ISOLDE Workshop and Users meeting 2005/2006

Monday, February 6, 2006 - Wednesday, February 8, 2006

CERN

Book of Abstracts

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Welcome

Author: Jean-Jacques Blaising[None]

Nuclear Physics IV / 1

Astrophysics using Radioaluminum beams at REX-ISOLDE

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This project involves two main components, namely the development of a ISOLDE production target (or targets) for the release of short-lived proton and/or neutron-rich aluminum isotopes, and to subsequently to use such beams, e.g. 25,26mAl to initiate a program in nuclear astrophysics using REX-ISOLDE involving particle transfer reactions and elastic/inelastic scattering reactions. Of particular interest are studies related to radiative proton capture reactions on 25,26mAl. These are considered of importance for the production/destruction of the gamma observable (using satellite detection systems) radioisotope, 26Al. Production of neutron-rich beams can be used for appropriate decay studies of key isotopes.

Summary:

An important question in nuclear astrophysics is what is the production site of the gamma observable isotope, 26Al, in the universe. Proposed sites include core collapse supernovae, ONe novae, Wolf-Rayet stars and Asymptotic Giant Branch stars. A large uncertainty in determining the production rate are due in part to the uncertainties in key nuclear reactions, namely 26g,mAl(p,g)27Si and 25Al(p,g)26Si. These are part of the production and destruction sequence for 26Al in such environments. Recently the 26gAl((p,g)27Si reaction was measured directly in inverse kinematics with an intense 26gAl beam (~5x109/s) and using the DRAGON facility at ISAC. However, the Al production target released aluminum relatively slowly which reduced significantly the intensity of the much shorter 25,26mAl isotopes. Given a relatively intense beam (>10e7 /s) of either isotope at ISOLDE, elastic scattering and particle transfer reactions could be performed which could be of importance to determining key parameters of these radiative capture reactions. This project involves two proposals, namely, the first to perform target R&D studies to obtain an appropriate, fast releasing aluminum production target, and the second, to initiate the development and use of appropriate detection systems to perform appropriate elastic scattering and perhaps transfer reaction studies at REX-ISOLDE with beams of 25,26mAl (as available). This nuclear astrophysics project is of interest to a new collaboration of scientists. Such developments can also lead to the development of a neutron rich production target which could be used to study decays of key neutron-rich isotopes of aluminum.

Nuclear Physics II / 2

Transient field g-factor measurements on radioactive nuclei following alpha transfer to energetic projectiles in inverse kinematics

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In recent measurements of g factors and lifetimes of short-lived nuclear states several radioactive nuclei have been investigated which were produced in alpha-transfer reactions to stable projectiles at the Coulomb barrier employing the techniques of transient magnetic fields and Doppler-Shift-Attenuation, respectively. In particular, this method has been applied to 44Ti [1], 52Ti [2], 62Zn [3] and 68Ge [4] providing new insights into their nuclear structure which has been discussed in the framework of large-scale shell model calculations.
This novel technique can be extended to many more neutron-deficient as well as neutron-rich nuclei of the nuclear chart using respective stable nuclei at the border lines of the valley of stability as projectiles. In this respect, this possibility manifests an interesting alternative to Coulomb excitation experiments on radioactive ion beams.
[1] S. Schielke et al., Phys. Lett. B 567 (2003)15
[2] K.-H. Speidel et al., Phys. Lett. B, in press
[3] O. Kenn et al., Phys. Rev. C 65 (2002) 034308
[4] J. Leske et al., Phys. Rev. C 71 (2005) 044316

Nuclear Physics III / **3**

Results from Transfer Reactions at REX-ISOLDE and future plans

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Transfer reactions yield important spectroscopic information about isotopes, including spin and parity assignments to nuclear levels and spectroscopic factors. The corresponding information is still lacking for many nuclei far from stability.

The results from transfer experiments with neutron rich Na and Mg isotopes in inverse kinematic with the MINIBALL setup at REX-ISOLDE will be presented, including a new level in ^{31}Mg. These results and the encountered difficulties with the existing setup will be discussed and plans for a new setup for transfer experiments with MINIBALL will be shown.

Nuclear Physics II / **4**

Coulomb Excitation of Neutron-rich Xe-Isotopes at REX-ISOLDE

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Recent studies on isotopes around the shell closure N=82 have shown that despite decreasing excitation energies the B(E2) values of Sn and Te isotopes above N=82 are lower than expected. The aim of our experiment was to measure B(E2) values in neutron-rich even-even isotopes around the double magic 132Sn. In a first campaign in 2004 we measured the gamma transitions of 122-126Cd. In 2005 we used the HPGe gamma detector array MINIBALL for measuring the deexcitation gammas following Coulex of 138-142Xe.
This will shed some light on the ambiguous measurements of the B(E2) value of 138Xe and gives us the possibility to evaluate the B(E2) values of 140,142Xe for the first time.
In this talk we will present first results of the analysis and discuss future experiments.

Technical Developments I / 5

The ISCOOL (ISOLDE COOLer) project

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A new Radio Frequency Quadrupole ion Cooler and Buncher (RFQCB) has been designed and manufactured at ISOLDE for the installation after the High Resolution Separator (HRS) as a quasi-permanent beam line element, to deliver cooled and bunched Radioactive Ion Beams (RIBs) with an enhanced optical beam quality beam to most of the ISOLDE experiments. In this contribution the key parts and the status of the ISCOOL project are described. In addition, expected ion optical improvements and their effect on various ISOLDE experiments are reviewed.

