ISOLDE Workshop and Users meeting 2016

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Book of Abstracts

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Shapes for a precise description of nuclear spectroscopy

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Despite the atomic nuclei are quantum many-body systems made of interacting protons and neutrons, their spectra can be in many cases described by simple geometrical models. The best framework to explain microscopically such a collective behavior is the self-consistent mean-field approach based on energy density functionals like Skyrme, Gogny or Relativistic Mean Field. These methods have been developed significantly in the last two decades. In particular, the inclusion of different intrinsic shapes and beyond mean effects, such as symmetry restorations and shape mixing, has improved remarkably the comparison with the experimental data. In this contribution I will discuss the theoretical tools needed to compute nuclear structure properties such as masses, radii, excitation energies and/or transition probabilities. Additionally, I will show some selected examples that illustrate the ability of the energy density functional methods to describe phenomena like shape evolution, shape coexistence and shape mixing in nuclei from a microscopic point of view.

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Laser Spectroscopy of Nobelium Isotopes at GSI

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Precision measurements of atomic properties by laser spectroscopy allow probing an element's electronic structure. In addition, measurements of the hyperfine splitting and the isotope shift of spectral lines gives a handle to obtain nuclear properties such as spins and moments.

Despite significant progress in laser spectroscopy in recent years, no experimental data on atomic levels of elements beyond fermium are available to date. However, their electronic structure is strongly affected by relativistic effects, quantum electrodynamics, and electron correlations. Moreover, many nuclear spin assignments are based on systematics.

A very sensitive method based on a two-step laser-ionization scheme has been developed for optical spectroscopy of nobelium. In 2015, for the first time atomic levels including several high-lying Rydberg-states in No-254 atoms were identified in an experiment at GSI Darmstadt. Moreover, the isotope shift in the isotopes No-252,253 was investigated.

In this contribution, recentexperimental results will be presented and compared to theoretical predictions. Future perspectives for measurements in even heavier elements will be discussed.

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Recent technical developments and mass measurements above the potentially doubly-magic nuclide ^{78}Ni at ISOLTRAP

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ISOLTRAP [1] mass measurements of neutron rich copper isotopes are presented. ^{79}Cu could be addressed by the first time using a Multi-Reflection Time-of-Flight Mass Spectrometer (MR-ToF MS) [2]. With only one proton above the $Z = 28$ core, the binding energies of the copper isotopes are sensitive to the evolution of nuclear shell structure close to the doubly-magic ^{78}Ni isotope. Preliminary results in combination with a shell-model theory will be shown.
To reach even more exotic nuclides and to improve ISOLTRAP's mass precision limit, a position-sensitive ion detector was installed upstream the precision Penning-trap. It will allow the application of the Phase-Imaging Ion-Cyclotron-Resonance (PI-ICR) detection method developed at SHIPTRAP/GSI [3]. This new method offers compared to the presently used Time-Of-Flight Ion-Cyclotron-Resonance detection technique [4] higher precision and resolution in shorter measurement time, and thus the ability to resolve low-lying isomers. The current status, first measurements, and an outlook on the implementation of the PI-ICR technique at ISOLTRAP will be presented.

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Shape staggering, shape coexistence and beta-delayed fission in bismuth isotopes studied by in-source laser spectroscopy (IS608)

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Shape staggering, shape coexistence and beta-delayed fission in bismuth isotopes studied by in-source laser spectroscopy (IS608)

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On behalf of Leuven-Gatchina-ISOLDE-Mainz-Manchester-York and Windmill-ISOLTRAP-RILIS collaboration

By combining the high sensitivity of the in-source laser spectroscopy technique, ISOLDE mass separation, Windmill alpha-decay spectroscopy setup and Multi-Reflection Time-of-Flight (MR-TOF, ISOLTRAP collaboration) mass separation technique it was possible to study the long isotopic chain of bismuth isotopes (187-218Bi) in the framework of the IS608 experiment [1]. The preliminary results of the charge radii changes and electromagnetic moments in bismuth isotopes, deduced from

the isotope shifts (IS) and hyperfine structure (hfs) measurements, are presented. The large odd-even shape staggering at 187-189Bi similar to the well-known staggering in the Hg isotopes at the same neutron numbers was observed. Shape coexistence in the odd-A Bi nuclei was demonstrated (intruder isomers, 191-201Bi). The noticeable deviation of the charge radii trend for the ground states of the neutron deficient odd-A Bi isotopes from that for the (spherical) Pb nuclei was found.

Along with the IS/hfs measurements, beta-delayed fission (βDF) in 188, 190Bi was studied. For the first time it was possible to implement the isomeric selective βDF-measurement to check the spin dependence of βDF-probability for two isomeric states in 188Bi.

[1] A.N. Andreyev. A. E. Barzakh, P. Van Duppen et al., http://cds.cern.ch/record/2059118/files/INTC-P-443.pdf

Solid State Physics / 33

Solid State Physics Program at ISOLDE

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The idea that "*new-is-small*" reflects a paradigm moving industries and research. New materials, new applications, new technologies, - but what do we need to make the *"new"*, understandable, applicable and reliable? Clearly, as things go smaller and smaller, it is more difficult to probe at the appropriate scale without influencing the subject of interest. Ideally, one needs tip-less (contactless) techniques, not interfering with the system under study. In fact, such an approach has been realized using nuclear probes, where radioactive nuclei interact with their surroundings in a solid on an atomic scale and transmit this information via their radioactive decay complementing current macroscopic techniques. Key microscopic features can be inspected in this way, such as lattice location, diffusion, interaction with defects present in the neighborhood of the probe atom, magnetic properties, percolation phenomena leading to structural and magnetic phase transitions, doping and transport phenomena, such as you can find in bulk nanomaterials and near surfaces or interfaces. Since the late 70s researchers at ISOLDE have been applying radioactive nuclear techniques to materials science and biophysics research. A considerable infrastructure has been built up on-site to allow scientists to perform experiments using short-lived isotopes. The production of radioactive isotopes online with big yields, elemental and isotopic purity allow the choice of the right probe radioactive element / isotope adequate to study each problem. In this context, Deep Level Transient Spectroscopy and Photoluminescence with radioactive Isotopes and nuclear techniques such as Perturbed Angular Correlations, Emission Channeling, ß-Nuclear Magnetic Resonance, Secondary Ion Mass Spectroscopy, Spreading Resistance Profiling and Mössbauer are very powerful to characterize new materials, particularly from an atomic point of view. ISOLDE is the world reference on production and delivery of radioactive beams of high purity dedicated to many different purposes for, e.g., atomic, nuclear, solid state, biophysics, and medical research. This laboratory is also a pioneer in the use of nuclear techniques – with an enriched potential due to the wide number of available radioactive probe elements – while studying the atomic scale interactions of the probe nuclei with its neighborhood. This contribution explores the **Solid State Physics Program at ISOLDE**, isotopes, projects, techniques and their development to analyze new materials.

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Solid State Challenges in Ferroelectrics

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Most ferroelectrics are oxides of a number of different crystal classes. Their polar ordering typically arises as soft phonon process with one or more of the ionic entities shifting within the unit cells. This lowers the symmetry into polar symmetry groups. If nuclear probes substitute the inherent ions in the structure, their local environment more or less reflects the crystal symmetry. One of the biggest challenges in oxides is the control of the oxygen stoichiometry. It will thus often occur that ionic probes are captured near vacancies or vacancy clusters, particularly if the long lived mother isotope is of different charge than the site in the unit cell which it substitutes. If we work on powders, most of the implanted ions will only enter the surface of the powder grains. In well polished ceramics, this can be circumvented to some degree, but grain boundaries offer another disordered environment. Thus, all interpretation of data must be done very carefully. Recently, conducting domain walls, photovoltaic effects and even potentially supraconductivity in domain walls have been reported. It is a challenge in the near future to be able to place nuclear probes into the relevant sites in the structure. This could enable access to effects, so far not reported about. This presentation will be speculative in certain parts.

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Lattice location of 27Mg in GaN: latest results using the emission channeling technique

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Mg-doped p-type GaN is nowadays a core component of many optoelectronic devices which we find in our homes, e.g. LEDs for solid state white lighting or blue lasers. Yet there are some basic properties related to p-type doping of GaN that are still poorly understood and also limit the performance of devices. One such major problem is an inherent doping limit: once the Mg concentration in GaN surpasses ~1E19-1E20 cm3, further introduction of Mg does not lead to an increase in the hole concentration. Recently a theory has been put forward [1] that explains this behaviour by suggesting an amphoteric nature of Mg: once the doping limit has been reached, additional Mg atoms are not incorporated on substitutional Ga sites any more (where they act as acceptors) but on interstitial sites (where they form compensating double donors).

The emission channeling technique with short-lived isotopes (EC-SLI) is an experimental method that gives direct information on the lattice location of radioactive isotopes implanted into single crystals. Using the isotope 27Mg (t1/2=9.5 min) produced at CERN's ISOLDE facility hence offers the unique opportunity of studying the Mg lattice location in GaN and other nitride semiconductors such as AlN and InN.

In this contribution, recent results on the lattice location of 27Mg ion implanted in different doping types of GaN (undoped, Si-doped n-type, Mg-doped p-type, Mg-doped as grown) will be discussed. We give direct evidence for the amphoteric nature of Mg, which is proven by the simultaneous

occupation of substitutional Ga and interstitial sites. After implantations between room temperature and 300℃, the majority of 27Mg occupies the substitutional Ga sites, however, significant fractions were found on interstitial positions ~0.6 Å from ideal octahedral sites. The interstitial fraction of Mg was correlated with the GaN doping character, being highest (up to 30%) in samples that were doped p-type with 2E19 cm3 stable Mg during epilayer growth, and lowest in Si-doped n-GaN, thus giving direct evidence for the amphoteric character of Mg. Implanting above 400℃ converts interstitial 27Mg to substitutional Ga sites, which allows estimating the activation energy for migration of interstitial Mg as between 1.4 and 2.1 eV.

