ISOLDE - EPIC 2019

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Book of Abstracts

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Welcome word from the CERN Directorate

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Goals of the workshop and the EPIC project

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LHC Intensity Upgrade (LIU) and its potential for ISOLDE / **5**

Feasibility of transferrring 2 GeV beams from the CERN PSB to ISOLDE

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This feasibility studies evaluates the possibility of transferring 2 GeV beams to the ISOLDE facility. Required upgrades of magnets, power converters and beam instrumentation will be shown together with a preliminary integration study. Expected beam parameters from Linac4 will be given together with a cost estimate for the beam transfer upgrade.

LHC Intensity Upgrade (LIU) and its potential for ISOLDE / **9**

EPIC target production

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The target and ion source unit is the core for radio isotope production at an ISOL facility. A steady supply of freshly custom made targets has to be maintained throughout the operation period following the tight physics schedule.
With the EPIC upgrade of the ISOLDE facility and the potential increase of irradiation points, target production has to be adapted.
The current target production process will be presented and constraints and implications of operating an extended facility will be discussed. We will highlight the aspects of target and ion source

development programme within EPIC, aiming for reliability and longevity improvement as well as compatibility with increased proton energy and intensity.

LHC Intensity Upgrade (LIU) and its potential for ISOLDE / 6

Upgrading the proton beam energy of ISOLDE from 1.4 to 2 GeV: the impact on the beam intensities

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During the Long Shutdown 2, CERN has connected the LINAC 4 to its accelerator complex and as well upgraded the PS Booster to be able to cope with the new LINAC proton beam energy (160 MeV), and acceleration of the protons up to 2.0 GeV (instead of up to 1.4 GeV as it was in the past). However for the moment, the transfer beam line connecting to ISOLDE (BTY) is not being prepared for 2.0 GeV and ISOLDE will still receive proton energies up to 1.4 GeV. Nonetheless, within the PS Booster upgrade it is possible that the proton beam maximum intensity available to ISOLDE will also be upgraded from 2.2 µA to 3 or even 4 µA. In the next long shutdown affecting ISOLDE (LS3 in 2024), the opportunity arises to upgrade the BTY line so it can deliver 2.0 GeV protons to ISOLDE.

In this talk, the main advantages of upgrading the primary beam of ISOLDE from 1.4 to 2.0 GeV will be detailed. The estimated yield gains across the nuclear chart, using simulation codes such as ABRABLA and FLUKA, for UCx, Ta target materials and the neutron converter and a few other materials will be shown together with particular isotope examples. On the intensity increase subject, measurements will be presented showing that using a longer proton pulse (increased space between bunches, STAGISO) instead of the standard pulses (NORMISO) has no influence in the release of isotopes. This has the advantage of reducing the peak power deposited in ISOLDE targets, possibly prolonging their lifetime.

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General Discussion

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A new ISOLDE Storage Ring-ISR

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A new storage ring is proposed for the HIE-ISOLDE facility in CERN. Such a facility will provide a capability for experiments with stored radioactive beams that are unique in the world. The physics program varies from investigations of nuclear ground-state properties, reaction studies of astrophysical relevance and systematic studies within the neutrino beam program. In addition to in-ring experiments, ion beams with the properties of an electron cooled ion beam can be slow extracted and

exploited by external spectrometers for high precision measurements. The technical details of the proposed ring facility for HIE-ISOLDE are presented.

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New opportunities for in-ring experiments using ISOLDE beams

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Experiments with exotic nuclei stored in a ring have shown a huge discovery potential in the last decades. Such experiments profit from high revolution frequencies of stored beams which allows for reaching relatively high luminosities even when using thin gaseous internal targets. Internal gas targets are windowless and thus the corresponding background contributions do simply not exist. Electron cooling of stored beams leads to small transversal size and high momentum definition.
Broad experimental programs with stored ions are being pursued at the ESR of GSI, the CSRe of IMP and R3 of RIKEN. However, these are dedicated machines tuned to store beams with a few hundred A MeV energies. The quest today is to approach lower, below 10 A MeV, energies, where numerous new physics cases have been proposed. For instance, deceleration of beams in the ESR enabled studies of proton-induced reactions for the astrophysical p-process. Furthermore, a dedicated low-energy storage ring CRYRING is being commissioned behind the ESR. However, the lengthy slowing down process at GSI limits the use of the ESR-CRYRING for investigations of short-lived nuclei.
Therefore the proposal to store HIE-ISOLDE beams in a dedicated storage ring and to perform nuclear and atomic physics experiments is extremely attractive. This will be a worldwide unique facility with an access to stored and cooled short-lived nuclei for in-ring experiments.