Nuclear Physics I / 6

Resonance laser spectroscopic studies of neutron deficient rare earth isotopes at the IRIS facility

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The laser ion source has been used for the study of the isotope shifts of neutron deficient Eu and Gd isotopes at the IRIS facility. The region of the applicability of the method by using the gamma- and beta- radiation detection has been extended. The isotope shifts of the europium optical line 576.520 nm for 137–139, 141, 142m, 143, 144 Eu and the gadolinium optical line 569.622 nm for 145, 145m, 143m Gd have been measured. To increase the laser ion source efficiency an axial magnetic field (350 Gauss) was applied. For Gd atoms investigation resonance ionization directly inside the target has been applied for the first time.
Changes in mean square charge radii for 145, 145m, 143 Gd and 137 Eu and magnetic moments for 145, 145m Gd have been determined for the first time. The new data for 137 Eu and refined data for 138 Eu point to a gradual increase of the deformation for these isotopes rather than the jump-like behaviour predicted by the microscopic-macroscopic calculations. The influence of the proton sub-shell closure Z=64 on the deformation behaviour at N<82 has not been observed in contrast with the region at N>82.

Nuclear Physics II / **7**

Coulomb excitation of 68,70Cu with radioactive beams

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Levels of (6,3,4,5)- multiplet in 68,70Cu were populated by Coulomb excitation using 6- radioactive beams delivered by REX-ISOLDE. B(E2)/B(M1) reduced transition probabilties can be extracted and information about the single particle structure of the multiplet can be obtained.

Trapping for Nuclear Physics / **8**

Proposal for a Nuclear Charge Radius Measurement of the Halo Isotope 11Be

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A measurement of the optical isotope shift in beryllium isotopes will allow a model-independent determination of the nuclear charge radius of Be-7,9,10 and the halo nucleus Be-11. This is based on an accurate calculation of the mass-dependent part of the isotope shift in the respective transition, combined with a precise measurement of the total isotope shift. Both values must be determined with an accuracy of better than 1E-5. Similar measurements have been performed recently on He-6 in a Magneto-Optical Trap [Wang et al. PRL 93, 142501 (2004)] and on Li-8,9,11 with Resonance Ionization Spectroscopy [Ewald et al., PRL 93, 113002 (2004)]. Corresponding atomic structure calculations with the required precision have so-far been demonstrated only for systems with up to three electrons. Thus, we propose to measure the isotope shift in the 2s-2p transition of laser-cooled Be-ions stored in a Paul trap.

Nuclear Physics I / **9**

Multiple particle break-up in the 11Li beta-decay

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Light nuclei near the neutron drip-line have been studied intensively since the discovery
of halos in this region. The complexity of their decays represent a great task for both theoretical and experimental nuclear physics. The 11Li, the nucleus studied in this work, exhibit a complex beta decay. The high Q-beta value (20.6 MeV) and the low nucleon binding energy
in the neighbour nuclei allows multiple decay channels, several of them involving the delayed emission
of charged particles.

We report here on the study of the decay channels involving charged particles in the final
states (IS-417). The aim of the experiment is to disentangle the multiple particle break-up channles taking advantage of the new
segmented silicon detectors, since the simultaneous detection of the particles energies and hit positions is crucial to determine
the correct decay scheme. The experimental set-up was designed to fulfill this condition, consisting in four DSSSD detectors in a compact
cubic geometry. The highly segmented nature of the DSSSD allows to reconstruct the particles momenta from their impinging
position.

The decay channels that involve two charged particles in the final state have been analysed. Special attention was given to the
11Li−>11Be−>*10Be*+n−>6He+alpha+n channel. The coincidence spectrum and reconstructed excitation energy of this channel will be shown.
The decay through the previously known resonance at 9.5 MeV in 10Be is identified in this resonance spectrum.
The excitation energy in 8Be will be shown as well, where possible resonances through the 11Li−>11Be*−>2alpha+3n decay channel were looked for.
Simulations of these decay channels will be shown.

Nuclear Physics I / 10

Nuclear level densities

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Atomic nuclei at low excitation energy are characterized by the motion of pairs of nucleons, known as Cooper
pairs, moving in time reversed orbitals. This picture becomes much more complicated as Cooper pairs are
broken by collective (Coriolis force) or intrinsic (temperature) excitations. In this talk we will focus on the
statistical properties of the system as function of the number of excited nucleons.

The Oslo group has investigated level densities for ~30 nuclei, from silicon and up to lead. The so-called Oslo
method is based on particle-gamma coincidences in light ion reactions with one charged ejectile. By the use of
the Brink-Axel hypothesis, the level density can be extracted from the primary gamma-ray spectra, which are
measured at all initial excitation energies up to the neutron binding energy.

Nuclear Physics II / 11

Results and experiences from Coulomb excitation experiments with radioactive beams at GANIL and ideas for future experiments at ISOLDE

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Shape-coexisting states in neutron-deficient krypton isotopes have been studied by low-energy multi-step Coulomb excitation of radioactive 74Kr and 76Kr beams at GANIL. States up to the 8+ in the ground-state band and several non-yrast states have been populated, and their excitation probability was measured as a function of the scattering angle. A large set of both transitional and diagonal matrix elements was obtained in the analysis using the code GOSIA. The spectroscopic quadrupole moments for the first and second 2+ states have opposite signs, confirming the scenario of coexisting prolate and oblate shapes. The results from the GANIL experiments will be discussed with a special emphasis on the experimental techniques and difficulties of reorientation measurements with low-intensity radioactive beams. Ideas for future experiments to investigate shape

coexistence in neutron-rich nuclei around N=60 at ISOLDE using the same techniques will be presented.

Nuclear Physics III / 12

Transfer reactions with light radioactive ions at REX-ISOLDE

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In the second half of 2005 the Aarhus-Gothenburg-Madrid collaboration performed two different experiments impinging 11Be and 9Li on deuterium targets to study transfer reactions to different final states.
This type of transfer reactions (at 2-3 Mev/u) gives information on several systems since both elastic scattering, stripping and pick-up channels are open.
I would therefore like to present the results of these two reactions, in particular concerning excited states in 8Li and 10Be, and try to outline the possibilities that REX-ISOLDE presents for light radioactive ions (A<30).