[1] G. Miceli and A. Pasquarello: "Self-compensation due to point defects in Mg-doped GaN", Phys. Rev. B 93 (2016) 165207

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Potassium self-diffusion in a K-rich single-crystal alkali feldspar

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The rock-forming alkali feldspars belong to the most abundant minerals in the Earth's crust and are formed as a solid solution between the sodium ($NaAlSi_3O_8$, albite) and potassium ($KAlSi_3O_8$, orthoclase) end-member compositions. Well-founded knowledge of self-diffusion data in alkali feldspar is a prerequisite for interpreting existing interdiffusion data that, in turn control re-equilibration features in alkali feldspar that pertain to evolution and dynamics of the crust. Previous studies on alkali diffusion in alkali feldspar mostly concern the sodium component. Potassium self-diffusion has hitherto been investigated employing a bulk-exchange method to investigate grains from crushed feldspar. However, this method is unable to provide any information about tracer depth distributions and suitable diffusion models must therefore be presumed, rendering the method non-sensitive towards diffusion anisotropy or structural inhomogeneities. The here presented results of potassium diffusion were obtained on gem-quality single-crystal alkali feldspar utilizing the on-line diffusion chamber located at the ISOLDE facility in off-line mode. The natural, single-crystal sanidine from Volkesfeld, Germany, was implanted with ^{43}K at the ISOLDE/CERN radioactive ion-beam facility normal to the (001) crystallographic plane. Afterwards, isothermal annealing was done in a temperature range from 1021 to 1169 K followed by serial sectioning via ion-beam sputtering and recording of the corresponding γ-spectra of each section with a NaI-detector. The diffusion coefficients, derived from the obtained tracer penetration depth profiles, can be well described by the Arrhenius equation with an activation energy of 2.4 eV and a pre-exponential factor of 5×10^{-6} m^2/s. This is more than three orders-of-magnitude lower than the ^{22}Na diffusivity in the same feldspar with the same crystallographic direction ruling out a vacancy controlled diffusion mechanism for alkali diffusion in alkali feldspar. State-of-the-art considerations including ionic conductivity data on the same crystal type and Monte Carlo simulations of diffusion in random binary alloy structures reveal a predominance of indirect interstitial jumps (I-S/S-I) over direct interstitial jumps (I-I), pointing towards correlated motion of K and Na through the interstitialcy mechanism.

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Probing the local structure in Multiferroic $SmCrO_3$

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Rare-earth orthochromites of the formula $RCrO_3$ R=Dy, Pr, Ho, Yb, Er, Y, Lu, Sm are currently at the center of great controversy regarding ferroelectricity. While dielectric constant anomalies near $400 - 500$ K in the heavier rare-earth chromites were associated with non-centrosymmetry, others claim that the polarization observed in these systems is due to the combined effect of the electric applied field, that breaks the symmetry, and exchange-field on the R ion from the Cr sub-lattice. Accordingly to these claims, no spontaneous ferroelectric polar-order exists in these systems and the presence of a magnetic R-ion is essential to induce a metastable ferroelectric state. Contrarily, the appearance of ferroelectricity without direct correlation to the magnetic order, arising from polar octahedral rotations and/or cation displacements, was recently claimed. [1,2]
Clearly, additional efforts are needed to definitely validate these claims. Since these properties might emerge from local structural landscapes that are not well described by long-range average structural methods, the use of local probe studies, such as Perturbed Angular Correlation (PAC) spectroscopy, provide relevant knowledge.
In this work the $SmCrO_3$ compound was studied. The temperature dependent of the electric field gradient (EFG) on $SmCrO_3$ compound was followed, using the ^{111}Cd PAC probe, in the 16 K<T$<$ 723 K temperature range. A temperature range that spans over the important transition temperatures, namely the reported ferroelectric transition (T_{FE} ≈220 K), the magnetic ordering of Cr atoms sublattice (T_N^{Cr} =133 K), the spin reorientation (T_{SR} =34 K) and magnetic ordering of Sm atoms sublattice (T_N^{Sm} =20 K). The ^{111m}Cd implantation and ^{111}Cd->^{111}In diffusion was followed by an annealing at high temperatures in air.
At high temperatures, T>300 K, a frequency triplet corresponding to a single EFG, $i.e.$, one probe local environment, was observed and in this temperature range no significant changes occur in the spectra when the temperature is lowered. However, below 300 K visible changes can be observed in the perturbation function ($R(t)$) data and in the corresponding Fourier transforms. In detail, a second EFG emerges and its relative abundance increases with decreasing temperature. Accordingly, the fits to the $R(t)$ experimental data were performed considering only one static EFG distribution, which was assumed to be Lorentzian-like, for T>300 K while two EFG distributions had to be considered to account for the features that emerge below that temperature.
The spectra obtained at high temperatures revealed an EFG characterized by a $V_{ZZ}^{\mathrm{Sm_1}}$ ≈76 V/m^2 and an asymmetry parameter $\eta \approx 0.2$ in good agreement with similar systems. The second EFG, that emerges at low temperatures, is characterized by a similar fundamental frequency but a higher asymmetry parameter $\eta \approx 0.6$.
From our data we observed that a distortion of the high temperature local environment start to develop below 300 K within the paramagnetic phase. Although our data might be compatible with the most recent reports, where polar octahedral rotations and/or cation displacements are at the origin of a polar order in the paramagnetic state, remarkably, our results point to a more subtle scenario, where locally an inhomogeneous state emerges. In this new state regular and distorted environments (most probably polar and non polar states) coexist.

[1] https://doi.org/10.1103/PhysRevB.86.214409.
[2] https://10.1209/0295-5075/107/47012.

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Looking Through Double Charge Exchange Reactions

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So far, double charge exchange reactions have been less explored than single charge exchange reactions. We have revisited double charge exchange reactions and found their discovery potentials in two cases: one is production of a tetraneutron state and the other is a search for double Gamow-Teller Giant resonances. In the both cases, new techniques which exploit properties of exotic nuclei

have been used[1].
The first case is a production of tetraneutron state via the double charge exchange 4He(8He; 8Be) reaction. This reaction with a large positiveQ-value (exothermic) is particularly efficient in producing the fragile tetraneutron state with a recoilless manner. We have identified a (narrow) peak that can be a candidate of the tetraneutron state[2]. The existence of the state close to the threshold may indicate
necessity of force(s) that is attractive among neutrons.
The second case is a search for double Gamow-Teller giant resonances (DGTGR). DGTGR has been kept yet-to-be-discovered since the first theoretical prediction in 1989[3]. We have started an experimental program to search for DGTGR with a newly-invented method based on use of the heavy-ion double charge exchange (12C;12 Be(0+2
))[4]. This reaction has strong points that are missing in previously employed reactions and is quite efficient in populating DGTGR. In the workshop, results of the first experiment performed for a 48Ca target with a 100-MeV 12C
beam at RCNP, Osaka University are presented.
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Septempber, 2016.

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Progress on the FRIB project and future plans

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The Facility for Rare Isotope Beams (FRIB) being built at Michigan State University (MSU), is based on a 400 kW, 200 MeV/u heavy ion driver linac. Once completed, FRIB will offer world-unique opportunities for rare isotope science. It will provide a wide variety of high-quality beams of unstable isotopes at unprecedented intensities, opening exciting research perspectives with fast, stopped, and reaccelerated beams. New experiments will become possible to explore nuclear structure very far from stability and to provide information critical for the explanation of the element abundances observed in the universe as well as for the study of fundamental symmetries. Moreover, new applications of isotopes to meet societal needs will become available at high intensities. This contribution will present the main scientific goals of FRIB as well as the status of the construction, with focus on accelerator techniques needed to reach the intense rare isotope beams FRIB will provide. Moreover, the present status and future plans for the various stopping beam facilities as well as the Reaccelerator will be presented.

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NUSTAR experiments on the way from GSI to FAIR

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The NUSTAR Collaboration will perform experiments with relativistic exotic nuclei at GSI and FAIR. Presently, several new FAIR detector systems are under construction for high-resolution spectrometer experiments, decay spectroscopy, reaction studies with internal or external targets, and for

experiments with stopped beams. Due to the delayed start of the FAIR project, several prototypes or start versions of larger detectors systems will be used at GSI with beams from the existing accelerators (UNILAC, SIS-18) and set the scene for new experimental avenues, not possible so far. The planned intermediate research programme, the new opportunities and recent results will be presented.

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Recent results and developments at CARIBU

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CARIBU provides neutron-rich low-energy and reaccelerated beams to the ATLAS user's community. It is unique in that it relies on spontaneous fission from a 252Cf source to produce the neutron-rich isotopes that are cooled and extracted as a low-energy beam using a large gas catcher and guiding radio-frequency structures. These beams are accelerated to 50 kV, purified by a compact high-resolution separator, and subsequently delivered to either a low-energy experimental area or reaccelerated to above the Coulomb barrier using the ATLAS superconducting linac. Recent highlights from the CARIBU programs, including the Coulomb excitation reaccelerated beam campaign using neutron-rich beams from CARIBU with the combination of GRETINA and Chico-II, and the new mass measurement results at low-energy using an improved Penning trap mass measurement technique, will be presented. In addition, recent upgrades to reduce beam contamination of both low-energy and reaccelerated beams using a new MRTOF spectrometer and an EBIS charge-breeder will be briefly described, together with the installation of a new low-energy experimental area with much lower radioactivity background for decay spectroscopy.

This work was supported by the US DOE, Office of Nuclear Physics, under contract DE-AC02-06CH11357.

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Light nuclei, new set-ups, persistent challenges

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The lightest nuclei present physics problems where progress is only made incrementally and slowly. New instrumentation is then essential for further advances. We present here two examples taken from ISOLDE runs in 2016.

The first problem is motivated in the astrophysically very important 12C(a,g)16O reaction. The cross section of this reaction at energies relevant to stellar helium burning is still not known with sufficient accuracy. An important constraint comes from the beta-delayed alpha spectrum from 16N, but the litterature value of the absolute branching ratio has recently been questioned. The improvement in experimental sensitivity coming from the IDS set-up triggered a new experiment that was performed in May 2016. Preliminary results from this run will be presented.