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The ISOLDE Solenoidal Spectrometer

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The ISOLDE Solenoidal Spectrometer (ISS) is a new experimental station based on the second HIE-ISOLDE beam line. Based on the HELIOS concept developed at Argonne National Laboratory (ANL) [1], the experiment consists of a 4 T former MRI magnet and on-axis silicon detector array for the detection of light ions. Various ancillary devices are to be used for the coincident detection of recoil partners from the reaction, such as downstream silicon telescopes or gas-filled ionisation chambers.

ISS will exploit the wide range of radioactive ion beams available at ISOLDE providing a new opening the possibility to study new physics across the nuclear chart. Few-nucleon transfer reactions to investigate single-particle structure of nuclei are expected to be the workhorse experiments performed at ISS, while new techniques such as inelastic scattering and transfer-induced fission in inverse kinematics are proposed. The bore of the magnet can also be cleared to accept the SpecMAT active target chamber, on which a poster is also presented in this session.
The first two experiments using the device were performed during the 2018 campaign with the device being commissioned in the ISOLDE hall during 2017 and early 2018. For this first exploitation using (*d,p*) reactions on ²⁸Mg [2] and ²⁰⁶Hg [3] beams, collaborators from ANL loaned their Si detector array and data acquisition in order to get the first results before CERN's long shutdown 2 (LS2). This poster will present the status of commissioning of the bespoke on-axis Si array and the ionisation chambers for recoils and fission. These advances mean that ISS will be ready for a full physics programme after LS2 in a number of potential configurations, depending on the reaction to be studied. This poster will also present the benefits that will be provided by the EPIC project that could be exploited by ISS in the future, including potential upgrades to ISS itself.

The ISS core collaboration consists of the University of Liverpool, University of Manchester, STFC Daresbury Laboratory, KU Leuven and has received crucial support during the construction from Argonne National Laboratory and ISOLDE, CERN.

References
[1] J.C.Lighthall et al., Nuclear Instruments and Methods in Physics Research A622 (2010) 97.
[2] D.K.Sharp et al., CERN-INTC-2016-030
[3] B.P.Kay et al., CERN-INTC-2016-024

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Transfer-induced fission in inverse kinematics with solenoidal spectrometers

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Studying transfer-induced fission in inverse kinematics offers advantages over neutron-induced fission measurements in normal kinematics. Two such advantages include the ability to measure fission barrier heights of fissile nuclei due to the addition of a third body to the system, and the possibility to study the fission properties of short-lived actinides where fixed targets are not feasible; these appealing features have been exploited in the past [1-2].

The approach that we are currently investigating is to use the single neutron-adding (d,p) reaction as a precursor to fission. With a solenoidal spectrometer such as the ISS coupled with a fission fragment detection array composed of Bragg chambers, measurement of the following parameters should be possible: fission barrier height, mass and charge yields, and by measuring fission probabilities as a function of excitation energy, the corresponding neutron-induced fission cross section can be

deduced. By measuring the angular distribution of the outgoing (d,p) protons, the dependence of fission probability on spin can also be investigated.

The feasibility for the measurement of the aforementioned quantities has been demonstrated by means of simulation, the results of which shall be presented. Calculations of transfer-induced fission rates based on ISOLDE target yields will also be presented to indicate the most viable cases, and where beam development would be beneficial to the project.

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[2] J. E. Escher, J. T. Burke, F. S. Dietrich, N. D. Scielzo, I. J. Thompson, and W. Younes. Reviews of modern physics, 84(1):353, 2012.