Nuclear Physics III / 13

Measuring the strength of the proton d5/2 - neutron d3/2 tensor-monopole interaction

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The replacement of the N=20 spherical shell gap in nuclei of the island of inversion by the N=14,16 gaps can be explained by the tensor monopole interaction between the proton and neutron Fermi levels. The next step in understanding the evolution of shell structure is to measure the strengh of this interaction, which is present throughout the nuclear chart. The ideal tool for this are transfer reactions where single-particle energies and spectroscopic factors can be extracted. Hence it is our aim to measure the neutron d3/2 strength function in nuclei where protons are gradually filling the d5/2 state (oxygen, neon, magnesium and silicon) by (d,p) reactions in inverse kinematics. Part of this program could be done at Rex-Isolde once the energy upgrade to 5 MeV/u is in place.

Technical Developments II / 15

ERAWAST - Exotic Radionuclides from Accelerator Waste for Science and Technology

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Exotic radionuclides such as for instance 44-Ti, 60-Fe, 26-Al, 10-Be and many others are of great interest in several research domains like astrophysics, nuclear medicine, geophysics, fundamental nuclear physics or radioactive beam facilities. The production of all these nuclides in sufficient amounts is very time consuming and extremely expensive. Conventional techniques in commercial radioisotope production - restricted mainly on reactor-based or accelerator-driven production routes – are approaching their limitations. Consequently, alternative production possibilities and ways of cooperation in large basic-physics facilities are discussed. One of these possibilities is the exploitation of accelerator waste.
At the moment, the spallation neutron source SINQ, located at the PSI, is one of the most powerful facilities of its kind in Europe. Several long-time proton-irradiated materials like a copper beam dump and graphite targets from th myon-production facility are available at the moment.
The talk is aimed to give an overview on the possibilites of separating long-lived isotopes from these materials and the search for potential collaboration partners/users.

Solid State Physics / **16**

First observation of new diffusion phenomena in CdTe

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Understanding and control of diffusion profiles of intrinsic and extrinsic defects in semiconductors is of central importance for developing electronic and optoelectronic devices. Common to all diffusion profiles in semiconductors reported so far is the monotonously decreasing depth profile if the source of the diffusing species is located at the surface of the crystal. In compound semiconductors, large concentrations of intrinsic point defects can be obtained by inducing slight deviations from stoichiometry by exposing the respective material to external vapor pressures of one of its constituents.
In CdTe, the diffusion of Ag was studied using the radiotracer 111-Ag implanted into typically 500 - 800 µm thick CdTe crystals [1] with surprising results. After implantation of 111-Ag into the front side of a CdTe crystal and a diffusion anneal under vacuum, the diffusion profile shows the expected ‘normal’behavior, a monotonously decreasing Ag concentration. But, performing the diffusion anneal under external Cd pressure results in a total different diffusion profile: two depletion layers of about 300 µm width appear at both surfaces of the crystal. In contrast, layers of increased Ag concentration, situated about 20 µm below each surface, with the Ag concentration in the interior of the crystal being significantly lower are observed if the diffusion is performed under Te pressure. Since in normal diffusion experiments the material flow has the inverse direction of the corresponding concentration gradients, these results can not be explained by simple diffusion according to Fick´s laws. The observed new type of diffusion profiles can be understood in the framework of a model based on defect reactions of the Ag dopant with intrinsic defects [2]. The flux of the Ag atoms essentially is determined by its interstitial fraction Agi while Ag atoms incorporated on substitutional Cd lattice sites are immobile. It can be shown that the flux of Ag consists of two contributions: i) a normal diffusion flux, directed opposite to the gradient of the Agi distribution and ii) a drift of the charged defects caused by the gradient of the

Fermi level, which essentially follows the distribution of the intrinsic defects. Moreover, the diffusion behavior of Ag can be manipulated by the presence of the group Ib elements Cu or Au. If Ag is diffused simultaneously with these elements a replacement of Ag atoms in favor of Cu or Au takes place. After evaporating of 20 nm Cu on the 111-Ag implanted side of a CdTe crystal and subsequent diffusion at 550 K for 30 min nearly all Ag atoms are located within a thin layer of 10 μm beneath the back of the sample. This phenomenon can be explained using the model outlined before where Cu acts as a replacement for interstitial Cd defects.

[1] H. Wolf, F. Wagner, Th. Wichert, and ISOLDE Collaboration, Phys. Rev. Lett. 94 (2005) 125901.
[2] H. Wolf, F. Wagner, Th. Wichert, R. Grill, and E. Belas, J. Electr. Mat., in press.

Trapping for Nuclear Physics / **17**

Production and trapping of francium at LNL Legnaro

Author: Giulio Stancari[1]

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A facility for the study of francium atoms is operating at the INFN Laboratories in Legnaro (LNL). Data on
production, transport and trapping is presented. Possible future developments at Legnaro and ISOLDE are
discussed.

Technical Developments II / **18**

Updated ISOLDE yield database

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An accurate value of yields is essential for the preparation of experimental proposals for the ISOLDE facility as well as for the success of the experiments themselves. After the adjustment of the target and ion source the ISOLDE technical group provides a first estimation of the measured yield, but in many cases the measurement of the yield in the experimental set-ups is required. Therefore, the user input is essential in order to maintain an updated yield database.

