ISAC Beam Delivery Strategy

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Outline

• Introduction
  • TRIUMF/ISAC/Accelerators
    • Strengths and weaknesses

• Beam delivery overview
  • New beam delivery group

• Moving Forward - Five year plan
  • ISAC Front end for three simultaneous beams
    • Mass-separators and switchyard
    • Low energy beam transport and switchyard
    • Second accelerator path
  • Schedule and Milestones
Canada's National Laboratory for Particle and Nuclear Physics

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**Cyclotron Capability**

Present stable performance limited to <300μA

Present requirements
- BL2A (70-100μA)
- BL2C (70-100μA)
- BL1A (100-140μA)
- Total (240-340μA)
ISAC-I and ISAC-II

- **SC-Linac**
- **S-bend**
- **RFQ**

### Areas
- **High Energy Area**
- **Low Energy Area**
- **Medium Energy Area**

**TRIUMF**

500MeV 50kW p+

**ISAC-I**

**ISAC-II**

Medium Energy Area

High Energy Area

Low Energy Area
ISAC Linear Accelerators

**ISAC 35MHz Split-ring RFQ**
- Accelerates ions with $3 \leq A/q \leq 30$
- From 2keV/u to 150keV/u
- Beam is stripped to raise charge state

**ISAC 106MHz Separated Function DTL**
- Accelerates ions with $2 \leq A/q \leq 6$
- Final energies fully variable from $0.15 \leq E \leq 1.8$ MeV/u

**Summary**
- ISAC-I Accelerators have been delivering high quality radioactive and stable beams to experimenters since 2001

**ISAC Linear Accelerators**
ISAC-II 106MHz Superconducting Linac

- Twenty bulk niobium quarter wave cavities housed in five cryomodules
- Boosts ion energy by 20MV to provide stable and RIB's above the Coulomb Barrier

Summary

- ISAC-II Accelerator commissioned in Spring 2006 with beam delivery of RIB's for three separate experiments in 2007
- A further 20MV will be added by the end of 2009

TRIUMF ISAC Experimental Areas

- Low Energy ≤60kV*q (δNMR, TITAN, 8PI, OSAKA)
- Medium energy 0.15-1.5MeV/u (DRAGON, TUDA (TACTIC))
- High energy 1.5-5MeV/u (TIGRESS, General Purpose (MAYA, Loveland))
• Now three experimental areas with eight target destinations (more to come) but only one RIB beam
  – Must make beam production and delivery as efficient as possible
    • New beam delivery group formed to improve efficiency and beam quality; new group has the expertise to utilize an expanded infrastructure

• Cyclotron is shutdown for maintenance ~4 months/year; beam development reduces experimental time further
  • Each experimental area gets an average of less than 4 weeks of radioactive beam time per year
  – Provide a second complimentary driver and increase the number of simultaneous beams
    • Five year plan – calls for increase in infrastructure to produce up to 3 simultaneous RIB beams
• Liaison between OPS and Experimenters
  – Gathers pertinent technical data from experimenter to facilitate delivery
  – Establishes a run plan prior to experiment
• Provides day to day beam physics input to OPS
  – Specific training, Targets/yield, low energy tuning, accelerator tuning, cyclotron tuning including proton beamlines, beam diagnostics, application programming
• Provides diagnostics for beam tuning and beam delivery
• Monitors yield, beam quality and transmission
• Tracks performance
Beam Delivery Chain

Experiments ISAC II

Medium Energy Experiments

High β SCRF

Med β SCRF

Low-Energy Experiments

ISIS

Medium Energy Experiments

BL2C

BL2A

Target/Source

Isotope Separator

DTL1

RFQ

CSB

TRIUMF Five Year Plan

Three Simultaneous Beams

• Concept
  • New low energy installation
  • Accelerator second path
  • Timeline and milestones
TRIUMF

Where are we?

- Charge State Booster on schedule to extend mass range to A=100 in 2008
- High beta SC-linac section on schedule for completion before end of 2009 to increase ISAC-II to final energy specification and to support an ISAC-II experimental program beyond the Coulomb barrier
- Actinide target test program should give meaningful results in 2008 to allow moving forward on actinide target development for FYP
- On site core expertise in room and SCRF linac technology will allow future developments on new accelerators including a low beta ISAC-II section and e-linac program
- Future Goal: To produce more science from ISAC
  - Produce up to three simultaneous radioactive beams by adding a second driver accelerator, new target area and expanded post-accelerator layout

TRIUMF and Future (2010-2017)

Proposal:
- BL4N is proposed to deliver 500MeV protons to two actinide target stations for beam production
- Take advantage of the shielded and unused proton hall to add a 50MeV electron driver to supply electrons to the new target area via a separate beamline;
- Develop new ISAC front end to permit three simultaneous RIB beams (two accelerated).
Cyclotron Upgrade

Need to increase cyclotron output to >400μA

Future requirements
• BL2A (70-100μA)
  • Shield for 200μA
• BL2C (70-100μA)
• BL1A (100-140μA)
• BL4N (70-100μA)
• Total (310-440μA)

ISAC-III: What is it?

