TRIUMF

CANADA'S NATIONAL LABORATORY FOR PARTICLE AND NUCLEAR PHYSICS

Owned and operated as a joint venture by a consortium of Canadian universities via a contribution through the National Research Council Canada

ISAC Beam Delivery Strategy

R. Laxdal, TRIUMF

Special EEC Meeting

March 25, 2008

LABORATOIRE NATIONAL CANADIEN POUR LA RECHERCHE EN PHYSIQUE NUCLÉAIRE ET EN PHYSIQUE DES PARTICULES

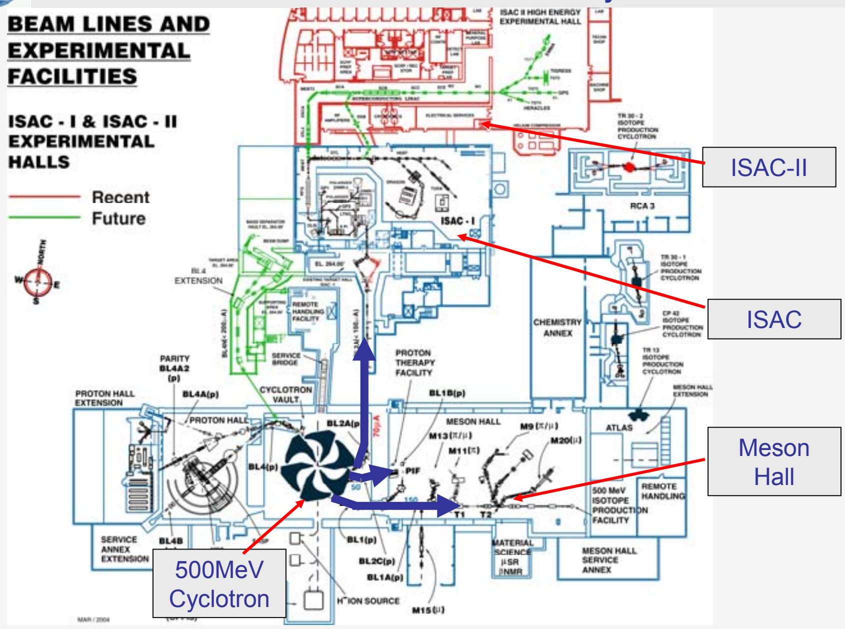
Propriété d'un consortium d'universités canadiennes, géré en co-entreprise à partir d'une contribution administrée par le Conseil national de recherches Canada

TRIUMF

Outline

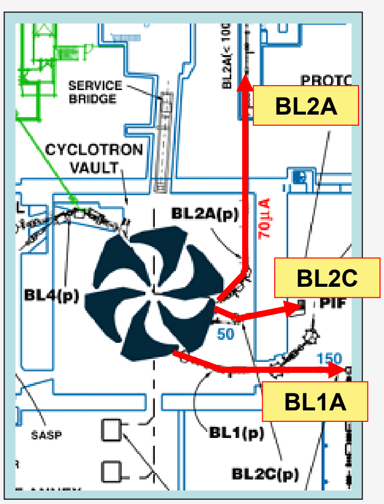
- Introduction
  - TRIUMF/ISAC/Accelerators
    - Strengths and weaknesses
- Beam delivery overview
  - New beam delivery group
- Moving Forward - Five year plan
  - ISAC Front end for three simultaneous beams
    - Mass-separators and switchyard
    - Low energy beam transport and switchyard
    - Second accelerator path
  - Schedule and Milestones

TRIUMF — Canada's National Laboratory for Particle and Nuclear Physics



TRIUMF — Cyclotron Capability

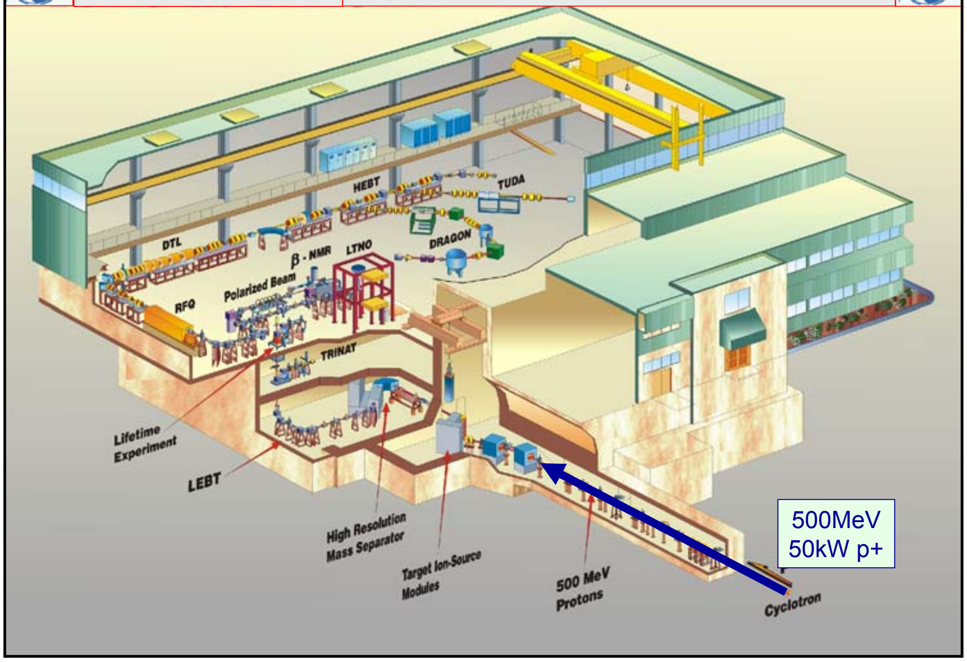
Present stable performance limited to <300μA



