ISOLDE - EPIC Workshop 2020

Tuesday 24 November 2020 - Wednesday 25 November 2020

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ISOLDE@CERN: near and long-term future

Corresponding Author: simone.gilardoni@cern.ch

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Nuclear Physics in Europe: Challenges and Perspectives

Author: Marek Lewitowicz[1]

[1] *GANIL/NuPECC*

Corresponding Author: lewitowicz@ganil.fr

The physics with Radioactive Ion Beams (RIB) and very high intensity stable-ion beams (SIB) is entering into a new area thanks to next generation RIB and SIB facilities, already in operation or under construction in Asia, North America and Europe. The presentation will focus on future plans of European nuclear physics. A content and importance of the recent NuPECC Long Range Plan [1] and the major European nuclear physics infrastructures will be presented with an emphasis on a role played by scientific program of ISOL facilities. Interplay between nuclear, particle and astroparticle physics will be shortly discussed in the context of the 2018-2020 update of European Strategy for Particle Physics [2].

[1] http://www.nupecc.org/lrp2016/Documents/lrp2017.pdf
[2] https://europeanstrategyupdate.web.cern.ch

ISOLDE at CERN and in the world / 2

”Synergies between AD and ISOLDE: antiprotons and radioactive ions”

Author: Michael Doser[1]

[1] *CERN*

Corresponding Author: michael.doser@cern.ch

The study of nuclei using antiprotons began at CERN with the first availability of antiprotons over 50 years ago. Developments in trapping and accumulation of low energy antiprotons and in formation of antiprotonic systems has made it possible to envisage more sensitive or completely novel approaches to studies of a wide range of nuclei and their isotopes. This talk will explore some of the more exotic possibilities that a combined antiproton-radioisotope facility might permit.

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Synergies between n_TOF and ISOLDE – neutron beams and radioactive ion

Author: Alberto Mengoni[1]

[1] *ENEA & INFN, Bologna*

Corresponding Author: alberto.mengoni@cern.ch

The n_TOF facility at CERN features two different beam lines, with rather different characteristics and possibilities for neutron cross section measurements, for applications in nuclear astrophysics, advanced nuclear technologies and basic nuclear science. The 185m horizontal beam line feeds the first experimental area (EAR1), where extremely high-resolution measurements can be performed. EAR2, placed at approximately 20m on top of the spallation target, provides a factor 50 higher neutron flux, while maintaining a good energy resolution. So far, several measurements low-mass radioactive samples have been possible at n_TOF. Several parameters determine the feasibility of a neutron capture cross section: intrinsic activity, type of emitted radiation, mass, cross section, and others.

The n_TOF Collaboration succeeded to measure capture cross sections on record-low half-lives of a few years and sub-milligram masses (corresponding to number of nuclei in the samples of 1017 – 1019) [1-3]. With the upgrade of spallation target area, the possibility of perform measurements at a distance of only 2-3 meters from the spallation assembly (NEAR Station) is being investigated. This will allow to measure neutron cross sections on even lower masses.

The possibility to produce sample material at the present or upgraded ISOLDE facility and then irradiated at n_TOF will represent, therefore, a great opportunity for synergy between these two CERN facilities.

These ideas will be put forward and examples of these opportunities will be presented.

[1] Neutron Capture on the s-Process Branching Point Tm-171 via Time-of-Flight and Activation
C. Guerrero, J. Lerendegui-Marco, M. Paul, M. Tessler, S. Heinitz, C. Domingo-Pardo, S. Cristallo, R. Dressler, S. Halfon, N. Kivel, et al. (The n_TOF Collaboration)
Physical Review Letters 125, 142701 (2020)
https://dx.doi/org/10.1103/physrevlett.125.142701

[2] Time-of-flight and activation experiments on Pm-147 and Tm-171 for astrophysics
C. Guerrero, J. Lerendegui-Marco, C. Domingo-Pardo, A. Casanovas, R. Dressler, S. Halfon, S. Heinitz, N. Kivel, U. Köster, M. Paul, et al. (The n_TOF Collaboration)
EPJ Web of Conferences 146, 01007 (2017)
https://dx.doi/org/10.1051/epjconf/201714601007

[3] Neutron Capture Cross Section of Unstable Ni-63: Implications for Stellar Nucleosynthesis
C. Lederer, C. Massimi, S. Altstadt, J. Andrzejewski, L. Audouin, M. Barbagallo, V. Bécares, F. Bečvář, F. Belloni, E. Berthoumieux, et al. (The n_TOF Collaboration)
Physical Review Letters 110, 022501 (2013)
https://dx.doi/org/10.1103/PhysRevLett.110.022501

