THE PROPOSED ISAC-III (ARIEL) LOW-ENERGY AREA AND ACCELERATOR UPGRADES

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Abstract

The ISAC-III proposal (now called ARIEL) is a ten year plan to triple the amount of radioactive ion beam (RIB) time at the facility. The plan includes the addition of two new independent target stations, a second 500 MeV proton beam line from the TRIUMF cyclotron and a new 50 MeV electron linac as a complementary driver to provide RIBs through photo-fission. A new mass-separator and low-energy beam-transport complex is foreseen to deliver the additional beams to the ISAC experimental facilities. A new linear accelerator section would provide the capability for two simultaneous accelerated RIBs to experimenters. This paper will describe the proposed installations in the low-energy transport and accelerator sections of the ISAC complex.

INTRODUCTION

In the ISAC-I facility[1] 500 MeV protons from the cyclotron at up to 100μA impinge on one of two production targets to produce radioactive isotopes. The isotopes are ionized and the resulting beam is mass-separated and transported in the low energy beam transport (LEBT) electrostatic beamline to either the low energy experimental area or through a series of room temperature accelerating structures (RFQ, DTL) to the ISAC-I medium energy experimental area. The RFQ accelerates ions with A/q$\leq$30 to 150 keV/u and the post-stripper variable energy DTL accelerates ions with A/q$\leq$6 up to 1.8 MeV/u. The accelerated beam can also be transported to the ISAC-II Superconducting Linear Accelerator (SC-linac)[3] for further acceleration above the Coulomb barrier. An ECR charge breeder (CSB) is presently being added to extend the mass range beyond A=30.

The cyclotron provides the highest power driver beam (50 kW) of any operating ISOL based facility. Two 50 kW target stations are available to reduce the switchover time between targets. But the present scientific output is oversubscribed with more experiments requested than available beam time would allow. The aim of the ISAC-III (ARIEL) proposal is to get more RIBs on target to produce more physics. Fundamental to the plan is the eventual delivery of three simultaneous RIBs to three experimental areas. The expansion requires the addition of two new driver beams - one from a second cyclotron proton beamline and one from a new high power electron linac[2]. Two new target areas with independent separators and a flexible beam delivery system would allow simultaneous operation of three production sources. A new accelerator front end including a second charge breeder provides a second simultaneous accelerated beam capability. The TRIUMF site with the prospoed addition is shown in Fig. 1.

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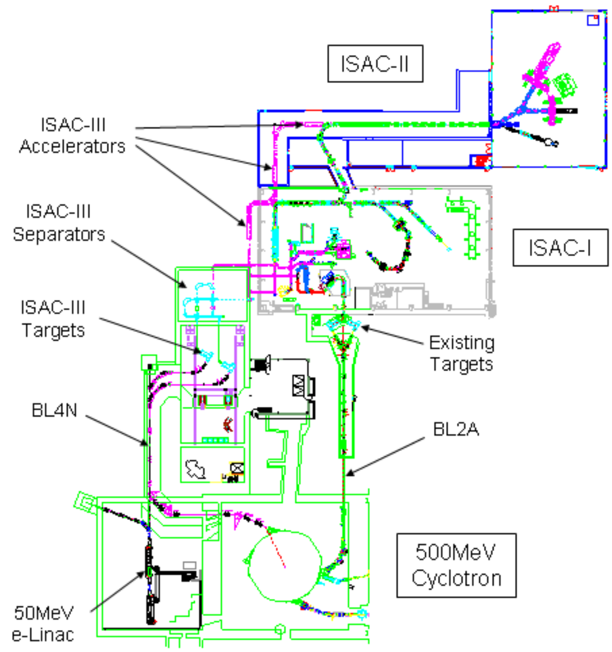

Figure 1: The TRIUMF site including the cyclotron, ISAC-I and ISAC-II and the proposed ISAC-III (ARIEL) facility. BL2A is the present proton line and the BL4N tunnel is proposed for the new ISAC-III driver beams.

MASS-SEPARATOR SWITCHYARD

It is useful to consider a switchyard that is capable of either low resolution, medium resolution or high resolution separation schemes depending on the experiment. In general reduced resolution schemes are desired since they reduce the tuning time required. The proposed configuration is shown in Fig. 2. Here each of the two target/source units has a pre-separator and individual transport lines directing the beams to a mass-separator switchyard. The beams after separation are directed to either one of two new vertical sections VS-2 or VS-3 for delivery to the upstairs experimental area. Standard ISAC LEBT electrostatic components are used to deliver the beam to either a Medium Resolution Spectrometer (MRS) or a High Resolution Spectrometer (HRS). The medium resolution leg has a resolution of ~2500 while the high resolution leg has a resolution of ∼15000. The high resolution leg is equipped with an rf cooler to reduce the transverse emittance and energy spread of the beam before separation. The switchyard is designed with sufficient flexibility that each of the targets can pass beams through the HRS while the beam from the other target is sent to the MRS. In addition a bypass line is available so that if not required a beam with pre-separation only can be sent to the experimental area. A first stage would require only the MRS section and vertical section to transport the single new RIB beam upstairs from the first target.

