1 Introduction and executive summary

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The ISOLDE facility has existed as a concept for four decades, after the decision in 1964 by the CERN management to construct the first radioactive beam facility at CERN. Throughout its various apparitions, the facility has been steadily increasing its scientific scope and user basis, and has been one of the emblematic installations leading to the current general recognition of the potential of research with radioactive beams. The last incarnation of the ISOLDE facility commissioned in 1992, PSB-ISOLDE, was largely motivated by the possibility of post-accelerated radioactive beams. Since 2001, this has been achieved through the addition of the REX-ISOLDE post-accelerator.

Several science planning organs [1–3] have highlighted that radioactive beam physics opens unprecedented possibilities in nuclear structure and astrophysics research, and that new and developed experimental facilities are needed to exploit these possibilities. In the European context, NuPECC has recommended that two complementary facilities be constructed [4]: FAIR-NUSTAR [5] and EURISOL [6], using the techniques of in-flight separation and ISOL-method, respectively. The EURISOL facility is slated to be a considerably upgraded version of the CERN-ISOLDE facility, able to deliver radioactive beams of 2–3 orders of magnitude higher intensity than today. This necessitates a proton driver accelerator capable of delivering 1–2 GeV protons with a beam power of 5 MW. The planned SPL Linac [7], which is a prerequisite for LHC luminosity upgrades but also for neutrino superbeams, ‘beta beams’ or the muon neutrino factory, has the optimal parameters for an advanced ISOL facility. Several sites are suited to host EURISOL, but owing to the evident technical and scientific synergies, CERN might emerge as the obvious choice.

However, as also recommended by NuPECC, the realization of EURISOL is still to be seen in a long-term perspective and exploitation and further developments of the existing RIB facilities are required. In the case of ISOLDE, a vigorous upgrade programme is planned that will transform the facility into High Intensity and Energy (HIE-ISOLDE) where the secondary beam intensities and the energy range attainable will be substantially improved. These developments are largely in line with necessary technical developments towards EURISOL. Thus to further exploit the potential of the existing facility, the Standing Group for Upgrade of the ISOLDE Facility was formed in 2002, based on a mandate from the then CERN Directors of Fixed-target physics and Accelerators. This group oversees and prioritizes the various technical developments, and the current report is meant as a tool in this process.

It is clearly recognized that user-demand-driven facility developments have historically been the main key to the success of ISOLDE, and that this has to be a continuous process. The continuously improved beams have attracted an increasing user community over the years. However, there is not only one sole parameter that is requested by the experimental collaborations, but several, and these are partly self-contradictory. The requests concern higher intensity, new isotopes/elements, beam purity, beam emittance, time structure, charge state, higher and lower beam energy; and the routes to these improvements are manifold.

The available intensity of radioactive ions to an experiment depends on a large number of factors (production cross-section, decay losses, diffusion and effusion constants in the production target, ion source efficiency, and ion beam transmission). For a post-accelerated beam in REX-ISOLDE, further losses have to be taken into account (efficiency and decay losses in the trapping and charge breeding phases, intensity in the chosen charge state, transmission) that vary strongly from element to element and the various isotopes. Increased intensity of a specific element does not only mean that the measurements can be performed in less time or to a higher statistical precision, but also that further, more exotic isotopes can become within reach for the experiments.

1.1 Increasing intensity, purity, and number of available radioactive beams

The most straightforward route to higher secondary beam intensities is to increase the primary proton beam intensity. The ISOLDE facility is currently coupled to the PS Booster synchrotron which can deliver a maximum beam current of 4 μA on the production targets. During operation until 2005, the effective current delivered to ISOLDE has been 1.92 μA due to sharing with other programmes. The prospects for proton beam availability in the coming years and increasing the proton intensities along the full injector chain at CERN has recently been reviewed by the High Intensity Proton (HIP) working group within the AB Department. Chapter 2 contains ISOLDE-relevant excerpts of their report, where the two main paths for increasing the average beam current available for ISOLDE are faster cycling of the PSB and the addition of a new injector, Linac-4.

The target and ion source system is a key link in the production of radioisotopes, and Chapters 3 and 4 sketch necessary R&D in order to handle increased primary beam intensities and to further increase the production yield and reach new elements and/or isotopes through tailored engineering. Increasing primary beam intensities implies new challenges concerning radioprotection and Chapter 6 summarizes the necessary actions in this respect.

The Resonant Ionization Laser Ion Source (RILIS) has proven to be an outstanding tool in selectively ionizing the desired element with, in most cases, the highest efficiency attainable. However, the set-up, optimization and running of the RILIS is still complex, and constitutes an experiment within the experiment. Chapter 5 describes the perspectives of upgrading the system in order to improve its scope while facilitating its operation.