The present ISOLDE yield database has been updated with a wide compilation of information taken from published data on scientific journals. A new store tool has been developed based on ORACLE, which guarantees reliability, security and provides an easy way of compilation of information. A new web application has been developed in which the yield of isotopes measured at the CERN synchrocyclotron as well as with the PS Booster from 1992 are compared and plotted on-line. Furthermore, yield information can be sought either by isotope or by target type, in such a way that it is possible to have an overview of all isotopes produced in a target and of their yields.

Technical Developments II / 19

Automating yield measurements and database storage (First Step of CERN database)

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Diverse data, such as yields, release curves or target ageing, have been collected for the last fifteen years at ISOLDE. We are now improving the procedure for their acquisition, storage and access. The measurements will be performed by an automatic application that controls the hardware settings and record data according to predefined parameters. A dedicated database with different access levels will be used to store the settings, the data and allow the publication of only the validated ones. The resulting curves and tables will be accessed through a website with the help of an additional application used to load, visualize and compare curves and variables of interest.
Yields and release curves, related to effusion, diffusion and ionization properties, are a valuable source of information and base for proper target and ion source development.

Technical Developments II / 20

Recent target development at ISOLDE and the 100kW direct targets for EURISOLDS

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Results obtained with prototypes comprising a graphitic line or a quartz insert will be presented. They will be complemented with data on halogen beams produced this year at ISOLDE with a LaB6 negative surface ion source. In a second part, I introduce how simulation and experimental tools recently acquired in the section are used for new developments for ISOLDE and EURISOLDS.

Technical Developments I / 21

Charge breeding studies at ISOLDE

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At ISOLDE, different charge breeding techniques are investigated with both an EBIS and an ECR charge breeder. The REXEBIS is an operational machine since three years,

running as the central part of the beam preparation stage of the REX-ISOLDE post-accelerator. A 14 GHz Phoenix ECR charge breeder is currently being tested in one of the beam line of the General Purpose Separator (GPS). According to the application, the requirements of the charge breeding process for efficiency and rapidity, and of the charge bred beam for purity, time structure, intensity and emittance can vary significantly. This presentation will summarize the latest results of the studies undertaken with the two charge breeders, for the development of advanced charge breeding techniques in the frame of the EURONS Charge breeding JRA, and for the investigation of the 1+ −>n+ scenario in the frame of the EURISOL Design Study.

Summary:

A review of the charge breeding studies at ISOLDE

Technical Developments I / **23**

HIE-ISOLDE

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The physics community that use radioactive ion beams, estimated to be about one thousand in Europe alone, requires diversity of ions species, diversity of beam energy, and high beam intensities. REX-ISOLDE already provides the first of these; the aim of HIE-ISOLDE is to achieve the second and the third. This requires developments in post-acceleration (the present energy restricts the application of REX to studies of light nuclei) and radioisotope selection as well as target-ion source development and charge-breeding to cope with the increase in proton intensity promised by LINAC4. A five-year development programme, with an injection of 9 MCHF from CERN together with contributions from member states and the EU, will realise this facility and make CERN the undisputed world centre for RIB physics by the end of this decade.

Solid State Physics / **24**

Studying atomic order of oxygen dopants in high TC superconductors

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We present a progress report of lattice sites and collective ordering studies of dopant oxygen atoms in HgBa2CaCu2O6.26 (Hg1212) samples with the perturbed angular correlation technique, PAC. By measuring electric field gradients (EFG) at 199mHg nuclei, information for characterizing the oxygen atoms, Oδ, which go to the Hg-planes and dope the superconducting CuO2 planes with double-hole charge carriers is obtained.
Due to the synthesis complexity of such materials an overview of the production methods is presented. A new process of producing highly pure precursors, CO2 free, has been developed, previously to the final step where Hg is introduced under very high pressure annealing. This was an essential work to obtain the pure phase of Hg1212 samples.
At ISOLDE small powder samples of Hg1212 were then implanted with low doses of 199mHg and first annealed to remove implantation defects. The PAC experiments have been performed under different Ar or O2 annealing conditions, up to 25 bar O2 pressure. While we identify different concentrations of oxygen atoms, depending on the annealing process, the maximum achieved concentration with $\delta O < 0.26$ was still low. In this situation most of the oxygen atoms occupy, as expected, mainly single interstices at the centre of the Hg mesh without collectively ordering. However, experiments performed after different annealing conditions and measured at different temperatures, have revealed differences in the charge distribution of the Hg surroundings, still under analysis. PAC experiments on Hg1212 and HgBa2Ca2Cu3O8 are being prepared where the samples should be annealed under higher O2 pressures, up to 100 bar, to obtain higher dopant concentrations.

Solid State Physics / 25

Lattice location of Ag in SrTiO3 and new developments in position-sensitive detectors for Emission Channeling

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Strontium-titanate is a perovskite ceramic material, which is of interest, e.g., for future devices based on metal-oxide Si heterostructures such as high-k field effect transistors. The electrical, optical and magnetic properties of SrTiO3 can be modified by the incorporation of dopants. For instance, transition metal doped SrTiO3 has been considered as a candidate for a room-temperature ferromagnetic semiconductor [1]. Ion implantation might thus represent an attractive approach for doping, especially in cases where the solubility of dopants is limited and they cannot be introduced during growth. However, very little is known about the fundamental question whether implants are incorporated on proper lattice sites in SrTiO3 (substitutional Sr, substitutional Ti and substitutional O sites, regular interstitial sites or randomly dispersed). This can be studied with the emission channelling technique, which unambiguously identifies and quantifies the impurity lattice site location.
Results for implanted 111Ag in SrTiO3 perovskite are reported to illustrate the EC technique capabilities. Electron channeling patterns were measured around several crystalline directions following in-situ-vacuum annealing up to 900ºC. It is shown that in the as-implanted state, Ag occupies several lattice sites and upon annealing, most of Ag goes to near-substitutional Sr sites [2], while for instance Fe is to a large extent incorporated on Ti substitutional sites.
In addition, a short description of a new data readout technology for electron Si pad detectors with a strong impact on the applications of the EC technique will be presented. The new technology improves the detection efficiency of very low energy conversion electrons below 40keV, and at the same time, allows very high readout