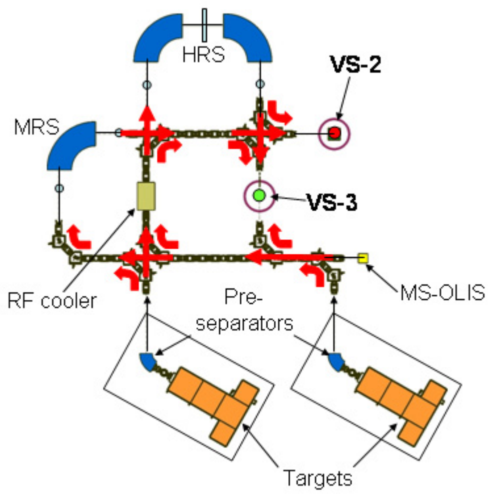

Figure 2: ISAC-III target stations and mass-separator switchyard. The red arrows indicate possible beam paths. An off-line source (MS-OLIS) is available for separator tuning.

LOW ENERGY BEAM TRANSPORT

The LEBT is the all electrostatic transport that takes the beam at source potential (≤60 kV) from the downstairs target/separator area to the upstairs experimental floor for delivery to the low energy areas or to the accelerators. Substantial LEBT transport has already been installed in ISAC. The design of the new installation will copy the standard building blocks that comprise the present installation. The new installation is designed to provide enough flexibility that any of the target stations, existing or new, can deliver beams to any of the three experimental areas, low energy, medium energy or high energy, so that the RIB beams from each target can be optimized for a given experiment. A second path to the low energy experimental area is provided since this is where there is the largest inventory of experimental infrastructure. The ground floor LEBT for ISAC-III is shown in Fig. 3.

A second charge state booster (CSB2) is added in Stage 1 to increase the charge state of beams selected for acceleration. An extra line is added so that beams from the existing target area can also be boosted in CSB2 if preferable. A second accelerator path is available with the addition of RFQ2 positioned beside the existing ISAC RFQ1.

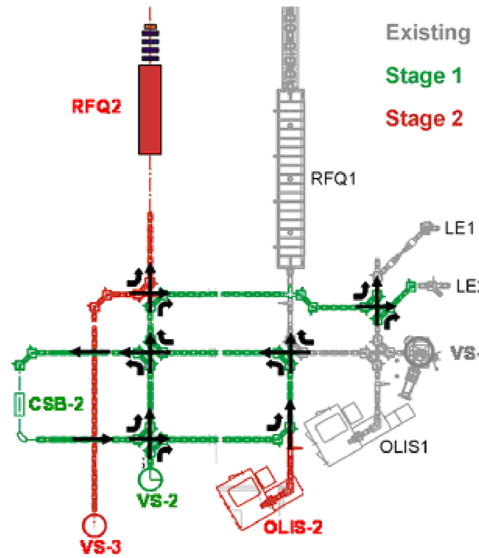

Figure 3: The new ground level LEBT (low energy beam transport) for ISAC-III. The existing section appears in grey. The first stage installation is shown in green and the second stage is shown in red. The black arrows indicate the available beam paths.

A second off line ion source (OLIS2) allows tuning of either accelerator line while delivering RIBs to the other. The LEBT vacuum normally reaches 2e-7 Torr. For transporting the higher charge states from the CSBs the vacuum will be improved to <5e-8 Torr to reduce transmission losses.

NEW ACCELERATOR LEG

The technique of accelerating a 1+ beam through a series of stripping and acceleration steps was considered but abandoned due to the high total accelerating voltages required. Instead a second charge breeder (CSB2) will be added to boost the 1+ ions from the on-line source. The technical choice for the ISAC-III CSB2 between an EBIS or an ECRIS charge breeder will be made by 2010 after the on-line performance of CSB1 (Phoenix 14.5 GHz ECRIS) with RIB delivery can be evaluated. TRIUMF also has a working EBIS on-site with the TITAN experimental installation. CSB1 produces charge states compatible with A/q≤9 for all masses and this sets the mass specification for the second accelerator leg.

The proposed accelerator addition is shown in Fig. 4. A new RFQ compatible with accelerating ions up to A/q=9 takes the beam to 150 keV/u. A new beamline running north of the existing RFQ will provide separate paths for ISAC-I and ISAC-II accelerated beams avoiding the ISAC-DTL1 bottleneck of 2 ≤ A/q ≤6. A new medium energy transport section incorporates a switchyard that allows sending either of the RFQ1 or RFQ2 beams to either of ISAC-I or ISAC-II simultaneously. The new beamline to ISAC-II will include a room temperature drift tube linac (DTL2) to boost the energy from 0.15 MeV/u to 0.7 MeV/u for beams up to A/q=9. A new low beta cryomodule (SCA) at 106 MHz would further boost the energy to at least 1.5 MeV/u for injection into the existing SC-linac. An optional stripper could be employed between DTL2 and SCA to boost the charge state to achieve a higher final energy.