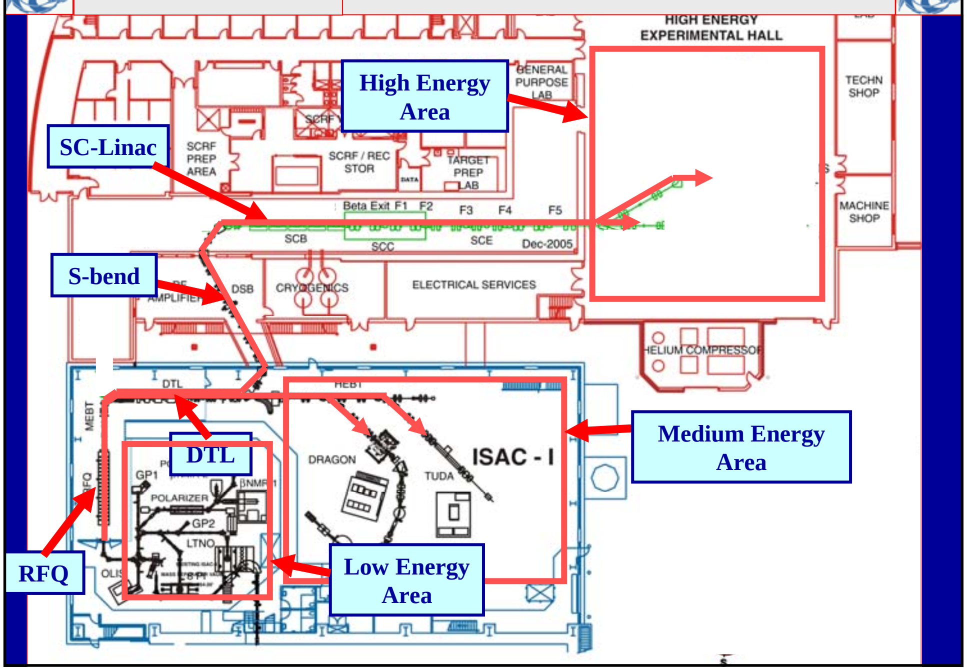
Present requirements

- BL2A (70-100μA)
- BL2C (70-100μA)
- BL1A (100-140μA)
- **Total (240-340μA)**

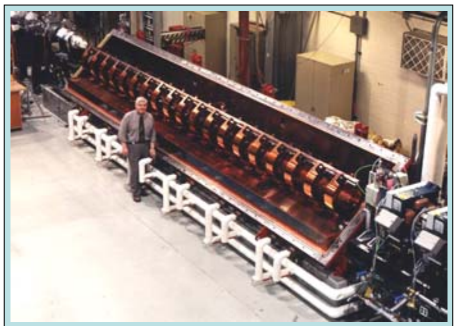
TRIUMF — ISAC-I

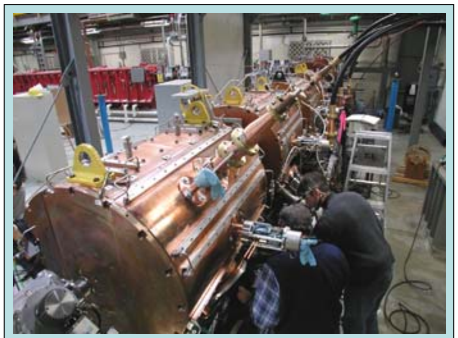


TRIUMF — ISAC-I and ISAC-II



ISAC Linear Accelerators





ISAC 35MHz Split-ring RFQ

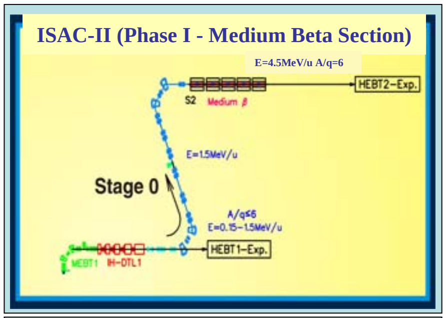
- accelerates ions with $3 \le A/q \le 30$ from 2keV/u to 150keV/u
- Beam is stripped to raise charge state

ISAC 106MHz Separated Function DTL

- accelerates ions with $2 \le A/q \le 6$ to final energies fully variable from $0.15<E<1.8$MeV/u

Summary

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



ISAC-II 106MHz Superconducting Linac

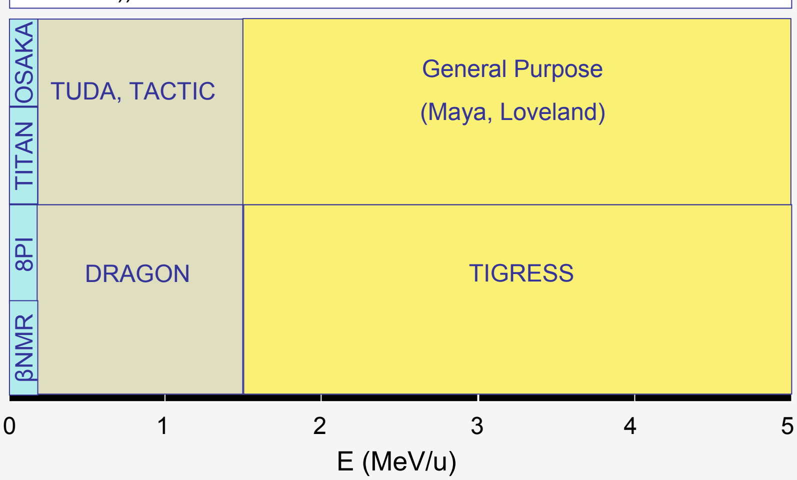
- ❑Twenty bulk niobium quarter wave cavities housed in five cryomodules
- ❑Boosts ion energy by 20MV to provide stable and RIB's above the Coulomb Barrier

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 (βNMR, TITAN, 8PI, OSAKA)
- •Medium energy 0.15-1.5MeV/u (DRAGON, TUDA (TACTIC))
- •High energy 1.5-5MeV/u (TIGRESS, General Purpose (MAYA, Loveland))



TRIUMF Increasing Output

- 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

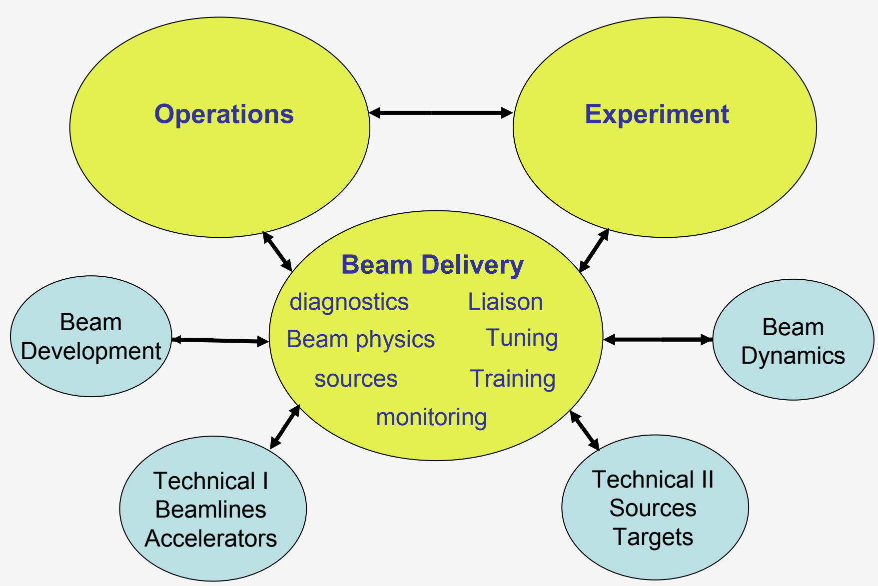
- Cyclotron is shutdown for maintenance ~4 months/year; beam development reduces experimental time further
    - Each experimental area gets an average of less than 4 weeks of radioactive beam time per year
  - Provide a second complimentary driver and increase the number of simultaneous beams
    - Five year plan – calls for increase in infrastructure to produce up to 3 simultaneous RIB beams

