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Book of Abstracts

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HIE-ISOLDE physics campaign 2018

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The experiments at HIE-ISOLDE [1] made use of all three beam lines in 2018. Higher than before maximum energies of the post-accelerated radioactive ion beams were achieved with the installation of the fourth cryomodule of the linac now pushing towards the design value of 10 MeV/u. Majority of the experiments utilised the first beam line with the MINIBALL HPGe-detector array [2] for Coulomb-excitation and transfer-reaction studies along with a few experiments conducted at the third beam line using a variety of different setups. The ISOLDE Solenoidal Spectrometer (ISS) [3] based on the HELIOS spectrometer concept [4] was successfully commissioned and performed the first two experiments using few-nucleon transfer reactions. An overview of the MINIBALL and ISS experiments that were conducted in the HIE-ISOLDE physics campaign of 2018 will be presented in this talk.

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First results from the ISOLDE Solenoidal Spectrometer

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The 28Mg(d,p)29Mg reaction has been carried out using a 9.47 MeV/u radioactive ion beam from HIE-ISOLDE. This is the first physics measurement using the newly commissioned ISOLDE Solenoidal Spectrometer (ISS), which was used to detect the outgoing ions from the reaction. ISS is a spectrometer optimized for the study of direct reactions in inverse kinematics and is conceptually similar to the HELIOS spectrometer [1] at Argonne National Laboratory. An overview of the ISS project will be given through installation and stable-beam commissioning before discussing the outcome of the physics measurements made using radioactive beam this year. The upgrades to ISS that are planned during LS2 will also be detailed.

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HIE-ISOLDE Physics / 24

Coulomb Excitation of Pear-shaped Nuclei

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We have carried out measurements, using Miniball, of the γ-ray de-excitation of ^{222,228}Ra and ^{222,224,226}Rn nuclei Coulomb-excited by bombarding ^{60}Ni and ^{120}Sn targets. The beams of radioactive ions, having energies of between 4.25 and 5.08 MeV.A, were provided by HIE-ISOLDE. The purpose of these measurements is to determine the intrinsic quadrupole and octupole moments in these nuclei and look for other cases of permanent octupole deformation to those of ^{224,226}Ra already reported[1,2]. One aim of this experiment is to determine the level schemes of ^{224,226}Rn in order to characterise these isotopes as octupole vibrational or octupole deformed. We present here the preliminary results of this analysis which suggests that radon even-even nuclei in this mass region are all octupole vibrational. The implications for EDM searches in radon atoms will be discussed.

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[2] Wollersheim H J et al. 1993 Nuclear Physics A **556** 261

HIE-ISOLDE Physics / 40

Study of shell evolution around the doubly magic 208Pb, via multi-nucleon transfer reaction

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The shell model nowadays can provide a comprehensive view of the atomic nucleus along the Segré chart. In fact, the regions around double-shell closures are a fantastic benchmark for nuclear structure studies, since they provide a direct source of information on the nucleon-nucleon effective interaction. A case of great interest is the study of the east region around the doubly magic ^{208}Pb, in fact it represents an ideal testing ground to understand the effects related to the effective three-body forces and the prospect of the state-of-the-art realistic shell-model calculations for heavy nuclei [1].

However, this region has been traditionally difficult to access experimentally due to its neutron richness and low cross sections. Although, it has been investigated using different techniques like fission, deep-inelastic and transfer reaction [2-4], all of them with stable beams. Even with the recent instrumental improvements and the new facilities, we still have a lack of information around this region.

On the other hand, Multi-Nucleon Transfer (MNT) reactions have proved to be an important tool in order to investigate exotic nuclei with stable beams in the region of interest [5]. With this technique, it is possible to excite yrast and close to the yrast states, to understand the different band structures of a nucleus and to investigate possible isomers and/or short-lived states. In addition, in one experiment it is possible to investigate several nuclei at the same time.

With this aim, a MNT experiment with a high intensity radioactive ion beam (RIB) was carried out in September 2017, at the ISOLDE facility. Several isotopes, in the south-east region of ^{208}Pb, were produced during the experiment, using a radioactive ^{94}Rb beam impinging on a ^{208}Pb target. As a consequence, different isotopes around the south-east region of ^{208}Pb were populated. An overview of all the nuclei produced will be reported and, for the cases where the statistic is enough, the level scheme will be constructed and if there are isomers, the lifetime will be calculated

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HIE-ISOLDE Physics / **29**

Coulomb Excitation of Semi-Magic ^{206}Hg at Miniball ISOLDE

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Singly-magic nuclei in the vicinity of a doubly-magic core are in the scope of interest of modern nuclear physics. Their properties can be described by the few protons (or neutrons) situated outside of the doubly-magic core, therefore, they provide information on the basic ingredients of the shell model, such as single particle energies and two-body matrix elements. One of the most interesting yet weakly known regions to investigate the nature of excitation near closed shells is placed south-east of the doubly-magic ^{208}Pb nucleus.

The successful Coulomb excitation of a singly-magic exotic ^{206}Hg (Z=80, N=126) nucleus was undertaken in November 2017 at the HIE-ISOLDE facility at CERN. The goal of this project was to investigate the electromagnetic structure of ^{206}Hg with a complex energy level scheme, much of which is still unexplored. To date, only the energy of the 2_1^+ state is known along with a number of higher-spin yrast states, while the rest of the low spin level scheme has been only predicted in shell model calculations due to the existence of the long-lived 5^- isomeric state at 2.1 MeV blocking the access to the low-spin region below it and to the non-yrast levels. The B(E2; $2_1^+ \rightarrow 0_1^+$) value as well as the assignment of the newly observed gamma transitions to the theoretically predicted low-energy level scheme of this nucleus were the focus of the recent project. Prior to the experiment, GOSIA simulations were performed based on the theoretical matrix elements, indicating which transitions would be expected.

The ^{206}Hg beam of 4.19 MeV/u energy and the 7.75×10^5 pps intensity was produced using an up to 0.63 μA proton beam impinging on a molten lead target. In order to enhance beam purity by eliminating the stable ^{206}Pb isobar, laser ionisation was implemented using the RILIS technique. As the Coulomb excitation involved a heavy beam, the experiment was conducted using inverse kinematics with a light target (^{104}Pd and ^{94}Mo, respectively for a number of shifts). This allowed the projectile-like and recoiling target nuclei to be kinematically separated. To detect the scattered particles a Double-Sided Silicon Strip Detector was placed in the forward laboratory angles. The 8 clusters of the MINIBALL HPGe detector array were used to measure the de-exicting gamma rays.

The Coulomb excitation experimental technique allows a wide range of nuclear properties to be extracted including the transition probabilities and spectroscopic quadrupole moments of the excited states. The level of collected statistics in the recent experiment will allow the collectivity and deformation of the ground state and the 2_1^+ state to be determined, as well as place the newly observed gamma transitions on the tentative level scheme of ^{206}Hg.

In this talk the preliminary results of the ongoing Coulomb excitation analysis using the GOSIA code will be discussed.

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Ab initio nuclear theory with uncertainty quantification

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Predictive power requires the ability to quantify theoretical uncertainties. While it is true that theoretical error estimates are difficult to obtain, the pursuit thereof plays a pivotal role in science. Reliable theoretical errors can help to determine to what extent a disagreement between experiment and theory hints at new physics, and they can provide input to identify the most relevant new experiments. In this talk I will show that nuclear theory is at a stage where such questions can be addressed.

In particular, chiral effective field theory can be used to systematically bridge the gap from low-energy quantum chromodynamics to nucleons and pions as effective nuclear-physics degrees of freedom. Following this avenue we are making the quantification of theoretical uncertainties possible through the incorporation of state-of-the-art statistical and computational tools. I will outline this procedure and present results from ab initio calculations that provide important steps towards quantifying our understanding of atomic nuclei from first principles.

Nuclear Structure and Astrophysics / 20

Exotic decay modes studied with the Optical TPC

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Over the last decade, the optical-readout time projection chamber developed in Warsaw has been applied to study a variety of rare and very exotic decay channels with emission of charged particles. The device, originally developed for studying two-proton radioactivity, turned out to be extremely well suited for studying delayed (multi) proton emission, in particular when low-energy protons are involved. Protons with energies down to ~150 keV have been detected and their energy measured. In this talk, those cases will be presented for which the OTPC presents advantages with respect to traditional, silicon-based, measurements. Particular focus will be given to those studied at ISOLDE. An outlook on future perspectives will be given.

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Total Absorption Spectroscopy of N=Z nuclei at ISOLDE: weak-decay rates in the rp-process

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Type I X-ray bursts (XRB) are generally suggested as possible sites for the rp-process. These explosive events take place in binary systems in which a neutron star accretes hydrogen-rich material from a low-mass companion star. When the temperature and density in the accreted envelope become high enough to allow for a breakout from the hot CNO cycle, nucleosynthesis eventually proceeds near the proton drip-line via the rp-process. In these scenarios of extremely high gravity, there is no matter released out of the system and the luminosity curve of the emitted x rays is the physical observable to fit by the XRB model calculations. In these calculations some of the main ingredients are the weak decay rates, i.e., the β^+/EC decay rates and the energies released in the process, but these are normally estimated theoretically, and in particular the contribution of electron capture to weak-decay rates has normally been neglected in XRB model calculations. However, theoretical calculations using different models [1-3] show that, in these high-density (~106 g/cm^3) and high-temperature (1 - 2 GK) scenarios, continuum electron capture rates might play an important role, up to one or two orders of magnitude above β^+ rates for species at and around the N=Z waiting point nuclei ^{64}Ge, ^{68}Se and ^{72}Kr.

In this contribution I will present results on different campaigns of experiments carried out with the TAS at ISOLDE to measure the decay of the nuclei mentioned above, focusing on the most recent IS570 experiment, whose aim was to measure accurately the B(GT) in the beta decay of the waiting-point nuclei ^{64}Ge, ^{68}Se and their N=Z+2 second neighbors ^{66}Ge and ^{70}Se. The goal is to evaluate the β^+/EC rates in global, and the EC to β^+ ratio in particular, to see their influence in the current XRB model calculations. We have used the Total Absorption Spectroscopy method which has shown to be the only possible tool sensible to B(GT) at high excitation energy within the Q$_{EC}$ window of medium mass and heavy nuclei [4]. The data analysis is ongoing, but in this talk I will present preliminary results on the isobaric chain A=64.

