Developments & Future Plans at ISAC/TRIUMF

P. W. Schmor
ISAC/TRIUMF

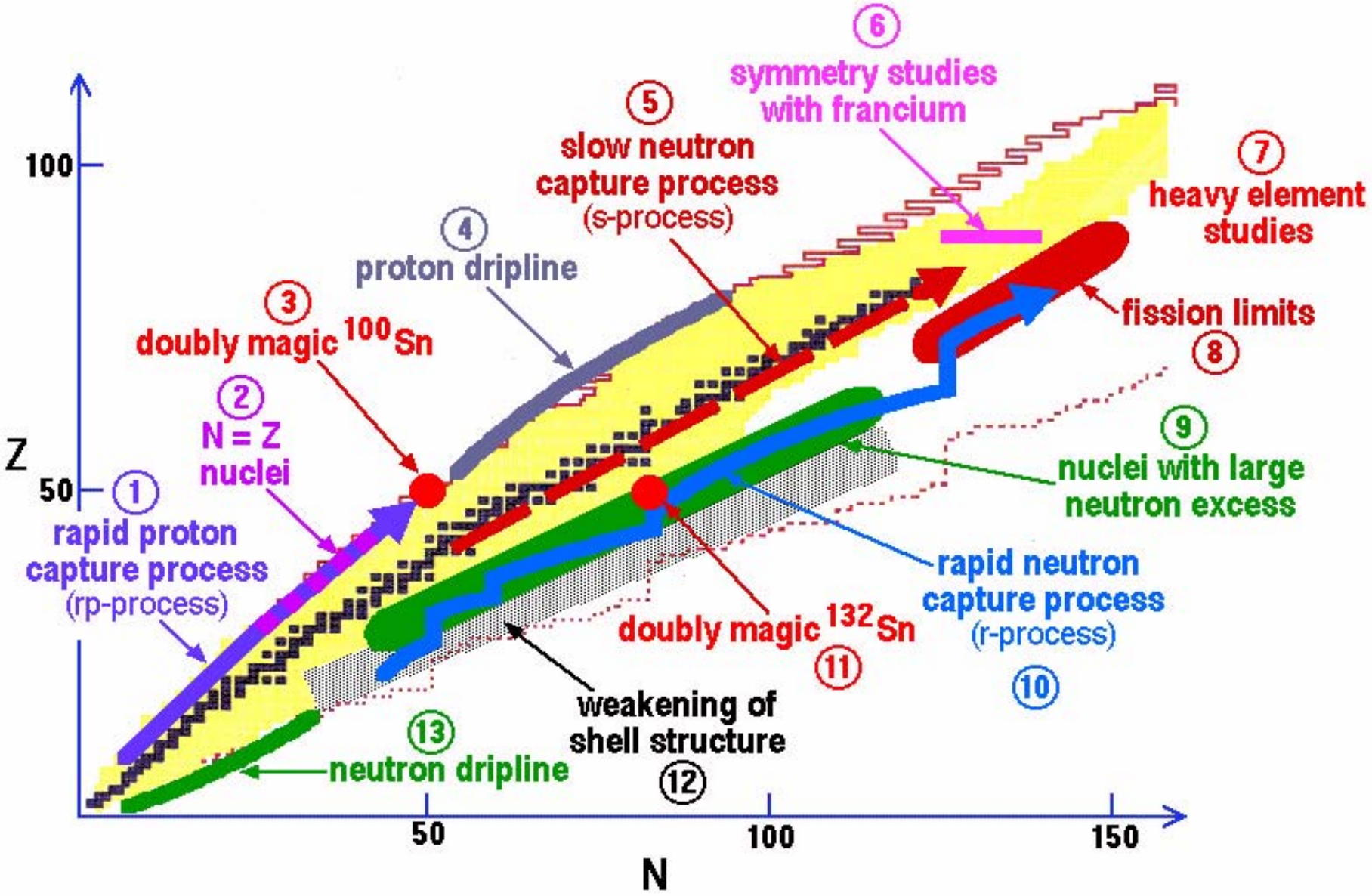
LINAC 2004

Tuesday, August 17, 2004

ISAC – an RIB ISOL FACILITY for Nuclear Astrophysics

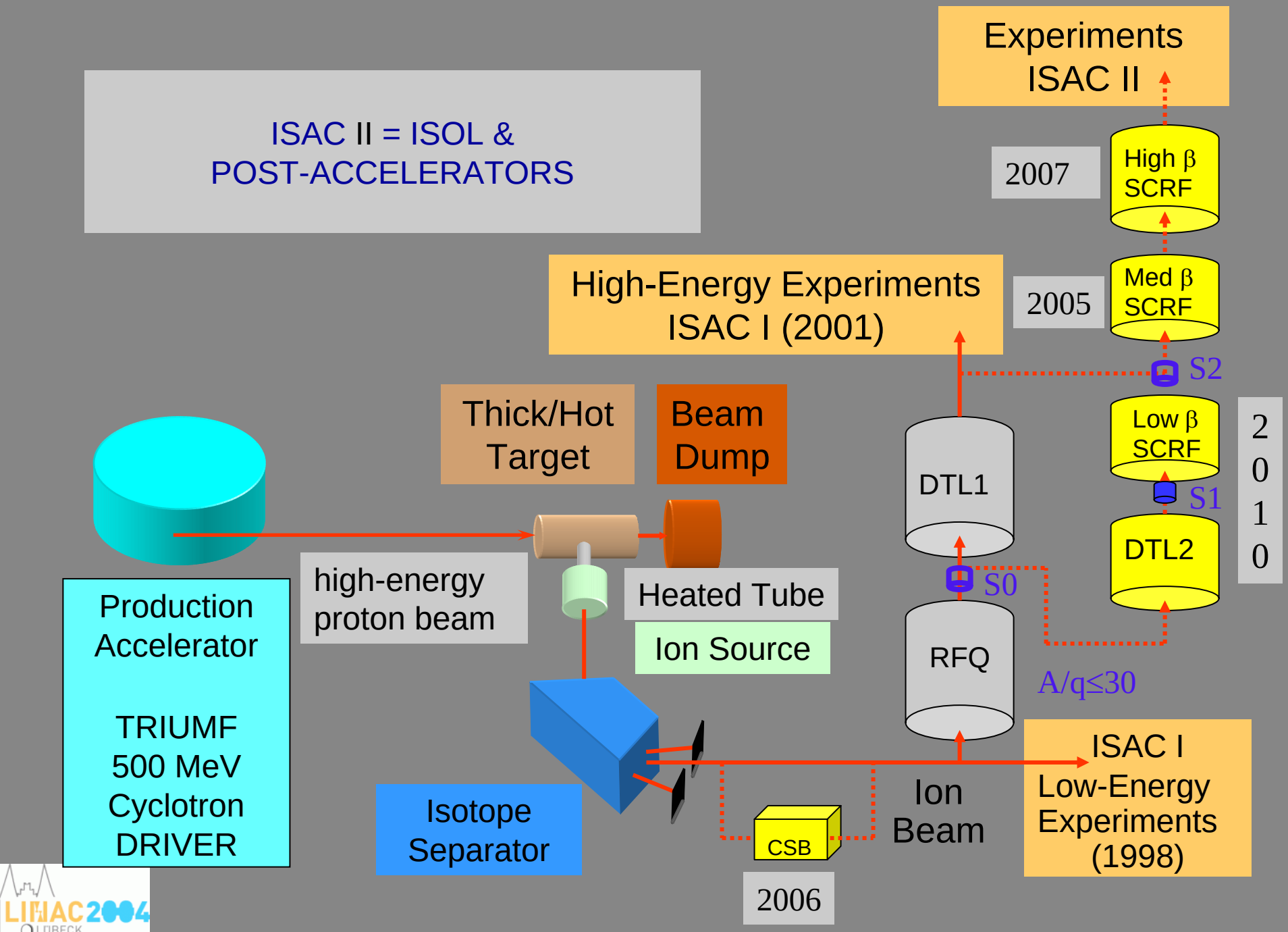
- Driver
  - 500 MeV H- Cyclotron
- Target
  - Thick Target of a refractory element at an elevated temperature (2000C) which undergoes Nuclear Reactions [Spallation, Fragmentation, Fission] when Bombarded by the 500 MeV Protons
- Ion Source
  - Ionizes Target Volatiles
    - (High Radiation Environment with Impure Gas Input)
- Isotope Selector
  - Separates a Desired Isotope from Many in the Ionized Beam
- Accelerator
  - Provide Variable Energy Beams of a Selected Isotope (from Various Masses) to Experimental Stations
  - Experiments use Reverse Kinematics for Nuclear Astrophysics
    - Isotope is Projectile on H or He Target
    - Energy is Appropriate for Stellar Temperatures

SCIENCE OF RARE ISOTOPES



ISAC I & II

- **ISAC** (ISOL + ACCELERATORS)
  - **ISAC-I**
    - Funded in 1995
    - Low Energy
      - **$E \leq 60$ keV & $A_{max} \approx 240$**
        - First RIB Experiment in November 1998
    - High Energy (Accelerated)
      - **Variable Energy from 0.15 to 1.5 MeV/u for $q/A \geq 1/30$**
        - First Beam in December 2000
  - **ISAC II**
    - Funded in April 2000
    - Civil Funded April 2001
      - **Variable Energy from 1.5 to 6.5 MeV/u for $A \leq 150$**
        - First Beam Scheduled for Late 2005 (4.3 MeV/u)
  - **Completion & Upgrade Proposed for 2005-2010**