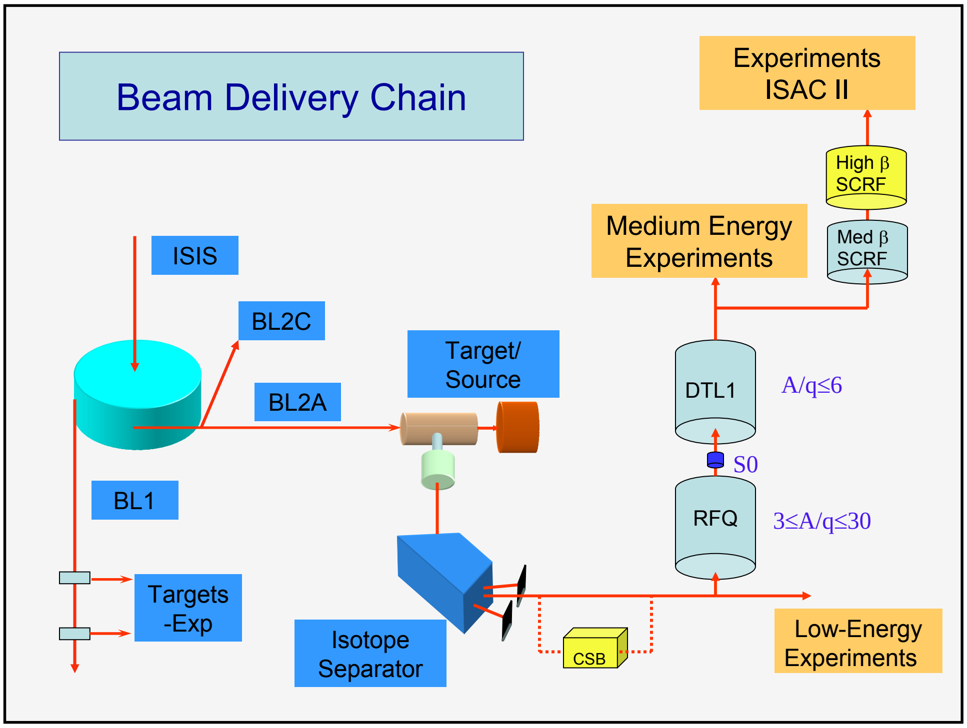
Beam Delivery Overview

TRIUMF Beam Delivery Group

- 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

TRIUMF Beam Delivery





TRIUMF Five Year Plan

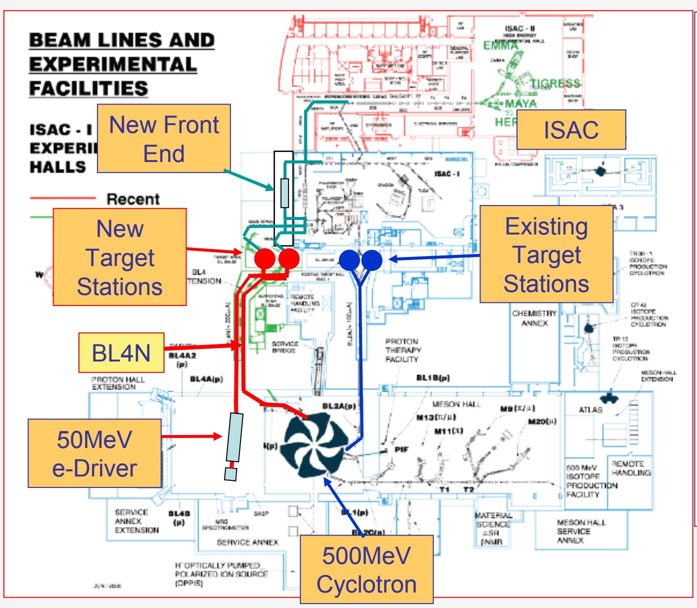
Three Simultaneous Beams

- 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)

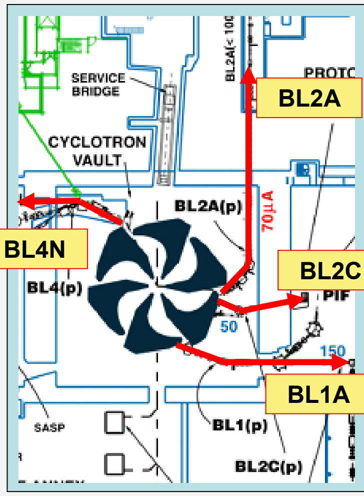


Proposal:

- **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).**

TRIUMF Cyclotron Upgrade

Need to increase cyclotron output to >400μA

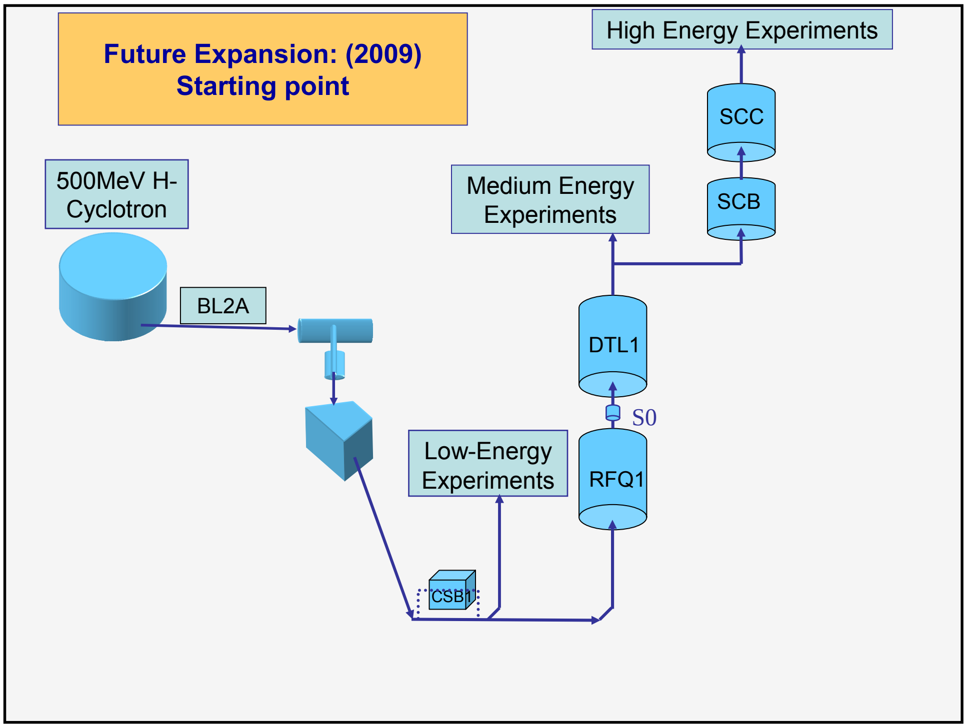


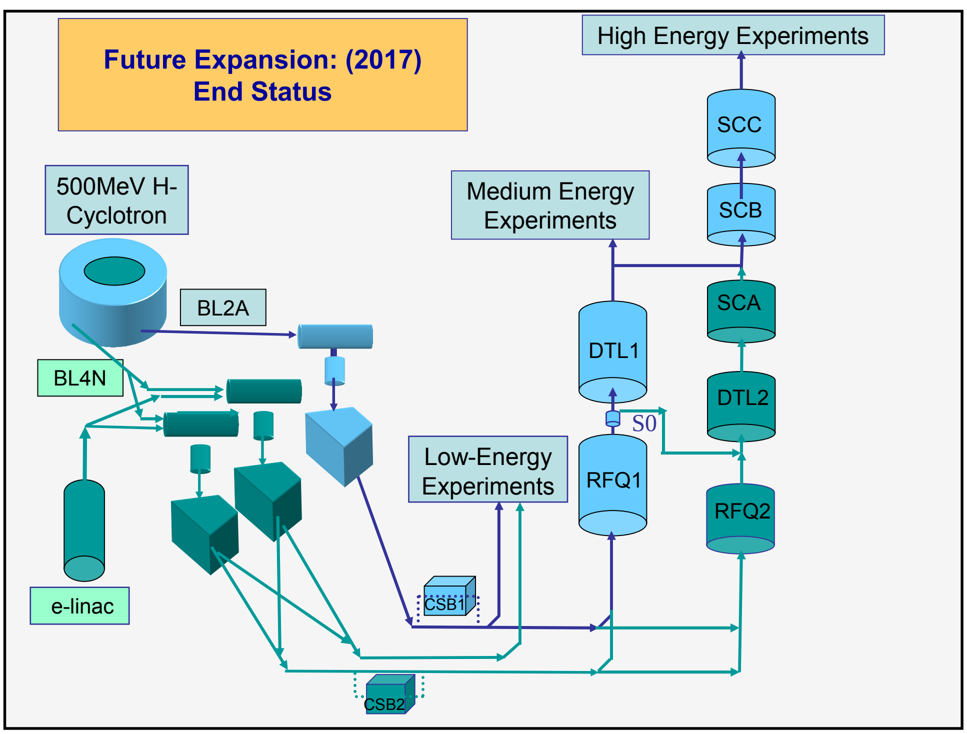
Future requirements

- 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


Future Expansion: (2009)
Starting point
High Energy Experiments
SCC
SCB
500MeV H-
Cyclotron
Medium Energy
Experiments
BL2A
DTL1
S0
Low-Energy
Experiments
RFQ1
CSB1