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Nuclear Structure and Astrophysics / **27**

The 59Cu(p,α) cross section and heavy element nucleosynthesis in core collapse supernovae

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The heavy element nucleosynthesis is the area of research looking to predict and/or explain the observed abundances of nuclei heavier than iron. The proton rich nuclei are thought to be produced in the in hot environments such as supernovae via proton capture and the photodisintegration processes. But the observed abundances of lighter p-nuclei ^{92,94}Mo and ^{96,98}Ru are not reproduced in the stellar models using these processes [1]. In a recent work, the p process has been suggested as an explanation for the abundances of p-nuclei with A>64 [2]. However, in an end-point nuclear cycle involving Co, Ni, and Cu, the competition between (p,α) and (p,γ) reaction rates on the ^{59}Cu isotope could hinder the reaction flow from proceeding towards heavier elements by cycling the material back [3]. This competition is temperature sensitive and therefore it is crucial to measure the ^{59}Cu(p,α)^{56}Ni reaction cross section in order to obtain the reliable modelling results. In addition to the reaction's importance in understanding the origin of heavy p-nuclei, it is also of key importance for X-ray light curve, and affect the composition of burst ashes on the surface of the neutron star significantly [4].

Currently, there is no direct measurement of the ^{59}Cu(p,α)^{56}Ni reaction cross section. I will present the preliminary results of the first such measurement. The experiment was performed at HIE-ISOLDE facility at CERN in inverse kinematics with high intensity ^{59}Cu beam on CH_2 foil target at 5 different beam energies between 3.6 - 5.0 MeV/u.

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[4] R. Cyburt et al, Astrophys. Jour. 830, (2016)

Solid State Physics / 55

Unraveling the atomic structure of quantum materials using radioactive ions

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ISOLDE has been a hub for the development of radioactive probe techniques and their application in solid state physics and other fields. In this talk, we review some recent highlights from the application of electron emission channeling and perturbed angular correlation spectroscopy to research on

functional quantum materials: from well-established research activities on doping of semiconductors, to emerging topics such as single-photon emitters for quantum technologies. We will describe the role played by the techniques and experiments developed at ISOLDE in the broader research programs to which they contribute, including the complementarity to other techniques available at large-scale facilities such as synchrotron light sources. As an outlook beyond the long shutdown 2, we will discuss opportunities for radioactive probe techniques in these emerging fields.

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Sub-lattice displacement in multiferroic Rashba semiconductor (Ge,Mn)Te (IS648)

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Multiferroic Rashba semiconductors (MUFERS) are novel functional materials based on the coupling between ferromagnetism, ferroelectricity and Rashba-Zeeman effects [1]. $Ge_{1-x}Mn_xTe$, the model MUFERS, inherits the robust ferroelectricity and giant Rashba splitting of α-GeTe, undergoing a ferroelectric phase transition at T_C^{FE}. Below the transition temperature, the cubic rocksalt symmetry is broken and a rhombohedral phase is formed by elongation along the <111> direction. This distortion induces a displacement Δr between the cation (Ge or Mn) and the anion (Te) sub-lattices, which is responsible for the spontaneous ferroelectric dipole. Ferromagnetism in (Ge,Mn)Te, stemming from exchange interaction between Mn^{2+} moments mediated by free carriers (holes), induces a Zeeman splitting in the electronic structure. Thanks to the high Mn solubility in GeTe, Curie temperatures T_C^{FM} as high as 180 K have been achieved, among the highest of all ferromagnetic semiconductors. Varying Mn concentration has not only a direct effect on the magnetization of (Ge,Mn)Te, but also influences the ferroelectric distortion. The direction and magnitude of Δr define the direction and magnitude of the FE polarization, which together with the magnetization determine the Rashba and Zeeman effects on the electronic structure.
In this experiment (IS648), we are developing a novel approach to measuring the direction and magnitude of the sub-lattice displacement Δr in (Ge,Mn)Te, based on the emission channeling technique. By implanting ^{56}Mn radioactive probes into $Ge_{1-x}Mn_xTe$ films, emission channeling can be used to directly measure Δr, with sub-Angstrom precision. Experiments both below and above the ferroelectric transition were performed in 2018 for a range of Mn concentrations up to 21%. In this talk, we will present and discuss the observed dependence of Δr on Mn concentration. These results set the basis for future experiments in which we will study how switching the magnetization direction (with a magnetic field applied in-situ) affects the direction of the FE polarization (Δr) through magnetoelectric coupling.

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Perturbed Angular Correlation γ-γ measurements on Naturally Layered Perovskites Ca_{n+1}Mn_{n}O_{3n+1}

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Magneto-electric multiferroics form an attractive class of materials, not only for the diversity of exciting fundamental phenomena they present but also by the potential technological applications foreseen. Among them are energy efficient memory devices, multiple state memories, as well highly sensible electrical-magnetic field sensors. Although the research in this area has increased dramatically in the last years, the number of systems presenting magnetoelectric coupling at room temperature is still very scarce.

Naturally layered perovskites (NLP) such as the Ruddlesden-Popper (R.P.) phases ($A_{n+1}B_nO_{3n+1}$) have appeared as a fascinating route to achieve nonexpensive room temperature multiferroic materials. In these NLP, distortions of the lattice such an BO_6 octahedron rotation and tilting modes couple to polar cation dislocation modes inducing a ferroelectric polarization, in a mechanism known as hybrid improper ferroelectricity. The novel idea behind these NLP is that the ferromagnetic and ferroelectric orders can be coupled through the same lattice instability, providing an indirect but very strong magneto-electric coupling.

Perturbed Angular Correlation γ- γ (PAC) hyperfine technique offers a unique opportunity to probe at the local scale the structural, charge and magnetic phase transitions of these NLP systems. At ISOLDE-CERN, by using metastable ^{111m}Cd isotopes as radioactive probes, PAC measurements were performed in a extensive range of temperatures (1150K - 11K), namely on the prototypical hybrid improper ferroelectric and novel multiferroic $Ca_3Mn_2O_7$, as well of its homologous non polar Ca_2MnO_4 and $CaMnO_3$ R.P. compounds. Combined Ab-initio electronic structure calculations in the framework of the Density Functional Theory (DFT) were also performed to understand and show how the measured Electrical Field Gradients at the Cd probing sites are sensitive to the BO_6 octahedron distortion modes present in these compounds.

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Evidence of p-type doping in Mn doped AlGaN following 57Mn/57Fe implantation

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Currently, intensive research in group III nitrides is focussed on improving the performance of commercial devices. This includes their heterostructures and/or alloys with other group III elements. Amongst the latter are ternary semiconductors such as $Al_xGa_{1-x}N$, which are expected to give rise to unexpected photonic and magnetic functionalities when doped with magnetic ion species. This has prompted our study of the lattice sites, valence states and annealing behaviour of Fe ions in virgin and Mn (1 at.%) doped $Al_xGa_{1-x}N$ using ^{57}Fe emission Mössbauer spectroscopy (eMS). Radioactive $^{57}Mn^+$ ($T_{1/2}$ = 1.5 min.) ions were implanted with 50 keV energy at ISOLDE/CERN into $Al_xGa_{1-x}N$ films grown by metalorganic vapour phase epitaxy (MOVPE) on sapphire substrates. eMS measurements were performed in the temperature range of 100 - 800 K. The room temperature spectra for $Al_{0.2}Ga_{0.8}N$ acquired at emission angles (θ_E) of 60° and 0°show the presence of magnetically-split sextets in the "wings", similar to features observed in GaN and AlN[1] and attributed to Fe^{3+} on Al/Ga sites showing slow paramagnetic relaxations[2]. The central part of the spectra is characterised by paramagnetic Fe^{2+} on Al/Ga sites associated with nitrogen vacancies. However, with Mn doping, the contribution of Fe^{3+} is considerably reduced or negligible. This is coupled with the corresponding emergence of a single line component with Mössbauer parameters typical of Fe^{4+} on Al/Ga sites, which are acceptors in AlGaN, suggesting the possibility of *p*-type doping. Results will be discussed and compared with Si doping.

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Solid State Physics / **37**

Defect structures of photocatalytic plasma treated and doped titania

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Titania TiO2 is a promising material candidate for batteries, water splitting and water purification. Its photocatalytical and Li-storage capabilities very much depend on the defect structure in the used

titania. Hydrogenation and N-doping have proven to improve this defect structure in such a way that the mentioned properties are drastically improved [1–3].
With the help of nuclear solid state methods like Mössbauer and PAC by using also radioactive isotopes from ISOLDE such defects could be analysed in detail [4–7]. With the support from a BMBF project a new Mössbauer system is generated for ISOLDE with which also the atomic mechanisms responsible for the photocatalytic properties are investigated by Mössbauer spectroscopy, in addition to PAC. First results will be presented.

Acknowledgment: The financially support by the Federal Ministry of Education and Research of Germany (BMBF) under contract 5K16SI1, within joint project 05K2016, is gratefully acknowledged.

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Other Facilities 1 / 63

Recent highlights and projects at the Antiproton Decelerator

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Experiments at the Antiproton Decelerator of CERN compare properties of matter and antimatter at low energies for precision tests of fundamental symmetries and interactions.
Using either atoms made of antiprotons (antihydrogen or antiprotonic-helium) or singly trapped antiproton, AD experiments address a broad range of physics questions via a spectrum of different experimental techniques.
The conservation of the combined charge-parity-time symmetry (CPT), a fundamental symmetry in quantum field theory, implies that properties of antimatter particles/atoms (electrical charge, mass, magnetic moment, atomic spectrum etc) should be equal or exactly opposite to that of matter. This symmetry was recently subject to high scrutinity at the AD through the first precision measurements of atomic transitions in trapped antihydrogen. Also, comparison of the charge to mass ratio of a single antiproton to that of an H- ion in a Penning trap provided the most stringent test of CPT invariance with baryons. The magnetic moment of the antiproton could be measured at the ppb level, even surpassing for a few weeks the knowledge on the proton magnetic moment.
Using exotic antiprotonic atoms, two-photon spectroscopy measurements determined the electron-to-antiproton mass ratio with better than ppm precision.
In addition to testing CPT invariance, experimental efforts are oriented towards the study of the interaction of antihydrogen atoms with the earth gravitational field.
Einstein's weak equivalence principle, central to the theory of relativity, has been tested with matter to a high degree of precision, but has never so far been experimentally verified to apply to antimatter.
Three experiments, all using different experimental approaches, are now set up to measure $\bar{g}$ with a first precision goal between 30% and 1%.

