h). We were thus able to determine the lattice location of Mn in GaN and of Co in ZnO in the as-implanted state and following annealing up to 900℃. In both cases it was found that the transition metals preferred substitutional cation (i.e. Ga or Zn) sites.
In order to explore the feasibility of using the isotope 27Mg for lattice location experiments, we also did a brief test of the decay chain 27Na (295 ms)->27Mg (4.6 s). However, in this case it was found that the ISOLDE beam consisted mainly of stable 27Al, making emission channeling experiments using this isotope from UC-W surface ionization targets not feasible.

Nuclear Physics I / **18**

Nuclear orientation in transfer reactions

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Measurements of nuclear magnetic moments are of current interest at RIB facilities, because they provide key information about the states of interest, e.g. about their wave functions.
A basic requirement for the measurement of magnetic moments is the existence of an initially spin-aligned nuclear ensemble. We report here that transfer reactions are applicable for such studies. As the orientation of the nuclear spins is induced directly by the reaction, transfer reactions allow the investigation of nuclear moments of very short lived states, in the range of nanosecond to microseconds. With the development of post-accelerated radioactive beams, available in ISOL facilities, highly-excited neutron-rich isomers will become accessible for measurement. These studies will yiels basic informations about the configuration of these states and thus provide a stringent test for nuclear theories.
The possibility of using transfer reactions for nuclear moment measurements of isomeric states in PAD experiment will be discussed. The results of four experiments held in the Tandem facility of the Insitut de Physique Nucleare (IPN Orsay, Paris), involving single-nucleon and multi-nucleon reactions will be illustrated, along with advantages and disadvantage of each reation method. The experiments aimed at studies of the g-factors of the 65mNi 9/2- and 66mCu 6- isomeric states, which were populated in single nucleon transfer reaction (d,p). In the 43mSc case, the 19/2- isomer was populated in the exchange of two neutrons and a proton from the target to the projectile nuclei. The 6- isomeric state in 64mCu was studied with a single-nucleon transfer in inverse kinematics. In all the cases the amplitude of the R(t) function, a measure of the nuclear spin orientation in TDPAD experiment, will be provided. For the case of multinucleon transfer, as different beam energies were used, the orientation is investigated as function of projectile's energy. The results from the fourth experiment have demonstrated the level of difficulties one can encounter using inverse kinematic reactions.

Trapping for Nuclear Physics / **19**

WITCH: first measurement and recent developments

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We present in detail the status of the WITCH experiment (Weak Interaction Trap for Charged particles). The primary aim is to investigate exotic weak currents in nuclear beta decay by measuring a recoil ion spectrum and deriving the beta neutrino angular correlation coefficient from its shape. At the end of the year 2006, we succeeded for the first time in measuring a recoil ion spectrum using 124In. The data have, in the meantime, been thoroughly analysed and the charge state distribution of the recoiling ions has been derived from it. In 2007 a lot effort has been made to improve the precision of the experiment; one of the topics in this respect was the improvement of the Penning traps. A direct result of this is a significant increase in the mass resolution, which is useful to remove isobaric contamination; currently a mass resolution of 200,000-300,000 can be routinely achieved in test conditions.

News from Other Laboratories / **20**

Rare isotope beams at MSU - present and future

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Status and future plans for research with rare isotope beams at the coupled cyclotron facility (CCF) at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) will be presented with emphasis on the re-acceleration of thermalized beams from projectile fragmentation.