Future Expansion: (2017)
End Status
High Energy Experiments
SCC
500MeV H-
Cyclotron
Medium Energy
Experiments
SCB
SCA
BL2A
DTL1
DTL2
BL4N
S0
Low-Energy
Experiments
RFQ1
RFQ2
CSB1
e-linac
CSB2

TRIUMF Five Year Plan

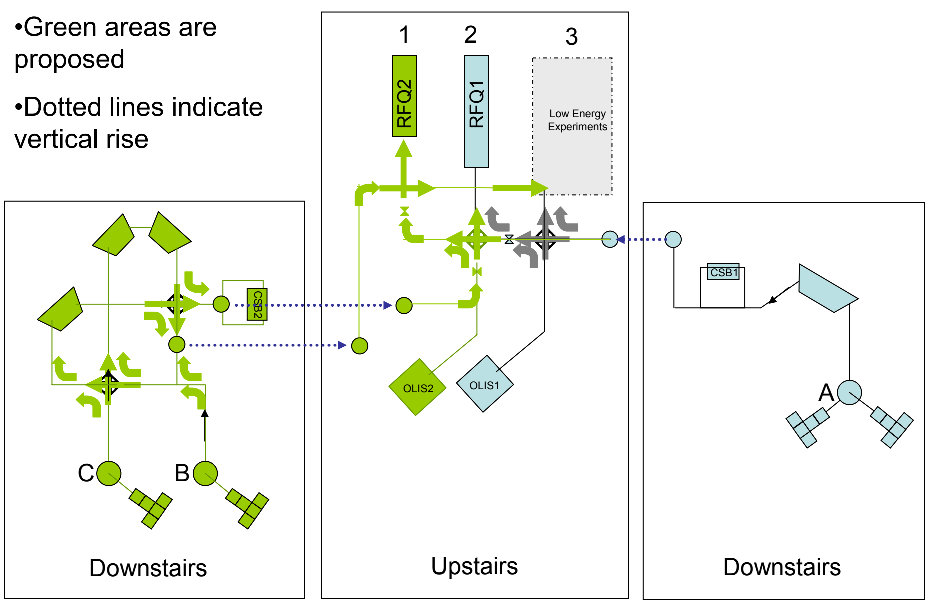
Three Simultaneous Beams

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

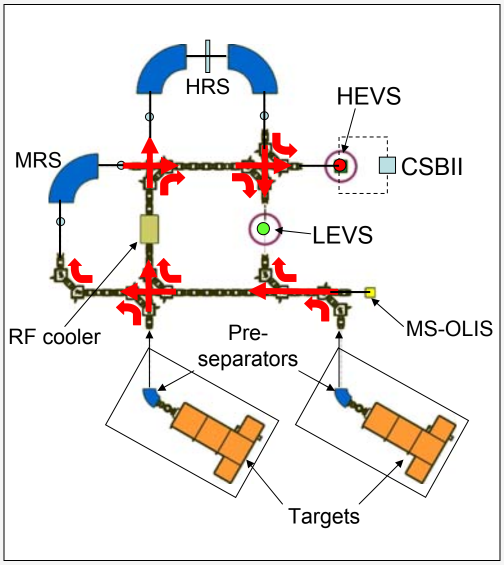
ISAC-III: Low Energy Switchyard

•Green areas are proposed

•Dotted lines indicate vertical rise

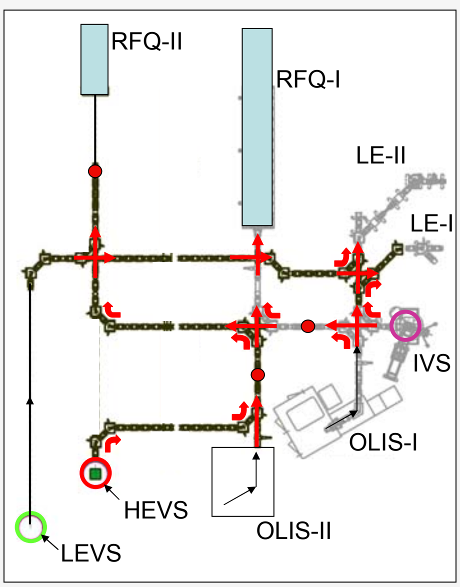


ISAC-III Separator switchyard



- 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
    - LEI– TITAN, beta-NMR, Osaka
    - LEII – 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

TRIUMF Five Year Plan

Three Simultaneous Beams

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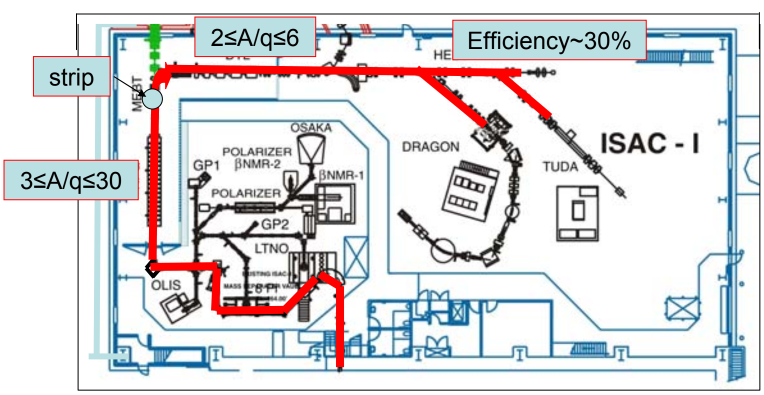
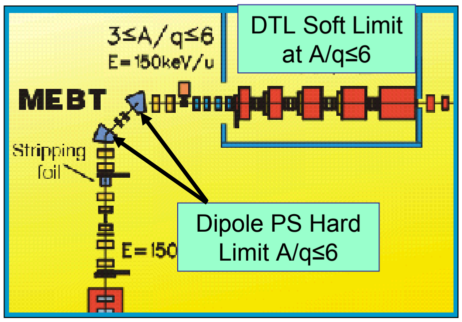
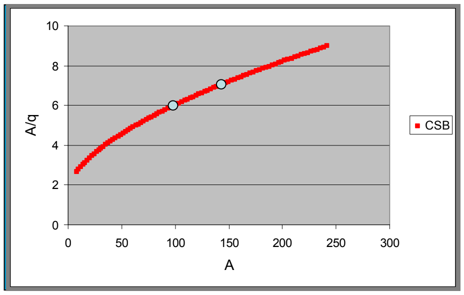
ISAC-III: Present MEBT Limit

- 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

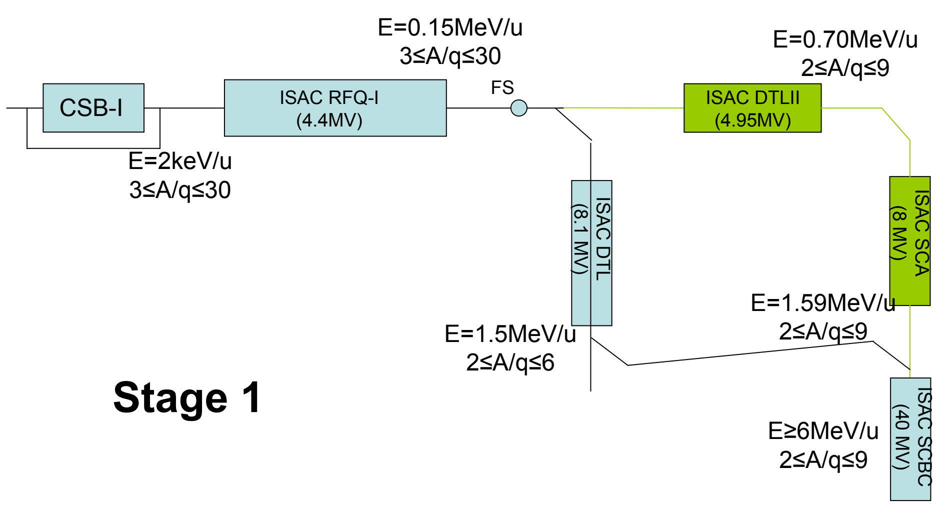




- •MEBT Dipoles presently limited to A/q=6; can go to A/q=7 with new power supplies
- •DTL can go to A/q=7 with modified tuning scenario and E<Emax
- •CSB attainable charge states limits ISAC performance
- •CSB most probable charge state limited to A/q=100 for A/q≤6 or A/q=150 for A/q≤7

