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Delivering multiple independent RIB simultaneously: Technical and operational challenges

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ABSTRACT

ISAC is an ISOL-type facility at which RIB are produced by direct reactions of 480 MeV protons from TRIUMFs main cyclotron on thick targets. Like other ISOL-type facilities, ISAC is limited to the production and delivery of a single RIB at any given time. ARIEL, the Advanced Rare-IsotopE Laboratory, will provide for the production and delivery of, ultimately, two additional RIB, the first produced by photofission on actinide targets using electrons from a new superconducting electron linac and the second by direct and indirect reactions with protons from TRIUMFs main cyclotron. This will allow for the simultaneous delivery of three independent RIB to experimental areas at ARIEL and ISAC.

The shift from single-user to multi-user operation will introduce significant technical and operational challenges that RIB facilities have not yet had to address. Almost all aspects of facility operation will become more complex as the first RIB from ARIEL targets become available.

1. Introduction

ISAC, the Isotope Separator and ACcelerator, is a high-power ISOL-type rare-isotope beam (RIB) facility located at TRIUMF in Vancouver, Canada [1]. RIB are produced by direct reactions of 480–520 MeV protons from TRIUMF's main cyclotron on thick production targets at beam currents of up to 100 μA. RIB may be delivered at energies of ~10–60 keV for low-energy experiments or post-accelerated to energies upwards of 6.5 MeV/u (for beams with $A/q \leq 6$) for experiments at high energies. However, with only one production driver and one mass separator, ISAC is only capable of delivering a single RIB at any given time. Even so, the facility typically delivers ~3000 h of RIB for experiments and development annually (Fig. 1).

ARIEL, the Advanced Rare IsotopE Laboratory currently under construction at TRIUMF, will ultimately provide for the delivery of two additional RIB. The first will be produced by photofission and other photon-induced reactions using electrons from a new 10-mA, 50-MeV superconducting electron linac (or e-linac); the second, by proton-induced reactions using a new high-current beamline from TRIUMF's main cyclotron (Fig. 2). With ISAC, this will allow the delivery of up to three simultaneous RIB when complete, tripling the number of hours of RIB available for experiments [2].

It should be noted that limited capabilities for the simultaneous delivery of multiple RIB do exist at other facilities. ISOLDE, for example, has two isotope separators with independent target stations for the production of RIB by the ISOL technique: the General Purpose Separator (GPS) has an electrostatic switchyard allowing up to three mass-separated beams to be extracted at one time and may also be operated concurrently with the High Resolution Separator (HRS) in a mode in which the pulsed driver beam from CERN's PS-Booster is shared between the two target stations [3]. At RIKEN, RIB produced by in-flight reactions with primary beams from the AVF cyclotron may be separated for study using the CNS RI-Beam Separator, CRIB [4], in parallel with operation of the laboratory's main RIB facility, RIBF [5], while at GANIL RIB may be produced by projectile fragmentation and separated using the LISE spectrometer [6] in parallel with operation of the SPIRAL1 and (in future) SPIRAL2 ISOL facilities [7] [8]. In each of these cases, however, delivery of at least one RIB is limited to only a small subset of the available experimental locations. The combined ISAC/ARIEL facility will be unique in having three independent ISOL RIB sources each capable of providing beam to any experimental location within the existing beamline complex with only minor exceptions. This will bring challenges not presently faced at other facilities.

2. Technical issues

There are a number of technical challenges associated with expanding TRIUMF's RIB infrastructure to include ARIEL. While

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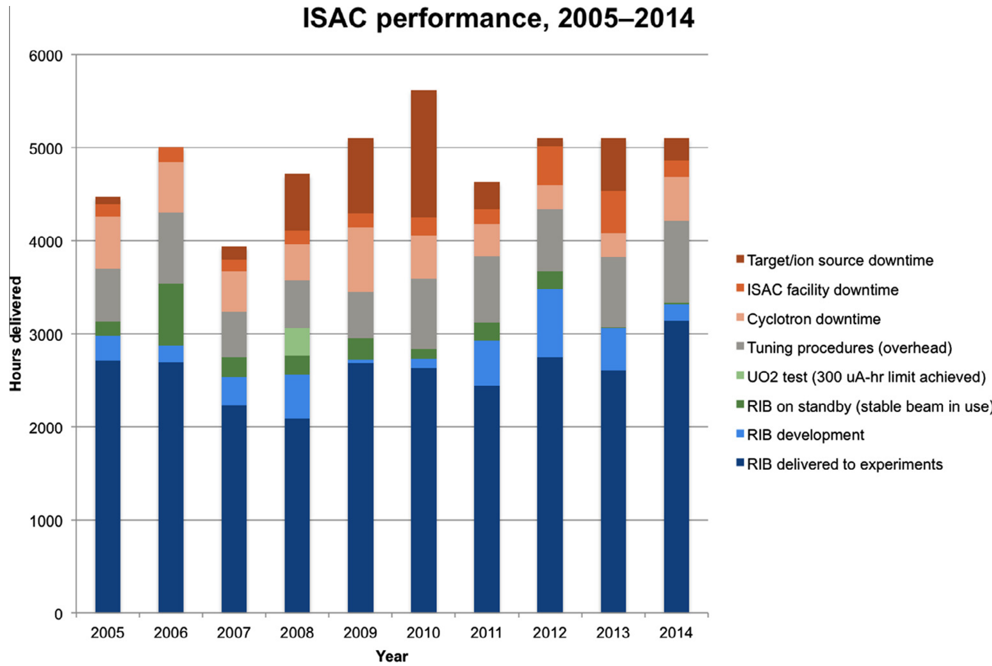