Trapping for Nuclear Physics / **21**

20 Years of ISOLTRAP

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Twenty years ago, the first publication on a Penning trap mass measurement of a radionuclide appeared in Hyperfine Interactions 38 (1987) 793 with the title "FIRST ABSOLUTE MASS MEASUREMENTS OF SHORT-LIVED ISOTOPES". The authors were Georg Bollen, Phillip Dabkiewicz, Peter Egelhof, Thomas Hilberath, Hartmut Kalinowsky, Franz Kern, Harald Schnatz, Lutz Schweikhard and Helmut Stolzenberg from the Institut für Physik, Universitiät Mainz, Robert B. Moore from the Foster Radiation Laboratory, McGill University, Montreal, H.-Jürgen Kluge from CERN, Geneva, Switzerland and the Institut für Physik, Universitiät Mainz and George M. TEMMER, and Gerhard ULM from CERN, Geneva, Switzerland and, last but not least, The ISOLDE Collaboration, CERN. Since then, the masses of several hundred radionuclides have been determined at ISOLDE with ever increasing accuracy, sensitivity and applicability. The talk presents an overview on these developments and on the results obtained by use of ISOLTRAP.

Solid State Physics / **22**

Mössbauer studies of dilute magnetic semiconductors (IS-443)

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Mössbauer studies of dilute magnetic semiconductors (IS-443)

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The study of materials showing multifunctional properties at room temperature (RT) is a challenging task for material science and of importance for future applications in spin-based electronics. The prediction of a Curie temperature above RT in Mn-doped ZnO [1] started a new field of research, with the aim to investigate magnetism in normally non-magnetic oxides. Despite the enormous experimental and theoretical efforts, the origin of the magnetism in (3d-elements) doped and pure ZnO is still a matter of debate in the scientific community. Calculations showing a vacancy-driven mechanism for the magnetism in ZnO have been proposed [2, 3], but clear experimental evidences for such mechanisms are still lacking.
In the framework of the experiment IS-443 at ISOLDE-CERN, we apply Mössbauer spectroscopy to investigate the magnetic properties in ZnO upon implantation with radioactive 57Mn+ (T½ = 1.5 min), decaying to the 57mFe Mössbauer state (T½ = 100 ns). We study the electronic and magnetic configurations of Fe atoms in the ZnO crystals, and the interaction between the Mn/Fe atoms with the defects induced during the implantation process [4]. Our results show that the majority of the Fe atoms are located on Zn sites in a high-spin Fe3+ state at ⊠ 600 K, giving a strong magnetic contribution in ZnO. The formation/annealing of the magnetism in ZnO is interpreted as occurring/disappearing upon the association/dissociation of Mn/Fe complexes with the lattice defects created in the implantation process [4]. We present an overview of our experimental findings focusing on the essential role played by the lattice defects in observing magnetism in ZnO.

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HIE-ISOLDE / 23

Results with ISCOOL a new Radio Frequency Quadrupole Cooler and Buncher at ISOLDE

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We will present the installation of the ISCOOL in the HRS beam line section and give the results from the tests performed during the on-line commissioning in November 2007.

News from Other Laboratories / 24

News from the RIKEN RI beam factory

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The RIKEN Radioactive Ion Beam Factory, a major upgrade of the existing heavy-ion accelerator facility at RIKEN, has recently been commissioned. Three new ring cyclotrons boost the beam energies to 440 and 350 MeV/u for light and heavy ions, respectively with an intensity goal for Uranium beams of 1p micro A.

From these primary beams intense secondary radioactive ion beams will be produced by the large acceptance, two-stage in-flight RI fragment separator BigRIPS.

A wide array of experiment equipment is existing, under construction or planned. The facility, major experimental equipment and first results of their operation will be presented.

25

Bremsstrahlung accompanied α-decay 210Po

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A high-statistics measurement of bremsstrahlung emitted in the alpha-decay of 210Po has been performed. The measured differential emission probabilities are in good agreement with our theoretical results obtained within the quasiclassical approximation as well as with an exact quantum mechanical treatment. Due to the small effective electric dipole charge of the radiating system, a significant interference between the electric dipole and quadrupole

contributions occurs, altering substantially the angular correlation between the alpha particle and the emitted photon.