The mass separation and the beam transport efficiency to the experiment are further crucial factors in achieving maximum beam intensity and purity. Ideas for improving the mass selectivity of the separators and the throughput by modifications of the beam transport system are described in Chapter 7, and Chapter 8 describes the envisaged developments concerning cooling, bunching, and charge breeding of ions before post-acceleration.

1.2 Improving beam characteristics

The low-energy radioactive beams from ISOLDE are, because of the production method, pseudo-continuous and have a relatively large emittance; moreover, the ions are singly charged. These circumstances can pose severe limitations on the possible experiments. The ISCOOL radiofrequency cooler and buncher described in Chapter 8 will provide low-emittance, low-energy beams to a large range of experiments. Collinear laser spectroscopy with completely new precision will be made possible by the small energy spread and time-tagged decay studies; improving the signal-to-noise ratio can be performed using bunched beams of the most exotic species.

1.3 Increasing the beam energy range

The first-generation experiments performed at REX-ISOLDE have demonstrated the potential of reactions around the Coulomb barrier using radioactive beams. However, the scientific scope can be drastically enlarged if the energy range is increased. Two options for increasing the energy are discussed in the report, a normal-conducting option described in Chapter 10 and a superconducting option in Chapter 11. With increasing energy, heavier nuclei and further classes of reactions can be utilized (see Fig. 1.1). Furthermore, enlarged dynamic energy range permits optimizations for each case with respect to cross-section and open reaction channels, e.g., Coulomb excitation experiments can be performed at the highest ‘safe’ energy still below the Coulomb barrier.

The energy range between the pure ISOL beam (60 keV) and the lowest possible extractable beam energy from REX-ISOLDE (300 keV/u) is also of major interest for astrophysically relevant reactions and condensed matter research. Combining highly charged ions from charge-breeder ion sources like the existing REXEBIS and PHOENIX ECRIS described in Chapter 9 with a moderate post-acceleration by electrostatic means, a small RFQ structure or by deceleration in a superconducting linac would yield high-intensity beams in this energy domain.

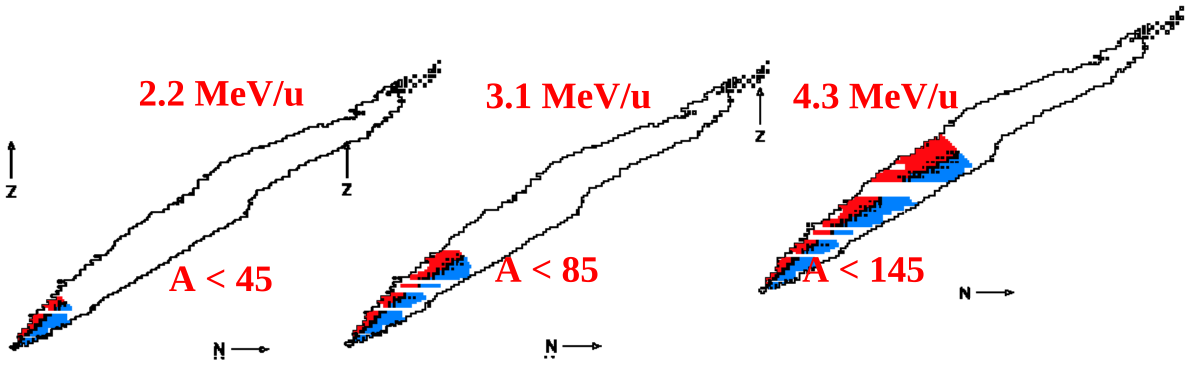

Fig. 1.1: The attainable range of isotopes at REX-ISOLDE reaching the Coulomb barrier for symmetric reactions.

References

[1] NuPECC Report, NuPECC Long Range Plan 2004: Perspectives for Nuclear Physics Research in Europe in the Coming Decade and Beyond (2004), http://www.nupecc.org/pub/lrp03/long_range_plan_2004.pdf

[2] The OECD Megascience Forum, Report of the Working Group on Nuclear Physics, 1999, http://www.oecd.org/dataoecd/23/62/2102613.pdf

[3] The DOE/NSF Nuclear Science Advisory Committee, Opportunities in Nuclear Science—A Long-Range Plan for the Next Decade, 2002, http://www.sc.doe.gov/henp/np/nsac/docs/LRP_5547_FINAL.pdf

[4] Roadmap for Construction of Nuclear Physics Research Infrastructures in Europe, 2005, http://www.nupecc.org/pub/NuPECC_Roadmap.pdf

[5] An International Accelerator Facility for Beams of Ions and Antiprotons—Conceptual Design Report, GSI, 2003, http://www.gsi.de/GSI-Future/cdr/

[6] The EURISOL Report, ed. J. Cornell, GANIL, 2003, http://www.ganil.fr/eurisol/Final_Report.html

[7] R. Garoby, *A new proton injector at CERN*, AB-Note-2003-048 (SPL), Geneva, 2003.