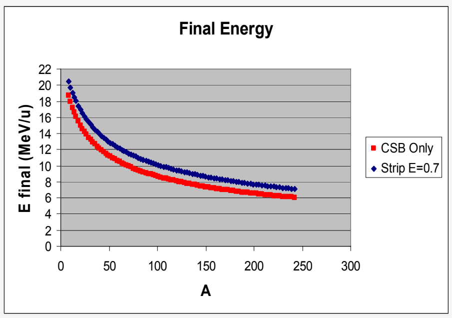
- •Must add new ISAC-II low beta injector to extend mass range to A=240 (Stage 1)
- •Includes room temperature DTL (5MV) and Superconducting linac section SCA (8MV)

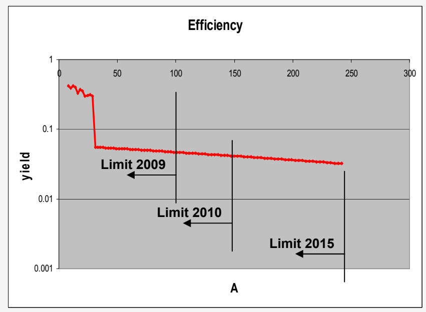
ISAC-III: 2nd Accelerator Path



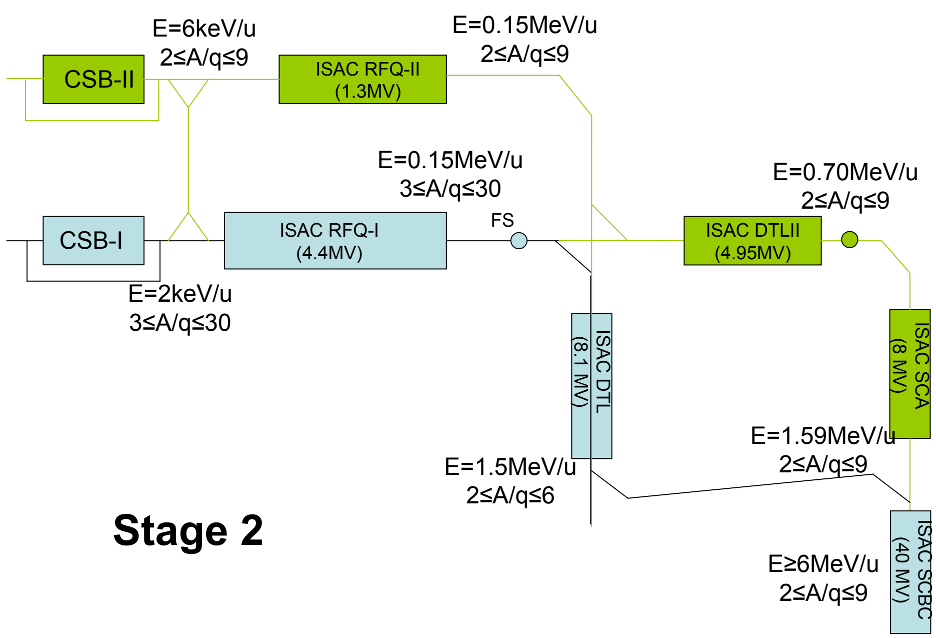
ISAC-III: 2nd Accelerator Path

- 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%



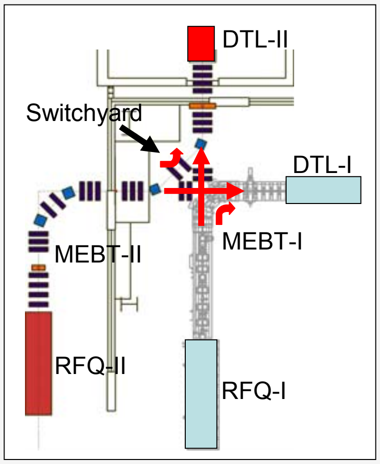


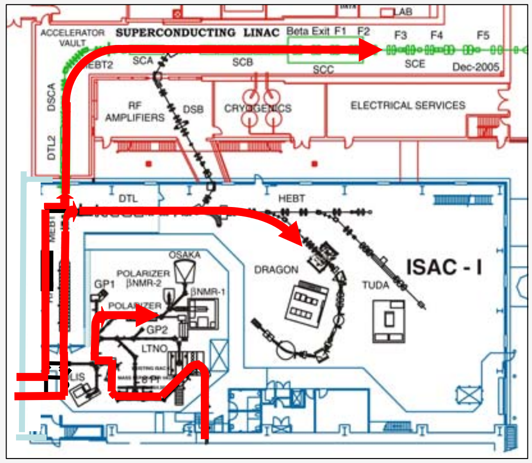