The second long-standing problem is to understand the structure of the unbound nucleus 10Li and of the two-neutron halo nucleus 11Li. Earlier reaction experiments at REX-ISOLDE suffered from the limited energy available, the recent energy upgrade in HIE-ISOLDE clearly allows for more detailed investigations. As a first step the neutron transfer reaction from 9Li +2H to 10Li+p was performed in the Scattering Experiments Chamber (SEC) at the XT02 beam-line in November 2016. The one-neutron transfer to 9Li will populate excited states as well as low lying resonances in 10Li. The higher reaction energy gives better solid angle and angular coverage for charged particles, the set-up furthermore included for the first time a neutron detector array. The semi-permanent installation in the SEC at the XT02 beam line, which will be able to host many of the forthcoming scattering experiments at HIE-ISOLDE, will be described and preliminary data shown.

Finally, the continuation of these experiments will be briefly discussed.

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Perspectives for nuclear astrophysics with radioactive beams

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The Nuclear Physics European Collaboration Committee (NuPECC) has launched Long Range Plan 2017 for nuclear physics. The working group on nuclear astrophysics has produced a review of the field with perspectives and recommendations for future. New and upgraded radioactive beam facilities will provide novel opportunities for nuclear astrophysics experiments in the near future. In this contribution, hot topics for nuclear astrophysics with radioactive beams will be discussed in light of the new Long Range Plan.

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7Be(n,a) AND 7Be(n,p) CROSS-SECTION SECTION MEASUREMENT FOR THE COSMOLOGICAL LITHIUM PROBLEM AT THE n_TOF FACILITY AT CERN

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One of the most important unresolved problems in Nuclear Astrophysics is the so-called "Cosmological Lithium problem" (CLiP). It refers to the large discrepancy (factor 3-5) between the abundance of primordial 7Li predicted by the standard theory of Big Bang Nucleosynthesis (BBN) and the value inferred from the so-called "Spite plateau" in halo stars.
In the framework of Standard Model, a possible explanation for this longstanding puzzle is related to the incorrect estimation of the destruction rate of 7Be. Indeed in the standard theory of BBN, 95% of primordial 7Li is produced by the decay of 7Be (t1/2=53.2 days), relatively late after the Big Bang, when lower temperature of Universe allows electrons and nuclei to combine into atoms. Therefore, the abundance of 7Li is essentially determined by the production and destruction of 7Be.
While charged-particle induced reactions responsible for the destruction of 7Be have mostly been ruled out by recent measurements, data on the 7Be(n,a) and 7Be(n,p) reactions were so far scarce or completely missing, mainly due to experimental difficulties arising from 7Be specific activity.
Recently, both reaction cross-sections have been measured at n_TOF (CERN) taking advantage also of state-of-art techniques for the production of high-purity radioactive samples at ISOLDE, of high performance detection systems and, especially, of the innovative features of the new measuring station n_TOF-EAR2 particularly suited for challenging measurements on short-lived radioisotopes.
The two measurements provide for the first time nuclear data on 7Be(n,a) and 7Be(n,p) cross-section

in a wide neutron energy range, namely in the energy range of interest for Nuclear Astrophysics.

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Spectroscopy of conversion electrons with LN2 cooled Si(Li) detector at the TATRA spectrometer

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183Hg -> 183Au decay was studied using the TATRA system. Conversion electrons were detected with the LN2 cooled windowless Si(Li) detector. The tape system was operated at 8E-8 mbar, therefore no deposition of mist on the surface of cold detector was observed during the run. The FWHM of 1.3 keV for conversion electrons above 100 keV was achieved, which is almost comparable with previous measurement, which employed magnetic spectrometer. Simultaneously, the gamma rays were detected with array of coaxial and novel Broad Energy germanium (BEGe) detectors. Very good energy resolution of BEGe detector was used to construct the level scheme of 183Au, which has large density of excited states at low energy. In the talk, fundaments of the shape coexistence in odd-Au isotopes, technical details of system for detection of conversion electrons and level scheme of 183Au will be presented.

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Towards On-Line High-resolution In-source Laser Spectroscopy: A Perpendicular Laser – Atom Beam Upgrade for the Laser Ion Source and Trap LIST

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Highly selective and efficient laser ion sources are of fundamental importance to study atomic and nuclear properties along the nuclear chart. Upgrading the well-established, highly element-selective laser resonance ionization technique with additional suppression of isobaric contaminations immediately at the exit of the hot ion source cavity led to the development of the Laser Ion Source and Trap LIST. In the past few years it was successfully used e.g. for investigations on neutron-rich polonium isotopes which were previously not experimentally accessible due to the overwhelming fraction of surface ionized francium [1, 2].
For highest precision in spectroscopic studies and isomer-selective ionization, a perpendicular laser -atom beam interaction geometry based on robust metal mirrors was integrated into the LIST's RFQ ion guide structure. This reduces the experimentally realized spectral linewidth dominated by the Doppler broadening in the hot atom vapor from a few GHz down to below 100 MHz. At the ISOLDE-like off-line RISIKO mass separator at Mainz University, hyperfine structure studies were performed on the long-lived radioisotopes 163,166mHo using frequency-doubled narrow band-width radiation

of an injection-locked high repetition rate titanium:sapphire laser. Measurements and first results as well as opportunities and constraints for a future on-line implementation of this novel PI-LIST (Perpendicularly Illuminated) design are discussed.

Poster Session / 55

Lattice location and properties of Fe in Mn doped (Al, Ga)N

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Gallium nitride (GaN) and related compounds represent a unique class of semiconductors with extraordinary properties related to their crystal structure, optical-, and electrical response.
Their exceptional properties have turned them into building-blocks for a wide range of state-of-the-art applications in optoelectronic and high-frequency devices including light emitting diodes, laser diodes and high power field effect transistors. When doped with a few percents of Mn cations and in the presence of free holes, GaN has been predicted to be a magnetic semiconductor with Curie temperature above room temperature. Mixed semiconductors of AlxGa1-xN (AlGaN) composition, give rise to unexpected and critical magnetic and photonic functionalities when doped with magnetic ion species. . In order to gain control on the properties of the systems, it is of paramount importance to determine the charge state and the arrangement of the metal ions in the lattice.
We have thoroughly characterized AlGaN doped with Mn utilizing extremely dilute 57Mn (T½ = 1.5 min) for 57Fe emission Mössbauer spectroscopy as a part of our IS576 experiment. The Mössbauer spectra give information on the electronic configuration of the implanted probe atoms and on the magnetic properties, thus providing insight into the physics of the materials at the atomic-scale.
Implantation damage i.e. Fe in non-crystalline regions generated by the implantation process is only observed for implantation temperatures below 200 K. This demonstrates the possibilities of doping AlGaN with ion-implantation. In non-Mn doped samples, most of the Fe (~70%) is observed as Fe2+ on substitutional Al/Ga sites associated with nitrogen vacancies and partly as Fe3+ on defect free substitutional sites. In Mn doped samples, Fe4+ is observed instead of Fe3+, pointing at Mn as acceptor. No evidence for magnetic ordering of Fe is observed.

Poster Session / 56

Investigation of single-particle states in the 132Sn region: study of the Beta decay of 133In and 134In

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The region of the chart of nuclei close to the doubly-magic nucleus 132Sn has been the object of enormous interest in both experimental and theoretical investigations for the last several years. This activity is well-motivated by the fact that nuclei with large neutron excess are an ideal playground to verify the reliability of shell model predictions for nuclei far from stability. Crossing of the major neutron (N=82) and proton (Z=50) shell closures allows for investigation of single-particle states and interaction strengths in this neutron-rich region.
Our studies focus on the closest neighbours of 132Sn in order to investigate neutron single-particle states: one-neutron particle 133Sn and two-neutron particle 134Sn. A better understanding of the neutron-rich 132Sn region requires not only more data but also more precise.
In June 2016 fast timing and spectroscopy were employed together at the ISOLDE Decay Station to study doubly magic 132Sn and its neighbours, including 132Sn,133Sn and 134Sn nuclei. Sn nuclei

were populated in decay of In isomers, produced from a UCx target unit equipped with a neutron converter. Selective isomer ionisation provided by ISOLDE RILIS for odd-A 133In enabled to extend knowledge about the structure of 133Sn, which is the main player to deduce single-particle states in this region. In particular, the analysis of decay branch of 133In in conjuction with -n decay branch of 134In can bring more information about the position of the p1=2 single-particle orbit, for which a strong candidate was proposed [1], while the question about the position of i13=2 still remains open for investigation.
Details of experimental setup and preliminary results will be presented. In comparison to previous measurements exploring 132Sn region, the sensitivity was enhanced thanks to the use of highly efficient clover-type Ge detectors and a new generation of fast timing detectors with LaBr3(Ce) crystals.
[1] P. Hoff et al., Phys. Rev. Lett. 77, 1020 (1996).

Poster Session / 9

Online prototype TiC-carbon nanocomposite target material: constant release properties and material development

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Highly porous nanograined materials have been developed throughout the last 10 years at ISOLDE-CERN, to deliver high and stable intensities of radioactive ion beams. The small grains provide short diffusion distances to the produced isotopes, while, after evaporation from the grain surface, the high porosity is beneficial for the isotope to escape the material envelope.

Embossed and rolled Ti metal foils of 30 µm thickness, have been used at ISOLDE to deliver beams of Sc, Ca and K. However, even though they provide good beam intensities in the beginning, their intensity rapidly decays over operation time. TiC is a highly refractory material with potential to become an ISOL nanometric material even though it has been discarded in the past in its 1-50 µm particle form.

Since nanometric TiC sinters at T>1500 ℃, TiC-C nanocomposites were developed to improve its stability, where C is either graphite, carbon black (CB) or multi wall carbon nanotubes (MWCNT). The selected nanocomposites were irradiated using the MEDICIS montrac system and studied for release using the solid state diffusion chamber at ISOLDE. TiC-CB presented the best release properties. This material was then upscaled to produce a full target and tested at ISOLDE as a prototype (#527) with a Re surface ion source.