count rates up to tens of kHz. These facts will broaden the range of available elements for EC studies, in particular, by using short-lived isotopes, already next year. Perspectives about the near future of the EC technique at ISOLDE-CERN will be given.
[1] S.J. Pearton, W.H. Heo, M. Ivill, D.P. Norton, and T. Steiner, Semicond. Sci. Tech. 19 (2004) R59-74.
[2] A.C. Marques, U. Wahl, J.G. Correia, E. Rita and J.C. Soares, "Lattice location and perturbed angular correlation studies of implanted Ag in SrTiO3", accepted by Nucl. Instr. And Meth B (2005).

Technical Developments II / **27**

Experimental results of the TARGISOL project

Author: Ulli Koester[1]

[1] *CERN*

Off- and on-line experiments within the TARGISOL project will be presented and resulting recent and future improvements of ISOLDE beams will be discussed.

Technical Developments I / **28**

REX operation 2005 and future plans and upgrades

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Operation and development in 2005:
REX- ISOLDE (the radioactive beam experiment at ISOLDE) has now been approved as a CERN facility. A number of tasks are underway to improve its operation and reliability. Already 2005 has been a very successful campaign with a record number of RIBs accelerated and delivered to the two experimental targets: 15 different isotopes have been accelerated at energies ranging from to 2.2 to 2.85MeV/u in 9 physics runs!
Energy upgrade of the linac:
A plan has now been drawn for the extension of the experimental beamlines into the new hall and the upgrade of the linac at 5.5MeV/u. Different solutions are also envisaged for a future 10 Mev/u upgrade.

Trapping for Nuclear Physics / **29**

WITCH: Studies made in 2005

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During the last year, efforts were made to improve and understand in more detail the WITCH experimental setup. At the end of 2004 several problems were uncovered and a number of them have already been dealt with in detail.
The MCP's used for tuning the ion beam in the setup where shown to have saturation effects but this problem is now understood and can be prevented.
The behavior of the Pulsed Drift Tube is, thanks to simulations, better understood although some effects which limit the present efficiency of the setup still have to be studied in more detail. Extensive simulation work has also been performed on the behavior of the beta-particles in the setup. This has revealed a possible problem of background events which will be urther investigated experimentally. Currently a large effort is being put into improving the total efficiency of the setup with the goal of measuring the first recoil ions in the coming year.

Nuclear Physics I / 30

Study of the neutron-rich tellurium isotopes by laser spectroscopy

Author: Brigitte Roussiere[1]

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Laser spectroscopy gives access to fundamental properties of the ground and rather long-lived isomeric states such as the change in the mean square charge radius (⊠⊠ ⊠) and the nuclear moments. Measurements on tellurium isotopes (Z = 52) can provide reliable information on the shape of nuclei, structure of states, and effects of dynamics. Indeed from A = 115 to 133, all the odd-A Te isotopes exhibit an isomeric state and the measurement of the isomeric shift gives us a direct indication of the influence of the neutron-core coupling on the nuclear deformation. Moreover the determination of the magnetic moments yields information on the structure of the states. In particular the measurements on the neutron-rich tellurium isotopes allow us to study the variation of the kink at N = 82 approaching the proton magic number Z = 50.
ISOLDE offers the opportunity for studying the tellurium isotope series over a wide mass range, from the nuclei located near the N = 66 neutron mid-shell to the neutron-rich ones beyond the neutron shell closure at N = 82. In this contribution we will present the laser spectroscopy experiment performed on the neutron-rich tellurium isotopes and the results obtained up to now. The neutron-rich Te isotopes have been produced by the 238U fission induced by 1 GeV protons in a uranium carbide target associated with a hot plasma ion source. The laser spectroscopy measurements have been performed on the 127-136Te ground states and on the 123,125,127,129,131,133Te isomeric states using the COMPLIS (COllaboration for Measurements using a Pulsed Laser Ion Source) setup that allows resonance ionization spectroscopy (RIS) on laser-desorbed atoms. To avoid direct and disturbing ionization of the isobars by the non-resonant step, a three step process had to be used to ionize selectively the tellurium isotopes: 214.35, 591.6 and 1064 nm. Spectroscopic information (isotope shift and hyperfine structure) has been obtained by scanning the first excitation step (the 5p4 3P2 ⊠ 5p3 6s 3S1 optical transition at 214.35 nm) of the RIS process. The analysis of the data is still in progress. However the ⊠⊠ ⊠ values obtained for the even-even isotopes show that the kink at N = 82 remains in Te, i. e. in an isotopic series with a proton number very close to the magic number Z = 50.

News from other Laboratories / 32

Nuclear Reactions with Radioactive Beams at GANIL

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[1] *IPNO*

The availability of radioactive beams at GANIL produced through both the projectile fragmentation (SISSI) and ISOL (SPIRAL) techniques have fostered the development of a broad programme of reaction studies. The subject will be illustrated with results from elastic, inelastic, transfer and fusion studies. Topics will include the influence of weakly bound neutrons on direct and compound reactions, changes of magic numbers far from stability and the search for tetra-neutron states. The future of the programme will be evoked in the light of new more powerful detection systems soon to come on-line.