Additionaly a new proposal to connect low energy antiprotons for radio-nuclei studies will be setting grounds at the AD and aim to bring the first antiprotons accross the road to ISOLDE.
The upcoming long shutdown 2 will be the opportunity for new developments. In particular, all experiments are now preparing for their connections to the newly commissioned ELENA ring which will provide lower-energy antiproton beams at an improved emittance, which will boost the experimental potentials.
The talk will summarize the recent highlights of the AD and give an outlook on the bright upcoming future of low energy antiproton research with ELENA.

Other Facilities 1 / 47

Physics opportunities at VAMOS

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In this talk, the recent experimental program and physics opportunities at the large acceptance VAMOS++ spectrometer in GANIL will be presented. The development of the new detection systems of the spectrometer and their performances will be reported. Further recent results ranging from prompt and prompt-delayed g-ray spectroscopy of isotopically identified fission fragments using the Advanced Gamma Ray Tracking Array (AGATA), VAMOS and EXOGAM to fission dynamics will be reported. Future experimental program including transfer reaction in inverse kinematics using MUGAST and AGATA at VAMOS++ will also be discussed.

Other Facilities 1 / 4

The SPES project: present and future with Radioactive ion Beams at LNL

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The SPES project is being built at the Legnaro National Laboratory of INFN. It is an interdisciplinary project, ranging over nuclear physics, nuclear medicine and materials science. SPES (SPES β) will provide a Radioactive Ion Beam facility for the study of neutron rich unstable nuclei of interest to nuclear physics and nuclear astrophysics research. At the same time ((SPES γ), it will host a laboratory for research and production of radioisotopes to be applied in nuclear medicine.
The facility is being built at the Legnaro National Laboratory (LNL) of INFN. The acronym stays for "Selective Production of Exotic Species". At the heart of the project is a new, high energy (up to 70 MeV) and high intensity (up to 700 μA) proton cyclotron which is capable of providing two separate beams at the same time. One of these will be used for the Radioactive Ion Beam (RIB) facility, the other for the applications.
The physics case for SPES β is the study of unstable nuclei, especially on the n-rich side, which are of crucial importance on the star evolution, for which new nuclear shapes, excitation levels and stability configurations are expected.
New instrumentation and upgrading of existing set-ups are foreseen to afford the challenges which will be opened due to the availability of exotic beams with good intensities and purity.
On the side of SPES γ, medical applications are the major goal. The properties of radioactive nuclei combined with molecular behavior in human body is of great advantage to diagnosis and therapy in nuclear medicine.
SPES γ was designed to pursue the aim of studying the production of innovative radionuclides for

medicine starting from the assumption that every new radioisotope may show unprecedented biological properties and that these properties may contribute to finding solutions to still open clinical problems.

Poster Session / 3

Measuring sub-barrier fusion cross sections of exotic nuclei using a novel radiochemical method

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Fusion reactions can play an important role in the dynamics of weakly-bound exotic nuclei at sub-Coulomb energies.
However, these measurements are usually difficult to perform due to the low value of cross sections and beam intensities.
In this contribution we discuss the advantages and limitations of applying radiochemical techniques using recent data
on the sub-barrier fusion of the systems 7Li+208Pb and 6He+208Pb.

Poster Session / 12

Searching for β-delayed protons from 11 Be

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11-Be is the neutron - rich nucleus expected to be a β-delayed proton emitter. The (very mall) branching ratio for this exotic decay mode (~ 10e−6) was obtained through indirect observations based on accelerator mass spectrometry [1, 2] and resulted to be about two orders of magnitude larger than predicted by theory [3]. The direct measurement of the delayed proton emission probability and energy spectrum is particulary challenging, given the small energy window available (~ 280 keV). The measurement of the βp energy spectrum is important for estimating the Gamow-Teller strength at high excitatiom energies and testing calculations that predict a direct relation between βp and halo structure.

Moreover, recently, a new hypothesis, which may explain results of the AMS experiment, appeard. According to it, the neutron may have another decay channel in which unknown particles are produced in the final state [4, 5].
In August 2018 we performed the experiment IS629 at the HIE-ISOLDE facility, searching for β-delayed protons from 11-Be. We used the Warsaw Optical Time Projection Chamber (OTPC) [6]. The OTPC detector is well suited for detecting charged particles of low energy backgroung-free. The measurement was extremly challenging because of the combination of very low branching ratio (10e−8 ~ 10e−6), long half-life (T_1/2 = 13.7 s) and low energy of the protons. It required development of new solutions for the acquisition system and analysis software.
The descriptions of the experiment and the status of the data analysis will be presented.
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Poster Session / 30

Solute diffusion of ^{64}Cu in single crystalline CoCrFeNi HEA

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High entropy alloys are multicomponent alloys, which consist of four or more elements in equiatomic or nearly equiatomic concentrations. These materials are hypothesized to show significantly decreased self-diffusivities. The understanding of the diffusion kinetics in HEAs is of fundamental significance, however the present knowledge is limited to several interdiffusion investigations on the one hand and the direct radiotracer measurements in single and polycrystalline CoCrFeNi and CoCrFeMnNi on the other hand. Recent studies were mainly focused on the radiotracer self-diffusion of the constituent elements in CoCrFeNi and CoCrFeMnNi. Further alloying the CoCrFeNi alloy with Cu in equiatomic proportion to the quinary CoCrCuFeNi HEA and additionally Al to the AlCoCrCuFeNi HEA, the knowledge of the Cu solute diffusion in the quaternary alloy is mandatory. The here presented results of copper diffusion were obtained on single crystalline CoCrFeNi HEAs utilizing the on-line diffusion chamber located at the ISOLDE facility in off-line mode. The CoCrFeNi HEA was implanted with ^{64}Cu at the ISOLDE/CERN radioactive ion-beam facility. Afterwards, isothermal annealing was performed in a temperature range from 973-1173 K followed by serial sectioning via ion-beam sputtering and recording of the corresponding γ-spectra of each section using 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 149 kJ/mol and a pre-exponential factor of 6.6×10^{-10} m^2 s^{-1}. This is comparable faster than the ^{57}Co, ^{51}Cr, ^{59}Fe and ^{54}Mn diffusivities in the same HEA with an activation enthalpy which is half of the activation enthalpies of the constituents.

Poster Session / 52

Study of the kinetics of complex formation and in vivo stability of novel radiometal-chelate conjugates for applications in nuclear medicine.

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Targeted Radionuclide Therapy (TRT) and diagnostics are currently the most intensively developing fields of nuclear medicine as they allow the very precise imaging of tumors (or other targeted tissues), and the minimization of healthy tissue damage during medical therapy. TRT relies on the labeling of a radionuclide to a targeting vector – a biomolecule that has a high affinity to over-expressed antigens on the surface of tumor cells. It targets tumors, or other diseases, at the cellular level and increases the radiation dose delivered to the target tissue relative to the healthy tissue during therapy. However, the design and synthesis of radiopharmaceuticals suitable for TRT require a solid understanding of the stability of radionuclide complexes in vivo. Conventional methods to characterize the thermodynamic stability of complexes often rely on non-radioactive surrogates under biologically irrelevant conditions; moreover, little information on the kinetics of formation and the kinetic inertness can be drawn. Over the past two years (2017-2018) we received multiple radioactive beams to study the complexation behaviour and preference of various radiometals with the use of Perturbed Angular Correlation of γ-rays (PAC) spectroscopy.
In August 2017, our team partook in a beam of Cd-111 at ISOLDE for chelation studies with various systems and comparisons with previous results obtained with In-111 (mother isotope). Later in September we probed beams of radiolanthanides (Nd-139, La-140, Gd-147, Gd-149 and Lu-172), some of which were produced for the first time, in order to test the complexation preference, the complex structures as well as several novel chelators synthesized by our collaborators at UBC Chemistry.
Furthermore, in September of 2018 our team tested the chelation of Hg-199 with the common chelators DOTA and EDTA. Later in October, the ISOLDE team made available for the first time a beam of Sb-118 and its first PAC spectra was measured.
All of the above stated results will be presented and further possible experiments and directions will be discussed for this project.

Poster Session / 35

IS634: First results on the temperature dependence of the ^{11}Be lattice location in GaN

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The interest in Be in GaN stems from the challenge to understand why it is technologically feasible to dope this wide band gap semiconductor *p*-type with Mg, while this does not work for Be. While theory has actually predicted an acceptor level for Be that is shallower than Mg [1,2], it was also argued that Be would not be a suitable acceptor because its amphoteric nature, i.e. its tendency to occupy both substitutional Ga and interstitial sites, would be considerably more pronounced than for Mg and hence lead to complete self-compensation [2].
Using the Emission Channeling with Short-Lived Isotopes (EC-SLI) technique, we determined the lattice location of ^{11}Be ($t_{1/2}$=13.8 s) in several doping types of GaN as a function of implantation temperature.
We found that interstitial ^{11}Be fractions were much higher than for ^{27}Mg, which confirms that indeed self-compensation should be considerably more pronounced for Be than for Mg. In addition there was much less influence from implantation damage for ^{11}Be than for ^{27}Mg, hence the above mentioned fractions could also be measured for longer implantation times. ^{11}Be is therefore a more convenient "probe for the Fermi-level" than ^{27}Mg.
Site changes of interstitial Be(i) to substitutional Be(Ga) started around 400°C in undoped GaN and *n*-GaN:Si, thus roughly at the same temperature as for ^{27}Mg. This is a bit of a surprise since the interstitial Be seems to show a similar migration energy as Mg, somewhat in contrast to theoretical predictions [2,3,]. In *p*-GaN:Mg the site change of ^{11}Be also started at 400°C, however, Be did then not completely disappear from interstitial sites, but was only reduced to ~15%, then there was a clear second stage at 750°C, so that only at 800°C Be(i) was completely converted to substitutional. Our best guess so far is possible formation of Be(i)-Mg(Ga) pairs that slow down Be(i) diffusion until these pairs are broken up.

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Poster Session / 18

γ-spectroscopy of low spin states of 232Ac following the β- decay of 232Ra

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The structure of the odd-odd 232Ac nucleus, produced in the β− decay of 232Ra, was investigated through γ-ray spectroscopy at the ISOLDE Decay Station at ISOLDE, CERN. A radioactive beam of 232Fr was implanted in the IDS. The γ-rays originating from the β − decay chain 232Fr - 232Ra - 232Ac - 232Th were registered using a mixed array consisting of 4 HPGe Clover and 2 LaBr3(Ce) detectors arranged in a close geometry.