ISAC-III: 2nd Accelerator Path



Stage 2

ISAC-III: 2nd Accelerator Path





TRIUMF Five Year Plan

Three Simultaneous Beams

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- New low energy installation
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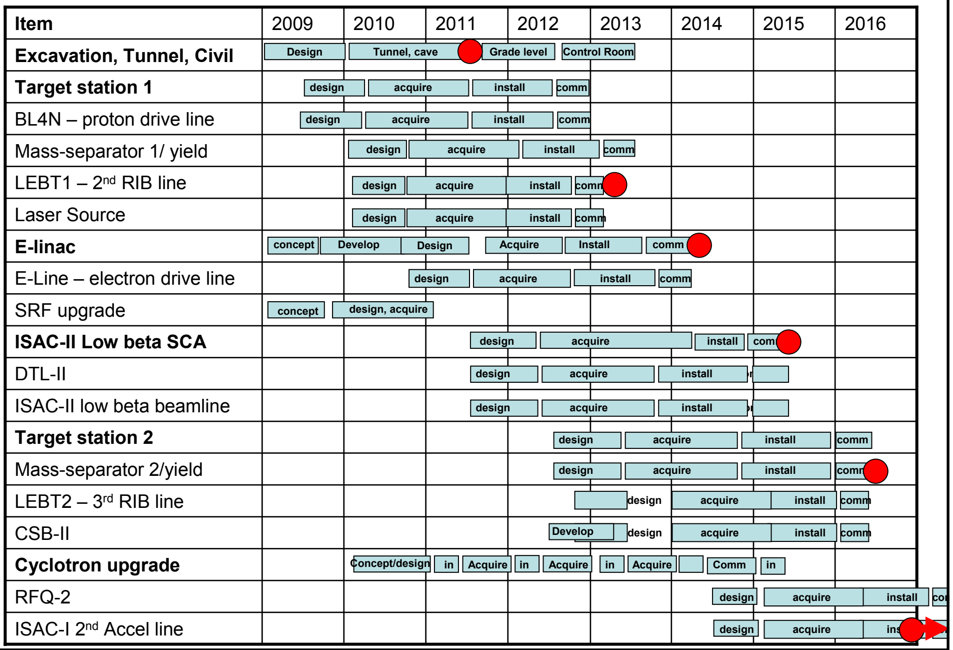
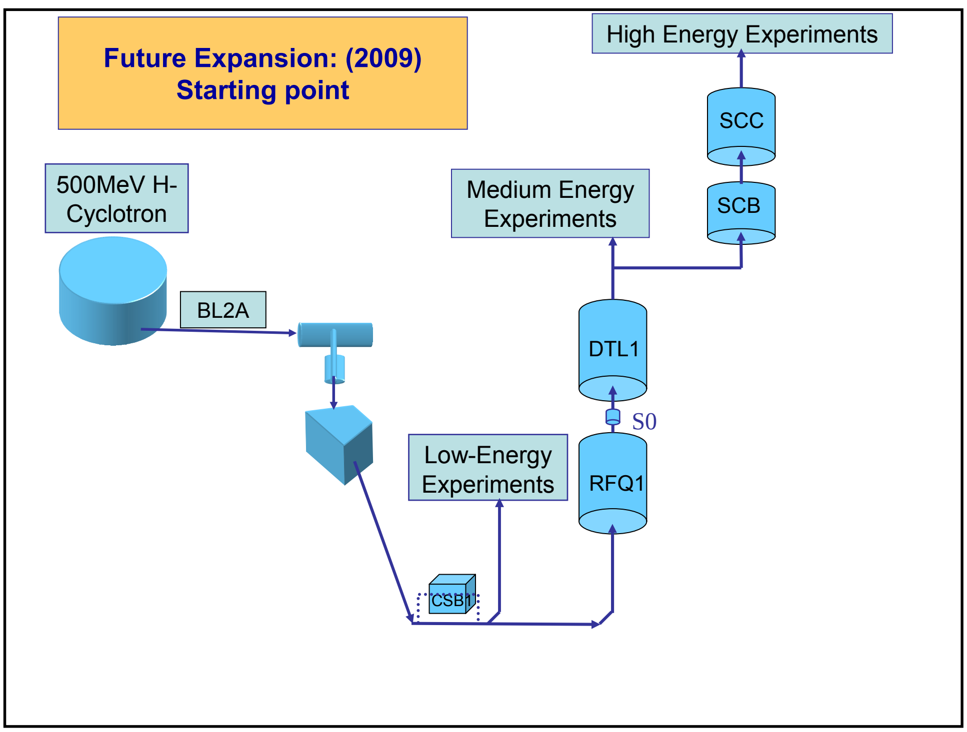
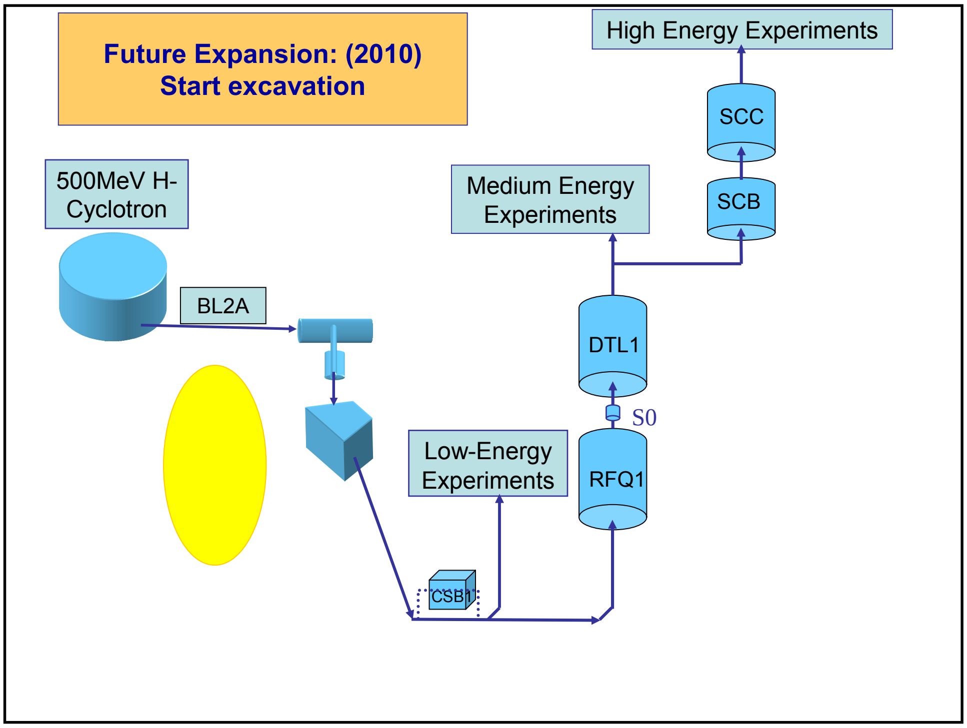
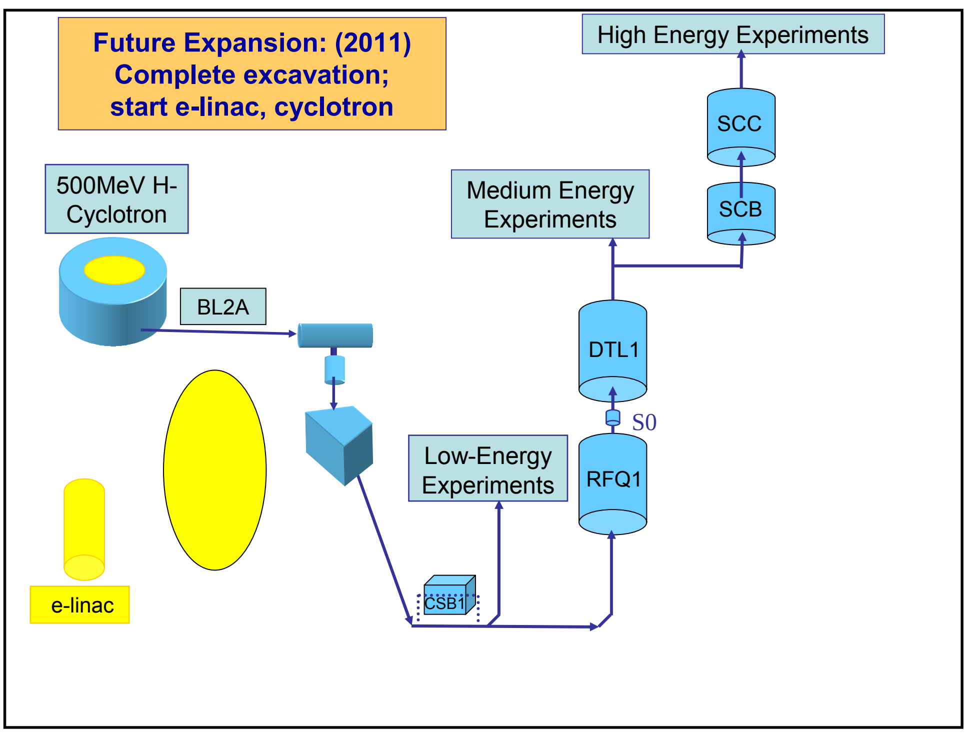
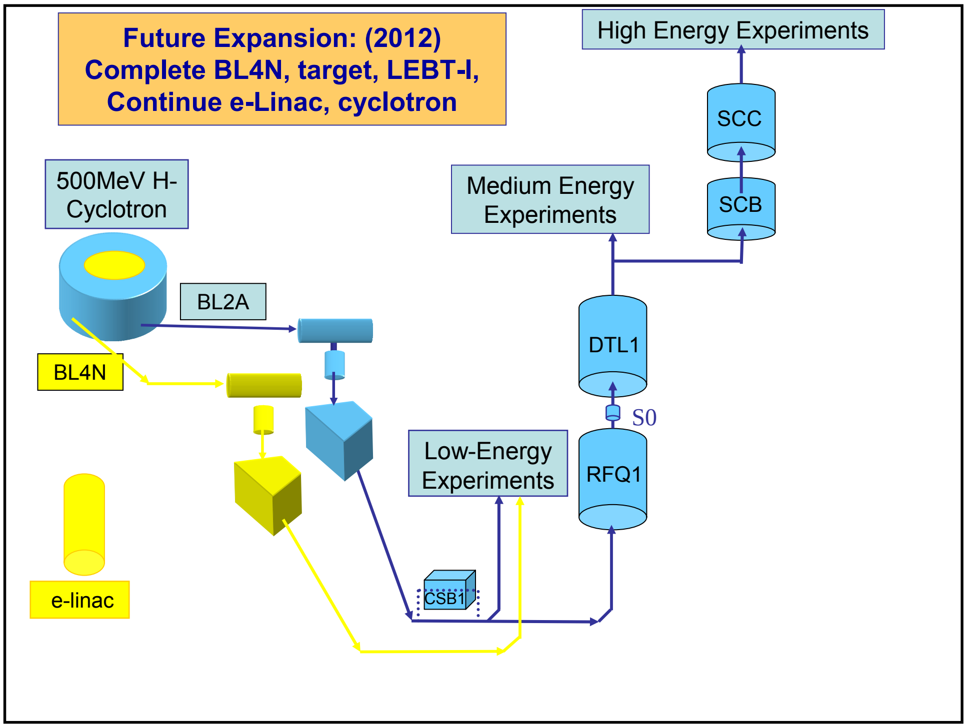
ISAC-III TImeline