• Two independent mass separators - one medium resolution and one high resolution - from two new target stations
• Flexible LEBT switchyard with new line to low energy area
• New accelerator path
  – CSB-II (presently ECR)
  – RFQ-II at A/q=9 accelerating to 150keV/u
  – DTL-II at A/q=9 accelerating to 700keV/u
  – SCA section adding 8MV at 4%c
Three Simultaneous Beams

- Concept
- New low energy installation
- Accelerator second path
- Timeline and milestones

ISAC-III: Low Energy Switchyard

- Green areas are proposed
- Dotted lines indicate vertical rise

Downstairs

Upstairs

Downstairs
**ISAC-III: Separator switchyard**

- Two target stations connected to flexible LEBT and mass separator switchyard
- One HRS (High Resolution Spectrometer) and one MRS (medium resolution spectrometer) can be selected from either target
  - HRS leg equipped with RF cooler for reducing beam emittance
  - Beam can be sent upstairs via LEVS (low energy vertical section) or HEVS (high energy vertical section)
- HEVS is equipped with CSB-II for raising charge state of accelerated beams

**ISAC-III: Low Energy Switchyard**

- Two target stations connected to flexible LEBT and mass separator switchyard
- A second line is added to the Low Energy Area to increase experimental output
  - LE-I – TITAN, beta-NMR, Osaka
  - LE-II – 8pi, GPS, EDM
- Existing target plus new target can be sent to the low energy area and the other to one of the accelerators
- A second off-line ion source added to allow beam delivery in one accelerator while tuning in the other
Three Simultaneous Beams

- Concept
- New low energy installation
- Accelerator second path
- Timeline and milestones

ISAC-III: Present MEBT Limit

- Strong for nuclear astrophysics (A ≤ 30)
  - No CSB and one stripping stage at 150 keVu
  - Accelerating efficiencies near 30% (dominated by stripping efficiency)
- Weak for nuclear physics in ISAC-II due to MEBT acceptance
  - Limited to A < 100 due to expected A/q from CSB
**ISAC**

**MEBT/DTL Limitation**

- MEBT Dipoles presently limited to A/q=6; can go to A/q=7 with new power supplies.
- DTL can go to A/q=7 with modified tuning scenario and E<Emax.
- CSB attainable charge states limits ISAC performance.
- CSB most probable charge state limited to A/q=100 for A/q≤6 or A/q=150 for A/q≤7.

**DTL Soft Limit at A/q≤6**

**Dipole PS Hard Limit A/q≤6**

**ISAC-III: 2nd Accelerator Path**

- CSB-I
  - E=2keV/u
  - 3≤A/q≤30

- ISAC RFQ-I
  - E=0.15MeV/u
  - 3≤A/q≤30

- ISAC DTLII (4.95MV)
  - E=0.70MeV/u
  - 2≤A/q≤9

- ISAC DTL (8.1MV)
  - E=1.5MeV/u
  - 2≤A/q≤6

- ISAC SCBC (40 MV)
  - E≥6MeV/u
  - 2≤A/q≤9

**Stage 1**
ISAC-III: 2nd Accelerator Path

- **Stage 2:**
  - Accelerating two simultaneous beams requires a new RFQ and MEBT switchyard
  - Accelerators sized to accelerate all CSB beams up to A/q=9
  - Acceleration efficiency set by CSB to ~5%

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**Graphs and Diagrams**

**Final Energy**

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**Efficiency**

Limit 2009

Limit 2010

Limit 2015

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**ISAC-III: 2nd Accelerator Path**

- **Stage 2**
- **CSB-II**
  - E=6keV/u
  - 2≤A/q≤9
- **ISAC RFQ-II (1.3MV)**
- **ISAC DTLII (4.95MV)**
- **CSB-I**
  - E=2keV/u
  - 3≤A/q≤30
- **ISAC RFQ-I (4.4MV)**
- **ISAC DTL (4.1MV)**
- **ISAC SCBC (40 MV)**
  - E≥6MeV/u
  - 2≤A/q≤9
- **ISAC SCA (8 MV)**
- **ISAC DTLI (8.1 MV)**
  - E=0.7MeV/u
  - 2≤A/q≤9