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MIRACLS: A novel approach for Collinear Laser Spectroscopy

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Due to its high accuracy and resolution, collinear laser spectroscopy (CLS) is a powerful tool to measure nuclear ground state properties such as nuclear spins, electromagnetic moments and mean-square charge radii of short-lived radionuclides. Performing CLS with fast beams (>30 keV) provides an excellent spectral resolution approaching the natural linewidth. However, its fluorescence-light detection limits its successful application to nuclides with yields of more than several 100 to 10,000 ions/s, depending on the specific case and spectroscopic transition.
To extend its reach to the most exotic nuclides with very low production yields far away from stability, more sensitive methods are needed. For this reason, the novel Multi Ion Reflection Apparatus for CLS (MIRACLS) is currently under development at ISOLDE/CERN. This setup aims to combine the high resolution of conventional fluorescence based CLS with a high experimental sensitivity, enhanced by a factor of 30 to 600. Within MIRACLS, this will be achieved by extending the effective observation time over a radionuclide's entire lifetime when the rare ions are stored in an Electrostatic Ion Beam Trap, also called Multi-Reflection Time-of-Flight (MR-ToF) device. A proof-of-principle apparatus, operating at ˜1.5 keV beam energy, has been assembled at ISOLDE/CERN with the goal of demonstrating the potential of the MIRACLS concept, to benchmark simulations that are employed to design a future device operating at 30 keV and to further develop the technique.
This talk will introduce the MIRACLS concept and present the first results with ions of stable magnesium and calcium isotopes which allow the systematic optimization of the MR-ToF operation for CLS. An outlook towards further developments will be given which includes the design of a "30 keV MR-ToF device", a necessity for the high resolution of CLS.

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MINIBALL - versatile HPGe array for experiments with post-accelerated RIBs at ISOLDE

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The MINIBALL array consists of 24 6-fold segmented, individually encapsulated, HPGe detectors [1]. MINIBALL was one of the first arrays of such size with a fully-digital triggerless DAQ system. It has been operated very successfully at ISOLDE since the beginning of REX-ISOLDE and is still the main instrumentation for experiments with post-accelerated radioactive ion beams from HIE-ISOLDE. For most experiments, in addition highly-segmented Si detectors for particle detection are used, e.g. the T-REX array [2]. The experimental programme to study the structure of exotic nuclei applies methods like Coulomb excitation and nucleon transfer reactions. The MINIBALL set-up has been continuously upgraded and auxiliary devices like a plunger or the conversion electron spectrometer SPEDE [3] have been added to broaden the experimental opportunities. In this contribution, the current status will be shown and ongoing updates like a new DAQ, the addition of Anti-Compton shields or the new T-REX array will be presented.

MINIBALL is supported by funding from Belgium, Finland, Germany, Sweden, United Kingdom and ISOLDE/CERN.

[1] N. Warr et al., EPJ A 49, 40 (2013)
[2] V. Bildstein et al., EPJ A 48, 85 (2012)
[3] P. Papadakis et al., EPJ A 54, 42 (2018)

Poster Session / 14

The PUMA experiment at CERN/ISOLDE

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Frank Wienholtz for the PUMA Collaboration

The PUMA experiment aims to use antiprotons as a tool for exploring the properties of exotic nuclei by probing the distribution of the protons and the neutrons on the surface of the nucleus. To be able to do this, a mobile Penning-trap system must be designed and built which will allow to transport antiprotons from CERNs antiproton decelerator (AD) facility to the ISOLDE experimental hall. This contribution will detail the general concept of the PUMA experimental setup, it will present its mayor physics goals and detail the feasibility within the current experimental infrastructure at ISOLDE.

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The SpecMAT active target for transfer reaction studies at HIE-ISOLDE

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The SpecMAT active target will be used for the study of isotopes in the exotic regions of the chart of nuclide, to investigate the fundamental questions related to the shell structure of nuclei far from stability via nucleon-transfer reactions in inverse kinematics. The active target will be placed in a high and homogeneous magnetic field of up to 2.4 T at HIE-ISOLDE (CERN) for reconstruction of the energy of the recoil particles based on the curvature of their trajectories in the magnetic field. To extract additional information about the populated low-lying states in the transfer reactions, SpecMAT will be surrounded by an array of scintillation detectors for gamma-ray spectroscopy.

Currently, simulations indicate that energy resolution of up to 100 keV can be achieved in transfer reactions in active targets from the energy of the ejected charged particle. In SpecMAT, gamma-ray energy resolution below 4 % at 662 keV gamma-line in the magnetic field can be achieved using modern developments and innovative technologies in scintillation detectors. The high detector efficiency, combined with the energy resolution and full kinematic reconstruction, unfold new horizons on the study of exotic isotopes.

The recent progress in the construction and characterization of the detector will be presented.