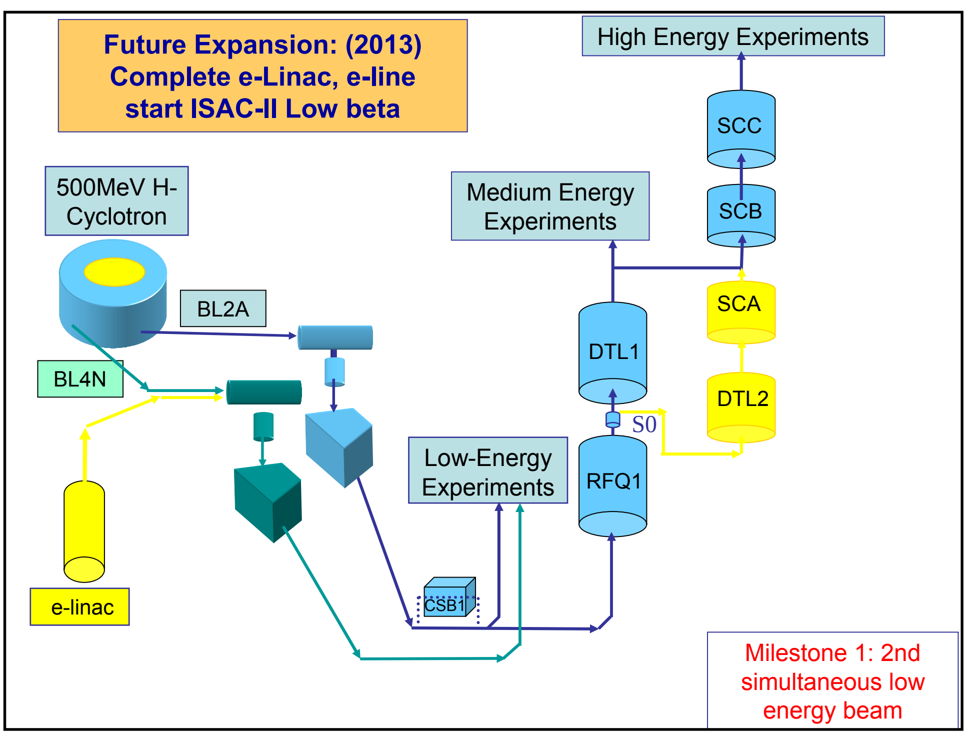


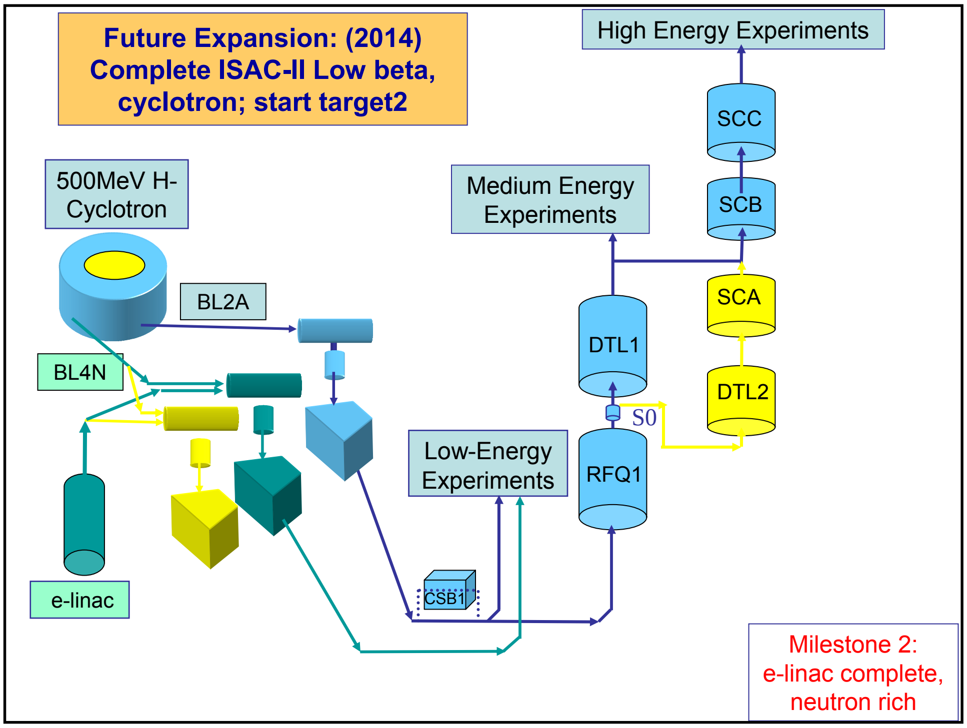


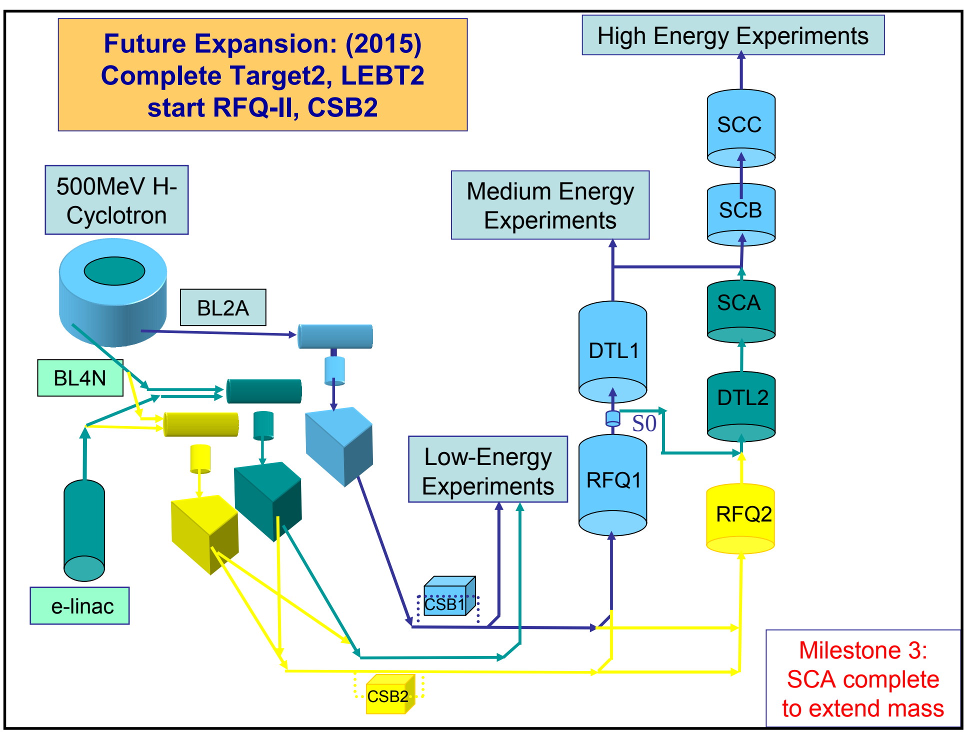

Future Expansion: (2010)
Start excavation
High Energy Experiments
SCC
SCB
Medium Energy Experiments
500MeV H- Cyclotron
BL2A
DTL1
S0
RFQ1
Low-Energy Experiments
CSB1