Trapping for Nuclear Physics / 26

Nuclear mass measurements for nucleosynthesis studies at ISOLTRAP

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In 2007 the mass measurements at the tandem Penning trap mass spectrometer ISOLTRAP focussed on nuclear structure and nucleosynthesis studies. The masses of about 20 nuclides have been measured with relative mass uncertainties as low as 1*10-8. The beam times were dedicated to the mass determination of neutron deficient and neutron rich nuclides relevant for the investigation of the rp- and r-process, respectively. For neutron-deficient Cd isotopes, close to the doubly magic 100Sn and the end-point region of the rp-process, the first direct mass measurement of 99Cd was performed, giving accurate data at the neutron shell closure N=50. Furthermore, measurements aimed at the masses of neutron-rich Ag and Cd nuclides which will give input values for astrophysics calculations for the r-process, especially at the waiting point 130Cd.

Nuclear Physics III / 27

Status report on g-factor measurements on Coulomb excited 138Xe nuclei using the Transient-Field technique (IS415)

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Two experimental campaigns have been carried out at REX-ISOLDE and MINIBALL in order to determine the magnetic moment of the first excited state in 138Xe with the technique of transient magnetic fields. 138Xe ion beams of 2.9 MeV/u and different multilayered targets were used for Coulomb excitation. De-excitation gamma rays were measured in four MINIBALL cluster detectors in coincidence with forward scattered target ions. We will report on our achievements and present first results. Technical improvements as well as experimental limits will be discussed followed by a vision of future g-factor projects on REX-ISOLDE.

Nuclear Physics I / 28

REX-ISOLDE - now also heavyweight champion

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A summary of the advances at the REX-ISOLDE facility during 2007 will be given. In total 3 new elements and 8 new isotopes were delivered for physics, coming either as atomic ions or molecular ions from ISOLDE. The REX-ISOLDE post accelerator has this year also seriously entered the arena of heavy ion beams by accelerating light Hg isotopes to full linac energy. The potential and constraints in terms of the machine for this 'heavyweight' region will be discussed. One of the experimental runs could be carried out in spite of a malfunctioning trap by operating the EBIS in continuous injection mode. This opens up future possibilities with the RFQ cooler now installed and operational. A number of technical developments were carried out at REX, for example: the extenstion of the beam transport line and move of the experimental stations were completed; new control systems were implemented and the linac RF amplifiers were consolidated. In addition, we will discuss foreseen accelerator improvements and beam developments.

Nuclear Physics II / 29

Beta-asymmetry measurements as a probe for non standard model physics

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The status of the beta-asymmetry measurements project will be presented. In these experiments we measure the beta-asymmetry parameter which is sensitive to deviations from the V –A character of the weak interaction, more precisely to tensor currents. The experimental technique we use to create a polarized ensemble of nuclei is low temperature nuclear orientation (LTNO).
The first (preliminary) results for the beta-asymmetry parameter will be presented for 60Co and 114In. These measurements were performed in Leuven and Louvain-la-Neuve preceding the on-line measurements with 67Cu at ISOLDE in the summer of 2006 and 2007. The first run 67Cu was successful but had a lack of statistics due to the low yield. This year the statistics was increased with a factor of 4 to 5. The data analysis is ongoing. 67Cu has a high sensitivity to possible tensor contributions in the weak interaction. We aim to improve the limits for tensor couplings which are currently of the order of 8 % in the amplitudes.
To reach the required precision we are using extensively GEANT4 Monte-Carlo simulations to get control of systematic effects such as scattering and magnetic field effects. A part of our research is therefore focussing on the performance of GEANT4 for beta decay measurements.

HIE-ISOLDE / 30

First laser measurements on radioactive beams using ISCOOL

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Collinear laser spectroscopy provides an excellent diagnostic tool for characterizing the ion beam extracted from the ISOLDE RFQ cooler-buncher.
Potassium and rubidium beams prepared in ISCOOL were delivered to the COLLAPS beam line and focussed to give 50% transmission through a 1mm iris. The iris was used to overlap a co-propagating Ti:Sa laser. The laser was tuned to resonance on a D-line component (766 nm for K, 780nm for Rb). The time-structure of the ion beam was determined from the fluorescent photon arrival times. This naturally eliminated any contribution from molecular ions formed in the RFQ, which cannot be easily discriminated if ion-detection were used.