Prior to our study, only very limited information was available for the 232Ra - 232Ac β− decay coming from a study in 1986. In that experiment, the multinucleon transfer reaction was used to produce the precursor 232Ra. Due to low statistics and the absence of γ-γ coincidences, only a few γ-ray transitions were associated with 232Ac. In this work, we report a revised and considerably extended level scheme for 232Ac by ascribing 25 new γ-transitions that link 15 new excited states. An isomeric state at Ex=97.7 keV was identified and its lifetime was measured using the HPGe detectors.

The experimental results will be discussed and compared with the available literature data for the neighbouring 230Ra β− decay.

Poster Session / 33

Simulations of Ion Trajectories inside the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy (MIRACLS)

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Due to its high precision, accuracy, and resolution, Collinear Laser Spectroscopy (CLS) is an important experimental technique to access nuclear spins, electromagnetic moments, and mean square charge radii of short-lived radionuclides and hence provides insight into the nuclear shell structure [1]. However, to experimentally probe the most exotic nuclides, which can only be produced with low production yields at today's radioactive ion beam facilities, new laser spectroscopy-techniques have to be envisioned.

This contribution will introduce the novel concept of the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy of radionuclides (MIRACLS). At MIRACLS, the goal is to increase the experimental sensitivity by a factor of 30-600 compared to traditional CLS by effectively extending the observation time. This can be achieved by trapping a bunched ion beam in a multi ion reflection time of flight (MR-ToF) device [2] in which the ion bunch and the laser can interact during each revolution.

A MIRACLS proof-of-principle experiment is currently carried out at ISOLDE/CERN to demonstrate the functionality of CLS inside an existing, low energy MR-ToF device [3], which has been modified for the purpose of CLS. Here, the experiment is performed with ion-beam energies of about 1.5 keV, whereas the future MIRACLS MR-ToF apparatus will operate at 30 keV in order to minimise the Doppler broadening.

The results of simulations of the ion trajectories inside the 1.5 keV MR-ToF device will be shown and their implications for CLS will be compared to the first experimental results. Moreover, the simulations of the ion trajectories inside the future 30 keV MR-ToF device will be presented.

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Poster Session / 14

The impact of dielectronic recombination on the charge state distribution at REXEBIS

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Dielectronic Recombination (DR) is a resonant process that describes the capture of an electron by a (highly charged) ion, occurring at sharply defined collision energies. In an electron beam ion source, where charge breeding is achieved through successive electron impact ionisation, DR transitions can be selectively driven by adjusting the electron beam energy. The increased recombination rate on a DR resonance can inhibit the breeding into higher charge states and shift the charge state distribution of the extracted ion beam. This study aims to understand the significance of DR for the operation a charge breeder and to learn if this effect can be exploited for a more selective charge breeding. We have performed simulations and measurements using REXEBIS at ISOLDE for the example of highly charged potassium ions (12+ to 17+). Here, we present our preliminary results which show a good agreement between the theoretical predictions and the measured charge state distributions. Our results suggest that the relevance of DR depends strongly on the ion species and the electron beam parameters. We conclude that DR can be of operational interest and potentially serve as a diagnostic mechanism in special cases.

Poster Session / 17

Study of the β decay of ^{133}In and ^{134}In

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Over the last years the advance in experimental techniques allowed to refine the experimental knowledge on ^{133}Sn, which is a key nucleus to deduce neutron single-particle (SP) energies above the doubly magic ^{132}Sn core. The different adopted techniques allowed to obtain mutually consistent information about SP energies for $\nu p_{3/2}$, $\nu p_{1/2}$, $\nu h_{9/2}$ and $\nu f_{5/2}$ neutron orbitals relative to the $\nu f_{7/2}$ ground state of ^{133}Sn [1-5]. Still, the knowledge about neutron SP states is not complete and the question of the position of the neutron-unbound $\nu i_{13/2}$ state remains open for investigation [6]. Moreover, information about other unbound states, corresponding to neutron-hole configurations, is also limited. The need to revise studies of ^{133}Sn via β decay of ^{133}In and ^{134}In emerges from the

recently-reported significant role of γ ray emission from states at excitation energies more than 1 MeV above the neutron separation energy [1].

Our experiment was performed at the ISOLDE Decay Station, where excited states in ^{133}Sn were studied via the β decay of ^{133}In and complemented by studies of the βn decay branch of ^{134}In. Isomer-selective ionization using the ISOLDE RILIS ion source enabled the β decays of ^{133g}In (I$^{\pi}$=9/2^{+}) and ^{133m}In (I$^{\pi}$=1/2^{-}) to be studied independently for the first time [7]. Preliminary results on γ decay of unbound states in ^{133}Sn are presented and discussed.

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Poster Session / 22

Time-of-Flight study of cooled molecular beams

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Molecular beams injected into the ISOLDE Radio-Frequency Quadrupole cooler and buncher (RFQcb), ISCOOL, have been studied under varying conditions using the new Time-of-Flight detector at ISOLDE.

When a beam of molecules is injected into the RFQcb and the molecules interact with the buffer gas collisional dissociation processes may occur. In this study, two different beams of molecules, CO^{+} and $N_2{}^{+}$, were injected into ISCOOL separately. Two tests were made with different buffer gases, pure helium and a mixture of helium and neon, in order to investigate collisions with different center of mass energies. The radio-frequency of the RFQcb was varied as the molecules, along with the fragments from the dissociation processes, were extracted from ISCOOL and studied via Time-of-Flight measurements.

The new ToF detector uses secondary electron emission techniques and an MCP detector to create a highly sensitive detector with sub nanosecond timing resolution. The detector is installed in the ISOLDE central beamline, approximately 10 meters downstream of ISCOOL, which makes it possible to study the time structure and mass spectrum of ion bunches extracted from the RFQcb. The results from the first Time-of-Flight study of the fragments from an injected molecular beam into ISCOOL will be presented.

Poster Session / 23

Laser spectroscopy on Germanium isotopes at COLLAPS-CERN

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Collinear laser spectroscopy (CLS) is a powerful technique to probe the structure information of the ground and long-lived isomeric states by measuring their nuclear spins, moments and charge radii [1, 2, 3]. Over the last decade, this technique has been intensively employed for the study of the exotic isotopes of the Ni region, namely around the major proton shell closure at Z = 28 and between two major neutron shell closures, N = 28 and N = 50 [4, 5]. Nuclear moments measured in this region have been used to systematically investigate the structure evolution information, such as the (sub-shell) effect of N = 40 and N = 50 and also act as an important input for the large-scale shell-model interaction. [6]. In addition, observed nuclear charge radii led to the discovery of previously unknown phenomena for the region, such as the inverted odd-even staggering in the Zn (Z = 30) and Ga (Z = 31) isotopic chains [7, 8], which however does not appear in the Ni (Z = 28) and Cu (Z = 29) isotopic chains. Thus, with more protons added beyond the Z = 28 closed shell, the study of the Ge isotopic chain (Z = 32) is interesting for the study of the nuclear shell evolution, the onset of the collectivity and triaxiality effects [9], and the nature of the inverted odd-even staggering effect. By taking the advantages of the frequency mixing technique, the $4s^24p^2\ {}^3P_1$ - $4s^24p5s\ {}^3P_1$ (269 nm) atomic transition of Ge atom could be probed for the first time with high-resolution laser spectroscopy technique, resulting in the hyperfine structure measurement of Ge isotopes around N = 40. Detail information related to the experiment will be presented, together with the preliminary results.

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Poster Session / **73**

Reducing the beamtime required for lifetime measurements with the Triple-foil Plunger for Exotic Nuclei (TPEN)

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The Recoil Distance Doppler-Shift (RDDS) technique has become a well established method of measuring the lifetimes of excited nuclear states. In the standard approach, a two-foil plunger allows excited nuclei to radiate either in flight or while stationary. This results in two gamma-ray energies associated with each transition due to Doppler shift. The relative intensity of each of these components can then be used to calculate the lifetime of the state.

The Triple-foil Plunger for Exotic Nuclei (TPEN) has recently been commissioned at the University of Jyväskylä, Finland, by studying the nuclear transitions of 156Dy through the inverse reaction 24Mg(136Xe, 4n)156Dy. TPEN consists of three foils, allowing nuclei of interest to radiate within three different velocity regimes. This results in gamma-rays of three different energies associated with each transition, one more than the standard RDDS technique. A third component can either act as a direct measurement of the differential of the decay curve, as opposed to differentiating a fitted function, or be used to probe two lifetimes of different magnitude simultaneously. The work presented demonstrates how the latter could be used to reduce the beam time required in future experiments and give access to more exotic nuclei further from stability with lower cross sections.

Poster Session / 36

WISARD: The 0.1% challenge

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The WISArD (Weak Interaction Studies with Argon Decay) experiment aims to determine the beta-neutrino angular correlation ($a_{\beta\nu}$) in the super-allowed Fermi decay of ^{32}Ar. The latter decays are sensitive probes to a possible scalar contribution in the weak interaction model. Deviation from the expected theoretical value will point to physics beyond the standard model.
The experiment itself relies on the coincidence detection of the beta particles of ^{32}Ar and the beta-delayed protons emitted from the isobaric analogue state in ^{32}Cl. If a proton energy resolution below 10 keV is achieved, a new limit for $a_{\beta\nu}$ of the order of 0.1% is attainable.
To enhance the sensitivity, a new detection system is designed and installed inside the former WITCH superconducting magnet at ISOLDE/CERN. The protons and positrons from the decays will be guided by a strong magnetic field to two different detectors located on either side of a catcher foil, where the primary ^{32}Ar beam is implanted. Details of the apparatus and the current status of the experiment will be presented.

Poster Session / 38

Technical developments and first studies of biological samples at the VITO beamline.

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In December 2017 we recorded the first beta-NMR signals of 26Na in liquid samples [Kow18]using the Bio Beta-NMR setup at the VITO beamline [Kow17, Gin18]. 2018 has seen many beamline upgrades including a new charge exchange cell [Gin18], a home-build vacuum-compatible NMR magnetometer, a new magnet giving better homogeneity and higher field strength, a new measurement chamber and a temporal magnetic field stabilization system. With these upgrades we are pleased to report the first beta detected NMR signals from biological samples, recorded in May 2018 and to-be measured in October 2018.
Our biological samples are Guanine Quadruplexes (G-Quadruplexes), which are special four strand DNA confirmations. G-quadruplexes can be formed in Guanine rich DNA sections in the presence of sodium and/or potassium cations. These DNA structures are found at the end of chromosomes (telomeric regions) and influences the behavior of the telomerase protein. Telomerase malfunctioning has been linked to effects of aging and cancer.

