ISOLDE AND N_TOF CONSOLIDATION

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Abstract

The ISOLDE Facility [1] resumed operation in July 2014 providing low energy radioactive ion beams (RIB) to a physics community of over 500 collaborators. While progress continues on the upgrade of the REX-ISOLDE post-accelerator within the HIE-ISOLDE project [2], assuring the production of RIB for an approved and demanding physics program will require extensive maintenance of the existing facility. The consolidation requests include; the replacement of the ISOLDE target stations, more commonly known as Frontends, renovation of the Resonant Laser Ionization (RILIS) equipment and operation of the REXEBIS and REXTRAP - the low energy systems of the REX-ISOLDE post-accelerator.

However, the radiation protection issues associated with the present performance of ISOLDE and the potential consequences associated with a possible increase in p-beam power should be considered [3]. Consequently, consolidation of the overall shielding of the ISOLDE target area is presented along with the need to replace the ISOLDE beam dumps, both crucial to the exploitation of ISOLDE after the commissioning of Linac 4.

The n_TOF Facility [4, 5] also successfully started its physics program in July 2014 making more efficient use of the neutron flux following the commissioning of EAR2, the second experimental area above the n_TOF target. Further consolidation requirements include the dismantling of the first n_TOF target cooling station and the replacement of the power converter and controls of the sweeping magnet in EAR1.

INTRODUCTION

The performance of ISOLDE and n_TOF has always been maintained largely due to regular winter shutdown periods defined by the CERN accelerator complex schedule. The change in CERN's schedule, brought upon by the operation of the LHC, now provides longer shutdown periods giving the possibility to execute major consolidation projects required for both maintaining the performance of the existing facility and to accommodate any future projects impacting operations. In 2014, ISOLDE celebrates 50 years of providing radioactive ion beams, 22 of which have been at the Proton Synchrotron Booster (PSB). Although various upgrades have been made, consolidation has been relatively minor. The consolidation requests described in this paper are driven by the need to maintain performance of the facility, to overcome issues due to aging, the difficulty in repairing due to high radiation dose rates and the commitment to improve safety standards, notably in radiation protection.

However, with the arrival of Linac 4 and the potential increase in proton beam intensity as well as the possible upgrade of the PSB to 2GeV, the longer shutdown periods provide a unique opportunity to improve on the existing infrastructure in order to accommodate these changes.

n_TOF on the other hand has been taking data since 2002 and the major consolidation request is to replace the second spallation target. After installation in 2007, this target has an expected lifetime of around 10 years yet in 2014, observations have already revealed signs of external corrosion. Once again, expected high dose rates and the time required for a target change make the LS2 period an ideal moment for the replacement of the n_TOF target #2.

ISOLDE

In this section, a brief description and justification of the consolidation requests for the ISOLDE Facility over the next 6 years are highlighted individually.

Frontends

Essential to the operation of ISOLDE, this equipment – also known as a target station - is at the heart of providing RIBs. They accommodate the vacuum, acceleration voltage, target power supply connections, cooling, beam diagnostics and focussing elements required for the production of the unseparated ion beams. There are two Frontends at ISOLDE; the HRS and the GPS installed in 2010 and 2011 respectively. Based on previous experience, the estimated lifetime of a Frontend is approximately 7 years. Should one Frontend fail during the operational period, its replacement can only be done during a shutdown period due to the high dose rates involved. Consequently, the ISOLDE physics program would be cut by 50% during the downtime of one Frontend. A change of Frontend also provides an opportunity to make substantial upgrades, often in line with safety requirements. Potential upgrades are being addressed in the HIE-ISOLDE Design Study due to be published by the end of 2014[6]

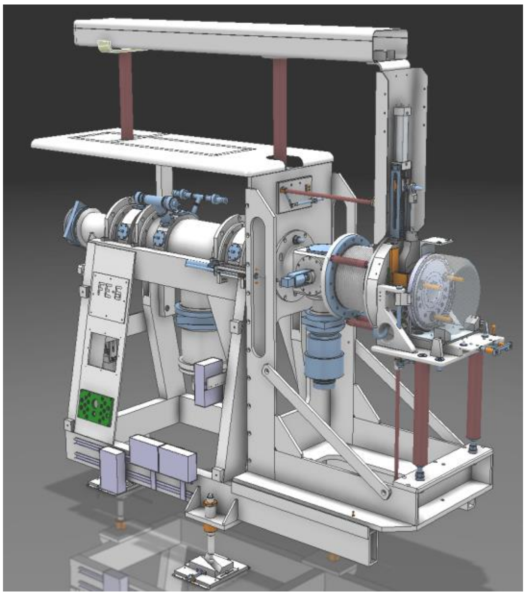

Figure 1. The ISOLDE Frontend

Vacuum

First beam line chamber. Situated directly behind the Frontend, this vacuum chamber was partly responsible for the delayed start-up of the HRS separator after the LS1 period. Corrosion issues are at the heart of the failure and since their initial installation in 1992, these chambers have never been replaced. A further option on this equipment would be to remove the wire grid and install it on the Frontend reducing the need to access for maintenance and assuring a regular replacement every 7 years.