The TiC-CB target release was tested from 1300 to 2000 ℃ showing improved yields of Na and Li in comparison with the best Ti foils target yields. However, lower yields on K and Ca were obtained, where we suspect that the CB may be hindering the release of these elements. Nonetheless, contrarily to Ti foils, the yields were stable during the full prototype operation period. An apparently longer release time-structure was observed for all isotopes as seen for other nanomaterials operated at ISOLDE.

The new TiC target provides improvements on some of the beams available for the physics program from the Ti-based target materials at ISOLDE. Nevertheless, an improved TiC-MWCNT nanocomposite has now been developed and waits prototype testing with the purpose of improving the n-def K and Ca yields, such as 35Ca and 35K.

Poster Session / 45

Emission Channeling with Timepix position sensitive dectectors

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Electron emission channeling accurately measures the lattice location of radioactive impurities in single crystals by looking at the anisotropic emission of decay electrons (beta particles or conversion electrons) in the vicinity of major crystallographic directions. Lately, the search for the advantages that modern position-sensitive detectors (PSDs) can bring motivated several emission channeling measurements with a Timepix detector. Timepix is a CERN developed PSD with a matrix of 512*512 pixels of 55 um size. The characteristics of the Timepix sensor and its readout system provide a method of measuring beta emission channeling patterns with lower background from X rays and gammas, and with higher angular resolution than provided by currently used PSDs with much larger pixel size. Here we will explain methods for using Timepix for electron emission channeling and illustrate this with the case of lattice location studies for 24Na in GaN. We will also look into the effect that improvements in detection characteristics have upon the observables in lattice location experiments, in particular the accuracy of locating the probe atoms in the crystallographic unit cell.

Poster Session / 35

Perturbed Angular Correlations with Short-Lived Isotopes, the PAC-SLI setup

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Time Differential Perturbed Angular Correlation of γ-rays (TDPAC) experiments were performed in late 2014 for the first time using the decay cascade from 68mCu (6-, 721 keV, 3.75 min) at the VITO beam line at ISOLDE-CERN. Due to the relatively short half-life the TDPAC measurements were performed online at an improvised provisional experimental setup, where selected samples were chosen such that implanted Cu was expected to occupy regular sites, defects free, at room temperature. The successful work allowed the characterization of the nuclear moments of 2+, 84.1 keV, 7.84 ns state and 68mCu/Cu can now be considered a new and unique Cu probe nucleus for TDPAC for future applications in the fields of materials physics, chemistry and biophysics [1].

Ideal experimental conditions to perform TDPAC measurement with short lived isotopes require a complex technical solution. In this work, we present one possible solution where we describe the main features of a "PAC Short Lived Isotope" set-up, PAC-SLI, set-up under development, motivated and dedicated to the use of the new 68mCu/68Cu TDPAC isotope.

Main features:

- All blocks (collecting chamber, furnace, 4 detector PAC, variable diaphragm, HV block) are mounted on a movable cradle, with full 3D regulation.

- The sample holder allows for very rapid heating and cooling cycles of the implanted sample. This block is easily extracted for sample changing. It includes measuring sockets for the beam current and sample temperature.
- Drive - actuated from the outside supports, the movable furnace that can be inserted/removed around the sample with an up-down movement. Includes: sockets for furnace power leads and temperature control and furnace up-down interlocks.
- Targeted parameters: impinging beam diameter from 18 to 5 mm (5 steps); furnace temperature over 700 ℃, sample cool down from maximum sample temperature in about 30 s, minimal full cycle around 5min. (collecting, measuring, heating, cooling).

References
[1] – A. S. Fenta et al., "The 68mCu/68Cu isotope as a new probe for hyperfine studies: the nuclear moments", Accepted by EPL – 10/2016.

Poster Session / 34

Determining the spectroscopic quadrupole moment of the first 2+ state in 36Ar

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The work presented here pertains measuring the sign and magnitude of the spectroscopic quadrupole moment for the first excited 2+ state, Qs(2+), in 36Ar. This was done through a Coulomb excitation measurement using the reorientation effect at safe energies. The measurement was performed using a distance between nuclear surfaces of at least 6.5 fm as proposed by Spear in 1981 for light nuclei [1]. This distance ensures that there are no nuclear excitations taking place which could obscure the results. The Qs(2+) value was previously measured in 1971 by Nakai and collaborators [2] using a 206Pb target with a minimum safe distance between nuclear surfaces of 4.3 fm, and may be influenced by nuclear excitations. The additional assumption of a spherical shape for the first 2+ state in 206Pb was also unadequate [3]. The yielded Qs(2+) value by Nakai and collaborators is Qs(2+)=+11(6) efm2, with a large uncertainty. This is the only measurent of Qs(2+) in 36Ar and the one currently accepted in the NNDC.
A particle-gamma coincidence experiment was carried out at iThemba LABS last May 2016 to study the first 2+ state in 36Ar. A 1mg/cm2 194Pt target was bombarded with 36Ar beams at 134 MeV. The gamma rays were detected using 8 clover detectors whereas the scattered particles were detected using an S3 double-sided silicon detector at backward angles. A GEANT simulation of Rutherford scattered particles onto the S3 detector was implemented for calibration and testing purposes. An accurate measurement of Qs will help in understanding the shape evolution and deformation of nuclei in this region, in particular the zig zag of quadrupole shapes observed at the end of the sd shell. Other measurements aimed at determinining the Qs(2+) values in 20Ne, 32S and 40Ar were also carried out at iThemba LABS during a two-month Coulomb-excitation campaign and will be presented at the ISOLDE workshop.

[1] R. H. Spear, Phys. Rep. 73 (1981) 369.
[2] K. Nakai, F. S. Stephens and R. M. Diamond, Phys. Lett. 34B (1971) 389.
[3] A.M.R. Joye, A. M. Baxter, S. Hinds, D. C. Kean and R. H. Spear, Phys. Lett. 72B (1978) 307.

Poster Session / 31

Optical mean square charge radii of Ni isotopes using collinear laser spectroscopy

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Laser spectroscopy enables a reliable determination of nuclear ground-state spins, moments and mean-square charge radii. Optical isotope shifts and hyperfine structures were measured for Ni (Z = 28) isotopes on the atomic transition $3d^9 4s^1\ ^3D_3 \rightarrow 3d^9 4p^1\ ^3P_2$ at 353.45nm. By using the COLLAPS setup at CERN-ISOLDE, measurements of $^{58-68,70}$Ni were made in the first online experiment.

The experiment provides results across *N* = 40 where a closed sub-shell nature has attracted substantial experimental and theoretical interest. The sub-shell gap is expected to be particularly significant for 68Ni where the excitation energy of the first 2^+ state is above 2 MeV. A signature of neutron-shell closures, which is always observed at magic number above *N* = 20 (i.e. \textit{N} = 28,50,82,126), would be a 'kink' in the mean square charge radii of an isotopic chain. Thus the present work provides a test of the structural significance of the *N* = 40 shell gap. The present preliminary results will be compared with the radii of Ga [1] and Cu [2] where weak charge radii effects at *N* = 40 have been observed.

[1] T. J. Procter $et\ al.$, Phys. Rev. C 6, 034329 (2012).

[2] M. L. Bissell $et\ al.$, Phys. Rev. C 93, 064318 (2016).

Poster Session / 26

Development and first results of the laser polarization and beta-asymmetry setups at the VITO beamline

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The VITO beamline (Versatile Ion-polarized Techniques Online) is the result of a recent initiative to combine several hyperfine interaction techniques requiring both spin-polarized and unpolarized nuclei for experiments relevant to material and life sciences, as well as nuclear physics and fundamental interactions studies. The first online experiment at VITO was performed at the end of 2014 and used the PAC technique on unpolarized ^{68m}Cu [1]. In 2016 extensive design and simulation effort was devoted to the laser polarization and β-NMR setups. As a result, starting this summer, the beamline has been modified significantly and the atomic and ionic laser polarization and β-detection setups have been added. These setups have been commissioned at the end of September with a radioactive ^{26}Na beam, whose atomic hyperfine structure has been successfully observed via its β-decay. This commissioning beamtime has pointed to possible improvements which are integrated into the beamline.

In this presentation the developments towards a dedicated beam line for laser-polarization of atoms and ions will be presented, along with the results from the first commissioning tests using a polarized ^{26}Na atom beam. An outlook towards the measurement of the β-asymmetry parameter in ^{35}Ar, relevant for the determination of the V_{ud} matrix element of the CKM matrix using a polarized ^{35}Ar beam [2], will be presented.

[1] Fenta A. S. et al., accepted in EPL (2016)

[2] IS601, Measurement of the Beta asymmetry parameter in Ar decay with a laser polarized beam, Velten, Ph. and Bissell, M. L.

Poster Session / 25

Collinear resonance ionization spectroscopy of francium and radium

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Co-authors: Adam Robert Vernon [1]; Agota Koszorus [2]; Bruce Marsh [3]; Christoph Seiffert [3]; Cory Binnersley [1]; Gerda Neyens [2]; Gregory James Farooq-Smith [1]; Hinko Henry Stroke [4]; Jonathan Billowes [1]; Kara Marie Lynch [3]; Kieran Flanagan [1]; Klaus Wendt [5]; Mark Bissell [1]; Maxim Seliverstov [6]; Pascal Naubereit [5]; Pavel Molkanov [7]; Ronald Fernando Garcia Ruiz [1]; Ruben Pieter De Groote [2]; Sebastian Rothe [1]; Serge Franchoo [8]; Thomas Day Goodacre [1]; Thomas Elias Cocolios [9]; Tobias Kron [5]; Wouter Anton M Gins [2]; Xiaofei Yang [2]; Zhengyu Xu [2]

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The propensity to adopt different shapes to minimize energy is a remarkable property of atomic nuclei. Nuclei around the $Z = 82$ shell closure exhibit a wide variety of these shapes. Low-lying excited states with different shape configurations to the ground state lead to shape-coexistence below the $N = 126$ shell closure. Additionally, octupole-deformed nuclei are found above the $N = 126$ shell closure. Model-independent measurements of nuclear spins, magnetic dipole moments, electric quadrupole moments and relative charge radii obtained through laser spectroscopy have played a key role in understanding the mechanisms driving these phenomena.

