THE PROPOSED ISAC-III UPGRADE AT TRIUMF

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Abstract

Presently, the ISAC radioactive beam facility employs a single 50kW proton driver beam onto one of two production targets. The targets are configured such that only one radioactive ion beam (RIB) is available for use at any one time. The ISAC-III upgrade, expected to span ten years, is proposed to increase the number of RIBs simultaneously available to three, including two simultaneous accelerated beams. The expansion requires the addition of two new driver beams one from a second cyclotron beamline and one from a new electron linac. The two new resulting RIBs would be delivered through a LEBT switchyard and new post-accelerator front end to the experimental areas.

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) for acceleration above the Coulomb barrier to the ISAC-II high energy area. The SC-linac provides 20MV of accelerating potential now with a further 20MV scheduled for installation by the end of 2009. An ECR charge breeder is presently being added to extend the mass range beyond A=30.

The present ISAC facility has several unique features. The cyclotron provides the highest power driver beam (50 kW) of any operating ISOL based facility. High power targets have been developed to fully utilize this beam power to produce high intensities of exotic nuclei. Two target stations are available to reduce the switchover time between targets. The present ISAC facility keys on nuclear astrophysics by accelerating lighter masses 4$\leq$A/q$\leq$30 with high efficiencies of the order of 20-25% dominated by the charge state distribution after stripping at 150 keV/u. The flexibility and reliability of the accelerators coupled with excellent beam quality provide for a successful user program.

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Nevertheless the facility has limitations. The present facility has nine major experimental infrastructures but only one RIB beam available at any given time. Since the cyclotron is typically shut down for four months of the year there is less than one month of radioactive beam time per experimental facility in a year. The beam time is further reduced due to target/source development since there is no on-line target test area. The present target design and hotcell arrangement coupled with hall access restrictions demands a lengthy (weeks) turn around for target replacement and periodic vault access is required during the switchover eating into the beam delivery from the other target. Even though two target areas exist the proton driver beam cannot be time shared since there is only one mass separator and LEBT. The use of actinide targets required for a full RIB program is problematic with the present target design since there is no provision for containment of any loose contamination during target moves.

ISAC-III PROPOSAL

Fundamental to the ISAC-III proposal is the eventual delivery of three simultaneous RIBs to three experimental areas. The upgrade involves the addition of a high power electron linac[2] (50 MeV/10 mA-0.5 MW), to irradiate one of two new independent targets and produce RIBs through photo-fission. A second beamline from the existing cyclotron delivers a new 500 MeV/100 μA-50kW proton-driver. The new driver beams are coupled with two new production areas with independent separators and a flexible beam delivery system allowing simultaneous operation. The new target stations are designed for actinide target use with hermetically sealed target volumes for self containment. They are engineered for a turn around of only a few days. A new accelerator front end including a second charge state booster provides the possibility of a second accelerated beam. The proposal addresses the key weaknesses inherent in the present ISAC facility. Three simultaneous beams will at least triple the beam hours on target. In addition the electron driver beam could be available during the cyclotron shutdown periods enhancing the beam time even further or augmenting development time. A view of the TRIUMF site including ISAC-I, ISAC-II and the proposed ISAC-III facility is shown in Fig. 1.

Stages

The ISAC-II proposal is staged to smooth manpower and cash flow. The first stage comprising the period 2010-2014 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, BL4N, to a capability of

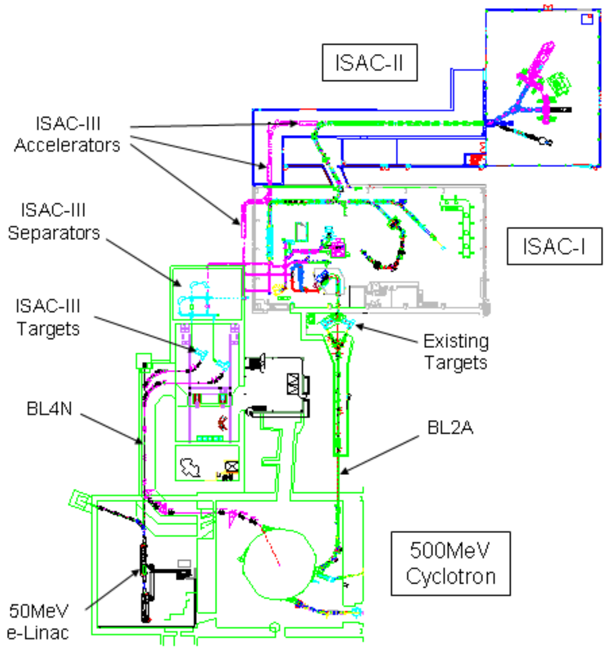

Figure 1: The TRIUMF site including the cyclotron, ISAC-I and ISAC-II and the proposed ISAC-III facility. BL2A is the present proton line and BL4N is proposed for ISAC-III.

500 MeV/200 μA-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 LEBT to deliver beams from the new target station to the low energy area by April 2013 and a new Charge State Booster (CSB2) to allow the acceleration of beams from the new target area by the end of 2014. The second stage through 2015-2019 would include the upgrade of the e-Linac to 50 MeV, 10 mA (500 kW), a second new target station with 500 kW electron and 50 kW proton 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. This enhancement, more than a factor of three, is due to the complimentary nature of the electron machine that allows delivery during traditional 'off' periods.

