Report on the session "ISOLDE" at the New Opportunities on the Physics Landscape at CERN.

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I. The Physics Programme at ISOLDE

ISOLDE is a radioactive ion beam facility using the ISOL production method. The radioactive species are produced by protons at 1 GeV or 1.4 GeV issued by the PS booster which impinge on various targets and induce spallation, fragmentation and fission reactions. The combination of different target materials and three types of ion sources (surface, plasma and laser) gives rise to the largest variety of beams available at any ISOL facility worldwide: over 600 isotopes of more than 60 different elements have been produced. These beams can be used in a wide energy domain:, at low energy (60 keV) for decay experiments and injection into ion traps or post accelerated up to 3 MeV/nucleon. In the original acceleration scheme developed at ISOLDE the beams are first bunched and cooled in the REXTRAP Penning trap, charge bred in the electron beam ion source REXEBIS and accelerated in the REX linear accelerator. All species produced can in principle be accelerated efficiently and so far post accelerated beams of 64 radioactive isotopes of 24 elements as light as Li and as heavy as Rn have been delivered to users, once again more than at any other post accelerated facility.

The diversity of the beams offered and the exceptional scientific and technical environment of CERN and ISOLDE have attracted a large user community. Over the last 5 years 68 approved experiments have been run by 579 scientists from 34 countries. During that period we count 236 publications in refereed journals including 42 letters and more than 20 PhD theses based on results from ISOLDE have been defended. The science studied at ISOLDE can be classified in 5 broad categories: Nuclear Physics, Atomic Methods, Nuclear Astrophysics, Fundamental Physics and Applied Physics. The latter, which uses approximately 20% of the available beam time, includes Condensed Matter Physics and Life Sciences.

As our knowledge of nuclei progresses away from the valley of stability, major advances are occurring in theoretical studies of nuclear systems. The explicit implementation of new aspects of QCD in the nuclear interactions used, as well as algorithmic and computational advances holds promise for breakthroughs in predictive power, enhancing the strong links between theory and experiment. The theoretical support for ISOLDE science is thus continuously evolving and improving. (see talk by Morten Hjorth-Jensen)

The ISOLDE user community has funded and implemented several unique experimental set ups, in particular ISOLTRAP, a Penning trap system for precision mass measurements; COLLAPS for Laser spectroscopy and ground state property measurements; WITCH, a trap for high precision fundamental measurements; MINIBALL, a segmented Ge array for high-resolution gamma-ray spectroscopy recently complemented by a close-to-4-pi Si array for transfer reactions… This equipment has assured ISOLDE of a leading position in subjects such as halo nuclei,

shell closures and magic numbers far from stability, shape coexistence in heavy nuclei, and more generally the Isospin dependence of the nuclear force. The solid state and biology studies are unique for a radioactive beam facility and made possible by technical advances in detectors inspired by R&D work driven by particle physics. (talk by Karsten Riisager).

II. The future science programme and HIE-ISOLDE

The recent work at ISOLDE and other Radioactive Beam facilities has clarified many issues but also posed further questions and opened new avenues of study, some of which can be uniquely addressed at ISOLDE due to the beams and/or the equipment available. The enthusiasm of the user community for these opportunities was underlined by the 31 abstracts concerning ISOLDE physics submitted to the workshop, of which only eight could be presented by their proponents. However, many of the others were summarized in the review talk by Piet van Duppen. The subjects addressed include the structure of light neutron-rich nuclei and the testing of ab-initio and cluster calculations, the study of extended neutron distributions such as neutron halos and neutron skins, the mapping of the nuclear shells far from stability, the study of pairing in both T=1 and T=0 channels, the study of octupole shapes and the search for atomic EDMs enhanced by octupole deformation of the nucleus. Solid state physicists may require deeper in radioactive samples. Proposals were made to post accelerate polarized beams as well as to develop new instrumentation such as a recoil spectrometer or an active target.

To ensure that these investigations will continue to be at the forefront of radioactive beam science, improvements will be required in three areas:

- ENERGY increase of the beams to 10MeV/A, which will increase cross sections and excitation energy range for Coulomb Excitation and open the domain of transfer reactions up to the heaviest available nuclides which are unique to ISOLDE (To give one example transfer reactions, which yield systematic measurements of single-particle centroids, a key observable, will be accessible throughout the entire nuclear chart).

- INTENSITY increase to reach further from stability and decrease measuring times

- QUALITY increase in emittance and beam purity to improve precision measurements and to allow the above mentioned experiments with inherently low intensity (increase of sensitivity).