Technical Developments I / 33

Multi-MW Spallation Target Design for the European Isotope Separation On-line Radioactive Ion Beam Facility (EURISOL)

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The EURISOL is set to be the 'next-generation' European Isotope Separation On-Line (ISOL) Radioactive Ion
Beam (RIB) facility, extending and amplifying beyond the year 2010 the research being performed at the
present RIB facilities in Europe and elsewhere, in the fields of Nuclear Physics, Nuclear Astrophysics and
Fundamental Interactions.
The proposed ISOL facility will include several 100 kW proton beams on a thick solid target to produce RIBs
directly, and a 3-5 MW liquid metal 'converter' target to achieve high fluxes of high-energy spallation
neutrons, which later will produce radioactive ions through fission in a secondary uranium carbide (UCx)
target. The design of such an innovative spallation neutron source, several times more intense than the
present ones, requires state-of-the-art simulation codes and concepts to address its technical challenges.
A preliminary conceptual design of a multi-MW liquid Hg converter is presented together with the detailed
thermo-nuclear characteristics obtained using the Monte Carlo code FLUKA. These include power density
distributions, necessary to assess the technical feasibility of the liquid spallation target by means of computational fluid-dynamics calculations. Special attention is given to the impact of high-energy neutrons
on the fission process in the UCx target, radiation damage to the internal structures and the radioprotection
issues of the facility.
We acknowledge the financial support of the EC under the FP6 "Research Infrastructure Action - Structuring
the European Research Area" EURISOL DS Project; Contract No. 515768 RIDS.

Nuclear Physics IV / 34

Nuclear Astrophysics with MINIBALL

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The origin in the cosmos of the so-called p nuclei is one of the most puzzling tasks to be solved by any model of heavy-element nucleosynthesis. These nuclei are by-passed by the s- and r-process pathways. To date, these nuclei have been observed only in the solar system. Understanding the synthesis of these p-process nuclei on the basis of astrophysical processes occurring outside the solar system, like e.g. in exploding supernovae (SNII) or on He-accreting white dwarves with sub-Chandrasekhar mass, which are both thought to be the most possible p-process sites, will enable us not only to understand the nuclidic composition of the solar system but also to further elucidate our fundamental picture of its creation.

Abundance calculations of the p nuclei make an extensive use of the nuclear statistical model for the calculation of the rates of an extended reaction network. Comparison with (p,gamma) and/or (n,gamma) cross section indicate that these rates can be predicted within a factor of two. However, some very scarce (alpha,gamma) data show that the reaction rates calculated using phenomenological alpha-particle optical potentials can be wrong by a factor of ten or more. These uncertainties might be reduced substantially by putting constraints on the alpha-particle optical potentials that are so far poorly known at such low energies (E<12 MeV). In order to achieve this goal, there exist different approaches, amongst which the (alpha,gamma) measurements at sub-Coulomb energies in inverse kinematics using state-of-the art detectors is the most transparent. The energies available at ISOLDE (<3 MeV/u) in combination with the MINIBALL array and radioactive beams may provide the most suitable experimental conditions to launch a nuclear astrophysics program aiming at the study of the alpha potential. In this direction some first ideas as well as first tests of the response of MINIBALL to capture events will be presented.

News from other Laboratories / **35**

Nuclear astrophysics at TRIUMF with the TUDA facility

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The TUDA facility (TRIUMF UK Detector Array) consists of a silicon strip array for the study of charged particle reactions of astrophysical interest in inverse kinematics. TUDA addresses the challenges presented by investigating such reactions, using both direct and indirect techniques. In particular, the low energies and low cross sections involved require the use of highly segemented, large solid angle detectors with excellent energy and timing resolution. TUDA is designed to be highly versatile and the experimental configuration can be optimised to the requirements of each individual measurement. An overview of TUDA will be presented together with experimental results and a discussion of the future programme.

Trapping for Nuclear Physics / **36**

The masses of neutron-rich zinc isotopes and their impact on nuclear astrophysics

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Nucleosynthesis theory describes how elements and nuclides are formed in stellar evolution, e.g., violent processes like supernovae explosions. For the calculations of the various pathways from hydrogen to the heavier elements the nuclear properties of a large number of nuclides need to be known [1,2]. Especially in the case of the r-process, where elements heavier than iron are formed by rapid neutron capture, nuclear structure data of neutron-rich nuclides far from the valley of stability are required.

The path of the r-process is determined by and reflects nuclear structure. For example at the neutron shell N=50 it crosses through the waiting point nuclide 80Zn. Slight deviations in the nuclear physics parameters can lead to large discrepancies in the modeling of the subsequent nucleosynthesis processes. One crucial parameter is the mass of the nuclides, which enters the determination of neutron separation energies and the Q-values for the beta decays. They are thus essential for the study of the r-process.

With the Penning trap mass spectrometer ISOLTRAP at ISOLDE/CERN very precise and accurate mass measurements with relative mass uncertainties down to dm/m=8x10-9 can be achieved. Recently, the atomic masses of the neutron-rich zinc isotopes 71-81Zn have been measured. For the first time the masses of 79Zn and 81Zn have been determined. The new experimental data allow the investigation of nuclear structure at the neutron shell N=50 for low Z. The possible impact on nuclear astrophysics is discussed.

[1] M. Mukherjee et al., Phys. Rev. 93, 150801 (2004)
[2] D. Rodriguez et al., Phys. Rev. Lett. 93, 161104 (2004)

Solid State Physics / 37

LOCAL PROBE STUDIES NEAR THE CHARGE ORDER AND MAGNETIC TRANSITIONS IN Pr1-xCaxMnO3

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The Pr1-xCaxMnO3 displays a variety of phase transitions associated with the spin, lattice, charge and orbital degrees of freedom [1],[2]. PrMnO3 and CaMnO3 are antifeerromagnetic, and low doped (x<0.32) samples are ferromagnetic below Tc~130K. For 0.32<x<0.90 the system presents a robust Charge Order state (CO) for temperatures below TCO~150-235 K and an antiferromagnetic insulator state below TN~100-180 K. Detailed real-space atomic-scale information is necessary to achieve better undertanding of such order/disorder effects.
111mCd→111Cd Perturbed Angular Correlation (PAC) studies were used to infer about atomic-scale distortions in the temperature range 10-600K encompassing the charge,orbital and magnetic ordering transitions. The electrical-field gradient (EFG) generated by the charge distribution around the probe shows strong anomalies when the system undergoes the charge-order transition. In particular, the principal component of the EFG (Vzz) presents a sharp discontinuity at the CO transition.