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Search for physics beyond the Standard Model with radioactive beams

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The search for physics beyond the standard electroweak model (SM), despite its remarkable success at the most elementary level, still continues on three frontiers - high-energy, precision and cosmic. The reason is the many yet unanswered questions such as the origin of parity violation [1].
Considering the precision frontier, experiments with radioactive nuclei offer large variety of nuclear states with optimal sensitivity to study the beta-neutrino angular correlation coefficient ($a_{\beta\nu}$) that are still competitive to today's high-energy and cosmic experiments. In particular, studies performed in pure transitions, Fermi or Gamow-Teller provide a direct probe to the presence of scalar or tensor currents, respectively. Measurements of this kind have been performed in various nuclear systems in the past [2], with ^{32}Ar being one of the most precisely known to date.

The experiment WISArD (Weak Interaction Studies with ^{32}Ar Decay) [3] is currently being prepared at ISOLDE/CERN, and will focus on determining $a_{\beta\nu}$ through beta-proton coincidence measurements. The ground state in ^{32}Ar beta decays via the super-allowed Fermi transition to the isobaric analogue state in ^{32}Cl which subsequently decays by proton emission. Measured kinematic shift of emitted protons reflects the energy spectrum of the recoiling nuclei after the previous beta-decay which depends on the character of the weak interaction. To enhance the measurement sensitivity emitted particles will be guided by a strong magnetic field. In this contribution the layout of the setup will be presented as well as preliminary results from a proof-of-principle campaign performed in the fall of 2018. Furthermore, a discussion about the
potential precision at reach applying this technique will be given.

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Poster Session / 17

Target developments at KU Leuven

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The Isotope Separation On-Line (ISOL) method is a powerful technique to produce radioactive ion beams (RIB), and thus, is an essential tool when studying the properties of atomic nuclei far away from the valley of stability. The ISOL method gives, in principle, access to a large number of the known (radio-)isotopes of the chart of nuclides, with relatively large intensity and purity. Key component of an on-line isotope separator is the target-ion source unit, which, depending on the RIB of interest, requires thoughtful optimization in view of target microstructural properties, radiochemistry and high temperature chemistry. In that regard, the choice of the target material and its processing routes is of utmost importance, since the release from the target matrix is often considered as one of the major bottlenecks in RIB production. Generally, small target grain sizes, high open porosity and high temperatures are favorable for increased release efficiencies. However, due to the high temperatures during target operation, issues such as grain growth and densification (pore shrinkage) need to be considered, and more importantly, avoided when developing new target materials. Therefore, a new research line was launched at KU Leuven (Belgium), focusing on new target developments and isotope purification systems based on laser ionization, which are to be implemented at ISOLDE, MEDICIS, and in the future at ISOL@MYRRHA. This contribution aims to present the target developments that are currently carried out in collaboration of the Institute of Nuclear and Radiation Physics (IKS) and the Department of Materials Engineering at KU Leuven. In detail, this comprises powder metallurgical routes for TaC and TiC target materials towards the production of ^{149,152,155}Tb and ^{44,47}Sc, respectively. Different processing routes are discussed, regarding their capability of yielding porous targets that present a stable microstructure during operation, i.e. limited or no densification. Furthermore, in 2018 a new test bench to measure release fractions was developed at MEDICIS, allowing to study, off-line, release characteristics of new targets. This is very useful, as from such measurements on-line release efficiencies can be estimated and target properties, such as diffusion coefficients, may be studied. In that regard, the fractional release of ^{11}C was measured from a porous boron nitride (BN) target, developed at IKS for the production of intense ^{11}C beams. The authors would like to acknowledge the strong support from the teams at ISOLDE, MEDICIS and SCK•CEN concerning the characterization and testing of those materials.