This work presents results from two experimental campaigns on neutron-deficient francium and neutron-rich radium exploring both sides of the $N = 126$ shell closure. By using collinear resonance ionization spectroscopy (CRIS), the quadrupole moment of ^{203}Fr was measured for the first time in addition to the ground-state properties of ^{231,233}Ra. These results allow an insight into the evolution of nuclear structure in two transitional regions: the approach of the $N = 104$ mid-shell from the $N = 126$ shell closure and the transition between octupole- and quadrupole-deformed nuclei above $N = 136$.

Poster Session / 30

Transfer reactions with 7Be to study the cosmological lithium problem

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Nuclear reactions involving the production and destruction of 7Be is very much relevant in search for a solution to the cosmological lithium problem. In the experiment IS 554, we plan to measure with better accuracy the destruction of 7Be through resonance excitation of 7Be (d,p) 8Be*. This is required before one can invoke solutions beyond nuclear physics, particularly the newly conjectured light electrically neutral particles X that have substantial interactions with nucleons. As of now, we

plan to use the scattering chamber installed on the second beamline of the HIE-ISOLDE facility. The chamber has sets of DSSD covering about 8 deg - 150 deg and thickness suitable for our experimental goals. We would be detecting the protons and alphas in coincidence. The Geant4 simulations in the NPTool framework would be presented.

Poster Session / 22

Development of a new RF cooler buncher for the CRIS experiment

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This poster will present the development of a new radio-frequency cooler buncher (RFCB) design for the collinear resonance ionisation spectroscopy (CRIS) experiment. A RFCB at CRIS would provide numerous benefits including the replication of online conditions during offline testing and would act as a beam energy reset; allowing CRIS to remain in a fixed setup. Due to spatial restrictions, a novel RFCB design based on an RF ion funnel has been constructed. This design has been developed using SIMION simulations, the results of which indicate that this could be a more compact option for a RFCB at CRIS.

Poster Session / 16

Investigation of octupole excitations in ^{207}Tl using $\gamma\gamma$ angular correlations at the ISOLDE Decay Station

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^{208}Pb is the heaviest stable doubly-magic nucleus and has been studied in great detail. Its first excited state occurs at 2.6 MeV and corresponds to an octupole vibration, resulting from the collective behaviour of a number of $E3$ ($\Delta l = \Delta j = 3$) particle excitations across the closed shell. This octupole transition has been observed in several other nuclei around ^{208}Pb, including the single proton-hole ^{207}Tl[1]. This nucleus has a number of known states; however, unambiguous spin-parity assignments are often missing[2]. It is expected that, given a $\frac{9}{2}^+$ ground state in ^{207}Hg and a Q-value of 4.8 MeV, β decay from ^{207}Hg should populate many of the states consisting of one of these proton-hole states coupled to the octupole 3^- vibration. \\

One experiment took place in 2014 and a second in 2016, both at the ISOLDE Decay Station (IDS) at CERN. Using the resident molten lead target on the General Purpose Separator (GPS), ^{207}Hg was produced at a rate of up to 5×10^4 pps in 2014, and $> 10^5$ pps in 2016. This was then impacted upon the tape at IDS and observed by an array of five HPGe detectors, the data sorted digitally with a Nutaq acquisition system. The first experiment utilised β gating to allow for the reliable observation of new γ transitions in ^{207}Tl, while the second operated at a higher rate un-gated in order to collect the necessary statistics for $\gamma - \gamma$ angular correlations between germanium crystals. \\

A new level scheme, including four new levels and many new transitions, has been established. While several types of spin-parity argument can be employed, the angular distribution of successive gamma rays in a cascade is known to give the most confident result. Here fourteen crystal-crystal angles were identified by modelling the detector arrangement in three dimensions. Single-crystal

add-back was also computed. From these calculations the spin of the level at 3273 keV is suggested to be equal to $\frac{7}{2}$. This would be the first successful application of angular correlation analysis at IDS, and an achievement given the limited granularity of the set-up. The aim of the analysis is to determine J^{π} for all levels observed here, before comparison with state-of-the-art shell model simulations. From this we plan to learn about how the vibration couples: a step towards the characterisation of the lead octupole excitation. \\[8mm]

\begin{footnotesize}
[1] O. Hansen \textit{et al.}, Nucl. Phys. A \textbf{127}, 71 (1969).

[2] B. Jonson \textit{et al.}, CERN 81-09 \textbf{2}, 640 (1981).

\end{footnotesize}

Poster Session / 10

The new implantation chamber at the GLM branch

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The new GLM chamber is being commissioned to replace the chamber that is currently in use at the GLM branch. It will greatly enhance the usability and the safety for the users as the operation will be completely automated. Users will only come into contact with the chamber when they place the sample into it. Every other step, like the evacuation and the actual implantation, will be handled by the software of the chamber. This will reduce the exposure to ionizing radiation for the user as well as the risk of damage to the chamber through misuse. The poster will present an overview of the chamber in general and will give an update to its software state.

HIE-ISOLDE Results / 6

Physics Results with HIE-ISOLDE

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In my talk, I will present first preliminary results of the 2016 campaign at HIE-ISOLDE with the MINIBALL and C-REX arrays and give an outlook for the planned experiments in the next years.

HIE-ISOLDE Results / 4

Coulomb excitation of ^{206}Po and ^{208,210}Rn

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The $B(E2; 2_1^+ \rightarrow 0_1^+)$ values have been measured in the ^{208,210}Rn and ^{206}Po nuclei by employing Coulomb excitation in inverse kinematics at CERN-ISOLDE using the MINIBALL γ-ray spectrometer. These nuclei have been proposed to lie in, or at the boundary of the region where the seniority scheme should persist. However, contributions from collective excitations are likely to be present

when moving away from the $N = 126$ shell closure. Such an effect is confirmed by the observed increased collective $2^+_1 \rightarrow 0^+_1$ transitions. Experimental results have been interpreted with the aid of theoretical studies carried out within the BCS-based QRPA framework. The present work contributes to understanding of nuclear structure around the doubly closed-shell nucleus ^{208}Pb.

HIE-ISOLDE Results / 42

Coulomb excitation of ^{110}Sn

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Neutron deficient ^{110}Sn has been studied in safe Coulomb excitation using the MINIBALL array at HIE-ISOLDE.
^{110}Sn was post accelerated to 4.5 MeV/u and excited against a ^{206}Pb target.
Previous measurements performed at REX-ISOLDE measured the reduced transition probability, B(E2), of ^{106,108,110}Sn to the first excited 2^+ state with a precision of ~10-20\%.
These values shows a deviation from predictions made by large-scale shell model calculations.
In this experiment the B(E2) value of ^{110}Sn has been remeasured with a higher precision.
Some preliminary results will be presented.

HIE-ISOLDE Results / 13

Studying the evolution of the nuclear structure along the zinc isotopic chain, close to ^{78}Ni, via multi-step Coulomb excitation

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Few nuclei have attracted as much attention as ^{78}Ni in the last decades, but unfortunately it remains out of reach of current generation ISOL facilities. For this reason, with only two protons above nickel, and the increasing occupation of neutrons in the $1g_{9/2}$ orbital, neutron-rich Zn isotopes are ideally suited to study the evolution of the proton shell gap, Z = 28, and the stability of the neutron shell gap, N = 50, near the doubly magic ^{78}Ni. During the last 10 years, several experiments were performed with the aim of studying the collectivity in the even-even Zn isotopes between N =40 and N = 50 [1-4], with different results. As a consequence, the interpretation of the neutron-rich Zn region is not fully understood.

For many years, several Coulomb excitation experiments have been successfully performed at REX-ISOLDE in combination with the powerful gamma spectrometer MINIBALL. These achievements have been produced due to the high intensity and the high purity of the exotic beams in this facility, being the energy of the beams the main limitation. Since middle of 2015, the post acceleration beam line at ISOLDE is being renewed, from 3.0 in 2012 to 10.0 MeV/u in 2018. Thanks to this new high beam energy, the multi-step Coulomb excitation process starts to play a relevant role, enabling us populate different low-lying and no-yrast states. Hence, this combination will allow going more in depth in the nuclear structure.

On this way, the first HIE-ISOLDE beam experiment in 2015 and one of the experiments performed this year were dedicated to the study of the evolution of the nuclear structure along the zinc isotopic

chain, close to the doubly magic nucleus ^{78}Ni. The status of the analysis and some results will be presented.

[1] J. Van de Walle, et al. Phys. Rev. Lett. 99 14501 (2007).

[2] J. Van de Walle, et al. Phys. Rev. C, 79:014309 (2009).

[3] M. Niikura et al., Phys. Rev. C 85 054321 (2012).

[4] C. Louchart, et al. Phys. Rev. C, 87:054302 (2013).

HIE-ISOLDE Results / 5

Transfer reaction measurements in inverse kinematics using a solenoid

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The availability of radioactive beams at energies (~10 MeV per nucleon) and intensities (>10^4 ions per second) conducive to transfer reaction measurements at HIE-ISOLDE will open up new opportunities for the study of the single-particle properties of nuclei in exotic systems. A new spectrometer, the ISOL Solenoidal Spectrometer (ISS), is being commissioned to exploit the available radioactive beams from HIE-ISOLDE. This spectrometer is based on the HELIOS concept [1], which has been successfully exploited for transfer reaction studies at Argonne National Laboratory. This presentation will provide an overview of a selection of measurements made using the HELIOS spectrometer at Argonne as well as providing an update on the current status of the ISS project and the science proposals for early implementation of the spectrometer.

[1] J.C.Lighthall et al., Nuclear Instruments and Methods in Physics Research A622 (2010) 97.