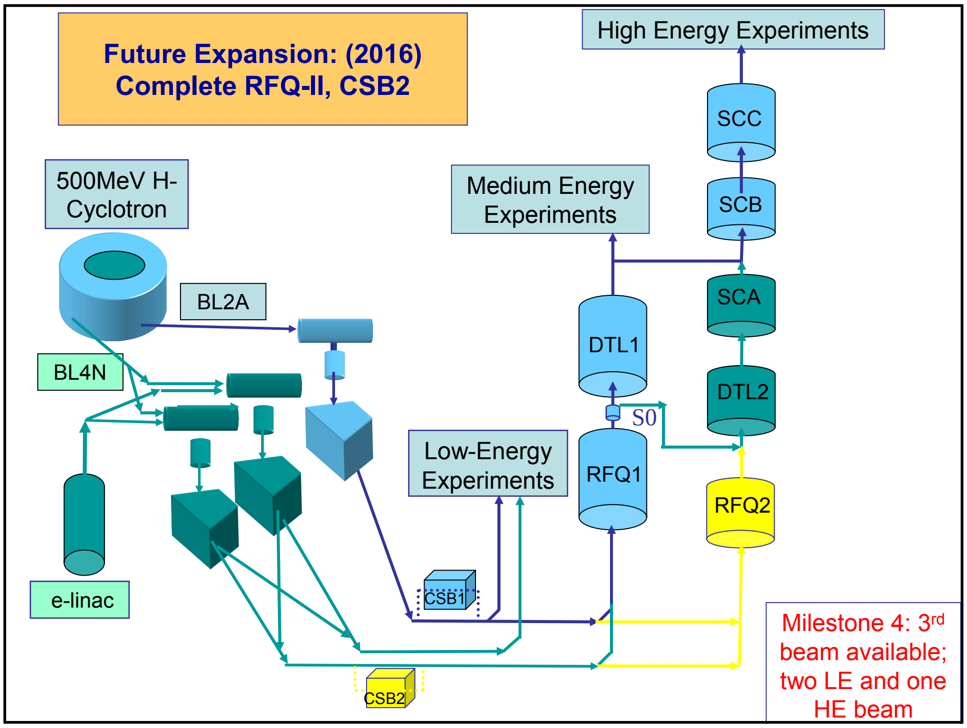

Future Expansion: (2011)
Complete excavation;
start e-linac, cyclotron
High Energy Experiments
SCC
SCB
Medium Energy Experiments
500MeV H- Cyclotron
BL2A
DTL1
S0
RFQ1
Low-Energy Experiments
CSB1
e-linac

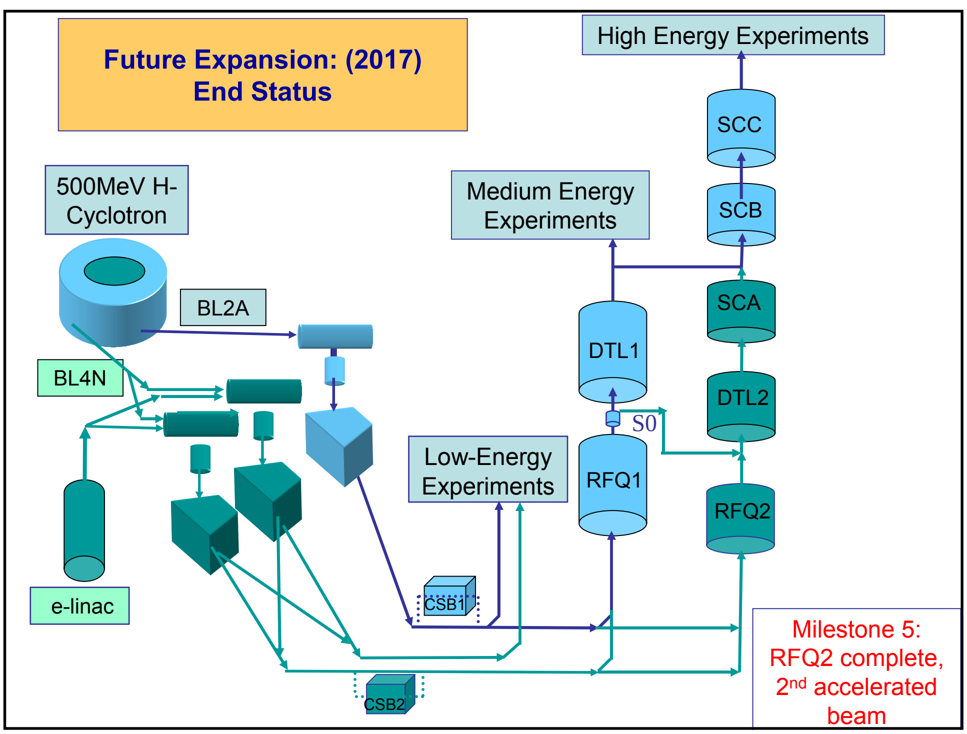

Future Expansion: (2012)
Complete BL4N, target, LEBT-I,
Continue e-Linac, cyclotron
High Energy Experiments
SCC
SCB
Medium Energy
Experiments
500MeV H-
Cyclotron
BL2A
BL4N
DTL1
S0
Low-Energy
Experiments
RFQ1
e-linac
CSB1


Future Expansion: (2013)
Complete e-Linac, e-line
start ISAC-II Low beta
High Energy Experiments
SCC
SCB
Medium Energy
Experiments
SCA
500MeV H-
Cyclotron
BL2A
BL4N
DTL1
DTL2
S0
Low-Energy
Experiments
RFQ1
e-linac
CSB1
Milestone 1: 2nd
simultaneous low
energy beam


Future Expansion: (2014)
Complete ISAC-II Low beta, cyclotron; start target2
High Energy Experiments
SCC
SCB
SCA
DTL2
500MeV H- Cyclotron
Medium Energy Experiments
BL2A
DTL1
BL4N
S0
RFQ1
Low-Energy Experiments
e-linac
CSB1
Milestone 2:
e-linac complete,
neutron rich


Future Expansion: (2015)
Complete Target2, LEBT2
start RFQ-II, CSB2
High Energy Experiments
SCC
SCB
SCA
DTL2
500MeV H- Cyclotron
Medium Energy Experiments
BL2A
DTL1
BL4N
S0
RFQ1
Low-Energy Experiments
RFQ2
e-linac
CSB1
CSB2
Milestone 3:
SCA complete
to extend mass


Future Expansion: (2016)
Complete RFQ-II, CSB2
High Energy Experiments
SCC
SCB
Medium Energy Experiments
500MeV H- Cyclotron
BL2A
BL4N
SCA
DTL1
DTL2
S0
Low-Energy Experiments
RFQ1
RFQ2
e-linac
CSB1
CSB2
Milestone 4: 3rd beam available; two LE and one HE beam


Future Expansion: (2017)
End Status
High Energy Experiments
SCC
SCB
Medium Energy Experiments
500MeV H- Cyclotron
BL2A
BL4N
SCA
DTL1
DTL2
S0
Low-Energy Experiments
RFQ1
RFQ2
e-linac
CSB1
CSB2
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 Summary

- 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

Thanks

TRIUMF

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