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Towards a beta spectrum shape measurement at WISArD

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There are indications that the measured number of antineutrinos emerging from reactor fission fragments inside a reactor is lower than theoretically predicted. Moreover, there is an additional anomaly in the energy spectrum of the antineutrinos. These observations are the reactor neutrino anomaly. One of the uncertainties in the theoretical description is the QCD influence on the β-decay of which the weak-magnetism term is the major contribution. Its value is unknown experimentally in the mass range of the reactor fission fragments. [1] A direct measurement is possible with the beta energy spectrum and would be the first of its kind in this mass range. In addition, the performed fit can include the Fierz interference term to probe beyond standard model (BSM) physics, i.e. weak tensor or scalar currents. BSM experiments aim for a precision close to 10^(-3) and, thus, complementarity to high energy experiments, e.g. LHC, within an effective field theory. [2]
Spectrum shapes were measured extensively in the past but only recently attracted renewed interest. The main sources of systematic uncertainties are energy losses in the source (foils), the detector dead layer and the rather high backscattering probability for electrons. Using the progress in Monte Carlo simulation (e.g. Geant4) over the last couple of years it is possible to improve on previous results. [2]
During the long shutdown at CERN we will adapt the existing WISArD set-up at CERN with the objective to measure the beta-spectrum shape of (_ ^114)In, a pure Gamow-Teller decay. With two energy detectors along a high magnetic field the set-up has a full solid angle. Moreover, backscattered particles are not lost but spiral towards the other detector. Using Geant4 a feasibility study is completed and first data taking is planned in short notice thus preliminary results might be shown.
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Development of a fast and highly selective ISOLDE MR-ToF device

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As experimental methods for fundamental science and applications at radioactive ion beam (RIB) facilities are expanding our scientific horizon, their demands on the quality of the RIB perpetually increase. In this regard, (isobaric) contaminants in the RIB have long been identified as a major obstacle. Indeed, when probing nuclides towards the limits of nuclear existence, an overwhelming amount of contaminants commonly prevents the study of the most exotic nuclides available at today' s (low energy branches of) RIB facilities. Similarly closer to stability, applications such as medical isotope production or solid state physics suffer from sizeable contamination levels.

Multi-Reflection Time-of-Flight (MR-ToF) devices such as the one operated very successfully by ISOLTRAP [1] at ISOLDE have over the last few years gained enormously in importance at RIB facilities for mass measurements as well as mass separation. This is due to their superb performance in terms of mass resolving power R=M/ΔM > 10^5 attainable in a few ms [2]. Naturally, such an MR-ToF device would be of great benefit for the entire ISOLDE community in order to provide purified beams of exotic nuclides to experimenters.
For this reason, a project to develop such a general purpose ISOLDE MR-ToF instrument has now been initiated at ISOLDE and proceeds in close collaboration with the construction of the Multi Reflection Ion Apparatus for Collinear Laser Spectroscopy (MIRACLS) [3]. The novel aspect of the ISOLDE MR-ToF device will be its unprecedented ion-beam energy of 30 keV compared to a few keV in today's instruments. Combined with advanced beam-preparation methods, this opens a path to a higher, mass separated ion flux. In this regard conventional, slower MR-ToF setups suffer from space-charge effects which compromise the superb mass resolving power when too many ions are stored in the trap simultaneously. In the ISOLDE MR-ToF device these space-charge effects are outwitted by keeping the number of ions trapped at a time below this limit but processing the mass separation significantly faster.

This poster contribution will introduce the project of the ISOLDE MR-ToF device and explain its status, challenges and potentials.

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see also poster by V. Lagaki

Poster Session / 24

The HIE-ISOLDE Superconducting Recoil Separator (HISRS)

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TITLE: The HIE-ISOLDE Superconducting Recoil Separator (HISRS)
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Abstract
The HIE-ISOLDE facility at CERN (Geneva, Switzerland) [1] produces a large variety of radioactive beams from 6He to 232Ra at 0.45-10 MeV/u. This energy range is ideal to study nuclear structure, low-energy dynamics and astrophysics by using nucleon transfer, Coulomb excitation and deep inelastic reactions. An important experimental problem is the separation of the primary beam from beam-like reaction fragments produced in heavy ion reactions. To meet the physics program needs, a high-resolution recoil separator based on a compact superconducting mini-ring storage system has been proposed.
A proof-of-concept preliminary design features a Φ= 1.5 m diameter ring built up of multifunction SC magnets of δ = 25 cm length (MFSCM) in a Fixed-Field Alternating-Gradient (FFAG) configuration [2]. The MFSCMs should be able to withstand magnetic fields as high as 6 T. The reaction fragments circulate typically for ⊠ = 10 µs being differentiated by their cyclotron frequency. After extraction the ions are identified and quantified in a focal plane detector by Time-of Flight (ToF) and Digital Pulse Shape Analysis (DPSA) techniques [3].
The White-Book of the HISRS facility addressing the most important physics cases and the technical requirements, is presently in preparation.
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Poster Session / **26**