New Physics Applications at ISOLDE / 4

The history and future of material science at ISOLDE, with recent feedback from the biophysics programme

Author: Karl Johnston[1]

[1] *CERN*

Corresponding Author: karl.johnston@cern.ch

The solid state programme at ISOLDE has been an integral part of the scientific priorities since the early 1970s. In addtion to solid state physics, a signficant biophysics programme also developed. As ISOLDE has expanded and evolved so too have the communities undertaking research in these areas.

This talk will summarise the initial motivations for pursuing these areas at ISOLDE and summarise the various upgrades and improvements which have been carried out in the recent past. As an introduction to subsequent talks in this session, experience from the ISOLDE biophysics programme will descibe the opportunities but also the challenges in carrying out such research along with the increased capabilities which the EPIC project could provide.

New Physics Applications at ISOLDE / 12

Quantum materials research with radioactive probes

Author: Lino M. C. Pereira[1]

[1] *KU Leuven (BE)*

Corresponding Author: lino.pereira@kuleuven.be

ISOLDE has been a hub for the development of radioactive probe techniques and their application in solid state physics and other fields. As we enter the second quantum revolution, where non-classical properties of quantum systems are being explored for practical applications, ISOLDE can play an important role in advancing our ability to detect and manipulate single quantum objects. In this talk, I will review some current and future opportunities for the use of radioactive ion beams for research on solid-state systems for quantum communication, computation and metrology. Examples will include 3-dimensional materials, such as color centers in diamond, and 2-dimensional materials, such as spin centers in graphene. In particular, in the context of the EPIC project and future facility upgrades, I will discuss the needs of these new user communities in terms of extended beam availability, on-site support laboratories and short-term proposal turnover.

New Physics Applications at ISOLDE / 11

Nuclear Probes in Multiferroics

Authors: Doru C. Lupascu[1]; Juliana Schell[2]; Merlin Schmuck[1]; Thien Thanh Dang[1]; Vladimir Shvartsman[1]; Marianela Escobar[1]; Eva Kröll[1]; Georg Marschick[3]

[1] *University of Duisburg-Essen*

[2] *ISOLDE, CERN*

[3] *Vienna University of Technology*

Corresponding Author: doru.lupascu@uni-due.de

Nuclear probes that have been used to sense magnetic ordering have mostly been the ^{57}Fe Mössbauer probe and a few nuclear magnetic resonance nuclei. For the latter, high external magnetic fields have to be applied in order to obtain high resolution data. If one tries to become more versatile in probes and field range, $\gamma\gamma$-angular correlations can by now be applied on a large number of probe nuclei. Many of these can be produced at ISOLDE.
This presentation will focus on what physics aspects from multiferroics can be addressed using such probes. The different types of intrinsic multiferroics are presented and classified. Data are shown on known and more recent data in multiferroics without external fields applied. The next set-up soon to be installed at ISOLDE allowing for multiple field applications to multiferroics is presented. Long term perspectives on interface physics in magnetic to ferroelectric interfaces are sketched.

New Physics Applications at ISOLDE / 15

Irradiations at CERN: a broad spectrum

Authors: Marco Calviani[1]; Matteo Ferrari[1]

[1] *CERN*

Corresponding Author: ferrari.matteo@cern.ch

Despite their sensitivity to radiations, non-metallic materials such as lubricants and elastomeric seals are used in high radiation areas at CERN. They can experience extreme degradation in the MGy dose range, leading to device failure and possibly compromising the operation of the accelerator complex. CERN therefore carries out irradiation tests of commercial materials, to select the most radiation resistant ones from the market. Experimental studies are underway to improve the understanding of radiation mechanisms and their dependence on several irradiation parameters.
The unique fields of secondary radiation produced by beam intercepting devices represent an opportunity for in-house irradiation of electronics and materials. CHARM and IRRAD facilities are already in use, providing mixed field and proton irradiation respectively, for electronics mostly. New irradiation facilities are being developed for the irradiation of polymeric materials. The ISIS irradiation station at ISOLDE and the NEAR station at n_TOF are being equipped with infrastructures to allow tests in mixed radiation fields.
Parasitic irradiations of selected materials will be possible in parallel to the normal facility operation, allowing unprecedented data to be collected. Materials will be exposed to a unique combination of ageing factors along with radiation doses in the MGy range during exposure times ranging from weeks to several years.
These mixed fields will closely represent the operating conditions at CERN, allowing the identification of usability thresholds for the analysed materials. Until now, gamma radiation has been mostly used to perform radiation tolerance tests under the assumption that equal effects would be induced by equivalent doses of different types of radiation. These new facilities will allow this assumption to be checked.