Technical Session 1 / 37

First photodetachment studies on radioactive negative ions - Towards the electron affinity measurement of astatine

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Negatively charged ions are mainly stabilized through the electron correlation effect. A measure of their stability is their binding energy which is termed the electron affinity (EA). This fundamental quantity is, due to the almost general lack of bound excited states, the only atomic property that can be determined with high accuracy for negative ions. Together with the ionization potential (IP) of the element it determines the properties of the inter-atomic bonds in chemical compounds. For radioactive elements such as astatine, a measurement of the EA is essential to benchmark and improve computational chemistry methods assisting conventional chemistry research on artificially produced samples. The standard method to measure the EA is Laser Photodetachment Threshold (LPT) spectroscopy where negative ions interact with light from a frequency tunable laser and the onset of the photodetachment is detected.
We will present the results of the first LPT studies of radioactive ion beams at ISOLDE. The photodetachment threshold for the radiogenic iodine isotope ^{128}I was measured successfully, demonstrating

the performance of the upgraded GANDALPH experimental beam line. The first detection of photo-detached astatine atoms marks a milestone towards the determination of the EA of the element. An outlook to our future campaigns to study the EA of polonium and isotope shifts in the EA will be given.

Technical Session 1 / 61

Recent target developments at Isolde

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For the past 60 years, the ISOLDE facility has delivered beams of high intensity and quality to the community worldwide. To keep a leading role in the development of ISOL beam production, beams and target developments are constantly done to reach new types of isotopes, yet unmet intensities or purity grades. These developments are done in various fields such as material science, ion source and mechanical design of the targets amongst others.
In this talk, an overview of the last beam developments of 2016 will be presented. A specific attention will be given to a few beams (8Boron beam, 64Germanium beam). Furthermore, a presentation of the results obtained with the Isolde negative ion source MK4 coupled to a mixed Th/Ta foil target operated in 2016 will be done, which could produce pure negative Astatine beams. An overview of the operational issues of 2016 will also be presented, together with the next required developments.
Finally, the upcoming development will be shown, with a specific highlight on the LIEBE target that should be operated in ISOLDE at the end of 2017, together with the development of a concentric neutron converter geometry or molecular refractory beams.

Technical Session 1 / 19

A fast recovery 60kV charging device for the ISOLDE target extraction voltage

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Among the different types of target, use of the neutron converter type has resulted in increased dynamic electrical load seen by the actual 60 kV extraction voltage modulator, with the consequence that the recovery time of the target voltage to the precision of 0.001% is delayed, which in turn reduce the possibilities for the detection of exotic isotopes with extremely short half-lives. This is the primary motivation for the development of a more robust charging device capable of re-establishing the target extraction high voltage with improved transient response. The validation of the performance of the new charging device has been realized in real operational condition at the ISOLDE facility considering the most severe beam induced leakage current at the maximum beam intensity. In this given case, representing the worst-case scenario, a substantial gain in term of recovery time over the actual modulator was achieved.

Technical Session 1 / 62

The ISOLDE RILIS in 2016, achievements, developments and future plans

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Highlights of the 2016 on-line period will be presented, together with the latest results from the continuous RILIS R&D undertaken at ISOLDE. Expanding RILIS capabilities increase the possibility for customized (experiment specific) operation.

The RILIS was requested for >75% of ISOLDE experiments in 2016. There have been a number highlights from the RILIS perspective. On the experimental side there have been two bismuth in-source spectroscopy experiments and by directing the RILIS lasers to GLM, a renewed campaign of electron affinity measurements at GANDALPH. On the ion beam production side, the RILIS mode of VADLIS operation was applied to selectively ionize magnesium for ISOLTRAP and operating with a reduced laser linewidth enabled both isomer selective ionization of indium for IDS and isotope selective ionization of beryllium for collections for n_TOF/SARAF.

There have also been a number of RILIS developments. The efficiency of the new RILIS tellurium ionization scheme was determined to be >18% at ISOLDE. New RILIS ionization schemes for radium were developed and applied twice for CRIS experiments. RILIS ionization of iron was demonstrated for the first time in collaboration with the ISOLTRAP MR-ToF MS team. Work on projects reported last year has continued, including the further application of an atomic beam unit (PISA) installed in the RILIS laser room for europium ionization scheme development and the re-establishing of 10 kHz ion beam micro-gating capabilities at ISOLDE.

Technical Session 2: HIE-ISOLDE / 59

Hardware commissioning of HIE ISOLDE in 2016

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After the first successful physics run with radioactive ion beams at HIE ISOLDE, in October 2015, the staged deployment of the linac continued in 2016 by adding a second cryomodule and by refurbishing the first one. During the physics run with one cryomodule, the second cryomodule was being assembled. The refurbishment of the first cryomodule was made necessary to overcome limits imposed by thermal instabilities of the fundamental coupler lines. A modified design for the power couplers was developed and implemented on all the cavities, after extensive validation tests in a vertical cryostat. The paper will describe the lessons learnt from the first commissioning campaign, in particular concerning the fundamental power coupler, the solution adopted, and the results of the 2106 commissioning campaign with two cryomodules, which will allow to reach 5.5 MeV/u for all the species available at ISOLDE.

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Beam Commissioning and Operations of the REX/HIE-ISOLDE Post-accelerator

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The High Intensity and Energy ISOLDE project (HIE-ISOLDE) is a major upgrade of the ISOLDE facility at CERN. The energy range of the post-accelerator will be extended from 2.85 MeV/u to 9.3 MeV/u for beams with A/q = 4.5 (and to 14.3 MeV/u for A/q = 2.5) once all the cryomodules of the superconducting accelerator are in place. The project has been divided into different phases, the first of which (two cryomodules and two HEBT lines) was completed in September 2016 after the machine was commissioned. A physics campaign followed with the delivery of radioactive beams to two different experimental stations. The main results of the tests conducted during the beam commissioning and the experience gained during the operations of the facility will be discussed in this presentation.

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Design of the Seamless HIE-ISOLDE Quarter Wave Resonator

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A new design of the Quarter Wave Resonator (QWR) for Cryomodule (CM) 4 will be presented. Since the performance of the recent QWRs produced seems limited by the welding at the highest radio-frequency (RF) magnetic field, intensive efforts have been made to design a seamless QWR without welding process. A beam port was removed for machining the whole shape of the cavity from a one single bulk copper material. This also benefited transit time factor of higher velocity inside CM4 than other CMs. A conicity was introduced on the outer wall in order to prevent RF leakage and recover the shunt impedance over quality factor. The beam dynamics in the new design was also calculated and turned out to be reasonable for CM4. A summary of mechanical design and current production status will be also shown.

Technical Session 2: HIE-ISOLDE / 32

RF operation of REX-ISOLDE

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The REX-ISOLDE post-accelerator comprises 7 RF cavities that are powered by their respective RF systems. Their purpose is the acceleration of radioactive ion beams of a wide spectrum of ion species from 5keV/u to up to 3MeV/u. This talk will provide a short introduction to the RF systems of this accelerator, and it will then focus on their operation and current limitations.

Nuclear Structure 2 / 63

Isospin mixing in nuclear states studied via beta-delayed proton emission

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We discuss a current status of the shell-model calculations with charge-dependent Hamiltonians. In an empirical approach, such a Hamiltonian includes a two-body Coulomb interaction and effective charge-dependent forces of nuclear origin, resulting in five or six additional parameters for an sd or pf shell, respectively.The accuracy of the method is demonstrated on the description of isobaric-mass multiplet splittings. We point out the main sources of uncertainties on theoretical values of the isospin mixing in nuclear states,resulting from the shell-model diagonalisation.

Then, we apply the shell model to study a beta-delayed proton emission process, including the isospin-forbidden particle emission from the IAS in a daughter nucleus. In particular, we show that experimental data on the proton to γ-ray branching ratio for the IAS, supplemented by a simple shell-model input, can be used to extract spectroscopic factors for that isospin-forbidden proton emission. In the case of a well-justified two-level mixing approximation, it is even possible to determine the amount of the isospin mixing in the IAS with robust precision. This conjecture is illustrated by the theoretical analysis of a number of pf shell emitters. The experimentally deduced values of the spectroscopic factors and isospin mixing are
confronted to theoretical values.

Nuclear Structure 2 / 23

Results from IDS

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A summary of the 2016 experimental campaign at the ISOLDE Decay Station will be presented alongside the preliminary results. The presentation will also include highlights of the already published results concerning the fast-timing study of 129Sn, the beta-delayed proton emission measurement of 20Mg and the 31Ar multi-particle decay experiment.

Nuclear Structure 2 / 38

Precision mass measurements of neutron-rich chromium isotopes and the development of ground-state collectivity towards N=40

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Exotic neutron-rich nuclei around *N*=40 exhibit rapid structural changes with proton and neutron number. While ⁶⁸Ni₄₀ shows signatures of a doubly magic nucleus, excitation energies and transition strengths suggest a rapid development of collectivity in the ground state of neutron-rich ₂₆Fe and ₂₄Cr isotopes towards *N*=40. Accurate masses in this region of the nuclear chart are essential to elaborate nuclear structure in what is now called the second "island of inversion". The masses of neutron-rich chromium isotopes were too imprecisely known to address the shape of the mass surface towards ⁶⁴Cr, where a maximal quadrupole deformation is thought to be reached. Although chromium was not considered to be a well-produced "ISOL" element, successful laser-ionization developments combined with high-sensitivity mass spectrometry enabled the mass measurements of ⁵²⁻⁶³Cr during two ISOLDE experimental campaigns in October 2014 and April 2016, using the Penning-trap mass spectrometer ISOLTRAP. These measurements greatly refine our knowledge of the mass surface in this region, indicating a progressive onset of collectivity towards *N*=40. The results of the measurement campaigns will be presented and compared to theoretical predictions.