**Legend**

- CSB Only
- Step E=0.2
ISAC-III: 2nd Accelerator Path

TRIUMF Five Year Plan

Three Simultaneous Beams

- Concept
- New low energy installation
- Accelerator second path
- Timeline and milestones
**ISAC-III Timeline**

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**Future Expansion: (2009)**

- **Starting point**
  - 500MeV H-Cyclotron
  - BL2A
  - Medium Energy Experiments
  - Low-Energy Experiments
  - High Energy Experiments
  - DTL1
  - RFQ1
  - SCB1
  - SCC
Future Expansion: (2010)
Start excavation

- 500MeV H-Cyclotron
- Medium Energy Experiments
- High Energy Experiments
- Low-Energy Experiments
- RFQ1
- DTL1
- SCB
- SCC
- BL2A
- CSB1
- RFQ

Future Expansion: (2011)
Complete excavation; start e-linac, cyclotron

- 500MeV H-Cyclotron
- Medium Energy Experiments
- High Energy Experiments
- Low-Energy Experiments
- RFQ1
- DTL1
- SCB
- SCC
- BL2A
- CSB1
- RFQ
- e-linac
Future Expansion: (2012)
Complete BL4N, target, LEBT-I, Continue e-Linac, cyclotron

Future Expansion: (2013)
Complete e-Linac, e-line start ISAC-II Low beta

Milestone 1: 2nd simultaneous low energy beam
Future Expansion: (2014)
Complete ISAC-II Low beta, cyclotron; start target2

500MeV H-Cyclotron

BL4N

BL2A

Medium Energy Experiments

RFQ1

Low-Energy Experiments

S0

DTL1

SCC

SCB

CSB1

SCB

S0

RFQ1

CSB1

CSB2

Milestone 2: e-linac complete, neutron rich

Future Expansion: (2015)
Complete Target2, LEBT2 start RFQ-II, CSB2

500MeV H-Cyclotron

BL4N

BL2A

e-linac

Low-Energy Experiments

RFQ1

CSB1

CSB2

Milestone 3: SCA complete to extend mass
**Future Expansion: (2016)**

Complete RFQ-II, CSB2

- Medium Energy Experiments
  - DTL1
  - SCB
- High Energy Experiments
  - SCC

**Future Expansion: (2017)**

End Status

- Medium Energy Experiments
  - DTL1
  - SCB
- High Energy Experiments
  - SCC

- Low-Energy Experiments
  - RFQ1
  - RFQ2

**Milestone 4:** 3rd beam available; two LE and one HE beam

**Milestone 5:** RFQ2 complete, 2nd accelerated beam
ISAC-III    Milestones

• 2010 – status quo
  – One simultaneous beam, A<100, proton driver
• 2011 – extend mass range to A<150
  – Upgrade MEBT
• 2013 – new beam
  – Two simultaneous beams (one accelerated, A<150), proton driver
• 2014 – electron machine – neutron rich
  – Two simultaneous beams (one accelerated, A<150), proton/electron driver
• 2015- low beta ISAC-II – extend mass range
  – Two simultaneous beams (one accelerated, A<240), proton/electron driver
• 2016 – add second target
  – Three simultaneous beams (one accelerated, A<240), proton/electron driver
• 2017 – add new accelerator front end
  – Three simultaneous beams (two accelerated, A<240), proton/electron driver

ISAC-III    Beam Delivery Strategy

• Staged expansion of beam delivery complex – will require more personnel to operate
  – Combine Cyclotron and ISAC control rooms to improve efficiency and communication
  – Add three more beam physicists to Beam Delivery Group to expand Experts on call
  – Require two more operators to get to five per shift
  – Require expanded maintenance crew; coordinators and technical groups; hire early to help build the complex – being evaluated
• New hires for beam delivery will help build infrastructure
**Future**

- **Our Goal: To produce more science from ISAC**
  - Produce up to three simultaneous radioactive beams
    - Add an e-driver to augment the cyclotron driver
    - Add a second proton beam line - BL4N
    - Add a new actinide target hall
  - Add electron accelerator technology to build the e-driver in house
    - SCRF technology at 1.3GHz
    - Cryomodule design and assembly
  - Add a new accelerator front end in ISAC to provide a second path for RIBS to the post-accelerator
- **The goal builds on core competencies**
  - We have built (very successfully) superconducting rf technology for in house heavy ion accelerators
    - The existing medium beta section is composed of cavity technology imported from Italy with ancillaries and cryomodules developed in house.
    - We are now modelling and fabricating cavities with a local supplier giving us the full capability to support heavy ion linac development and installation

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**Summary**

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**Thanks**

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