[1] Y. Tomioka et al. Phys. Rev. B 53, 1689 (1996)
[2] M. S. Reis et al., Phys. Rev. B 71, 144413 (2005)

Opening Session / **38**

Parity Non-Conservation in the gamma decay of 180mHf(8-);revisited

Author: Micha Hass[1]

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Since the discovery of parity violation in beta decay, Parity Non-Conservation (PNC) in bound nuclei has provided a means to address the parity violating term in the nuclear Hamiltonian due to the weak interaction component. The few cases identified as promising ones have been studied but showed marginal or no effects.
In the case of 180Hf(8-) isomer, the PNC effect was studied nearly four decades ago by observing its 501 keV gamma decay from a polarized source which showed a large effect of ~10 standard deviations, i.e. 1.66±0.18%. Since then it has been the only bound nucleus where the parity violation in its gamma decay is clearly and unambiguously observed. This very uniqueness of the 180mHf case, and the availability of a 180mHf(8-) beam from ISOLDE, are the basis for the present renewed interest in this PNC case.
The 180mHf beam with 3.105 particles/s was implanted into a magnetized Fe host in the NICOLE dilution refrigerator and is polarized using the low temperature orientation method. The gamma decays from a total of ~5.1013 implanted 180mHf nuclei are observed in 4 HPGe detectors placed at 90 degrees to each other and at a distance of ~12 cm from the Fe foil and ~1cm from the cryostat wall. The direction of magnetic field was changed every ~5 hrs. to left (L) or right (R) by changing the direction of the current sent through the coil. This ensured minimization of systematic errors.
The measured 0 to 180 degree asymmetry from a preliminary analysis yields A(gamma) =1.14±0.052% in basic agreement with the earlier measurement. A careful analysis of the complete data is underway and is expected to further improve upon the error. The complete results, together with a detailed discussion, will be presented.

Nuclear Physics IV / **39**

Gas catchers for radioactive ion beam research

Author: Mark Huyse[1]

[1] *IKS*

A gas can be a good alternative to a solid or liquid to catch, store and transport radioactive ions, especially for short-living species and/or isotopes from refractory elements. A short overview of the evolution in gas catchers will be given. Then the different processes taking place in gas-catchers and influencing the overal behavior will be discussed. The contribution will end by a critical assessment of the role that gas catchers can play in the next generation of radioactive ion beam facilities.

Nuclear Physics III / **41**

Perspectives for 2n transfer reactions at REX-ISOLDE

Author: Reiner Krücken[1]

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Two-neutron transfer reactions offer the possibility to study pairing correlations, shape coexistence and other strcutural issues in nuclei. Our recent development of a tritium target opens the possibility to perform (t,p) reactions in inverse kinematics at REX-ISOLDE with beam intensities as low as approx. 10^5 pps. In this talk I will report on results of recent transfer experiments in inverse kinematics with stable beams. The results will be discussed in the context of future requirements and possibhilites for experiments at REX-ISOLDE and HIE-ISOLDE.

Opening Session / **42**

Nucleosynthesis from the first generation of stars in the universe.

Author: Georges Meynet[1]

[1] *Geneva Observatory*

TBA

Solid State Physics / **43**

Solid state physics research at ISOLDE

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Solid state physics at ISOLDE aims at the study of the structural, electrical, optical, magnetic and transport properties related to impurities in a variety of technologically and fundamentally relevant materials, including semiconductors, metals, high-Tc superconductors and ceramic oxides.
This talk will give an overview on the recent ISOLDE activities in this field, including
- lattice location of dopants and impurities in wide band gap semiconductors by means of emission channeling,
- identification of the chemical identity of optical centers in semiconductors using photoluminescence studies of radioactive impurities,
- characterization of deep levels in semiconductors using radioactive Deep Level Transient Spectroscopy (DLTS),
- study of the structural and magnetic properties of Fe in semiconductors by means of the Moessbauer effect,
- configuration of excess O and F dopants in Hg-based High-Tc superconductors,
- probing of charge ordering effects in phase transitions of colossal magneto-resistive oxides,
- understanding of magnetic hyperfine fields at impurities on metal surfaces and within the bulk obtained by means of perturbed angular correlation (PAC).
An outlook on experiments planned for the near future will be given as well.

Opening Session / **44**

”The fate of the N=20, 28, 32 and 34 closures in very neutron rich nuclei. Where is the magic?”

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I will discuss the present status of the theoretical description of very neutron rich nuclei with particular emphasis in the subshell closures at N=20, 28, 32 and 34.

News from other Laboratories / **45**

RISING: Phases and recent results

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Nuclear structure studies at GSI gained recently an increased interest for the present activities as well as for the future project FAIR. A broad range of physical phenomena can be addressed by high-resolution in-beam γ-ray spectroscopy measurements with radioactive beams offered within the Rare ISotopes INvestigation at GSI (RISING) project. It combines the EUROBALL Ge-Cluster detectors, the MINIBALL Ge detectors, HECTOR-BaF detectors, and the fragment separator FRS. The secondary beams produced at relativistic energies are used for Coulomb excitation or secondary fragmentation experiments to study projectile like nuclei by measuring de-excitation photons. Alternatively, the relativistic radioactive beams are implanted into a detector/stopper and their decay can be investigated, or slowed down to the energies suited for the fusion or transfer reactions and a “classical”

in-beam spectroscopy.
Future ideas born from the experience with the RISING project will lead to a new instrumentation within NUSTAR at FAIR. A number of projects consider a use of γ-ray detectors. In particular, γ-ray spectroscopy will be a main goal of the HISPEC and DESPEC experiments.