The effects of using different extraction potential gradients on the ion beam bunch width were studied. The energy spread was characterized by taking fluorescence spectra obtained using the COLLAPS laser setup. This was measured for each of the extraction potential gradients. An upper limit of the ion energy spread was determined.

To complete these tests, the cooler was tuned to provide bunches of 20 micro-seconds with low energy spread for a demonstration of the bunched-beam laser spectroscopy application on neutron-rich radioisotopes of potassium.

Nuclear Physics II / 31

Studies of the 12C nucleus using beta-decay of 12N and 12B

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Experimental studies of the 12C nucleus are important to both nuclear theory and astrophysics. Improved knowledge of states in 12C is necessary for our understanding of the triple alpha reaction in stars. Especially the Hoyle state at just 0.38 MeV above the triple alpha threshold is vital for this process, but also a predicted 2+ state at 1.7 MeV above the triple alpha threshold in 12C has been included in the NACRE reaction rate calculations, and its existence needs to be verified experimentally.

The structure of the 12C nucleus is not fully understood. Some properties are well described by cluster models and others by mean field theory. New ab-initio calculations have been published and the results are promising giving good agreement with experimental data in the literature.

In a new experiment at KVI in Groningen, the Netherlands, 12C was populated in beta-decay of 12B and 12N. Beams of 12B and 12N ions were implanted in a 48 times 48 strip detector (DSSSD) and let decay. Because of the segmentation of the DSSSD into very small pixels the background of beta particles is significantly reduced and essentially confined to low energies. The implanted ions and emitted alpha particles are stopped in one pixel of the detector so very precise absolute branching ratios and decay spectra can be obtained. Measurements at very low energies are possible because detector deadlayer effects are avoided in the implantation method, so new information about the Hoyle state can be achieved. Results of the analysis will be presented including new energy spectra, branching ratios and comparisons to earlier work and theory.

Trapping for Nuclear Physics / **32**

JYFLTRAP at IGISOL - Atomic masses from nuclear structure physics to fundamental physics

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JYFLTRAP and IGISOL-facility has been in high-precision operation now for few years producing vast amount of atomic mass data for nuclear structure studies and fundamental physics. All in all more than 200 atomic masses of ground and isomeric states has been measured from sub-keV to few keV precision. In this contribution the recent highlights from the facility will be reviewed and few examples will be described in more detail.

In neutron-rich side of the nuclide chart proton-induced fission of 238U has been applied to produce isotopes from Ni to Pd for mass spectroscopy in JYFL. In this contribution, new data on the evolution of the N=50 shell gap will be discussed.

On neutron-deficient side, a large fraction of our mass measurement program has concentrated on the refractory isotopes below 100Sn. These measurements contribute to nuclear structure and nuclear astrophysics questions in this region. In this contribution, recent measurements around 94Ag will be discussed in detail to shed light on the puzzle of highly disputed two-proton decaying high-spin (21+) isomer in 94Ag.

Finally, precision Q-value measurements for super allowed beta decay and double beta decay will be discussed in context of CVC-hypothesis, unitarity of CKM-matrix and neutrino physics.