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Poster Session / 39

Collinear resonant ionization spectroscopy of neutron-deficient Tin approaching N=50

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Collinear resonant laser ionization spectroscopy is a powerful technique which can provide a unique insight in nuclear properties such as spin, electromagnetic moments and changes in mean-square charge radii from near doppler-free measurement of the hyperfine structure of exotic isotopes. This technique was recently used at the collinear resonant ionization spectroscopy (CRIS) beam line at ISOLDE-CERN, for studying nuclear structure properties of neutron-deficient Tin isotopes in the proximity of the heaviest self-conjugate doubly magic nucleus 100Sn. Extensive testing using a recently commissioned ion source allowed the development of several laser ionization schemes of Tin. The insight of their sensitivity to nuclear observables and overall efficiency laid foundation for the online study of the unstable nuclei. The successful experiment performed in August 2018 provided hyperfine spectrum of the neutron-deficient Sn isotopes, extending from 124Sn down to 104Sn. These new measurements allowed the determination of previously unknown electromagnetic properties of both ground states and isomeric states, shedding light on the nuclear structure evolution towards 100Sn.

Poster Session / 43

Glowing VME backplanes - recent upgrades of the SEC and IDS DAQ

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The experiments at the SEC and IDS with segmented silicon detectors utilize a VME-based DAQ with between 100 and 300 channels, typically. The achievable acquisition rates of modern triggered nuclear physics experiments are heavily dependent on the readout software. This contribution presents a novel readout scheme that minimizes the deadtime associated with data readout, thus lowering the deadtime to the theoretical minimum. Depending on the case, this enhances the data throughput by up to a factor of 2.

Poster Session / 6

The d + ^{7}Be reaction to study the cosmological lithium problem

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It is well known that there is a serious anomaly between the observed and Big Bang Nucleosythesis predicted abundance of ^{7}Li. Since the ^{7}Li abundance is known to be intimately related to the production and destruction of ^{7}Be, it is pertinent to study reactions involving ^{7}Be. An experiment measuring the transfer reaction ^{7}Be(d,p)^{8}Be* at E = 5 MeV/A (IS 554) at CERN-HIE-ISOLDE is scheduled in November 2018. Detailed study of this ^{7}Be destruction reaction is required before one can invoke solutions of the ^{7}Li problem beyond nuclear physics, particularly in the context of the newly conjectured light electrically neutral particles X. We would utilize the scattering chamber installed in the third beamlineof the HIE-ISOLDE facility, having sets of DSSD in a pentagon geometry. Detailed Geant4 simulations in the NPTool framework have been carried out. Reports on the experiment would be presented.

Poster Session / 44

Bunching studies with the ISOLDE RFQcb

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The RadioFrequency Quadrupole cooler buncher (RFQcb or ISCOOL) is a permanent beam cooling installation on the High Resolution Separator (HRS) at ISOLDE. It is extensively used by many of the downstream experiments for beam preparation by reducing the transverse emittance and converting a DC beam into pulsed bunches.

An extensive investigation into the RFQcb bunching properties was carried out using the new electrostatic mirror Time Of Flight (TOF) detector installed at a distance of ~10 m downstream of the bunch extraction. The performance of the RFQcb was methodically and thoroughly investigated to characterise its bunching performance for a selection of masses with four main parameters to probe, injection pressure, number of charges, extraction voltages and cooling time. The results from these investigations will be presented here along with a general introduction to the RFQcb to better aid the users understanding and the tunes required for their experiments.

Poster Session / 7

Electron capture of 8B into highly excited states of 8Be

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In this talk, I will present the study of the decay of 8B into highly excited states of 8Be with the aim of determining the branching ratios. Our interest lies in the 2+ doublet at 16.6 and 16.9 MeV populated via β+ and electron capture (EC) respectively and also the so far unobserved EC-delayed proton emission via the 17.640 MeV state, that has a theoretical branching ratio of 2.3·10-8. The 2+ doublet is interesting due to the high isospin mixing [1], leading to dominant configurations as 7Li+p and 7Be+n respectively

I will discuss the aims of the experiment, the setup and I will give the results obtained so far in the analysis.

Poster Session / 32

Study of octupole collectivity in 146Nd and 148Sm

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For certain combination of protons and neutrons an appearance of reflection asymmetry is expected. In particular, the experimentally determined E3 strengths as a function of the neutron number are peaked around N~88 and N~134. Many theoretical approaches have been applied to describe the regions of enhanced octupole collectivity and its experimental signatures, such as parity doublets in odd-mass nuclei, and low-lying opposite-parity bands and high E3 transition probabilities in even-even nuclei.

Low-energy Coulomb excitation is a highly successful method for establishing the evolution of nuclear shapes via measurements of cross sections to populate excited states that can be directly related to the static and dynamic moments of the charge distribution of the nucleus.

The octupole correlations in the ^{146}Nd (N=86, Z=60) and ^{148}Sm (N=86, Z=62) nuclei were investigated in a Coulomb excitation experiment with stable ^{58}Ni and ^{32}S beams. The experiment was part of the MINORCA Campaign (MINIBALL spectrometer coupled with ORGAM Array) at IPN Orsay.

We present the status of data analysis from this experiment with a particular focus on the $<3^{-}||E3||0^{+}>$ and $<1^{-}||E3||4^{+}>$ matrix elements that are expected to provide a distinction between an octupole vibration and a rigid deformation.

Poster Session / 76

Progress of the IS559 experiment

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The IS559 experiment is the first ever attempt of utilising the Oslo Method with a radioactive beam in inverse kinematics reactions. A ^{66}Ni beam with 4.5 MeV/u hit a deuterated polyethylene target for a total of ≈ 10 days. The ultimate goal of the experiment is to look for particle-gamma coincidences from the d(^{66}Ni,p)^{67}Ni reaction, reconstructing the excitation energy from the proton energy on an event-by-event basis. Six large volume (3.5x8") LaBr3:Ce detectors were coupled to the Miniball setup to boost the overall gamma detection efficiency. The charged particles were detected with the C-REX silicon setup. Level density and gamma strength function will be extracted from the resulting gamma-excitation matrix. Preliminary particle, gamma and time spectra will be presented.

Poster Session / 5

Coulomb dissociation of ^{14}O in the context of the hot CNO cycle

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The radiative capture reaction ^{13}N(p,γ)^{14}O is an important reaction determining the transit from the Carbon-Nitrogen-Oxygen (CNO) cycle to the hot CNO cycle occurring in several astrophysical situations such as super-massive stars, novae etc. Since the direct measurement is difficult due to low cross section, Coulomb dissociation of ^{14}O in the presence of a heavy target appears to be a robust alternative. In this context, the radiation width (Γ_γ) of the first excited state of ^{14}O (5.713 MeV) needs to be accurately measured. Discrepancies exist between theoretical works and two experimental measurements till now covering a range of values of Γ_γ from around 1 eV to 10 eV. We plan to measure Coulomb dissociation of ^{14}O and deduce the radiative width Γ_γ with better accuracy using the highly efficient and granular detector array MUST2 at GANIL. This is indeed necessary to conclude if the hot CNO cycle may be ignited at lower densities to prevent the collapse of supermassive stars.

Poster Session / 11

Isolde V

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The Isolde facility was established in 1967 and since then has been rebuilt three times, in 1976, 1983 and in 1992. The fourth and current incarnation is 26 years old, and there is now a strong case for another major upgrade to address increasing demands on the targets, the isotope separators, and the experimental hall.

The existing target areas are well designed and have already been upgraded with new frontends in 2010 and 2011. However the scope for further upgrades is limited. For this reason an extension of the target area is proposed, with two new target stations along with new isotope separators and a modern beam delivery system. This would modernise and expand Isolde's capabilities whilst minimising perturbation of the existing facility.

The new target stations would be designed for the 2 GeV 4μA proton beam from the upgraded PS-Booster synchrotron. The eventual performance of the upgraded PS-Booster is uncertain, and the target stations should be capable of accepting up to 6 μA of protons.

The proposed beam-line layout would permit routine delivery of 3 to 4 simultaneous beams to the Isolde experimental area. This would dramatically increase the amount of beam time available, and along with the intensity increase of the driver beam the overall output of Isolde should be increased by at least four times over the current level.

Other features of the Isolde V proposal include a new beam-cooler and HRS for routine isobar separation, a dedicated non-radioactive ion-source for testing and machine development, and a flexible beam switching system for improved scheduling. A layout for a new experimental area will be shown for new or upgraded experiments. This could even free up sufficient space inside the existing hall for the proposed ISR compact ion storage ring.

Poster Session / 34

Coulomb Excitation of 66Ge

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This work pertains to determining the spectroscopic quadrupole moment for the first 2+ state in 66Ge using "safe" Coulomb excitation measurements. Motivation to study 66Ge arises from the anomalous rotational behaviour of the high-lying first 2+ state observed in even-even isotopes in the A ~ 70 region [1]. Low-lying 0+ excited states have been suggested for even-even neutron-deficient nuclei Se [2] and Kr [3] which may be an indication of shape coexistence [4]. The same trend was observed in 198Pt and is interpreted as the result of the presence of an intruder state [4]. The A ~ 70 region near the N = Z line is a region of rapidly changing nuclear shapes due to the shell gaps at proton and neutron number 34 and 36, making this region an excellent testing ground to study the phenomenon of shape coexistence. In addition, macroscopic-microscopic models suggest gamma-softness for 64Ge through oblate-prolate shape coexistence in 68Se and 72Kr to some of the most deformed nuclei at 76Sr and 80Zr.

Our experiment was performed at HIE-ISOLDE during July 2017. A 4 mg/cm2 target of 196Pt was bombarded with 66Ge beams at 4.395 MeV/u. This was the first experiment carried out using accelerated unstable Ge beams. The initial aim was to study 70Se, but the beam was contaminated with 66Ge. At first it was thought not to be a problem, but it became clear that the ratio between 70Se and 66Ge grew in favour of 66Ge. The beam was then tuned to run 66Ge for the rest of the experiement. The gamma rays were detected using the MINIBALL array containing 8 cluster of HPGe detectors. Scattered particles were detected using an annular CD detector placed a distance of 27.34 mm, covering scattering angles from 19 to 56 degrees. Studying the shape of 66Ge may shed light on some of the systematics in this rapidly changing region of nuclear shapes. Preliminary results for the spectroscopic quadrupole moment of the first 2+ state in 66Ge will be presented during the ISOLDE Workshop.