These upgrades are referred to as the HIE ISOLDE project. Details about the science case and technical options can be found in the CERN reports CERN Report 2007-08, "HIE-ISOLDE: The scientific opportunities" and CERN Report 2006-13, "HIE-ISOLDE: The Technical options".

III. Technical options and time scale for HIE-ISOLDE (talk by Mats Lindroos)

The HIE-ISOLDE project is planned in two phases:

HIE-ISOLDE 1:

- Energy upgrade up to 10 MeV/u with a superconducting linac; R&D for the LINAC is funded, prototype sputtered cavities are built and ready to be tested
- beam quality improvements : RILIS laser ion source upgrade and test laboratory LARIS as well as RFQ cooler ISCOOL already implemented
- design study of the intensity upgrade to accept beams from LINAC4 and later Light SPL.

HIE-ISOLDE 2:

- Intensity upgrade for 30 kW on target
- Building of new Super-High Resolution Spectrometer

HIE ISOLDE 1 is currently ongoing with funding from several external grants. Acceptance by CERN of this first phase of HIE ISOLDE as an official project is now urgent in order to secure additional external grants and put in place an official project management structure. CERN funding to match the external grants (approx 12 MCHF) and construct the local infrastructure will be necessary over the period 2011-2013. If these requests are satisfied, first experiments with the upgraded facility are expected in 2014. New instrumentation is expected to be funded by external grants. HIE ISOLDE 2 should be completed in 2019 to accept the beams from the light SPL. After a broad consultation of the community, a funding of HIE ISOLDE 2 will be requested in due time.

IV. ISOLDE and HIE ISOLDE in the international context.

Radioactive beams, for which ISOLDE was a precursor, have transformed the landscape of low energy Nuclear Physics and several new or upgraded facilities are currently being constructed or discussed. It is important to evaluate the position of ISOLDE in this new era for our field. Today, the main competitors of ISOLDE outside of Europe are ISAC at TRIUMF and HRIBF at Oak Ridge. ISOLDE has by far the broadest range of available nuclei and is the only facility up to now which has post accelerated nuclides of mass up to 200. This variety is of great importance since on one hand heavy nuclei exhibit unique phenomena and on the other many discoveries in nuclear physics stem from systematic studies over wide ranges of nuclei. In Europe, SPIRAL1 at GANIL provides beams of gaseous elements up to mass 80 of higher energy than that at ISOLDE; the physics programmes at ISOLDE and GANIL are therefore complementary.

HIE-ISOLDE will provide the same extensive range of nuclides as ISOLDE with the same or higher energies than at other ISOL facilities. It will offer unique possibilities for physics studied using accelerated radioactive nuclei. ISAC2, which is an upgrade for ISAC, will not be competitive with HIE-ISOLDE for many species due to its immaturity in target, ion-source and charge-breeding development.

At GANIL, the range of nuclei from SPIRAL1 produced using light-medium mass fragmentation beams will be expanded to alkalis and other elements over the next years. SPIRAL2 is a new facility (new driver) but will use the same post-accelerator as SPIRAL1. It will provide intense beams of fission fragments from 2015, and neutron-rich light nuclei, fusion (neutron-deficient) and other reaction products will be developed after this date. HIE-ISOLDE will provide a wide range of neutron-deficient and neutron-rich nuclei from spallation and fragmentation reactions induced by 1.4 GeV protons, that are not available at GANIL. For example, while SPIRAL2 will ultimately provide higher fission fragment intensities than HIE-ISOLDE, heavier nuclei produced by spallation reactions will only be available at ISOLDE. Again, the physics programmes at HIE-ISOLDE and SPIRAL2 will be highly complementary.

SPES (INFN Legnaro) will provide beams of accelerated fission fragments with similar characteristics to that of SPIRAL-2.

FAIR will deliver very high energies or stopped beams, but will not overlap with HIE-ISOLDE in the energy range necessary for precision measurements of nuclear transition moments and single-particle states. Moreover, except for the most exotic nuclei, intensities at FAIR will be lower than at the ISOL facilities.

All three European ISOL facilities (HIE-ISOLDE, SPIRAL2 and SPES) as well as FAIR will be necessary to cover the broad physics programme laid out for radioactive beams in the next decade and the needs of the community. This has been recognized in the long range plan of NuPECC, in which HIE-ISOLDE is cited as an essential “intermediate generation” facility on the path to EURISOL. Only when EURISOL comes on-line will there be a facility covering all facets of our science. It should be noted that a review panel commissioned by the EURISOL Design Study has concluded that CERN meets the criteria for hosting EURISOL, particularly if the full version of SPL is constructed (see talk by Yorick Blumenfeld).