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High-sensitivity and high-resolution laser spectroscopy of 76,77,78Cu at CRIS

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The Collinear Resonance Ionization Spectroscopy experiment (CRIS) at ISOLDE combines the high sensitivity of resonance ionization spectroscopy with the high resolution offered by collinear laser spectroscopy. The first experiments at CRIS demonstrated the ability to reach exotic isotopes, normally out of reach for collinear laser spectroscopy methods based on photon detection, with an intermediate resolution [1]. Further developments have focused on improving the resolving power, to the point where it now matches the resolution of other collinear laser spectroscopy methods [2]. With this performance, the CRIS experiment is ideally suited to study the evolution of nuclear structure in regions far from stability.

Several ISOLDE experiments have been working towards the region around the doubly magic 78Ni. Previous laser spectroscopy work [3-7] clearly demonstrated the inversion of the πf5/2 and the πp3/2 orbitals between 73Cu and 75Cu as the νg9/2 orbital is filled. This inversion is currently understood in terms of the tensor interaction between the neutrons and protons [8] which could potentially result in a quenching of the Z=28 shell gap towards N=50 [9].

This contribution will focus on the application of the high-resolution CRIS technique to the study of neutron-rich copper isotopes in the vicinity of N=50. The g-factors, quadrupole moments and charge radii of these neutron rich copper isotopes will provide additional information to gauge the robustness of the Z=28 shell in 78Ni. During the last campaign in April 2016, measurements have been performed on 15 Cu isotopes, including for the first time high resolution measurements of the very exotic isotopes 76,77,78Cu. These measurements, where 78Cu was produced at a rate of only 20 ions/s, provide information on the spin, magnetic moment, quadrupole moment and charge radius. The obtained data will be compared to large scale shell model calculations.

A brief discussion of the required technical developments for future work on even more exotic isotopes, including the doubly-magic+1p isotope 79Cu, will also be presented.

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Collinear Laser Spectroscopy of Bismuth at COLLAPS- The complementarity of optical and non-optical laser spectroscopy techniques.

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Bunched-beam collinear laser spectroscopy was added to the extensive list of techniques used to study the Bi isotopic chain at ISOLDE. The atomic hyperfine splitting in the transition previously employed for in-source laser spectroscopy was not fully resolved in the in-source measurements. As Bi is a well-known example of the Bohr-Weisskopf effect or "Hyperfine anomaly", it became apparent that to maximize the information available from the in-source campaign (IS608) a number of high-resolution measurements would be beneficial. In order to fix the hyperfine anomaly parameter in the fitting of the in-source data, systematic measurements of similar nuclear states are required. With this objective, high-resolution measurements were performed at COLLAPS for

209,208,205,201,199,198,197,196Bi. The results from these high-resolution scans will be presented and future opportunities to fully exploit this often underutilized nuclear structure observable, "the hyperfine anomaly" will be explored.
On behalf of the IS608 collaboration.

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Multi-particle emission from 31Ar at IDS

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In the beta decay of exotic nuclei, far from stability, the daughter nuclei might be formed in an excited state, which is unstable against particle emission. This phenomenon is called β-delayed particle emission and is due to a high Q-value and low separation energy for particle emission. The decay of the proton drip-line nucleus ^{31}Ar is one of the most exotic β-delayed multi-particle decays. It has a large Q-window and as a consequence many different β-delayed decay channels are open: βγ, βp, βpγ, β2p, β2pγ, β3p and perhaps also β3pγ [1].

<p>The aim of the IS577 experiment performed at the ISOLDE Decay Station (IDS) was the identification of the β3p and β3pγ-decays in ^{31}Ar as well as to provide important information on the resonances of ^{30}S and ^{29}P, relevant for the astrophysical rp-process [2].<p>The IDS is a new installation at ISOLDE devoted to β-decay measurements. This is the first time that one of these kind of experiments based on decay studies is carried out taking advantage of this permanent station. Our collaboration installed a new implantation chamber; the MAGISOL Si-Plugin Chamber, consisting in 5 Double Sided Si Strip Detectors (DSSSD) backed by un-segmented Si-pad detectors in ΔE-E telescope configuration. In addition, there are 4 HPGe clover-detectors surrounding the chamber for gamma detection. This setup is compact with high efficiency for both multi-particle emission and gamma ray detection with low cutoff energy as well.The Si-array detects multi proton emission over a wide energy range with the good energy (25 KeV) and angular (3^o) resolution that are needed to characterize the different p-channels of ^{31}Ar. Further, with this setup it is possible to measure proton-gamma and proton-proton coincidences, therefore, we can see gamma transitions from levels of ^{30}S and ^{29}P and determine the spin of levels of ^{30}S and ^{31}Cl, respectively. I will present here preliminary results, as one-proton-gated gamma spectrum and proton-proton angular correlations. [1]

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Neutrinoless double beta decay: An overview of the different experiments and latest results from GERDA

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The Standard Model of particle physics cannot explain the dominance of matter over anti-matter in our Universe. In many model extensions this is a very natural consequence of neutrinos being their own anti-particles (Majorana particles) which implies that a lepton number violating radioactive decay named neutrinoless double beta (0νββ) decay should exist. The detection of this extremely rare hypothetical process requires utmost suppression of any kind of backgrounds. In this talk I will summarize the current experimental projects and future perspectives. Special emphasis will be given to the latest results from the GERDA experiment that will be background-free up to its design exposure.

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First clinical SPECT imaging and characterisation of 155Tb from CERN-ISOLDE: towards a theranostic isotope quartet

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Introduction

Interest in the element terbium (Tb) for medical application has grown recently [1]. Four Tb isotopes have been identified with the potential to provide unique theranostic treatment strategies which combine cancer therapy with diagnostic imaging. The isotopes ^{155}Tb and ^{152}Tb can provide SPECT and PET imaging respectively [2], whilst ^{161}Tb can be used for beta− therapy and auger electron therapy [3] and ^{149}Tb for alpha therapy [4][5]. Using a combination of these isotopes as labels for radio-pharmaceuticals can provide both pre-therapy diagnostic imaging and post-therapy dosimetry and treatment optimisation using the same delivery vector. In order to validate the use of these isotopes for patient treatments extensive pre-clinical studies [1] are required to provide the foundation for future clinical trails.

Accurate determination of administered activity, traceable to a primary standard of radioactivity is essential for all radio-pharmaceuticals. Molecular radiotherapy (MRT) is a cancer therapy technique in which radioactive pharmaceuticals are administered to deliver a lethal radiation dose to malignant cells whilst sparing surrounding healthy tissue. Calculations of absorbed dose for MRT require the determination of the specific distribution of radioisotopes within the body - primarily from SPECT imaging. Clinical SPECT camera systems are typically optimised for imaging with 99mTc (Eγ = 140 keV), in contrast the decay of ^{155}Tb produces gamma rays of 87 keV, 105 keV, 180 keV and 262 keV. Establishing optimised SPECT imaging protocols for ^{155}Tb with a clinical camera system is a crucial first step in demonstrating the efficacy of ^{155}Tb for clinical applications.

Methods

Samples of ^{155}Tb were collected at the ISOLDE GLM beamline. The samples were imaged using a GE Discovery 670 SPECT/CT camera at The Christie NHS Foundation Trust (Manchester, UK). Data was acquired in 'list-mode' enabling retrospective projected SPECT images to be produced from scan data after the initial samples had decayed. Experimental SPECT/CT data was combined with a Monte Carlo simulation of the Discovery 670 SPECT camera [6] to optimise the energy windows and collimators used to acquire ^{155}Tb SPECT images. An additional sample of ^{155}Tb has been characterised for purity and activity using high precision gamma-ray spectroscopy at the UK National Physical Laboratory.

Results

Preliminary results will be presented on the characterisation of ^{155}Tb samples produced at CERN-ISOLDE. These results will be discussed in the context of providing a primary standard of activity for this isotope.

The first isotope-specific photopeak and scatter imaging energy windows for ^{155}Tb will be presented. The effect of applying these energy windows, calculated using a minimization method applied to data from a full MC simulated SPECT acquisition, to clinical SPECT/CT imaging will be discussed.

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[159Dy]THCPSi production at ISOLDE for radiation theranostics together with the IS528 collaboration

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The study of porous nanoparticles as drug carriers is a growing field in cancer-therapy research. The porous properties of the particle enable the anti-cancer drugs to be loaded inside the particles and the surface of the particle can be modified with targeting moieties. The nanoparticles are then injected into the bloodstream and with the penetrative capabilities of the nanoparticle the carried drugs can be targeted precisely to the tumour. This enables a high treatment efficiency together with a low strain on the surrounding tissue. Furthermore, as multiple drugs can be simultaneously loaded into the nanoparticle, a lower amount of pharmaceuticals could be needed.

Our project uses mesoporous silicon nanoparticles (PSi) which are biodegradable, and thus suitable for use in a living body [1]. As the PSi particles are loaded with drugs for cancer treatment, they can also be loaded with radionuclides. These nuclides can be used for tracing the migration of the particles inside the living body using nuclear imaging such as PET or SPECT tomography. The radionuclide implanted into the PSi particle can be chosen so that its specific radiative properties allow for both imaging and therapy at the same time [2]. Therefore, as the PSi particles reach the tumour cells, the loaded radionuclide can provide radiation treatment on a very local level.

To load the radioactivity into the PSi particles, we irradiated silicon wafers with a mesoporous THCPSi surface at ISOLDE in the spring of 2016 as part of the IS528 collaboration. The chosen radionuclide 159Dy with a half-life suitable for long in-vivo tests, was produced through proton-induced spallation of a tantalum target. The extracted ions were separated with the GPS and implanted into the silicon wafers in the GHM chamber. Close to 30 MBq of activity was obtained in four wafers, with a sufficient purity. The wafers were then post-processed into a particle distribution at the University of Helsinki, with roughly 20 MBq of total activity remaining for injection.

Prostate xenografts (5x106 PC-3MM2) were injected subcutaneously into the hip of 15 NMRI-Foxn1 nude mice. The [159Dy]THCPSi solution was then injected into the tumour. The injected activity varied between 20–150 kBq. In-vivo stability tests of the [159Dy]THCPSi particles were performed over three weeks on the tumour bearing nude mice. The activity of the tumour was measured at even time points and a biodistribution of ^{159}Dy was performed based on the harvested organs. Autoradiographic studies of histological sections of the tumours were performed with the state-of-the-art MPGD detector Le Beaver [3]. We have obtained very promising results on the stability of the [159Dy]THCPSi particles inside the tumour and we wish to present these together with our recent activities.