A new ISOLDE building and target stations / 14

A new ISOLDE building and target stations

Author: Erwin Siesling[1]

Co-authors: Jose Alberto Rodriguez Rodriguez [2]; Eliseo Perez-Duenas [3]

[1] *CERN ISOLDE Technical Coordination and Operation*

[2] *CERN ISOLDE Operation*

[3] *CERN Civil Engineering*

Corresponding Author: erwin.siesling@cern.ch

Over the last 25 years the ISOLDE facility has grown steadily with adding extensions to the hall to house new experiments as well as the post-accelerator REX and the HIE ISOLDE super conducting linac and its HEBT lines. On the target zone and radioactive laboratory side the facility has extended with a Class A lab and MEDICIS and lately the nano Lab.
We now reached a situation where further expansion has become significantly difficult. The experimental hall is cramped and ISOLDE has reached the boundaries of its present area.
In the frame of EPIC and the upcoming upgrade of the proton beam to 2GeV and higher intensity as well as the growing number of new experiments, demand for parallel operation and higher efficiency in mind, we are looking into a possible whole new ISOLDE Low Energy facility at CERN close to the existing one so infrastructure such as the control room and DAQ rooms can be common. An ideal area is the space actually occupied by the recuperation building B133. The underlaying unused tunnel infrastructure TT70 would serve to bring the proton beam to new underground target stations and a new hall above would house a large number of comfortable large experimental zones for Low Energy RIB experiments provided by the new target stations and separators. Future connections to the AD facility and n-Tof are possible opening up exciting new physics.
Another significant advantage is that construction of such a new ISOLDE facility would take place in parallel to the existing running ISOLDE Low Energy physics in the present experimental hall 170. After finalizing the new facility and the move of the Low Energy experiments from 170 to the new hall the existing hall 170 and its target stations would be fully dedicated to REX/HIE ISOLDE post-acceleration physics with even a possible compact future storage ring occupying the space in the existing experimental hall that would become free.
This presentation will show you the concept and feasibility of such a new ISOLDE building and target stations in the area of the TT70 tunnel and building 133.

A new ISOLDE building and target stations / 16

ISOLDE as a multi-user facility

Author: Jose Alberto Rodriguez[1]

[1] *CERN*

Corresponding Author: alberto.rodriguez@cern.ch

The construction of a new experimental hall dedicated to low-energy physics is under consideration in the framework of the EPIC project. The hall would be located in front of building 508, in the space currently occupied by the CERN's recuperation facility. The additional space could host between fifteen and twenty experimental stations and it is believed to be enough to satisfy the future needs of the ISOLDE user community. However, producing and delivering sufficient radioactive beams to serve all these stations with the limited number of protons that the PS Booster is able to provide is not trivial. In this contribution, several ideas on how to optimize the use of the protons and therefore, maximize the amount of radioactive beam available, will be presented. In addition, a possible layout of the beamlines in the hall will also be discussed.

A new ISOLDE building and target stations / 1

The TRIUMF-ARIEL Multi-User Facility and Potential Synergies with EPIC

Author: Alexander Gottberg[1]

[1] *TRIUMF (CA)*

Corresponding Author: gottberg@triumf.ca

ISAC-TRIUMF is routinely operating targets under particle irradiation in excess of 10 kW making it the only ISOL facility that operates in the high-power regime. TRIUMF's current flagship project ARIEL, Advanced Rare IsotopE Laboratory, will add two new target stations providing isotopes to the existing experimental stations in ISAC I and ISAC II at energies between 15 keV and 16 MeV/u. Together with the recently commissioned additional 200 m of RIB beamlines and an additional EBIS CSB within the radioisotope distribution complex, this will put TRIUMF in the unprecedented capability of delivering three RIBs to different experiments, while producing radioisotopes for medical applications simultaneously – enhancing the scientific output of the laboratory significantly.
With recent developments of modern target stations, remote handling and shielding technologies, beam purification and delivery systems, ARIEL and EPIC have significant potential overlap in technology and scientific scope, opening ample opportunities for cross-pollination.