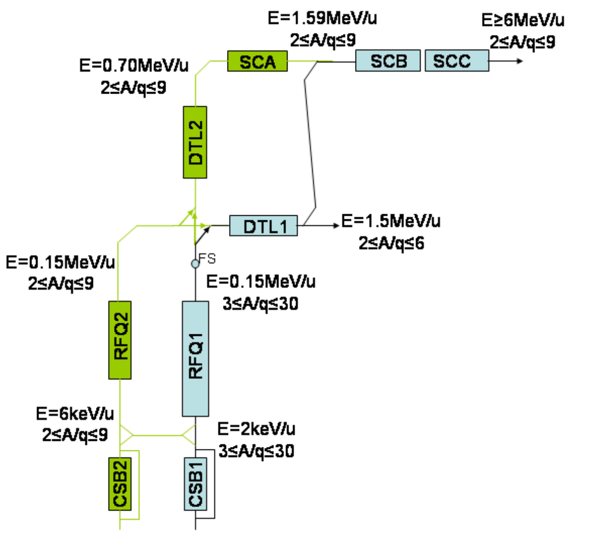

Figure 4: The existing ISAC-1 and ISAC-II accelerator chain in (blue) and the upgrade of the ISAC-III accelerator system in green.

RFQ2 is a room temperature device that accelerates beams from 6 keV/u to 150 keV/u for ions up to A/q=9. The rf structure has not yet been chosen but preliminary beam dynamics have been completed. The rf is specified at 70 MHz with ΔV=1.3 MV. A length of 3.2 m is estimated.

DTL2 is presently specified as a room temperature device at 106 MHz. A four tank IH structure is chosen with magnetic triplets in between tanks for transverse focussing. Design values for number of gaps and rf parameters are shown in Table 1. The DTL is designed to accelerate at 0° synchronous phase with -60° bunching sections in the first several gaps of each tank.

Table 1: DTL2 tank design parameters.

Tank	$N_{\rm gap}$	L(m)	D(m)	V(MV)	P(kW)
1	10	0.28	0.92	0.83	6.1
2	16	0.55	0.7	1.66	10.8
3	18	0.75	0.7	2.25	11.9
4	21	1.04	0.7	3.13	14.3

The SCA accelerator section represents the low energy front end to the ISAC-II linac. The injection energy is 0.7 MeV/u and the section accelerates A/q values up to 9. The SCA section is comprised of one cryomodule with eight cavities and three superconducting solenoids for transverse focussing. The cavities are 70 MHz with a design geometry corresponding to $\beta_0 = 4.6\%$.

Initial beam simulations from RFQ2 to the end of the SC-Linac have been completed. The transversal RMS envelopes are shown in Fig. 5. The initial Twiss parameters for the simulation at the exit of RFQ2 are $\alpha_x = 1.3$, $\beta_x = 0.202$ (mm/mrad), $\alpha_y = -1.65$, $\beta_y = 0.283$ (mm/mrad), $\alpha_z = -0.5$, $\beta_z = 10$ (degree/%) with normalized emittances of $\epsilon_{x,y} = 0.3\pi$ mm-mrad, $\epsilon_z = 0.6\pi$ keV/u-nsec. Emittance growth of 10% and 6% are estimated for the full acceleration in the transverse and longitudinal dimensions respectively.

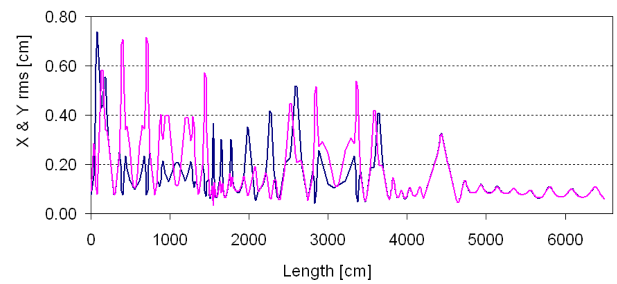

Figure 5: The x (magneta) and y (blue) beam envelopes from RFQ2 to the end of the ISAC-II SC-linac.

STAGING

The first stage comprising the period 2010-2015 includes the additions of the e-Linac to 50 MeV, 1 mA (50 kW) capability; 25 MeV by the end of 2012, the completion of the new proton line to a capability of 500 MeV, 200μA (100 kW) by the end of 2014, one new target station with 50 kW electron/proton capability by April 2013, a new medium resolution mass separator (MRS) and low energy beam transport (LEBT) to deliver beams from the new target station to the low energy area by April 2013 and CSB2 and LEBT to allow the acceleration of beams from the new target area by the end of 2014. The second stage through 2015-2020 would include the addition of the upgrade of the e-Linac to 50 MeV, 10 mA (500 kW), a second new target station with 500 kW electron capability, an expanded low energy section with high resolution separator (HRS) allowing simultaneous beams from the two new target areas and a new accelerator front end to allow two simultaneous accelerated beams. Presently ISAC runs at ∼2900 RIB hours a year. With ISAC-III this is expected to rise to 6500 by the end of 2014 with a further rise to 10700 by the end of 2019.

REFERENCES

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