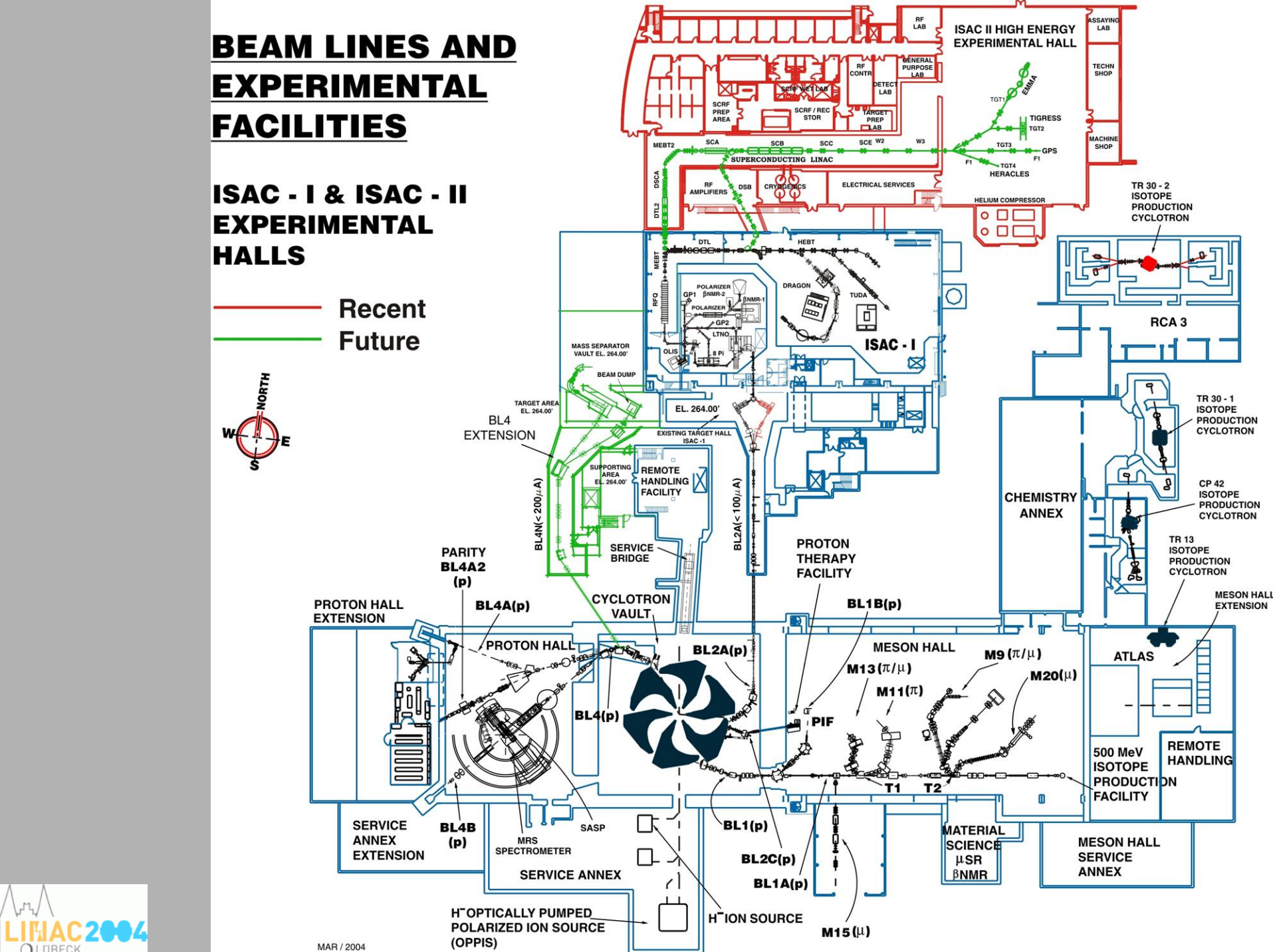

ISAC II = ISOL &
POST-ACCELERATORS
Experiments
ISAC II
2007
High β
SCRF
Med β
SCRF
2005
High-Energy Experiments
ISAC I (2001)
S2
Low β
SCRF
S1
DTL1
DTL2
2010
Thick/Hot
Target
Beam
Dump
Production
Accelerator
TRIUMF
500 MeV
Cyclotron
DRIVER
high-energy
proton beam
Heated Tube
Ion Source
S0
RFQ
A/q≤30
ISAC I
Low-Energy
Experiments
(1998)
Isotope
Separator
CSB
Ion
Beam
2006