Nuclear Physics III / **33**

Coulomb excitation of neutron-rich 44Ar at SPIRAL

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The weakening of the N=28 shell closure for neutron-rich nuclei and the development of deformation and shape coexistence in this mass region were addressed in a low-energy Coulomb excitation experiment using a radioactive 44Ar beam from SPIRAL facility of GANIL. The Ar44 ions were post-accelerated to 2.7 and 3.7 MeV/nucleon and Coulomb excited on 109Ag and 208Pb targets, respectively. The scattered projectiles and recoiling target nuclei were detected in a highly segmented double-sided silicon detector and the gamma rays were detected with the EXOGAM germanium detector array. In addition to the first excited 2+ state, one higher-lying level was populated and two gamma lines from its deexcitation were observed. With the 109Ag target both projectile and target nuclei were excited, which has been used to normalize the excitation probability in 44Ar with the well known transition strengths in 109Ag. The level of statistics was sufficient to subdivide the data into several sub-sets corresponding to different ranges of scattering angles. Since the influence of the quadrupole moment of the first 2+ state on its excitation probability varies significantly with scattering angle, it was possible to obtain from one experiment information on both the transitional and diagonal matrix elements involved in the excitation process.

Trapping for Nuclear Physics / 34

TRIGA-TRAP: Mass measurements on exotic and heavy nuclides

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The TRIGA Mainz research reactor offers unique possibilities for online mass measurements on neutron-rich isotopes as produced by fission of U-235, Pu-239 or Cf-249 targets. A new Penning trap mass spectrometer will be installed, featuring not only the commonly used time-of-flight resonance technique, but also the non-destructive narrow-band image current technique, enabling the detection of a single singly-charged ion stored in the trap. TRIGA-TRAP is the first online mass spectrometer for singly-charged heavy ions using this image current detection technique in combination with cryogenic Penning traps. In case of many heavy and superheavy nuclides, the production rates are often less than a few ions per second, but some isotopes exhibit comparably long half-lifes in the order of seconds, which allows for repeated measurement cycles of the same trap content.
The status of TRIGA-TRAP will be presented.

Nuclear Physics I / 35

Shell structure and shape changes in neutron rich krypton isotopes

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The krypton isotopes are located roughly in the middle of the Z=28 and Z=50 shell closures, where competition of various structures and shapes at low-excitation energy occurs. For example, this can be seen in the case of Z=40 Zirconium Isotopes. In 96Zr (N=56) a strong shell closure was found, interpreted to be reinforced by the Z=40 shell gap. Such a shell gap should quickly disappear moving away from Z=40. Indeed, no influence of this gap was found for isotopes Z>40. Adding more neutrons to the Zirconium Isotopes leads to a unique increase of B(E2) values from 8 W.u. to about 100 W.u. by adding only a few neutrons. This abrupt phase transition from sperical to deformed nuclei may demonstrate the complexity of this region of the nuclear chart.
In the case of Krypton isotopes (Z=36) the energy of the first excited state peaks at 92Kr (N=56) like in the case of Zirconium isotopes. In the past it was extensivly discussed whether the N=56 shell gap is active or deformation starts to set in. Up to now, only information about energies and masses were available for the neutron rich krypton isotopes to discuss this topic. We were able to meassure B(E2) values for 88Kr (N=52) and 92Kr (N=56) for the first time by Coulomb excitation in inverse kinematics at REX-ISOLDE using the MINIBALL array. The analysis was done using the newly developed Coulex Code Gosia2, that can handle target and projectile excitations simultaneously. We present our results and discuss the consequences for the understanding of the structure of neutron-rich krypton isotopes.

Solid State Physics / 36

Magnetoresistive materials: hyperfine studies using radioactive isotopes.

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This year the Physics Nobel Prize was awarded to Albert Fert and Peter Grunberg for the discovery of the magnetic effect of giant magnetoresistance, the basis of today's magnetic recording in computer hard disks. This discovery is an example of using magnetism to control the electrical current flow through materials built at the nanometer scale. More recently, colossal magnetoresistance was discovered in magnetic oxides such as mixed valence manganites, leading to even larger changes of resistance (up to several orders of magnitude). In this talk the properties associated to spin dependent electron transport are addressed. The relation to local structure, spin- polarized electron band and charge localization phenomena is discussed. The talk will point out the application of hyperfine studies, performed using radioactive isotopes, mainly at ISOLDE, that contribute to explore this exciting research field.