Upgrades to the current ISOLDE facility / 13

Beam switching at the current ISOLDE Facility

Author: Sebastian Rothe[1]

[1] *CERN*

Corresponding Author: sebastian.rothe@cern.ch

ISOLDE beam time is a precious resource for which the annual demand exceeds the amount that is available. Generally, at any one time, ISOLDE is a single USER facility with the exception of the GLM and GHM beam-lines at GPS which can be used in parallel with HRS operations. One major limitation preventing parallel delivery of the HRS and GPS beams to experimental setups downstream the merging switchyard is the fact that the ion optical elements in that section need to be matched to either the HRS or the GPS.
We will discuss a solution that would allow switching the required electrical potentials in a short time.
A second, complementary concept will be presented, in which any ISOLDE switchyard can be operated in a fast switching mode, allowing the quasi d.c. sharing of the ion beam downstream.
Different scenarios will be discussed in which these modes of beamline and beam sharing sharing will be beneficial.

Upgrades to the current ISOLDE facility / 6

Prospects for New Beam Dumps at ISOLDE

Author: Ana-Paula Bernardes[1]

Co-authors: Marco Calviani [1]; Joachim Vollaire [1]; Jose Maria Martin Ruiz [1]; Keith Kershaw [1]; Richard Catherall [1]

[1] *CERN*

Corresponding Author: ana-paula.bernardes@cern.ch

The contribution will describe the project organisation put in place for the upgrade of the ISOLDE GPS and HRS beam dumps. This challenging project will allow an increase of the proton beam power to ISOLDE. It will require the partial removal of earth shielding covering the target area. For the first time since 1991, when Booster-ISOLDE was built, it will be possible to access the faraday cages and the surroundings of the separator areas, that make this project an unique occasion to consider future perspectives for the ISOLDE facility.

Upgrades to the current ISOLDE facility / 10

Status of the ISOLDE MR-TOF project for advanced beam purification

Author: Markus Kristian Vilen[1]

Co-authors: Paul Fischer [2]; Hanne Heylen [1]; Carina Kanitz [3]; Varvara Lagaki [4]; Simon Lechner [5]; Franziska Maria Maier [6]; Peter Plattner [7]; Simon Mark C Sels [1]; Gerda Neyens [8]; Wilfried Nörtershäuser [9]; Lutz Schweikhard [2]; Frank Wienholtz [9]; Stephan Malbrunot [1]

[1] *CERN*

[2] *Institut für Physik, Universität Greifswald, 17487 Greifswald, Germany*

[3] *CERN; Friedrich Alexander Univ. Erlangen (DE)*

[4] *CERN; Ernst Moritz Arndt Universitaet (DE)*

[5] *CERN, TU Wien*

[6] *CERN, Universität Greifswald*

[7] *CERN; University of Innsbruck (AT)*

[8] *ISOLDE, CERN Experimental Physics Department, CH-1211 Geneve 23, Switzerland; Instituut voor kern- en stralingsfysica, KU Leuven, Celestijnenlaan 200D, Leuven, Belgium*

[9] *Institut für Kernphysik, Technische Universität Darmstadt, Schlossgartenstr. 9, 64289 Darmstadt, Germany*

Corresponding Author: markus.kristian.vilen@cern.ch

With the continuous development of experimental techniques at radioactive ion beam (RIB) facilities, the demand for high quality ion beams is ever increasing. Significant isobaric contamination levels commonly present in RIBs have proven to be a major challenge, preventing the study of the most exotic isotopes produced at low energy branches of RIB facilities. Furthermore, as the study of radioactive nuclides reaches ever shorter half lives, fast ion sample preparation becomes highly desirable. Similar challenges with isobaric contamination are encountered also in other applications, such as medical isotope production and solid state physics.

The challenge of combining high ion beam purity with fast sample processing and high ion flux can be met by a Multi-Reflection Time-of-Flight (MR-ToF) Mass Spectrometer operating at an unprecedented 30 keV beam energy, together with a cryogenic Paul trap for ion sample preparation. The system will offer improved ion flux compared to existing MR-ToF devices and deliver ion beams of high isobaric purity to downstream experiments.

In this talk, the status of the ISOLDE MR-ToF project for beam purification will be presented. Performance of the system will be discussed together with its challenges.