Fig. 1. ISAC performance, 2005–2014. The blue and green columns represent RIB available for experiments or development. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this article.)

many of those are largely independent of other TRIUMF facilities, there are a few that affect both ARIEL and ISAC.

Configuration and work management. Effective management of both the facility configuration and of work that might affect that configuration or ongoing operations is critical to the safe, reliable operation of any accelerator facility. At TRIUMF, various systems including work permits and work requests are used to enable this. These systems are presently being extended to include ARIEL and its components. A comprehensive list of laboratory facilities and their managers is being developed to facilitate this effort with the goal of integrating all such facilities into a single framework for configuration and work management.

Controls integration. The ARIEL Control System (ACS) represents an evolution of the existing EPICS-based ISAC Control System (ICS) and is dedicated to the control of the e-linac and its associated subsystems [9]. The ARIEL and ISAC RIB beamlines, however, will share a common control system as they are fully interconnected. Just as lessons learned at ISAC have been applied to the development of the ACS, lessons learned in the development of the ACS will guide the integration of the ARIEL RIB beamlines into an upgraded ICS.

Tuning overhead. RIB tuning is presently carried out by the ISAC Operations group under the guidance of low- and high-energy systems experts and accounts for ~20% of the available RIB hours. This is expected to increase with the shift to multi-user operation due to the additional complexity associated with delivering multiple RIB within the constraints of the existing beamline layout. Efforts are being made to identify aspects of beam tuning and beam maintenance that could be automated within the appropriate control systems and to develop high-level applications to assist with those tasks.

3. Operational challenges

The combined ISAC/ARIEL facility will include three RIB production drivers (the ARIEL e-linac and two high-current proton beamlines) with their own mass separators and low-energy beamlines coupled to the existing ISAC RIB infrastructure (Fig. 3). That

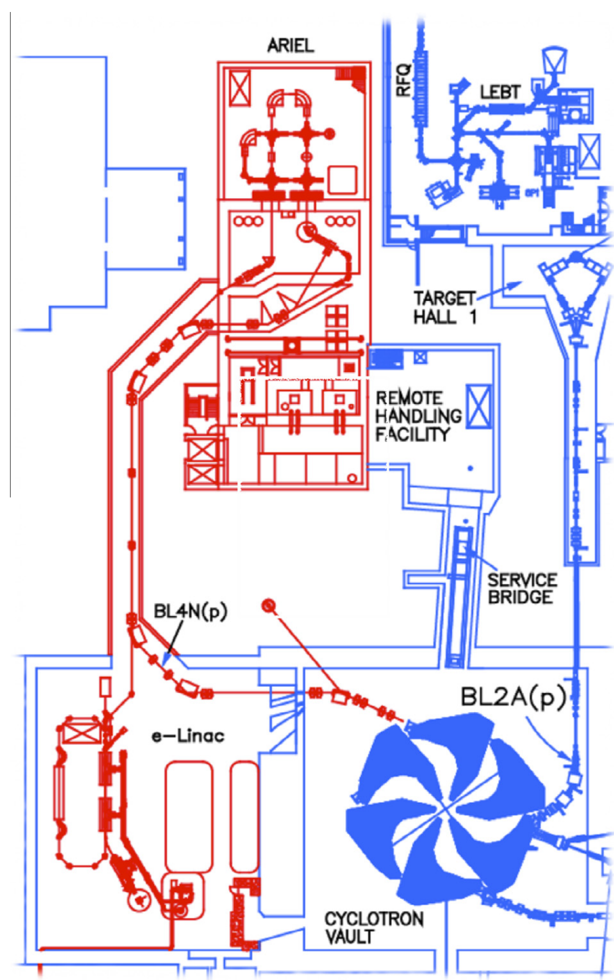

Fig. 2. The ARIEL beamline layout (in red) relative to existing facilities (in blue). ISAC is at top right. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this article.)