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Poster Session / 1

STRUCTURE OF β-DECAY STRENGTH FUNCTION Sβ(E), WIGNER SPIN-ISOSPIN SU(4) SYMMETRY, AND SU(4) REGION

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The strength function $S_\beta(E)$ governs [1,2] the nuclear energy distribution of elementary charge-exchange excitations and their combinations like proton particle (πp)-neutron hole (νh) coupled into a spin-parity I^π : $[\pi p \otimes \nu h]I^\pi$ and neutron particle (νp)-proton hole (πh) coupled into a spin-parity I^π : $[\nu p \otimes \pi h]I^\pi$. The strength function of Fermi-type β-transitions takes into account excitations $[\pi p \otimes \nu h]0^+$ or $[\nu p \otimes \pi h]0^+$. Since isospin is a quite good quantum number, the strength of the Fermi-type transitions is concentrated in the region of the isobar-analogue resonance (IAR). The strength function for β-transitions of the Gamow–Teller (GT) type describes excitations $[\pi p \otimes \nu h]1^+$ or $[\nu p \otimes \pi h]1^+$. Residual interaction can cause collectivization of these configurations and occurrence of resonances in $S_\beta(E)$. In heavy and middle nuclei, because of repulsive character of the spin-isospin residual interaction [1,2], the energy of GT resonance is larger than the energy of $IAR(E_{GT} > E_{IAR})$. One of the consequence of the Wigner spin-isospin $SU(4)$ symmetry is $E_{GT} = E_{IAR}$. $SU(4)$ symmetry-restoration effect induced by the residual interaction, which displaces the GT towards the IAR with increasing $(N - Z)/A$. In ^6Li nucleus (g.s. is the tango halo [3] state, IAR is the Borromean halo resonance) for low energy GT phonon (reduced GT strength $B(GT) \approx 5{g_A}^2/4\pi(\Sigma(\text{Ikeda sum rule}) = 6{g_A}^2/4\pi$ we have $E_{GT} < E_{IAR}, E_{GT} - E_{IAR} = -3562.88keV$, and $(N - Z)/A = 0.33$ for ^6He (^6He g.s. is the parent, Borromean halo state). Such situation may be connected with contribution of the attractive [4] component of residual interaction in this nucleus. It will be very interesting to find a region of atomic nuclei, where the $E \approx E_{IAR}$ and spin-isospin $SU(4)$ symmetry determine the nuclear properties ($SU(4)$ region). Difference of the $E_{GT} - E_{IAR}$ energies as a function of the neutron [1,2] excess was analyzed. Datum for $^6He\ \beta^-$ - decay was added to the data analyzed in [1,2].
Estimations shows that the value $Z/N \approx 0.6$ corresponds to the $SU(4)$ region. Different manifestations of the $SU(4)$ symmetry and possible experiments are discussed.

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Poster Session / 46

Studying shape coexistence in the neutron-deficient lead region with few-nucleon transfer reactions

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In the atomic nucleus, the interplay between single-particle motion, collectivity and
pairing is seen as a rich tapestry of shape coexisting states and exotic excitations, often associated with so called intruder states. One region where this shape coexistence phenomenon is especially prevalent is in the very neutron-deficient nuclei close to Z=82 with a neutron number close to the

mid-shell of N=104. Whilst a plethora of spectroscopic techniques have been developed to study this phenomenon, the one technique yet to be employed is transfer reactions. Recent developments of HIE-ISOLDE, with the availability of significantly higher beam energies, provides a perfect opportunity to employ transfer measurements on the highly exotic beam species available. This coupled with the new ISOLDE Solenoidal Spectrometer and the existing Miniball and T-REX setup, provides a strong opportunity to use transfer measurements to shed some light on the shape coexistence phenomenon. Here we present an overview of the physics case and prospective initial measurements following on from LS2.

Poster Session / 75

A compact RFQ cooler buncher for CRIS experiments

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B. S. Cooper, H. A. Perrett, C. Ricketts, K. T Flanagan and the CRIS collaboration.

The CRIS technique (Collinear Resonance Ionisation Spectroscopy) has been shown to be an efficient method for accessing fundamental nuclear properties of exotic isotopes [1]. Currently, radioactive ion beams are produced via proton impact with a suitable target at the ISOLDE (Ion separator On-line) facility at CERN. The resulting beam is then trapped, cooled, and bunched using the ISCOOL RFQ cooler buncher following mass separation. The ion bunches are then directed through a charge exchange cell for the purpose of neutralisation via interactions within an alkali vapour. The beam of atoms is then collinearly overlapped with multiple pulsed laser fields. This enables Doppler-free measurements of atomic hyperfine structure, leading to the determination of model-free nuclear properties. The technique has been shown to reveal properties such as nuclear spins, magnetic and electric quadrupole moments, and isotopic variations in the nuclear mean square charge radii. We envisage significant improvements to the technique following the installation of an independent RFQ cooler buncher as an alternative to ISCOOL. This would reduce set up times prior to time constrained experiments at the ISOLDE facility. It would enable constant optimisation of beam transport and quality. It would also trivialise switching from an exotic beam to a stable reference isotope from our independent offline ion source. Spatial limitations at CRIS require that the new RFQ cooler buncher is compact (<80 cm in length). SIMION calculations estimate that an early prototype device could achieve a trapping efficiency of ~ 40% with a mean energy spread of ~ 4 eV. Testing of the device is being conducted using an offline Ga ion source at the University of Manchester. Rapid prototyping has been enabled with the use of 3D printed parts, UHV compatibility of these parts is discussed.

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The MEDICIS Facility – overview, 2018 operation report and plans for CERN long shutdown 2

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The ISOLDE facility uses about 50-60% of all the CERN protons on its two targets to produce radioactive isotopes for physics research. Most of these protons go through the ISOLDE targets into the dumps, without any interaction, only having their energy slightly reduced. To "recycle" these protons, the MEDICIS facility (MEDical Isotopes Collected from ISOLDE) was created to fulfill the demand for research of radioactive isotopes in medical and life science applications.
Using an automated rail conveyor system, a target is positioned between the ISOLDE HRS target and the beam dumps. The MEDICIS target is bombarded indirectly, while cold, and in a transparent way to the ISOLDE physics program. After, it is retrieved and installed in the MEDICIS frontend and mass separator to extract the medical isotopes using the ISOL method (Isotope Separation OnLine) but in an "OffLine" mode, since the production and isotope extraction/collection happen in different moments in time. The collected isotopes can then be chemically separated and delivered to hospitals or institutes for medical research studies.
Since May 2018, MEDICIS has been for the first time operating with radioactive beam (after a short radioactive commissioning in December 2017). During this year, more than 20 irradiations have been performed in more than 10 targets for experiments previously approved by the MEDICIS Collaboration board. MEDICIS has been progressing at a very steady step reaching its milestones and isotope release efficiency goals successfully. Meanwhile the infrastructure of MEDICIS is still evolving with the implementation of radiochemistry fume hood and safety procedures, the development of GMPs – good manufacturing practices – and the commissioning of the MEDICIS Laser Ion Source Setup At CERN – MELISSA.
In this talk a full overview of the MEDICIS facility will be given together with the operation report of 2018. The plan to operate MEDICIS during CERN long shutdown 2, contrarily to the great majority of CERN facilities, will also be presented.

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An update on the chemical separation of 149Tb and its subsequent application for preclinical therapy studies

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Terbium is a unique element, as it provides a quadruplet of radionuclides suited for diagnostics and therapy in nuclear medicine [1]. Much success has been gained from the PSI-ISOLDE collaboration, with the collection and purification of 149Tb (α-emitter, T1/2 = 4.1 h – for potential therapy), used for preclinical therapy studies [2] and PET imaging [3], and 152Tb (β+-emitter, T1/2 = 17.5 h – for use in PET imaging), for preclinical [4] and clinical [5] PET imaging, respectively.
A single campaign to produce 149Tb took place in June 2018. Initially, collections were performed using 0.2 mm thick Zn foils and the chemical separations performed using an updated method. The results were erratic, with low yields being obtained due to the tardiness of the separation process and poor labeling capability of the product. Similar yields were obtained when switching to Zn-coated gold foils as before, however, the product could label to PSMA – albeit poorly. Usable product (and yields around 100 MBq) were produced when reverting to the previously-used chemical separation method (which consisted of a smaller column), allowing the labeling of 149Tb to PSMA-617 and its use for preclinical studies.
149Tb-PSMA-617 was obtained with more than 98% radiochemical purity at up to 6 MBq/nmol specific activity. Groups of 6 mice bearing tumor PC-3 PIP xenografts were intravenously injected with ~6 MBq 149Tb-PSMA-617 or 2 x 3 MBq 149Tb-PSMA-617 at Day 1 and 2 or at Day 1 and 4, respectively. The mice were monitored over several weeks with regard to the tumor growth and body weight. The tumor growth delay was more pronounced in the groups that received 2 x 3 MBq than in mice that received the whole activity in just one injection. The median survival time was 26 days

in the group that received 1 x 6 MBq, significantly longer than in untreated control mice (median survival time 20 days). Mice which received 2 x 3 MBq at Day 1 and 2 or Day 1 and 4, respectively, had a median survival of 36 days and 32 days, respectively.
Support by ENSAR2 (EU H2020 project Nr. 654002) is gratefully acknowledged.
The authors thank the ISOLDE RILIS team for efficient Dy ionization and the ISOLTRAP-MR-TOF-MS team for beam characterization.
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MIRACLS: A novel approach for Collinear Laser Spectroscopy

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Collinear laser spectroscopy (CLS) is a powerful tool to access nuclear ground state properties such as nuclear spins, electromagnetic moments and mean-square charge radii of short-lived radionuclides far from stability with high precision and accuracy [1,2]. Performing CLS with fast beams (>30 keV) provides an excellent spectral resolution approaching the natural linewidth [1]. However, depending on the specific case and spectroscopic transition, its fluorescence-light detection limits its successful application to nuclides with yields of several 100 to 10,000 ions/s [3].