Contributed Talks / 5

Mini-Orange conversion electron setup for ISOLDE

Authors: Thorsten Kröll[1]; Matthias Rudigier[2]; Steffen Meyer[2]; Corinna Henrich[1]; Kathrin Wimmer[3]; Peter Thirolf[4]

[1] *Technische Universitaet Darmstadt (DE)*

[2] *TU Darmstadt*

[3] *CSIC Madrid*

[4] *Ludwig Maximilians Universitat (DE)*

Corresponding Author: thorsten.kroell@cern.ch

The measurement of conversion electrons adds additional observables in decay spectroscopy. High-resolution studies for electron energies of typically some hundreds keV are done best with LN2-cooled Si(Li) detectors located at the focal point of a magnetic transport system, e.g. a so-called Mini-Orange consisting of permanent magnets. The optical properties of Mini-Oranges (MO) enable an effective increase of the solid angle acceptance in combination with a reduction of the total electron rate, e.g. from β-decays or, in in-beam experiments, δ-electrons, by a suitable choice of a transmission function focused on the region of interest. In addition, a lead blocker in the direct line between source and detector suppresses hits by x- and γ-rays. As stand-alone device or combined with α-, β- and/or γ-detection, this allows for the determination of E0 transition strengths or conversion coefficients which are of particular interest e.g. in regions of shape coexistence.

Such a setup comprising three MOs is currently under recommissioning at TU Darmstadt. Parts of this MO setup have been used by us at ISOLDE already in the past to study E0 strengths [1] and isomeric transitions of high multipolarity [2]. Depending on the physics case, additional devices, i.e. HPGe, $LaBr_3$(Ce), Si or plastic detectors, are added. We intend to install this setup as travelling device at the LA1 or LA2 low-energy beamline at ISOLDE. The status of the project will be presented.

[1] W. Schwerdtfeger et al., Phys. Rev. Lett. 103, 012501 (2009)
[2] K. Wimmer et al., Phys. Rev. C 84, 014329 (2011)

Contributed Talks / 3

Present status of the HIE-ISOLDE Superconducting Recoil Separator

Author: Ismael Martel Bravo[1]

[1] *University of Huelva (ES)*

Corresponding Author: ismael.martel.bravo@cern.ch

Present status of the HIE-ISOLDE Superconducting Recoil Separator

I. Martel(1,6), J.L. Aguado(1), M. Assie(2), M.A.M. Al-Aqee(l3,21), R. Berjillos(4), M.J.G. Borge(5), L. Bottura(6), W. Catford(7), J. Cederkall(8), T. Davinson(9), G. De Angelis(10), T. Ekelof(11), A.P. Foussat(6), , L. Gaffney(3), E. Galanis(12), T. García-Fernández(1), C. García-Ramos(1), H. Glass(12), K. Johnston(6), T. Junquera(13), O. Kochebina(13), T. Kurtukian-Nieto(14), M. Losasso(6), A. Laird(15), J. L. Muñoz(16), B.S. Nara Singh(19), G. Neyens(6), D. O'Donnell(19), R. D. Page(3), A.R. Pinto(1), J.A. Rodriguez(6), J. Resta-López(3), V. Rodin(18), J. Sánchez-Segovia(1), K. Riisager(17), A.M. Sánchez-Benítez(1), J. Sánchez-Segovia(1), B. Shepherd(18), E. Siesling(6), J. Smallcombe(3), O. Tengblad(5), D. Tommasini(6), J. Uusitalo(20), C.P. Welsch(3).

1.Univ. Huelva, Spain. 2.IPNO, Univ. Paris-Sud, Orsay, France. 3.Univ. Liverpool, United Kingdom. 4.TTI Norte, Santander, Spain. 5.IEM-CSIC, Madrid, Spain. 6.CERN, Geneva, Switzerland. 7.Univ. Surrey, United Kingdom. 8.Univ. Lund, Sweden. 9.Univ. Edinburgh, United Kingdom. 10.LNL-INFN Legnaro, Italy. 11.Uppsala University, Sweden. 12.PARAGRAF, Somersham, United Kingdom. 13.ACS, Orsay, France. 14.CENGB, Gradignan, France. 15.Univ. York, United Kingdom. 16.ESS-BILBAO, Bilbao, Spain. 17.Univ. Aarhus, Denmark. 18.Cockcroft Institute, Daresbury, United Kingdom. 19.Univ. West Scotland, United Kingdom. 20.Univ. Jyvaskyla, Finland. 21.IMIS Univ., Riyadh, Saudi Arabia.

