HIE ISOLDE

Introduction

The provision of accelerated radioactive ion beams (RIB) has been established by NuPECC, the expert committee on nuclear physics within the European Science Foundation, as of the highest priority in the next decade. Within this priority, NuPECC singles out as goals FAIR, the future GSI facility that exploits intense high-energy heavy-ions for fast RIB, hadron & equation-of-state physics and plasma physics, and EURISOL, the ultimate ISOL (isotope separator on-line) facility for RIB precision measurements in nuclear structure and applications in weak-interaction, astro- and solid-state physics. NuPECC recognises that EURISOL can only evolve from next-generation RIB projects such as HIE (High Intensity and Energy)-ISOLDE and SPIRAL-2 (intense source of accelerated fission-fragments at GANIL).

The case for high intensity and energy radioactive ion beams can be found at http://isolde.cern.ch/hie-isolde.pdf . The community benefiting from RIB covers a wide spectrum of research fields. For example in nuclear physics the derivation of realistic mean-field theories of nuclear matter require nuclear properties to be established far from the valley of nuclear stability, allowing studies of neutron-proton pairing, shell behaviour under extreme conditions, superheavy nuclei, etc. In nuclear astrophysics, the understanding of critical steps in nuclear synthesis requires RIB for reaching the conditions of nuclear formation (r-process, rp-process) found in violent stellar processes. As a third example, the most sensitive tests of fundamental symmetries using nuclear systems, for example CP violation from atomic electric dipole measurements or scalar/tensor components in the weak interaction, require high production yields for particular radioactive nuclei.

The existing facility for accelerated RIB at ISOLDE, REX-ISOLDE, exploits innovative techniques using ion traps and new methods for charge breeding of atoms that are unique worldwide. REX was originally constructed for specific experiments and was funded (15 CHF) by several CERN member states. The success of REX, which now utilises nearly 50% of the ISOLDE running time, has necessitated the taking over by CERN as a facility in 2004. The genius of choosing its method of trapping and ionisation enables REX to have the potential to transport and accelerate most of the 700 radioisotopes from 60 elements of ISOLDE’s repertoire. The present production yield of RIB at ISOLDE allows about 10% of these isotopes to be used for accelerated beam experiments. In the last two years, REX has accelerated 25 different radioactive isotopes on demand from users, which surpasses any other ISOL RIB facility currently existing in Europe (only the HRIBF facility at Oak Ridge, operational since 1997, offers a similar number of ion species but for different radioisotopes to those produced by REX).

The physics community that use radioactive ion beams, estimated to be about one thousand in Europe alone, requires diversity of ions species, diversity of beam energy, and high beam intensities. REX-ISOLDE already provides the first of these; the aim of HIE-ISOLDE is to achieve the second and the third. This requires developments in post-acceleration (the present energy restricts the application of REX to studies of light nuclei) and radioisotope selection as well as target-ion source development and charge-breeding to cope with the increase in proton intensity promised by LINAC4.

A five-year development programme, with an injection of 9 MCHF from CERN together with contributions from member states and the EU, will realise this facility and make CERN the undisputed world centre for RIB physics by the end of this decade.

In the period 2005-2009, the EU Design Study for EURISOL (in parallel with the EU I3 EURONS) will carry out R&D necessary to overcome the most technologically demanding challenges presented by this third-generation high intensity ISOL source. CERN plays a key role in this Design Study, providing one third of the task leaders. CERN staff and ex-staff also comprise half the management of the Design Study, and the chairman of its steering committee. Clearly CERN is able to host EURISOL, and the synergies with neutrino physics particularly through the beta-beam concept strengthen the physics case for such facilities based on a new multi-MW proton driver at CERN. It should be pointed out that HIE-ISOLDE would be transformed by the construction of a new proton driver such as the SPL and new target stations capable of accepting 100μA proton beams, with possible injection into the redundant PS-booster for high-energy RIB, into a first-stage EURISOL that would achieve many of its physics goals.