Complementary to Collinear Resonance Ionization Spectroscopy (CRIS) [4], the novel MIRACLS project at ISOLDE/CERN, aims to combine the high resolution of conventional fluorescence based CLS with a high experimental sensitivity enhanced by a factor of 30 to 600. This will be achieved by extending the effective observation time, depending on the specific nuclides' mass and lifetime, by trapping ion bunches in an MR-ToF (Multi-Reflection Time of Flight) device [5-14] where they can be probed multiple times.

In order to demonstrate the functionality of this novel technique, a proof-of-principle experiment for MIRACLS was being set up around an existing MR-ToF device [15] operating at a beam energy of ~1.5 keV, which was modified for the purpose of CLS. CLS measurements in Mg ions were successfully carried out with up to 300 revolutions inside the MR-ToF device allowing the determination of the isotope shift of 24Mg+ vs 26Mg+.
This contribution will present some preliminary results of the MIRACLS proof-of-principle experiment as well as the outlook towards further developments. These includes the design of a 30 keV MR-ToF device, a necessity for the high resolution of CLS.
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Photo

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The ISOLDE target production: Highlights of 2018

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The ISOLDE target and ion source units are manufactured on demand, following the specifications implied the physics schedule. The production of each target typically takes few days, but can also take up to weeks, depending on the complexity. After the units are manufactured, they are tested at the ISOLDE OFF-LINE mass separator before they are delivered to ISOLDE for irradiation. The OFF-LINE has been operated continuously throughout the year, both for target production and target and ion source development.
We will give insights to the the ISOLDE target lifecycle, followed by a summary of the figures for the 2018 target production, highlights of delivered beams and results of our research and development work. The presentation will conclude with an outlook for the development work for envisaged during the long shutdown period.

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Plans for ISOLDE during LS2 and Outlook for the Future

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CERN's long shutdown periods provide an ideal window of opportunity to revise and consolidate the ISOLDE Facility. The Long Shutdown period 2 (LS2) starts in December 2018 and terminates in December 2020 with protons to ISOLDE, under normal operating conditions, expected in April 2021. ISOLDE will use this time to prepare the facility for the next operational period and to address the backlog of technical issues often pending due to the inability to access certain areas or to other priorities. The relatively long radioactive cool down period also provides an opportunity to change the ISOLDE Frontends both of which have overrun their expected lifetime. This presentation will give an overview of the different activities planned at ISOLDE for the LS2 period.

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The ISOLDE RILIS in 2018

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The Resonance Ionization Laser Ion Source (RILIS) at ISOLDE continued its status as the most frequently used ion source at the facility in 2018, providing laser-ionized beams of 14 elements over 20 experimental runs. Additional beams were provided during a dedicated target and ion source development period. Highlights from the 2018 on-line period will be presented.

Experimentally, the in-source spectroscopy programme continued with two experiments in the summer investigating neutron-rich bismuth isotopes and, for the first time, dysprosium isotopes. The RILIS infrastructure was used for a third spectroscopy experiment by providing laser light to perform electron photodetachment of negative ions with GANDALPH.

There were numerous technical developments throughout the year. In a continued effort to extend the applicability of solid-state lasers for on-line operation, alternative ionization schemes for copper and antimony were tested. Significant investment has been made in narrow-linewidth laser systems to extend the RILIS spectroscopic capabilities. A narrowband injection-seeded titanium-sapphire (Ti:Sa) laser was constructed, commissioned and successfully employed in the first two-photon ionization measurements at ISOLDE. Additionally, work on commissioning a pulsed-dye amplifier of continuous-wave laser light is underway.

Progress towards the construction of the new MEDICIS and Offline 2 laser laboratories will also be reported. Finally, an outlook to the planned activities during Long Shutdown 2 (LS2) will be given.

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Negative ion beams at ISOLDE

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Most commonly, ISOLDE uses positively charged ion beams produced by a variety of ion sources such as the positive surface ion source, the Resonance Ionization Laser Ion Source (RILIS) or the Forced Electron Beam Induced Arc Discharge (FEBIAD) ion source. In recent years, the availability of negative ion beams at ISOLDE was re-established and the development program of negative ion sources was revitalized to increase the production efficiency of low electron affinity elements. Currently, negative ions are created by means of surface ionization with a lanthanum hexaboride (LaB6) surface ionizer in pellet or tubular form.

In order to promote the negative ion source development, a dedicated ion source test stand was conceived and constructed, the two main features being an ion extraction system that allows measuring the total ion beam current, and a residual gas analyzer that allows us to monitor source degradation and outgassing. This test stand was used to perform measurements of the electron emission of candidates of new ion source materials and compare with the performance of LaB6. Additionally, a campaign of simulations has been initiated to gain more insight in the negative surface source.

We will give an introduction to the negative ion sources at ISOLDE and present first results from the low work-function materials study. We will conclude highlighting the results of the negative ion campaign 2018 where the electron affinity of astatine could be measured for the first time. The negative astatine ions were produced by a MK4 surface ion source giving an ion current of about 300fA. The beam of negative ions was overlapped with a laser beam and the wavelength of the laser light was scanned and the onset for the photodetachment process was observed.

Low Energy Physics 1 / 62

Staying in shape after 35: COLLAPS's recent results and perspectives

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Since the 1980s, high-resolution laser spectroscopy has been used at COLLAPS to study the structure, size and shape of radioactive nuclei [1,2]. By probing the atomic hyperfine structure and isotope shifts, nuclear moments and mean-square charge radii can be extracted and nuclear spins can unambiguously be determined. These fundamental properties provide key insights in the nuclear structure far from stability and its evolution along an isotopic chain, as will be illustrated by some recent COLLAPS' highlights in the Ni (Z = 28) and Sn (Z = 50) regions. Additionally, the relevance of this (almost) 40-year-old technique beyond LS2 will be discussed.

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Recent results from the ISOLDE Decay Station

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The ISOLDE Decay Station (IDS) [1] has been a permanent experiment used for studies of low-energy nuclear physics at the CERN-ISOLDE facility, since 2014. The core of the setup consists of four, high-efficiency, clover-type germanium detectors and a tape transportation system. These can be coupled to a number of ancillary detector arrays, used for alpha/beta/gamma spectroscopy, neutron time-of-flight studies, or fast-timing measurements, making IDS a powerful and versatile tool for studying the wide range of radioactive species that are readily produced at ISOLDE.

In this contribution, an overview the IDS system and its detectors will be presented, along with preliminary results from recent experiments performed at IDS [2]. In particular, results from an in-source laser spectroscopy study of bismuth isotopes [3] will be shown, in which a new high-spin isomer was identified and studied in 214Bi, thanks to the high gamma-ray detection efficiency of IDS, as well as results from a study of the low-lying excited states in 182,184,186Hg [5], using a newly incorporated SPEDE conversion electron detector [4] at IDS.

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Collinear Resonance Ionization Spectroscopy (CRIS) studies of neutrondefcient and neutron-rich Indium isotopes

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With a proton hole in the Z = 50 shell closure, the indium isotopic chain (Z = 49) offers a compelling scenario to explore the evolution of nuclear-structure properties in the neighbourhood of the doubly-magic isotopes 100Sn (Z, N = 50) and 132Sn (N = 82).

This contribution will present two recent successful campaigns to measure the hyperfine spectra of the neutron-deficient neutron-rich indium isotopes 101-113In and 113-131In at the Collinear Resonance Ionization Spectroscopy (CRIS) experiment. Offline developments which aided in the success of these measurements will be discussed [1].

From these measurements, the spins, electromagnetic moments, and changes in root-mean-squared charge radii of several ground and isomeric states have been determined for the first time, extending our experimental knowledge from down to N=53 and up to N = 82.
The importance of these results, in connection with long-standing nuclear structure puzzles in the area and with modern developments of nuclear theory will be outlined.

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Study of beta-delayed neutron decay of 8He

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The nucleus of ^{8}He is characterized by the largest neutron-to-proton ratio among all known particle-stable nuclei. Beta decay of ^{8}He has been investigated by Björnstadt et al. [1] and Borge et al. [2, 3] where β-delayed γ-ray, neutron and triton spectra were measured. In this contribution, the results of the new study of β-delayed neutron decay branch of ^{8}He will be presented. The energy spectra of the emitted neutrons were measured in the energy range of 0.5 − 7 MeV using the time of flight VANDLE spectrometer at the ISOLDE Decay Station. Using coincident gamma ray measurement, components of the βn spectrum corresponding to transitions to the ground- and first excited state of ^{8}Li were disentangled for the first time. The new data will be compared with the results of previous measurements and confronted with the predictions of theoretical models.

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Precision spectroscopy of ”hot” molecules

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Other Facilities 2 / 72

In-beam gamma-ray spectroscopy of exotic nuclei at the RIBF

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At the Radioactive Isotope Beam Factory in-beam gamma-ray spectroscopy experiments take advantage of the wide range of radioactive ion beams produced by the projectile fragmentation and fission. Isotopes of interest are separated by the BigRIPS fragment separator and guide to a secondary reactions target. Reaction residues are identified either in the ZeroDegree spectrometer or with the SAMURAI setup. Gamma rays emitted at the reaction target are detected with high efficiency in the DALI2 NaI(Tl) array.
The physics program includes a wide range of topics in nuclear structure addressing collective and single-particle structure of nuclei very far from stability.
In this talk I will give an overview of recent results on proton- and neutron-rich nuclei and discuss future experimental campaigns at the RIBF.

Other Facilities 2 / 57

Spectroscopy of muonic atoms and the proton radius puzzle

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We have measured several 2S-2P transitions in muonic hydrogen (μp), muonic deuterium (μd) and muonic helium ions (μ3He, μ4He). From muonic hydrogen we extracted a proton charge radius 20 times more precise than obtained from electron-proton scattering and hydrogen high-precision laser spectroscopy but at a variance of 7σ from these values. This discrepancy is nowadays referred to as the “proton radius puzzle”.
New insight has been recently provided by the first determination of the deuteron charge radius from laser spectroscopy of μd. The status of the proton charge radius puzzle including the new insights obtained from μD and μHe spectroscopy will be discussed. Moreover, a novel scheme for spectroscopy of high-Z muonic atoms will be briefly presented.