Abstract
The availability of post-accelerated radioactive beams (RIB) has unprecedently expanded our knowledge of nuclear structure and nucleon correlations. RIB facilities like HIE-ISOLDE [1] at CERN (Geneva, Switzerland) can deliver high intensity low-energy RIBS (5-10 MeV/u) where relevant features of the atomic nucleus are investigated by Coulomb excitation, transfer, deep inelastic and fusion-evaporation reactions. These studies can benefit from the use of a high-resolution recoil separator which selects and quantifies the beam-like reaction fragments from the intense primary beam [2]. At the focal plane decay studies of very short-lived species produced through multi-nucleon transfer reactions can also extend nuclear structure studies beyond currently available beams. In

this contribution an update on beam dynamics [3], design concepts of SC magnets [4] and cryostats [5], and possible location at the HIE-ISOLDE hall, will be presented and discussed.

[1] Y. Kadi, M.A. Fraser, A. Papageorgiou-Koufidou (Eds.), HIE-ISOLDE: Technical Design Report for the Energy Upgrade, CERN Yellow Reports: Monographs, Vol. 1/2018, CERN-2018-002-M.
[2] C. Bontoiu et al., Nuclear Inst. and Methods in Physics Research, A 969 (2020) 164048. [3] I. Martel et al., "The Isolde Superconducting Recoil Separator (ISRS)". 84th ISOLDE Collaboration Committee meeting. CERN (Geneva, Switzerland) 19 March 2019, https://indico.cern.ch/event/801266/
[4] A.P. Foussat. ISOLDE - EPIC 2019, 3-4 December 2019, CERN (Geneva, Switzerland). https://indico.cern.ch/event/838820/cor
[5] O. Kochebina. ISOLDE - EPIC 2019, 3-4 December 2019, CERN (Geneva, Switzerland). https://indico.cern.ch/event/838820/cc

Contributed Talks / **7**

Polarised short-lived nuclei and excited states: a versatile tool for ISOLDE science

Author: Magdalena Kowalska[1]

[1] *CERN*

Corresponding Author: kowalska@cern.ch

In unstable nuclei or excited nuclear states spin polarisation leads to anisotropic distribution of emitted radiation, and modified cross-sections for Coulomb excitation or nuclear reactions. These effects can be used in a variety of ways in different fields of research. In the weak-interaction studies, they can contribute to searches for New Physics by measuring the asymmetry in beta decay of mirror nuclei. In nuclear physics, through angular correlations between emitted or scattered particles and emitted radiation, they can be used to determine spins and parities of excited nuclear states, which are often interesting also for astrophysics studies. In the form of ultrasensitive beta-NMR, they allow to measure precisely magnetic dipole moments and electric quadrupole moments for nuclear ground-states or long-lived isomers. The latter technique can be also used in material science, and since recently chemistry and biology. Asymmetric emission of gamma radiation might even be applicable in medical diagnosis.
In this contribution I will discuss briefly selected topics that can be addressed with spin-polarised nuclei, and I will concentrate on what would be required to extend the present polarised-beam capabilities in an upgraded or even a new ISOLDE experimental hall.

Contributed Talks / **9**

Decay of Highly Polarized Nuclei at the Isolde Decay Station

Authors: Miguel Madurga Flores[1]; Magdalena Kowalska[2]; Razvan Lica[3]

[1] *University of Tennessee (US)*

[2] *CERN*

[3] *Horia Hulubei National Institute of Physics and Nuclear Enginee*

Corresponding Author: miguel.madurga.flores@cern.ch

The capability to deliver highly polarized beams to the Isolde Decay Station (IDS) detector system will offer an capability beyond any other nuclear physics facility in the world. Typical beta decay experiments are limited to estimating the spin-parity of the excited states to gamma-gamma correlation measurements, which require large statistics, or estimates from the decay strength. Nuclei will be laser polarized and delivered to the IDS with a dedicated beamline using small gauss coils to maintain polarization. Polarized nuclei can then be readily oriented in a magnetic field, providing an absolute reference frame. The IDS will provide a highly efficient, granular detector system, allowing for the precise measurement of the degree of asymmetry of delayed beta, gamma, and neutron radiation. Possible measurements will be discussed, such as the identification of intruder states in the decay of neutron rich Mg, Mn, and Cu isotopes, or the identification of single particle spin parities in magic or semi magic nuclei such as ^{53}Ca and ^{133}In.

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Concluding Remarks

Corresponding Author: kieran.flanagan@cern.ch