Exhaust gas tanks. All vacuum exhaust gases from the Frontend and separator vacuum vessels are stored in two tanks where the volatile radioactive species are allowed to decay before being released to the atmosphere. As an environmental safety measure, when both tanks are full, the vacuum systems at ISOLDE are stopped. The addition of a third tank would both increase storage capacity and provide more decay time prior to release.

Beam line turbo pumps. This request is driven by the need to replace the aging beam line turbo pumps throughout the entire low energy part of the facility.

Beam dumps

Based on the little known characteristics of the existing ISOLDE beam dumps, calculations have shown that they are operating at their limits in terms of compressive and thermal stresses and that these limits are exceeded for certain primary proton-beam conditions. Replacement of the beam dumps during the LS2 period would not only ensure safe operation for existing primary proton-beam conditions but modifications would also allow for an increase in proton beam intensity and energy. Two options have been identified for the consolidation of the beam dumps, both of which imply the installation of a water-cooled copper alloy block with its associated disadvantages in terms of the cooling system maintenance and activated water..

Option 1: insertion of a water-cooled PSB-like beam dump in front of the existing beam dumps.

Based on a known design and probably the cheaper version, this option would be relatively easy to install. But, placing a copper alloy block in front of the original dump reduces the collimator effect of the existing beam dump shielding and would lead to an increase of activated air during operation and possibly a decrease in performance with regards to the air ionization and the pulsed high-voltage recovery time. Installation of the beam dump would also require spending an unacceptable amount of time in a highly radioactive environment.

Option 2: Complete replacement of the beam dumps.

The main advantages of this option include; replacing an unknown device with a well-specified beam dump, an overall lower collective dose compared to option 1 and the possibility to improve the beam dump shielding. The main disadvantages however, are both the cost and issues associated with the handling of over 3500m^3 of shielding earth. Above the HRS beam dump, recent sampling down to 4.5 meters of the 9 meter thick layer of soil has revealed unnaturally high levels of specific radioisotopes which only add to the difficulties of excavation work.

Shielding

There are two aspects to the consolidation of the shielding. The first is the impact on the environment during operation and the ambient dose equivalent rate measured external to the ISOLDE shielding. During the operation of thick targets with 2μA of primary proton-beam on the HRS target, measurements of up to 18μSvh^{-1} have been recorded directly above the target station. This area has been fenced off but attention must be paid to the contribution of future ISOLDE operation to the ambient dose equivalent rates in the non-designated and low occupancy areas – 0.5μSvh^{-1} and 2.5μSvh^{-1} respectively – in the vicinity. This includes the future laser laboratory above building 179 and building 199. At present, the contribution by ISOLDE to any prompt ambient dose equivalent rate beyond the ISOLDE perimeter has not been determined.

The second issue is air activation. In order to maintain an under-pressure in the target area, the ISOLDE ventilation system extracts 2900 m^{3}h^{-1} of activated air with an average count rate of 500 kBqm^{-3}. While every effort is being made to reduce the air extraction, the alternative is to improve the shielding especially around the beam dumps; the main source of air activation.

Off-line Separator

In compliance with quality assurance, all targets, with the exception of actinide targets, are tested under nominal operational conditions on an off-line separator prior to irradiation on-line. Full testing of the actinide targets is not done due to the absence of an off-line separator in the Class A laboratories. Since the commissioning of the

Class A laboratories in building 179, all handling of open radioactive sources, including the actinide target material, is confined to these laboratories alone therefore prohibiting the transport of actinide targets to building 3 for off-line testing. Over the years, the versatile uranium carbide targets now represent up to 60% of target production at ISOLDE; generating a shortfall in quality assurance. The consequences of a non-performing actinide target on-line can amount to a two week loss in the physics program and incalculable losses in time, resources and preparation.

REX-ISOLDE

The low energy part of REX cools, bunches (REXTRAP) and ionizes to a multi-charged state (REXEBIS) the singly-charged ion beams from ISOLDE before injecting into the REX-Linac for post-acceleration up to 3MeV/u. REX_ISOLDE provides up to 200 x 8 hour shifts per year of physics to the ISOLDE community and a failure in the low energy part would not only jeopardize the physics program but also undermine the effort being put into the upgrade in energy of the REX-Linac within the HIE-ISOLDE project.

Consolidation implies the replacement of critical components for the REXTRAP and REXEBIS, however, this may be off-set should funding be made available to replace the REXEBIS with an upgraded version currently being investigated within the HIE-ISOLDE Design Study.

RILIS

The Resonant Ionization Laser Ion Source contributes up to ~3000 hours of operation at ISOLDE with 70% of beam requests asking for this highly selective and efficient ionization technique. Consolidation requests for RILIS are for the provision of spare laser systems to assure operation in the event of a failure as well as the replacement of laser systems every 15000 hours; the typical lifetime of laser equipment.

Magnets

Any failure of the ISOLDE or REX-ISOLDE magnets would result in a 50% loss in the yearly physics schedule and this may increase significantly depending on when the failure occurred and the need to order spare parts. At present, there are no spare coils or magnets available for the ISOLDE Facility and with more than 20 years of operation, the TE-MSC group at CERN have identified the importance of providing adequate spares.