Other Facilities 2 / 53

R3B-NeuLAND - Detection of Fast Neutrons

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The high-resolution, large-acceptance neutron time-of-flight spectrometer NeuLAND is the new neutron detector being developed for
the R3B setup (Reactions with Relativistic Radioactive Beams) at
FAIR. NeuLAND is dedicated to the detection of high-energy neutrons
up to 1GeV. In this talk, I will report on the design concept and the status of construction. An overview over the experimental campaign carried out with the NeuLAND demonstrator at the SAMURAI setup at RIKEN will be accompanied by an outlook on the R3B phase0 program at GSI.

Other Facilities 2 / 31

Evidence for clustering in ^{20}Ne: the Morinaga nucleus

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The reduced transition probability or $B(E2;0_1^+ \rightarrow 2_1^+)$ value and the spectroscopic quadrupole moment of the first excited 2_1^+ state, $Q_S(2_1^+)$, at 1.633 MeV in ^{20}Ne have been determined at safe energies using the {\small TIGRESS} and AFRODITE arrays at TRIUMF and iThemba LABS, respectively. Large values of $B(E2;0_1^+ \rightarrow 2_1^+) = 22.4(16)$ W.u. and $Q_s(2_1^+) = -0.26(3)$ eb present strong discrepancies when compared with mean-filed calculations and the collective model of Bohr and Mottelson. Modern relativistic mean-field calculations predict a dominant ^{16}O+α configuration for the 2_1^+ state in ^{20}Ne, which may explain current failures of collective and mean-field models, which underestimate the $Q_s(2_1^+)$ value in ^{20}Ne by about 30%. These findings are relevant to understanding the mixing between mean-field and α cluster states and provide evidence for clustering formation in nuclei at low excitation energies below the α separation energy.

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Workshop Dinner

Technical Session 2 / 51

Operations of the REX/HIE-ISOLDE linac during the 2018 Physics Campaign

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The 2018 ISOLDE high energy Physics campaign started last July, immediately after Phase 2B of the HIE-ISOLDE project was completed. Since then, multiple stable and Radioactive Ion Beams (RIBs) have been delivered to the three different experimental stations (Miniball, ISS and the Scattering chamber) and fourteen experiments have been conducted. The main issues and the operational highlights for each of the experiments as well as the reliability of the different subsystems of the linac will be discussed in this presentation. l be discussed in this presentation.

Technical Session 2 / 50

REX and HIE ISOLDE post-accelerator shutdown work

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This presentation will give you an overview of the foreseen maintenance and modifications during the Long-Shutdown 2 period related to the ISOLDE post-accelerator REX and HIE ISOLDE as well as the High Energy Beam Transferlines.

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REX/HIE-ISOLDE Machine Development

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Several aspects of optimisation or development towards a more complete understanding of the REX/HIE-ISOLDE linear accelerator will be presented.

We will first demonstrate the possibility to map a spectrum of contamination from residual gas ions, on a wide mass-to-charge ratio range, helping on the anticipation of the ion beam purity. Additionally, an effort for the optimisation of the ion pulse time distribution extracted from the REXEBIS charge breeder, called Slow Extraction, will be described. Moreover, recent measurements will exhibit a potential performance improvement of the REXEBIS by operating its electron beam at specific energies related to resonance peaks of the di-electronic recombination process.

The precise knowledge of the ion beam transversal and longitudinal properties are also of primary importance for the experimental apparatus. For this purpose, a new method will be depicted, that allow for the determination of the transversal and the longitudinal ion beam properties, at intensities too weak to make use of conventional beam-line monitoring detectors (for instance, Faraday cups). The principle behind the identification of the transversal and the longitudinal beam properties are well-known and based on multiple acquisitions of the respective trace-space projections or slices (notably: the quadrupole-scan method, the double-slit method or the three-gradient method). The novelty of the presented techniques resides in the use of a silicon detector.

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Charge breeding investigations for a future 11C treatment facility

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Within work-package 2 of the MEDICIS-Promed ITN we study the possibilities of using a radioactive therapy beam in hadron therapy. In particular, 11C (β+ emitter, t1/2=20.3 min) is investigated as it has excellent properties for both on-line and off-line PET imaging, which can be used for dose verification. While ions are produced abundantly in conventional hadron therapy with stable carbon, it is highly challenging to provide a radioactive beam of adequate intensity for treatment. The main challenge of this work lies in linking the production of a continuous, molecular CO+ beam from an ISOL-target with a low repetition-rate medical accelerator. The concept of accumulation, breeding and post-acceleration of radioactive carbon beams was tested at REX-ISOLDE.

Different possibilities of using a charge breeding stage as a CO beam preparation tool for hadron therapy with a synchrotron are laid out and investigated with regard to their feasibility and technical limitations. Measurement data taken at ISOLDE is presented that quantifies the behaviour and limitations of the Penning trap and EBIS under the extreme conditions of high-intensity, low repetition-rate beams. Thereby, various injection scenarios that correspond to different design options for a hadron therapy beam preparation stage are compared. Finally, a green field approach is presented, that discusses possibilities of matching the radioactive beam with future medical accelerators, in particular with a fast all-linac system.

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Mass measurements at the extreme of the nuclear landscape with ISOLTRAP

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Key in the establishment of the traditional concepts of nuclear shells, binding-energy studies were also pivotal to the early realization of the demise of the traditional shell closures away from stability [1]. Extensive effort has followed to examine the classical signatures for magicity in exotic nuclei and more than three decades later, the robustness of all major shell closures has been assessed [2]. Along the way, a number of subshells (e.g N = 32 in ^{52}Ca) have even been shown to exhibit localized magic behaviour [3].

Over the past year, the online Penning-trap mass spectrometer ISOLTRAP [4,5] has dedicated most of its experimental effort to the study of two topical regions for the study of the shell-evolution phenomenon. On the one hand, extending the study of the N = 32 sub-shell closure from the cadmium (Z =20) to the scandium (Z =21) chain was attempted. On the other hand, a mass-measurement campaign was dedicated to the study of neutron-deficient indium isotopes in the vicinity of the doubly-magic ^{100}Sn. This campaign performed at extreme of the nuclear landscape was successful to measure $^{99-101}$In and allows the study of the Z=N=50 shell closure in close proximity with the proton drip-line. This contribution will present highlights from both measurement campaigns.

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Standard Model tests in nuclei

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I will discuss which kind of new phenomena can be probed through precision measurements in nuclear processes. Using a model-independent description I will discuss the interplay between the different experiments and which ones are the most sensitive and promising. Finally I will analyze the synergy with searches at high-energy colliders, such as the LHC, and with other electroweak precision observables.

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186Hg ground state deformation from total absorption studies

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Extracting the shape of a nucleus in its ground state when its spin is less than 1 is not possible by a direct measurement of the quadrupole moment. This limits the sources of information available for the study of the ground state shapes of even-even nuclei. Common alternatives are the extraction of the information from electromagnetic transitions along the ground state band or measurements of changes of the nuclear radii along an isotopic chain. Apart from these options, in particular cases it is possible to extract shape information from the distribution of the beta strength in the daughter nuclei [1-5]. This is possible when theoretical calculations predict different patterns of the beta strength distributions depending on the shape.

In this work we will present the analysis of the total absorption measurement of the beta decay of 186Hg performed using the total absorption spectrometer LUCRECIA at ISOLDE. Comparisons with theoretical calculations [6] allow us to infer the shape of this nucleus in its ground state. This result is of particular interest, since 186Hg lies in the region of shape transition [7].

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Beta-delayed fission investigation of ^{188m1,m2}Bi employing isomer-selective laser ionization

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A dedicated and world-wide unique program to study β-delayed fission (βDF) is being performed by our collaboration since a decade ago at the ISOLDE (CERN), e.g. [1,2,3]. In βDF, the mother nucleus undergoes β decay to excited state in the daughter nucleus with the energy comparable to the fission barrier height and the daughter nucleus then fissions. The excitation energy is limited by Q_β value of parent nucleus, which is usually below 10 MeV. Therefore, βDF represents so called low-energy fission, which is sensitive to structure of the nucleus. It allows us to investigate fission properties of exotic isotopes, for which other low-energy fission studies would be extremely difficult or currently impossible. For example, βDF measurements established a new region (and a new type) of asymmetric fission [1,2].

Beta delayed-fission of ^{188}Bi was previously studied in JINR Dubna [4,5] and at SHIP, GSI Darmstadt [6]. There are two predominantly α-decaying isomers in ^{188}Bi with half-lives of 60 ms and 265 ms [7], and in these studies it was not possible to assign the fission to specific isomer, neither the total kinetic energy (TKE) nor fission fragment mass distribution measurements were done.

In this contribution, we report on the recent βDF measurement of ^{188}Bi performed at ISOLDE. The key goal of our study was to investigate βDF properties of the isomers in ^{188}Bi separately, and to attempt to probe the spin dependence of fission. To obtain isomerically-pure beams, we employed selective power of RILIS. Results of these investigations will be presented, including partial half-lives of βDF for each isomer, and TKE and fission fragment mass distribution for longer-lived isomer. Findings will be discussed in connection to partial half-lives systematics and theoretical calculation of fission fragment mass distribution.

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Closing Remarks and Prize announcements

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Fast-timing studies in ^{214,216,218}Po following the beta-minus decay of ^{214,216,218}Bi isotopes at the ISOLDE Decay Station

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Po isotopes, having 2 valence protons in the $h_{9/2}$ orbital above the Z=82 Pb core, demonstrate a multitude of interesting phenomena, such as widespread shape coexistence and the presence of high spin isomers in the neutron-deficient region. The structure of the Po isotopes is ideally suited to test the applicability of the seniority scheme across the long isotopic chain, spanning many neutron subshells both above and below N=126.
While extensive studies of 8^+ isomers in neutron-deficient even-even Po isotopes were performed in the past, not much is known on them in the neutron-rich cases. Such isomers can arise from several configurations, e.g. $\pi(h_{9/2})^2$, $\nu(g_{9/2})^n$, an α cluster coupled to a ^{208}Pb core or even from a mixture of these configurations.
The lifetime measurements for the aforementioned 8^+ states (also for the other states of the yrast band, such as 2^+, 4^+, 6^+) can provide important information on $B(E2)$ values, which can then be used to test the different theoretical approaches and underlying configurations.
We report on the IS650 experiment performed at the ISOLDE Decay Station in July 2018 where intense and high-purity laser-ionized ^{214,216,218}Bi beams were implanted on the IDS moving tape and, by employing the fast-timing technique, the lifetimes of nuclear levels Po daughter isotopes were studied. The experiment overview will be followed by a brief discussion of preliminary first-time lifetime measurements of the 8_1^+ states in ^{214,216,218}Po.