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VITO Laser Polarisation setup and bio Beta-NMR

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The VITO (Versatile Ion-polarized Techniques Online) is a new beamline at ISOLDE that was initiated in 2014 due to the high demand for polarized beams in different areas of research, such as atomic physics, nuclear physics, solid state physics and biophysics [1].

In 2016, intensive designing and off line testing of the laser polarization β-asymmetry setup took place. The first on-line tests with a radioactive laser polarized 26Na (I=3) ion beam were carried out in autumn. The hyperfine structure of 26Na was successfully observed through the β-decay asymmetry in a NaF crystal.

The present talk will focus on the spin polarized beams of atomic 26Na and ionic 31Mg (I=1/2) towards biological applications [2]. The beamline configuration for these cases will be shown and the challenges and possible solutions for liquid β-NMR experiments will be addressed. The talk will then focus on the search of the best liquid target candidate based on a series of conventional NMR experiments performed at 11.7 T using 25Mg (I=5/2) and 23Na (I=3/2) NMR on Mg and Na salts in different ionic liquids. The chemical shifts of the different samples and the relaxation times of selected samples, using the inversion recovery technique were determined and will be used as the reference for the upcoming β-NMR experiments. In this context it should be noted that similar chemical shifts for different isotopes are anticipated, whereas the relaxation times will be strongly dependent on the nuclear spin of the particular isotope. That is, whether it is a quadrupolar nucleus (I> ½) or not (I=1/2).

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Utilization of PAC of radioisotope trackers and DFT calculations to determine local environment of Hg(II) in dithiocarbamate functionalized particles for magnetic removal of Hg2+ from water

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Application of nanoparticles in water treatments attracts growing interest due to their high specific surface area and ability for chemical functionalization. In particular, functionalized iron oxide nanoparticles are promising sorbents because several pollutants (e.g. heavy metals) can be adsorbed and then removed from the solution by the application of an external magnetic field [1-2].
The present work aims to study the chemical mechanism behind the adsorption of the highly toxic mercury by magnetite particles with silica shells enriched in dithiocarbamate (DTC) groups [3-4], with total side diameters of approximately 50 and 100 nm.
Combining Perturbed Angular Correlations (PAC) Spectroscopy [5] of 199mHg with DFT calculations (LDA and GGA-PBE) we identify different local environments that characterize the position where the Hg is retained during the adsorption. For the non-enriched nanoparticles, we find that Hg mostly coordinates in a SiO2 environment, while for the nanoparticles functionalized with DTC groups Hg coordinates in an environment with two DTC units, at almost perpendicular HgS2 planes for each unit. In the functionalized nanoparticles which had been previously saturated with Hg, this environment is also predominant, but other fractions with SiO2 and SiO3 environments are now detected.
We also present an alternative method to determine the adhesion/uptake of Hg(II) by the different

types of nanoparticles, resorting to direct tracking of the radioisotope. This method presents some advantages with respect to the fluorometry analysis [3], such as a lower detection limit (pg/L should be easily achieved, in comparison to tens of ng/L in typical fluorescence spectroscopy) and a direct detection in the nanoparticles. This paves the way to studies of recycling and manipulation conditions as well as studies of the path taken by heavy metals in flora and fauna.

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Lattice location of implanted transition metals in 3C-SiC

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SiC is a wide band-gap semiconductor with several decades of material research and device development in high-power electronics with commercially successful applications. Transition metals (TM) impurities are invariably found in bulk samples of SiC due to the production processes normally employed. It is known that those impurities, either in their isolated form or when in complexes with other defects, generate electrically active levels deep in the band gap of SiC, changing its electrical properties and thus affecting the performance of devices. Currently hardly any experimental data exist on the preferential lattice sites that TM impurities occupy in any of the SiC polytypes.
We have investigated the lattice location of implanted 56Mn, 59Fe and 65Ni transition metals (TMs) in undoped single-crystalline cubic 3C-SiC by means of the emission channeling technique using radioactive isotopes produced at the CERN-ISOLDE facility. We find that in the room temperature as-implanted state the majority of Mn, Fe and Ni occupy the carbon coordinated tetrahedral interstitial sites (TC). Smaller TM fractions were also found on the Si substitutional (SSi) sites. The TM atoms partially disappear from ideal-TC positions during annealing at temperatures between 500 ℃ and 700℃ which is accompanied by an increase in both the TM fraction occupying the SSi sites and on random sites. An explanation is given according to what is known about the annealing mechanisms of silicon vacancies in silicon carbide. The origin of the observed lattice sites and their changes with thermal annealing are discussed and compared to the case of Si, highlighting the feature that the interstitial migration of TMs in SiC is much slower than in Si.

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The Electric Field Gradient: A systematic Density Functional Study for Hg adatoms on Graphene

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Graphene is a two-dimensional (2D) atomic crystal which consists of a single graphite layer with strong covalent bonds between carbon arranged in a hexagonal lattice. Since it was isolated by André Geim and Konstantin Novoselov in 2004, graphene has become a remarkable subject of research, exhibiting novel phenomena that extend to virtually every domain of material's science and applications [1,2]. Engineering of graphene with specific chemical and physical properties predicts a revolution in electronics technology such as field-effect transistors, transparent electrodes, energy-storage materials, composites, chemical and biosensing, among others. Thus, modifying graphene in a controllable way is envisaged in this context and, particularly, adsorption of atoms (adatoms) on graphene could be used to tailor physical and chemical properties [3,4].

In this context, we present density functional theory (DFT) calculations analysing the interaction between graphene and Hg adatoms: hence atomic positions and stability, binding energies, electronic structure, and electric field gradients (EFG) are predicted in this way. Particularly, the EFG is highly sensitive to the signature of the atomic position with respect to the graphene layer, charge state, and type of bonding (ionic, covalent, van der Waals). These calculations, actually, form the interpretation basis for the experiments, which are currently being prepared at the ISOLDE facility at CERN, using the ASPIC (Apparatus for Surface Physics and Interfaces at CERN) [5] setup, and further prepare the interpretation and modelling of already performed experiments studying water molecules interacting with graphene and heavy metal ions.

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Radioisotope Beam Production at TRIUMF in the ARIEL Era

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As the only ISOL facility worldwide, ISAC-TRIUMF is routinely operating targets under particle irradiation in the high-power regime in excess of 10 kW. TRIUMF's current flagship project ARIEL, Advanced Rare IsotopE Laboratory, will add three new target stations providing isotopes to the existing experimental stations in ISAC, to a dedicated collection station as well as for chemical post-processing and subsequent use for medical imaging and treatment. In addition to the existing 500 MeV, 50 kW proton driver from TRIUMF's cyclotron, ARIEL will make use of a 35 MeV, 100 kW electron beam from a newly installed superconducting linear accelerator. Together with additional 200 m of RIB beamlines within the radioisotope distribution complex, this will put TRIUMF in the unprecedented capability of delivering three RIB beams to different experiments, while producing radioisotopes for medical applications simultaneously – enhancing the scientific output of the laboratory significantly. General characteristics of the high-power target and beam delivery technology at ISAC and ARIEL will be presented, showing the opportunities and limitations. Moreover, the current status of the facility as well as the path to completion and ramp-up will be discussed.

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ISAC and ARIEL at TRIUMF

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An overview of the current science program for the ISAC facility at TRIUMF is given, and the status

and plans for the upcoming ARIEL facility will be presented.

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News from JYFL and studies of 0+ -> 0+ decays

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In this talk, I will give an overview of activities in the accelerator laboratory of University of Jyväskylä (JYFL) and most recent studies related to superallowed 0+ -> 0+ beta decays. Related to JYFL, I will mainly focus on mass measurements performed with the IGISOL ion guide technique and JYFLTRAP Penning trap combination, show news related to vacuum mode recoil separator MARA and also insight into the new ECR ion source HIISI development. In the 0+ -> 0+ decays I will show the most recent Q-value, branching ratio and half-life measurement results and what is currently going on in the world in these studies.

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Weak-interaction studies with radioactive nuclei

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Beta decay is formidable laboratory for the study of weak interaction. These decays give today the most precise value of the Vud quark-mixing matrix and competitive limits on physics beyond the standard model like scalar or tensor currents. In my talk, I will cover the present status of 0+-0+ and mirror beta decays to determine the Vud matrix element and describe present and future activities to improve the quality and precision of these measurements. Measurements of angular correlation coefficients in nuclear beta decay allow for a determination of limits of scalar currents in Fermi beta decay and of tensor contributions in Gamow-Teller beta decay. The status of these measurements will be presented and future initiatives at ISOLDE described.

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Muonic X-rays for the precise measurement of the nuclear charge radius of 226Ra

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The charge radius of a nucleus is one of its defining parameters and of inherent importance for the understanding and the calculation of its interactions. For elements heavier than Z=83, where no stable isotopes exist, only few nuclear charge radii have been measured. These measurements are of paramount importance to complement the measurements of relative difference in mean-square radii along the isotopic chain available from the optical spectroscopy.
Muonic atoms have been used to extract the most accurate nuclear charge radii based on the detection of the X-ray emitted in the muonic cascades. Most stable and a few unstable isotopes have been investigated with muonic atom spectroscopy techniques. However, experiments with muonic atoms have been limited by low muon rates, poor beam quality and large muon stop volumes, but also by available detector technology for this environment. While beam intensities and quality have been improved in recent years, still no higher multiplicity spectroscopy of muonic cascades has been performed.
A new research project recently started at the Paul Scherrer Institut aims to exploit the potential of high-resolution muonic X-rays spectroscopy for the precise determination of nuclear charge radii of radioactive isotopes and other nuclear ground state properties. The first experimental goal is the measurement of the charge radius of 226Ra, which is one of the missing parameters for the measurement of atomic parity violation in radium. Status and perspectives of the project will be presented.

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Concluding Remarks

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