This project aims to improve the target and front-end part of ISOLDE to fully profit from potential upgrades of the existing CERN proton injectors e.g faster cycling of the PS Booster and LINAC4. The beam emittance will be improved with an RFQ cooler implemented after a pre-separator but before a new High-Resolution Separator. The new HRS, based on the latest magnet technology, will have sufficient mass resolution to permit isobaric separation. The RFQ cooler will also permit a tailoring of the time structure of the beam, removing the dependence on the proton beam time structure and diffusion-effusion properties of the target and ion source units. Highly charged ions will be provided for REX and other users through an improved low energy stage of REX-ISOLDE and a possible parallel installation of an ECR charge breeder. The top energy of REX-ISOLDE will be increased in two stages with a first upgrade to 5.5 MeV/u and a second to 10 MeV/u. The material costs and manpower requests in this proposal are for the construction of the proposed devices at ISOLDE. Several on-going EU programmes, e.g. JRAs in the EURONS I3 and tasks in the EURISOL design study contribute towards the development and design costs.

The operation costs of ISOLDE will increase as a result of the project. The operation team needs to be expanded, with three additional technicians. This would allow full service for HIE-ISOLDE operation, and provide technical support at the facility, including software developments. The ISOLDE target and front-end section will need staff reinforcements at the level of 2 FTE considering the new demands on target construction, front-end maintenance and target handling. In addition, the physics group (PH-IS) requires 1 FTE for data acquisition support and 0.5 FTE for administration/secretariat services.

The cost for the existing REX operation will have to be transferred to CERN in May 2006 (end of present agreement). The annual staff cost for REX operation is close to 500 kCHF per year corresponding to 2 engineers and 3 technicians. The annual operational material budget for 120 eight-hour shifts of radioactive beam is 120 kCHF.

Up-grade of ISOLDE facility: accelerator R&D

To benefit from injector upgrades as CERN:
900 ms cycling of PSB
Linac 4

To increase the energy and intensity of REX-ISOLDE
TRAP/EBIS upgrades and possible ECR source in parallel
First stage to 5.5 MeV/u
Second stage in collaboration with IHEP to 10 MeV/u

To improve the beam quality at ISOLDE
Controlled time structure, smaller transverse emittance and lower energy spread
High charge state beams and low energy capability

Total material cost (kCHF):	**15290**								
Total external (kCHF):	5110								
Total CERN (kCHF):	10180								
Year:		2004	2005	2006	2007	2008	2009	2010	2011
Annual external:		255	180	1480	360	1060	775	500	500
Annual CERN:		0	20	1405	1800	4380	1775	550	250
Annual totals:		255	200	2885	2160	5440	2550	1050	750

Total personyear:	**42.5**								
Year:		2004	2005	2006	2007	2008	2009	2010	2011
Annual staff in personyear:		1	2	3.5	6.5	13.5	6.4	5.1	4.5

All costs in kCHF

Task No	Task name	Cost	
		Material (kCHF)	*Staff (FTE)*
1	REX upgrade 5.5 MeV/u	2950	8.6
2	REX upgrade 10 MeV/u	3000	7.8
3	REX TRAP and EBIS upgrades	255	0.5
4	REX ECR chargebreeder	750	1.9
5	RFQ cooler	275	0.9
6	High charge state beam line	400	0.9
7	New HRS	1000	1.6
8	Targetry for linac 4 proton beam	3130	9.5
9	RILIS upgrade	880	1.2
10	Ti:Saphire lasers	400	0.6
11	TS infrastructure improvements	700	1.5
12	AT/VAC consolidations	1550	1.5
13	ISOLDE physics group		6
	Total:	15290	42.5

External contributors	***Material (kCHF)***	***Comment***
ISOLDE collaboration	775	Available from 2006
IKS Leuven, BE	900	Approved
ISTC, EU and RU	2000	Application being prepared
EPSCR, UK	255	Approved
VR, SE	830	Applied for
BMBF, D	350	Design study already approved
Total	5110	

Associated approved projects	***Material (kCHF)***	***Staff (FTE)***
EURISOL DS Targets	100	7
EURISOL DS Safety		2
EURISOL DS Beampreparation		3
EURONS chargebreeding		1
EURONS mass separators		1
Total	**100**	14