MASS SEPARATORS

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. The pre-separator, associated optics and object and image slits are housed in a shielded cave where the main radioactivity is contained. The key elements are engineered for remote handling. Standard ISAC LEBT electrostatic components are used to deliver the beam to either a MRS or a HRS. The MRS leg has a resolution of $\sim$2500 while the HRS leg has a resolution of $\sim$15000. The HRS 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 can be sent to the experimental area directly after the pre-separator. The first stage requires only one mass separator and vertical section to transport the single new RIB beam upstairs from the first target.

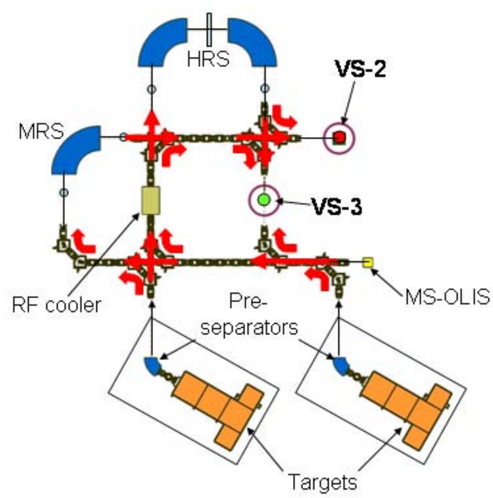

Figure 2: ISAC-III target stations and mass-separator switchyard. The red arrows indicate possible beam paths. An off-line source (MS-OLIS) is available for separator tuning.

LOW ENERGY BEAM TRANSPORT

The LEBT is the all electrostatic transport that takes the beam at source potential ($\leq$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 with the exception of the line downstream CSB2. Here the vacuum will be improved from the standard 2×10^{-7} Torr to $< 5 \times 10^{-8}$ Torr to facilitate transportation of the higher charge states. A design goal of the new installation is 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. Another goal is to provide a second path to the low energy experimental area since this is where there is the largest inventory of experimental infrastructure. The ground floor LEBT for ISAC-III is shown in Fig. 3. Two vertical lines VS-2 and VS-3 bring RIBs from the new downstairs target area adding to existing RIB line VS-1 to provide three simultaneous RIBs. A new line is added to the low energy experimental area splitting the area into two halves; with each line serving three experimental areas. 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. A second off line ion source (OLIS-2) allows tuning of either accelerator line while delivering RIBs to the other.

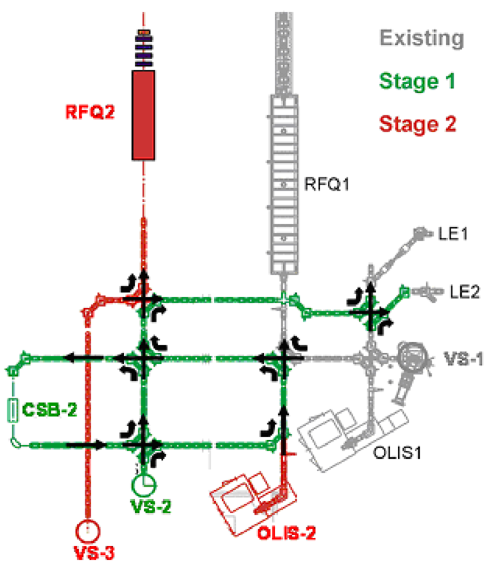

Figure 3: The new ground level LEBT (low energy beam transport) for ISAC-III. The existing section appears in grey. The first stage installation is shown in green and the second stage is shown in red. The black arrows indicate the available beam paths.

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 radioactive ion beam 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. A new 70 MHz RFQ2 is compatible with accelerating ions up to A/q=9 and delivers up to 1.3 MV to take the beam to 150 keV/u. A new beamline running north of the existing RFQ1 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) at 106 MHz 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.

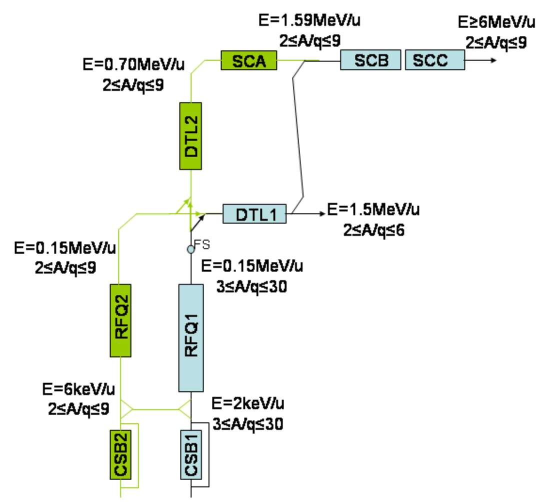

Figure 4: The existing ISAC-1 and ISAC-II accelerator chain in (blue) and the upgrade of the ISAC-III accelerator system in green.

CONCLUSION

The goal of the ISAC-III Project is to maintain ISAC as a worldleader in ISOL based radioactive beam research by tripling the RIB hours delivered and extending the reach of available ions. The ISAC-III proposal is the centerpiece of the next TRIUMF five-year plan for the period 2010-2014. The proposal goes before the funding body late this year.

REFERENCES

[1] P. Schmor, et al, “Development and Future Plans at ISAC”, LINAC2004, Lubeck, Germany, Aug. 2004.

[2] S. Koscielniak, et al, “Accelerator Design for a 1/2 MW Electron Linac for RIB Production”, these proceedings.