Double target front-ends: an inexpensive alternative to additional front-ends

Authors: Miguel Luis Lozano Benito[1]; Jose Alberto Rodriguez[1]; Simon Mataguez[1]; Erwin Siesling[1]

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One of the core components of the EPIC project is the installation of two additional target stations following the existing GPS and HRS ones. Protons from the PS Booster (PSB) could be shared among two or more of these four target stations producing several Radioactive Ion Beams (RIBs) that could be delivered to different experimental stations in parallel. However, the effective proton current in each of the targets would be reduced and therefore, the production of the RIBs would also be limited. Alternatively, two targets could be installed in series a single front-end profiting from the full proton current simultaneously. In addition to a significant cost reduction in civil engineering and ancillary equipment, the overall RIB production would increase significantly. In this contribution, initial considerations on this target configuration will be presented and the advantages and disadvantages compared to the separated four targets alternative will be discussed.

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An alternative layout proposal for ISOLDE Target Area

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This is an alternative conceptual design of a target area layout of ISOLDE. This concept will require shielding consolidation and a different approach to operational scenarios. In a first approach, this design focuses on the handling and maintenance aspects for future upgrades in the target area. The increase of radiation levels due to higher proton beam current and energy after LS3 will complicate personnel access into the target area. This concept also has the advantage of having a minor impact on the actual beam line distribution. The increase of available areas on the two new floors (2x700 m2) offers many opportunities for future evolution such as a radioactive off-line mass separator, an additional Class A laboratory, radioactive storage and repair areas. This solution also has the advantage of respecting the minimal allowed distance (10m for a visible building) from the French border.

Needs and benefits of 2 GeV high intensity protons for ISOLDE / 8

New beam dumps for ISOLDE: status and perspectives

Author: Marco Calviani[1]

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The contribution will detail the challenges and perspectives for the upgrade of the ISOLDE GPS and HRS beam dumps. Ideas and feasibility on the design of the new devices as well as the works required for the exchange of the assemblies will be given, together with a roadmap towards the implementation of the required activities during LS3.

Needs and benefits of 2 GeV high intensity protons for ISOLDE / 13

Extending the irradiation capabilities in the ISOLDE target area: Possibilities and Benefits

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The LHC Injector Upgrade (LIU) will increase the reliability and the performance of the LHC beams required for reaching the goals of HL-LHC. For ISOLDE, the higher beam intensity with the new Linac4 as injector and the increase of the PS Booster energy open new perspectives in terms of beam usage. In particular, an upgrade of the target area and the construction of new target stations could be a unique opportunity to foresee an infrastructure adapted to material irradiations in parallel to ISOLDE operation. Parasitic or dedicated irradiations have occasionally been performed in the past to serve mainly the needs of target developments. Considering that only a small fraction of the proton beam interacts with the target material and that the interactions result in the production of secondary particles with a higher emission probability in the forward direction, there is a substantial benefit in order to maximize the beam usage to exploit the area between the target and the beam dump for irradiations in parallel to ISOLDE operation. The presentation summarizes how irradiation possibilities have been exploited in the past at ISOLDE and outlines the technical and operational limitations observed. FLUKA calculations of the radiation field in the areas of interest are presented in order to allow the assessment of the ISOLDE performances as an irradiation facility. In addition, an overview of the strengths of ISOLDE with the presence of the Class A laboratory, remote handling capabilities as well as a shielded hot cell to address the radiation protection challenges associated to irradiation experiment are outlined. Finally, some ideas to enhance and generalize the material irradiation possibilities with the objective of addressing the needs of a community wider than the one of target experts are presented.

Needs and benefits of 2 GeV high intensity protons for ISOLDE / 21

Isotope production in the beam dumps: Present and future options

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The MEDICIS project was launched in 2013 with the construction of dedicated laboratories in the class A work sector of ISOLDE, with an irradiation station located in the HRS beam dump combined with a Rail Conveyor System, with an irradiated target storage area and with an isotope mass separator [1]. The facility was commissioned in 2017 and started operation in 2018. Last year allowed the new facility to gain operational experience and showed a smooth coordination with the development of the ISOLDE physics program, while 2019 has been focused on operation with isotopes received from external institutes before dispatch to the collaboration.
The present-day configuration of the target irradiation stations allows to "reuse"about half of the 1.4 GeV protons delivered by the PSBooster to ISOLDE, which would otherwise be lost in the beam dumps. It is used for the isotope medical program approved by the MEDICIS collaboration, and for target irradiation either for beam development techniques or for the so-called "ISOLDE winter physics program"[2].
In the presentation, we will introduce the characteristics of the present target irradiation station and of its mode of operation. We will also show on how this program can be further developed along with different options under consideration in the EPIC project as introduced during this workshop [3].