News from Other Laboratories / 37

Hyperdeformation in Xe Nuclei.

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Nuclear structure physics is testing nuclei to the limits of their existence by imposing extreme values of Isospin, Exitation energy and Angular momentum on them. In hyperdeformed nuclei the deformation parameter is the central issue. Theoretical predictions are that nuclei at extreme angular momentum might acquire shapes with small axis ratio 3:1 and that rotational bands might exist in the corresponding potential well. Signals from hyperdeformed structures have been in the experimental focus for more than a decade and whether the existence of hyperdeformation at high spin has been firmly identified, is still debated. A recent experiment at ANL using the GAMMASPHERE array provides preliminary results on hyperdeformation in 124Xe, and forms the basis for the present report. So far, discrete line rotational bands corresponding to hyperdeformation have not been identified, but weak signals from the analysis of unresolved spectra indicate cascades with a moment of inertia 128h2 MeV-1 which is expected for hyperdeformed rotors.

Opening Session / 38

Between Bose-Einstein condensate and fermionic superfluid.

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In the last couple of years we have witnessed a tremendous progress in the field of cold fermionic atoms. Ultra cold atomic gases provide a remarkable opportunity to investigate strongly correlated Fermisystems. They are dilute and their interactions can be precisely controlled over an enormous range. In particular, they form unique laboratories where the crossover between the Bose-Einstein condensate and the BCS superfluid can be explored. In this limit, which is relevant for the dilute neutron matter, the scattering length greatly exceeds the average inter-particle separations. Consequently, the system is believed to be strongly paired and the size of Cooper pairs is comparable to the Fermi wavelength.

On the theoretical side, our overall understanding of these remarkable many body systems has improved tremendously, even though many questions remain yet unanswered. During the talk I shall discuss the properties of dilute and strongly interacting Fermi system, emphasizing the link with the nuclear matter properties and the neutron star structure. I will discuss the equation of state for fermions in the so-called unitary regime, where the scattering length tends to infinity. The comparison with recent experiments concerning trapped atomic gases will be presented.

Opening Session / 39

Double-beta decay and neutrino physics

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In the last decade many spectacular advances have been performed in neutrino physics. Still, crucial questions remain open, in particular the knowledge of the Dirac versus Majorana
nature of neutrinos. The most feasible way of knowing the answer to this issue is through the observation of a nuclear process called neutrinoless double-beta decay.
Its search presents serious experimental and theoretical challenges, in particular, the precise knowledge of the nuclear matrix elements determining the half-lives.

In this talk, we will review the status in this field and emphasize the difficulties as well as the crucial role played by nuclear physics.
We will discuss that beta-decay, muon capture and charge-exchange studies offer important constraints to the neutrinoless half-life predictions.
We will conclude discussing the interest of neutrino-nucleus interaction studies.

Nuclear Physics I / 40

Coulomb excitation of 31Mg - at the shore of the island of inversion

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The first safe Coulomb excitation measurements of 30Mg and 32Mg at safe energies with REX-ISOLDE and MINIBALL clearly confirms the transition in the neutron-rich magnesium isotopes from normal to intruder-dominated configurations between these two Mg isotopes by measuring the B(E2;
0gs+-21+) values of the even-even nuclei. A recent Coulomb excitation
experiment with a post-accelerated odd 31Mg beam from REX-ISOLDE showed the transition from the 945 keV state into the first excited state at 50.5 keV. The ongoing analysis will concentrate on the quadrupole properties of the 945 keV state, the intriguing interpretation as a 5/2 state of the positive yrast band of 31Mg on top of the 1/2+ ground state and comparison with recent shell model calculations [1].
[1] F. Marechal, et al., Phys. Rev. C 72, 044314 (2005)

Nuclear Physics III / 41

Inelastic Branch of the Stellar Reaction 14O(alpha,p)17F

Author: Philip Woods[1]

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The miniball and CD array have been used on Rex Isolde to measure particle gamma-coincidences between inelastically scattered protons and gamma-rays from the first excited state of 17F. This method can be used to infer the significance of the inelastic branch in the 14O(alpha p)17F reaction which is a key reaction in X-ray bursters scenarios. Current analysis of the results from this recent experiment will be reported.