High Voltage

The present high voltage power supplies purchased from Astec in the early nineties our now approaching the end of their lifetime with failure rates becoming more and more frequent. Fortunately, the TE-ABT group have already identified this issue and have been allocated funding for their replacement in 2015. In parallel to the procurement of new power supplies, the development of a new compatible modulator system is progressing well within the HIE-ISOLDE Design Study. The specifications of both power supply and modulators take into account the potential increase in primary proton-beam intensity and energy associated with the arrival of Linac 4 and the upgrade of the PSB.

Cooling and Ventilation

The coupling of the Class A laboratory ventilation system to that of the target area is far from optimal in terms of activated air release. While efforts have been made to propose a new solution, modifications will be implemented sooner than expected thanks to the approval and construction of the MEDICIS project [7]. The MEDICIS laboratory is adjacent to the Class A laboratory in building 179 and, after being physically connected during the 2014-2015 shutdown period, they will have their own dedicated ventilation system. During the same period, the Class A laboratory ventilation system will be decoupled from that of the target area.

While funding for adjoining the two laboratories has been approved within the MEDICIS project, funding for the modification or replacement of the obsolete target area ventilation controls has yet to be assured. Furthermore, the completion of the latter is of paramount importance for the start-up of ISOLDE operations in April 2015.

Safety

Any consolidation or modification of the ISOLDE infrastructure will require a detailed risk analysis at the design stage. Furthermore, detailed installation planning, testing and preparation of Work and Dose rate Planning (WDP) will be important for all interventions taking place within a highly radioactive environment. This will be complemented by detailed documentation on feedback and intervention reporting.

Consolidation Budget Request for ISOLDE

The 6 year consolidation budget request for each topic is presented in Table 1. Contributions have been provided by the equipment groups who will drive the consolidation work package should funding be made available. Depending on decisions taken, further research is required for the unknown costs.

Table 1. Consolidation budget requests for ISOLDE

WU/kCHF	2015	2016	2017	2018	2019	2020	Groups
Frontends x 2		300	300		50		EN-STI-RBS
Spare FE						300	
Beam dumps Option 1				1000			EN-STI-TCD
Option 2				?	?		
Shielding				?	?		GS-SE
Off-line separator	400	400					EN-STI-RBS
REX-ISOLDE		100	100	100			BE-ABP
RILIS	325					435	EN-STI-LP
Magnets	200	300	300				TE-MSC
Vacuum		70	60	160	60	60	TE-VSC
High Voltage	93	100					TE-ABT
CV controls	?						EN-CV
Safety	120	120	120	120	120	120	EN-STI

n_TOF

Three topics have been highlighted for consolidation at n_TOF and although the work will be done during the LS2 period, preparations will be started as early as 2015.

Target #2

Target #2 is the result of a major upgrade of the original n_TOF target #1 following issues related to damage, oxidation and the migration of spallation products into the cooling water system. However, installed in 2007 and with a projected lifetime of approximately 10 years, the present n_TOF neutron spallation target is already showing initial signs of surface corrosion. The monolithic Pb block along with its cooling system cannot be repaired due to both its design and expected dose rate after removal and will therefore have to be replaced during the LS2 period to ensure reliable physics after LS2. It is worth noting that a target change at n-TOF is a lengthy process and would jeopardize the physics program for at least 1 year if done in during the physic’s period.

Target #1 Cooling Station

After being removed from the service gallery in 2013, the original n-TOF target is now under preparation for shipment to PSI, Villigen for final storage as radioactive waste. However, the original target cooling station remains in the FTN transfer tunnel between TT2 and the n_TOF target area. Plans are now under way for the decommissioning and conditioning of the cooling station during the LS2 period.

Figure 2. Initial signs of corrosion at the target neutron window

Sweeping Magnet Power Converter

Situated in the EAR1 experimental hall, the sweeping magnet is essential to assuring the physics program in that it prevents high-energy charged particles from entering the target area and saturating the sensitive detectors during operation. While the magnet itself is sound, consolidation requests are for a replacement of its associated power converter and control system; both of which are obsolete and are currently maintained on a best effort basis.

Consolidation Budget Request for n_TOF

The budget request for the consolidation of n_TOF over the next 4 years is given in table 2.

Table 2. Consolidation budget request for n_TOF

WU/kCHF	**2015**	**2016**	**2017**	**2018**	**Total**
Design and construction of a new neutron spallation target	250	500	350	200	1300
Dismantling of the target #1 cooling station	0	0	0	200	200
Consolidation of EAR1 sweeping magnet power supply	0	0	100	100	200
Total/year	250	500	450	500	1700

CONCLUSION

To exploit the long LS2 shutdown period and to benefit from the inherent extended radioactive cooling, both ISOLDE and n_TOF have made provisional requests for major consolidation projects. Most of these requests assure the operation and performance of both facilities beyond the LS2 period and in the case of ISOLDE, will allow for any upgrade in intensity and energy of the primary proton beam.

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