[1] dos Santos Augusto, Ricardo, et al. Applied Sciences 4.2, 265-281 (2014)
[2] Webster, Ben, et al., Scientific Reports, 9, 10884 (2019)
[3] https://indico.cern.ch/event/838820/overview

Needs and benefits of 2 GeV high intensity protons for ISOLDE / 31

General Discussion

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Photo - Data protection information

If you choose to be on the ISOLDE-EPIC Workshop group photograph it will be assumed that you give your permission for the photograph to be published on the ISOLDE website and on other outreach platforms.

HIE-ISOLDE accelerator / 25

Initial considerations on a room temperature upgrade of the REX linac

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Phase 2B of the HIE-ISOLDE project was completed in July 2018 after the last of four high-beta cryomodules was installed and commissioned. Phase 3 of the project called for the replacement of four of the REX normal conducting structures by two low-beta cryomodules. However, this phase of the project has not been approved and it is on hold for the moment. In this contribution, initial considerations on a possible room temperature upgrade of the REX linac will be presented and the advantages and disadvantages compared to the superconducting alternative will be discussed.

HIE-ISOLDE accelerator / 27

Beam characteristics for reaction experiments

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In this presentation a summary will be presented of typical beam characteristics needed for experiments using spectrometers and mass separators for reaction studies at HIE-ISOLDE. Focus will be on time-of-flight spectrometers with an introduction to the techniques currently used, and the requirements these methods put on temporal beam structure and energy spread. Some physics cases will also be introduced to show how the physics reach of the facility will be increased by the introduction of this kind of instrumentation.

HIE-ISOLDE accelerator / 33

General Discussion

New physics with an upgraded ISOLDE facility / 10

New Physics Opportunities with HIE-ISOLDE beams from a 2 GeV upgrade

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The EPIC upgrade at ISOLDE will bring with it a whole new range of opportunities for physics with post-accelerated beams. The advantage for HIE-ISOLDE will be two-fold, an increase in the primary yield of the most exotic beams from the 2 GeV upgrade and the reduction in setup time required afforded by freeing the central beam line. This will allow for the maximum use of available beam time; coupled with higher beam intensities delivered to the experimental stations the upgrade will enable measurements of the weakest cross-section reactions or isotopes further from stability. Furthermore, some species with large isobaric contamination or low ionisation/extraction efficiency will be in reach due to the complementary upgrades of the ISOLDE front ends.

Currently, calibrations and detector commissioning using stable, noble gas beams from the residual gas of REX-TRAP are routinely performed at all three of HIE-ISOLDE's experimental stations. The addition of a dedicated ion source or independent feeding of the linac from one of the new target stations could also bring opportunities for physics with stable or long-lived isotopes. This takes advantage of HIE-ISOLDE's unique capabilities in delivering low-intensity beams at energies around the Coulomb barrier across the entire mass range, thanks to the electron beam ion source (EBIS) and state of the art diagnostics.

This talk will describe the different HIE-ISOLDE experimental stations and selected physics cases from each. New opportunities will be highlighted and discussed in terms of the physics impact and current experimental limitations.

New physics with an upgraded ISOLDE facility / 22

Nuclear ground-state properties: new opportunities for nuclear physics and precision tests of fundamental interactions

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The studies of ground-state properties of short-lived nuclei –masses, spins and parities, charge radii, electromagnetic moments and radioactive decay –have been ISOLDE's strength since a long time. This is thanks to the large choice in beams, their very good quality and high intensity, but also because many of the most precise techniques needed for these investigations have been initiated and/or mastered at ISOLDE. To these belong Penning traps, collinear (resonance) laser spectroscopy, or laser-induced nuclear spin- polarisation and beta-detected NMR, and high-precision nuclear decay spectroscopy.
The upgrades included in the EPIC project will allow to strengthen the leading role that ISOLDE plays in the above studies. This concerns higher production rates, parallel beam delivery, or the addition of a storage ring.
In this contribution I will give a general overview how the EPIC project can profit studies of nuclear

ground-state properties. I will then illustrate it with selected examples across the techniques and the physics cases, both in nuclear physics and in precision tests of nuclear decay aiming at tests of the Standard model, such as the unitarity of the CKM-matrix or the appearance of new interactions.