HIE-ISOLDE / 42

Future physics at HIE-ISOLDE: a personal view

Author: Philip Woods[1]

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The Rex Isolde, and Miniball and CD arrays, already constitute a world class facility for nuclear structure physics with radioactive beams, with nuclear astrophysics studies also starting up. The future HIE-ISOLDE project promises to open up significantly the possiblities for new physics with the uniquely wide range of beam species available on Rex Isolde. The talk will explore these possibilities and the implications for plans for new equipment developments.

Opening Session / 43

Gamma-ray nucleosynthesis: results from the INTEGRAL satellite

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The International Gamma Ray Astrophysics Laboratory has been launched in 2002 to observed the Universe at energies between a few keV to a few MeV. Among the objectives was the study of gamma-ray lines, probing, among others, specific nucleosynthesis processes that occur in stars. I present a review of the observations performed by INTEGRAL in this respect, and discuss them in relation with the astrophysical sites at the origin of those gamma-ray nuclei.

Trapping for Nuclear Physics / 44

Masses of halo nuclides and decay-spectroscopy in the lead region: new developments at ISOLTRAP

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The ISOLTRAP experiment has up to now provided precise values of masses of more than 300 radionuclides with relative uncertainty below 10-7 and many cases reaching 10-8. Presently, there are two main projects under way at ISOLTRAP, which aim at widening the number of nuclides to study and the type of the performed measurements. The first is devoted to studying masses of halo nuclei, which provide important input e.g. for deriving their charge radii. Since the present cooling scheme using helium is not effective for such light nuclides, hydrogen cooling has to be used instead, and necessary simulations and tests are presently under way. The other development will allow using ISOLTRAP for isobaric and even isomeric purification to performing beta- and gamma-decay studies. Presently, the setup is being prepared for the measurements on neutron-rich Hg and Tl isotopes beyond N=126. In this talk I will present the physics motivation of these two developments, their status and future plans.

Opening Session / 45

The first 40 years of physics at ISOLDE

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In this talk I will give some selected comments to the present and future physics at ISOLDE, REX ISOLDE and HIE-ISOLDE. I will also give examples of some of the pioneering experiments at ISOLDE that have lead to the success of this field of nuclear physics. As a basis for my talk I give below some dates and developments that have been important on the way towards the present Facility. 1951:The first experiment of ISOL type was carried out by Otto Kofoed-Hansen and Karl-Ove Nielsen in Copenhagen, Denmark. 1961:The Nuclear Chemistry Group built an electromagnetic isotope separator and showed that the capacity for production of radioactive nuclides in an internal beam of the SC was very high. 1964:December 17. CERN decides to build an ISOL(DE) experiment at the SC. 1967:September 23. The first experiment was performed at ISOLDE. The results were published in a paper with 29 authors [1]. 1973:Shutdown and reconstruction of ISOLDE. The external beam from the SC was increased to 4 uA. 1974:First experiments at ISOLDE 2. 1987:Installation of a high-resolution separator in the SC proton hall. 1989:Start of the civil engineering work for the ISOLDE site close to the PS Booster. 1990:December 17, 12.00. The SC was shut down. 1992:June 26. The first experiment was performed at the ISOLDE PSB Facility. 2001:October 30. The first beams were delivered from REX ISOLDE. [1] Decay Characteristics of Short-Lived Radio-Nuclides Studied by On-Line Isotope Separator Techniques.
P.G.Hansen, P.Hornshoj, H.L.Nielsen, K.Wilsky, H.Kugler, G.Astner, E.Hagebo, J.Hudis, A.Kjelberg, F.Munnich, P.Patzelt, M.Alpsten, G.Andersson, A.Appelqvist, B.Bengtsson, R.A.Naumann, O.B.Nielsen, E.Beck, R.Foucher, J.P.Husson, J.Jastrzebski, A.Johnson, J.Alstad, T.Jahnsen, A.C.Pappas, T.Tunaal, R.Henck, P.Siffert, G.Rudstam, Phys.Lett. 28B, 415 (1969).