Nuclear Physics I / **46**

Moments and spins of neutron rich Mg isotopes: towards 33Mg

Author: Deyan D. Yordanov[1]

[1] *IKS*

Our research on the neutron rich side of the Mg chain will be presented, which is of interest in the frame of understanding nuclear structure in the region of the “Island of inversion”. Nuclei around 32Mg exhibit properties in disagreement with the standard shell model. Advanced modeling of the region requires experimental data, crucial parts of which are the nuclear moments data. The research taking place the last years at the collinear laser spectroscopy setup COLLAPS at ISOLDE, CERN has significantly contributed in this aspect. The obtained nuclear moments and hyperfine structure of 27, 29, 31Mg will be presented, illustrating the actuality of the technique of nuclear magnetic resonance in combination with laser spectroscopy. Interpretation in the frame of the shell model will be given, and in the case of 31Mg the results will be linked with a resent β − decay study and discussed in the terms of particle − hole excitations over N=20 shell gap. Our recent measurement of the hyperfine structure of 33Mg will be presented for a very first time, revealing possibilities for tentative ground state spin − magnetic moment assignments. The necessity of combining an NMR measurement with a hyperfine structure measurement in order to unambiguously determine the ground state spin will be illustrated. The isotope shifts between 24, 25, 26, 27Mg, revealing the changes in mean square charge radii, have been measured as well. The point of extending the sequence to get access to changes in deformation towards N=20, particularly for isotopes with spin 0 or 1/2 − unreachable with other techniques, will be discussed as well.

Information / **47**

Information to ISOLDE users

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ISOLDE users can since 2005 benefit from the transnational access program through EURONS (EC FP6). A few important practical points will be summarized.

Summary:

A brief reminder to ISOLDE users concerning (1) how to get EU support for participation in experiments and (2) what information we need from you in return. Publications based on experiments at ISOLDE should be registered at CERN.

Trapping for Nuclear Physics / 48

The Ramsey method in high-precision Penning trap mass spectroscopy

Author: Sebastian George[1]

[1] *GSI*

The mass is a fundamental property of a nuclide. Its measurement contributes to a variety of fundamental studies including tests of the Standard Model and the weak interaction. The limits of mass measurements of exotic nuclei have been extended considerably by improving and developing the Penning trap mass spectrometer ISOLTRAP at the ISOLDE facility at CERN. The mass resolving power of ISOLTRAP reaches 107 and the uncertainty of the resulting mass values has been pushed down to 8*10-9. The mass is determined via a time-of-flight cyclotron resonance detection technique. To reduce the measurement uncertainty a number of improvements in ion detection and data taking have been developed. One of these is the use of the Ramsey method, i.e. time separated oscillating fields, for the excitation of the ions' motion. The advantage of this method is a reduction of the line width of the resonance. In addition the weights of the individual frequency points of the resonance curve are analyzed, which results in a step-size optimization. The methods as well as the results will be presented.

Technical Developments II / 49

Proton induced thermal stress wave measurements for ISOLDE and CNGS

Author: Roman Wilfinger[1]

[1] *CERN*

TBA

Nuclear Physics III / 50

Low energy Coulomb excitation of neutron-deficient 70Se at REX-ISOLDE

Author: Aaron Hurst[1]

Co-authors: David Jenkins [2]; Peter Butler [1]

[1] *Liverpool University*

[2] *Univeristy of York*

There is much ongoing experimental and theoretical interest surrounding nuclei in the $A = 70$ region of the nuclear chart. A definitive measurement of the reorientation matrix element of the first 2+ state in 70Se would provide information on the nature of shape coexistence in this nucleus. Preliminary results following the Coulomb excitation of a radioactive beam of 70Se at 2.94 MeV/u obtained from the REX-ISOLDE facility will be presented.

Nuclear Physics II / **51**

Nuclear Moments of Isomeric States at REX-ISOLDE - Ideas and Necessities

Author: Georgi Georgiev[1]

[1] *IPNO*

The nuclear moments are an important ingredient of our nuclear structure knowledge. Their contribution is crucial when one discusses the development of the nuclear shells far from stability. However, presently there are no techniques that can be directly applied for the studies of short-lived isomeric states produced by ISOL beams. Some ideas about the use of post-accelerated radioactive beams for nuclear moment studies of short-lived isomeric states will be presented. The emphasis will be on possible methods of producing the isomeric states in a spin-oriented manner. The difficulties resulting from the use of radioactive beams and the demands towards the technical characteristics will be discussed. Some ideas about possible near future experiments will be presented as well

Trapping for Nuclear Physics / **52**

Possible Physics interests for the trapping of radioactive Rb atoms

Author: Amine Cassimi[1]

[1] *Ciril-Ganil*

At LPC Caen, a magnetic optical trap (MOT) has been developed for the trapping of Rb atoms. This device is a powerful tool for atomic physics studies when used in combination with the well-established Recoil Ion Mass Spectrometry method (MOTRIMS). At ISOLDE, this kind of trap could be used for the trapping of radioactive Rb, and possibly of radioactive K and Li atoms with a slightly modified laser setup. Recent experiments at Los Alamos, Triumf, and experiments in preparation at Legnaro or Stony Brook for example have shown that this device could be valuably used for precision experiments in the domain of nuclear and particle physics, or for the study of fundamental symmetries. After a brief presentation of the trap set-up, different potentialities of this trap for Physics experiment with radioactive atoms will be discussed.