New physics with an upgraded ISOLDE facility / 23

Opportunities for New Physics searches using exotic molecules and atoms at EPIC-ISOLDE

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In atoms and molecules, electron-nucleon and nucleon-nucleon interactions are sensitive to the electromagnetic, weak and strong forces. Hence, these systems can provide versatile laboratories for precision studies of fundamental symmetries and the searches for New Physics beyond the Standard Model of particle physics.

Until now, symmetry-violating measurements have been performed in only a few stable systems, putting constraints on physics at the TeV scale. Atomic parity violation experiments, for example, constitute our best low-energy test of the Standard Model, and measurements of stable molecules have provided the most stringent constraint to the electron Electric Dipole Moment (eEDM) to date.

This contribution will present a brief summary of different experimental efforts that are being pursued worldwide for the study of fundamental physics with atomic and molecular spectroscopy. The discussion will be focused on the new opportunities that can be explored at EPIC-ISOLDE using radioactive atoms and molecules. The exotic systems can contain heavy and deformed nuclei offering enhanced and, in some cases, unique sensitivity to explore symmetry-violation nuclear effects in addition to the possible existence of new fundamental particles and forces. Future precision studies of these systems at radioactive beam facilities could provide new opportunities in fundamental physics research, offering complementary probes to ongoing studies at high-energy colliders.

New physics with an upgraded ISOLDE facility / 34

Summary and aim of the working groups

Parallel working group meetings to define strategies / 37

Applied/medical/radiation stations related physics and developments

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Parallel working group meetings to define strategies / 35

New opportunities with accelerated beams

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Parallel working group meetings to define strategies / 36

New opportunities using low-energy beams

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Parallel working group meetings to define strategies / 39

ISRS working group

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Parallel working group meetings to define strategies / 38

Technical working group (design, layout, pre-studies, ⋯)

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Parallel working group meetings to define strategies / 40

Report back from parallel sessions

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Concluding remarks

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Concluding remarks

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The new set up at SSP ISOLDE CERN

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Ion implantation is a useful way for a modification of a substance. It allows us to introduce the desired nuclide into a substance (substrate) quickly, without impurities, and without formation of the local accumulations (clusters) of the respective element. Moreover, the implantation does not change the structure, temperature etc. of the substrate, though local changes are possible. These circumstances allow us to use the implantation for examining the substrate, receiving information about the environment of the local positions of the atoms-probes as well as some characteristics of the substance as a whole (e.g. magnetic properties).

At the same time, the implantation makes local defects in the structure. To eliminate such defective structure, to incorporate the implanted atom into positions in regular crystal structure definite treatment is necessary. There are very few options for such a treatment. The simplest way is to heat the substrate. But in-line heating is possible in vacuum only. The other approaches (e.g. irradiation by light) seems less effective and limited to definite types of substrates.

The removal of the substrate from the implantation zone allows us to noticeably expand the selection of the treatment technique including complete transformation of the substrate into a new form. This removal should be fast enough because the implantation process of each nuclide is strictly limited in time (relating to the number of substrates under study). Fast removal is also necessary when the implanting nuclide has a short lifetime.

We designed, manufactured, and tested under high vacuum under a simple and reliable mechanism which allows to remove the substrate from the evacuated implantation chamber in a second and without vacuum release. The satellite automation is currently being designed. We hope to test it on-line when ISOLDE starts in 2021. For the test the short-lived nuclide Mn-57 seems very interesting because manganese can be easily transferred into different oxidation states, the research technique being emission Mossbauer spectroscopy.

The designing automation will not only increase the efficiency of the implantation experiments but will also improve the radiation safety because no hand operations with radioactive matter will be necessary anymore.

For radioactive nuclides the optimal time of implantation cycles can be calculated based on the radioactive decay law. In case of multiple repetitions, to obtain maxim average count rate with Mn-57 the valve should be turned approx. every minute, which seems reasonable time for the treatment of a substrate and the accompanying manipulations.