News from Other Laboratories / 46

The ISAC facility at TRIUMF and Halo-nuclei mass measurements at TITAN

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The ISAC facility at TRIUMF is providing over 200 different radioactive beams to users at energies
up to 5 MeV/u. Plans exist to extend the facility by an additional 200muA proton beam line and
a photo-fission facility based on a mega-watt class superconducting electron linac.
One of the experimental facilities at ISAC is TITAN, a high precision Penning trap mass spectrometer.
First experiments with radioactive beams were carried out this year with the aim to determine the masses of
halo nuclei. In a first run, the mass of Li-8 and Li-9 were investigated with a precision of about 2*10-8.
The goal of an upcoming experiment (Dec 2007) is the mass measurement of Li-11.
The talk will give an overview of ISAC and present the future plans. It will introduce the TITAN facility
and show first experimental results.

Nuclear Physics II / 47

MAYA active target for the study of extremely exotic nuclei

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This talk will discuss some recent experiments using the MAYA active target at GANIL and TRIUMF.

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Shell structure evolution in nuclei : future collaboration between GANIL and

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I will try in my talk to single out some ideas of collaboration between GANIL and REX-ISOLDE for the study of shell structure evolution in nuclei. Among other possibilities, this could be based on the exchange and/or merge of detections systems available in both facilities which should increase the experimental capabilities and allow the study of weekly produced keys nuclei.

HIE-ISOLDE / 49

The HIE-ISOLDE project

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This talk will present the plans for the HIE-ISOLDE project.

Solid State Physics / 50

Soft-landing of Radioactive Probes on Clean Metal Surfaces and at Interfaces

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Soft-landing techniques of radioactive probe atoms have been developed in the ASPIC facility which is installed at ISOLDE. The probe atoms were deposited at interfaces and on surfaces of metals and ferromagnets where they can be manipulated to occupy specific sites. Utilizing sensitive nuclear techniques for analysis, magnetic hyperfine fields and electric field gradients have been determined. In the light of density-functional methods, these parameters can be linked to parameters which are commonly used in complementary techniques in solid state physics.

A review shall be given over the achievements of the measurements and targets for further investigations shall be identified.

Technical Developments / **51**

Target and Ion Source Development

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The activities related to the development of new radioactive ion beams at ISOLDE will be reviewed, with an emphasis on high power targetry. Some items wil be more precisely presented. New submicrometric and nanomaterials are under development at ISOLDE and within the EURISOL Design Study. Their use will be illustrated with the delivered 21Mg and 17F beams produced with pure submicrometric SiC targets. Post-irradiation analysis of the target material has started. Preserving good extraction efficiencies when dealing with high incoming primary driver beams is a challenging task. A prototype testing the characteristics of a multibody target unit linked to a single FEBIAD ion source has been operated for the first time this year at ISOLDE. This test opens up the possibility of accommodating 100kW incoming primary beam driver while preserving compact target characteristics and good ionization efficiencies.

Nuclear Physics III / **52**

Pb(II) and Hg(II) binding to proteins and model systems studied by 204mPb- and 199mHg-Perturbed Angular Correlation of γ-rays (PAC) spectroscopy

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We aim to elucidate the fundamental chemistry of heavy metal - protein interactions. This involves both studies of model systems, designed proteins and naturally occurring proteins, as well as the interpretation of the spectroscopic data using quantum mechanical calculations. We will present data on model systems (coordination compounds) and proteins recorded recently at ISOLDE.

Opening Session / **54**

Welcome

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