BEAM LINES AND EXPERIMENTAL FACILITIES

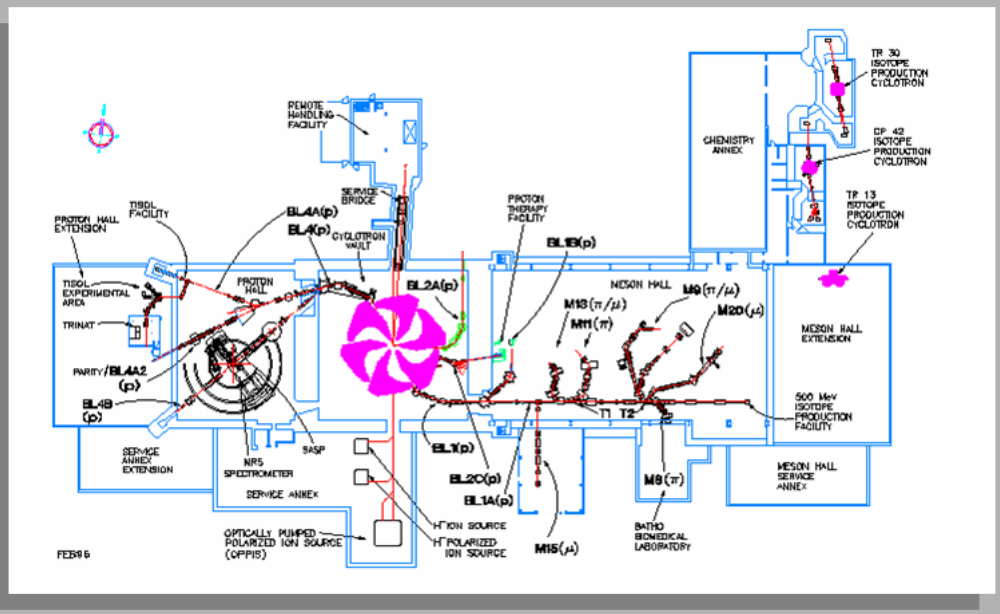
ISAC - I & ISAC - II EXPERIMENTAL HALLS

Recent

Future



MAR / 2004



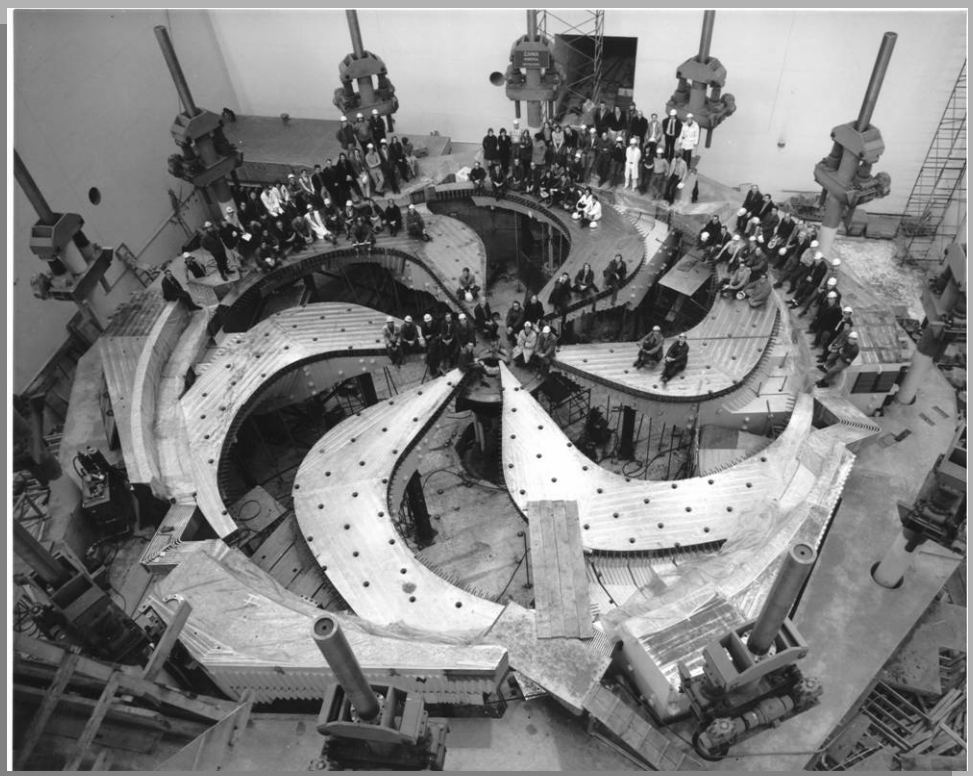
TRIUMF Driver

500 MeV H- Cyclotron

Provides Simultaneous, Independent, Variable Energy, Protons to Multiple Locations

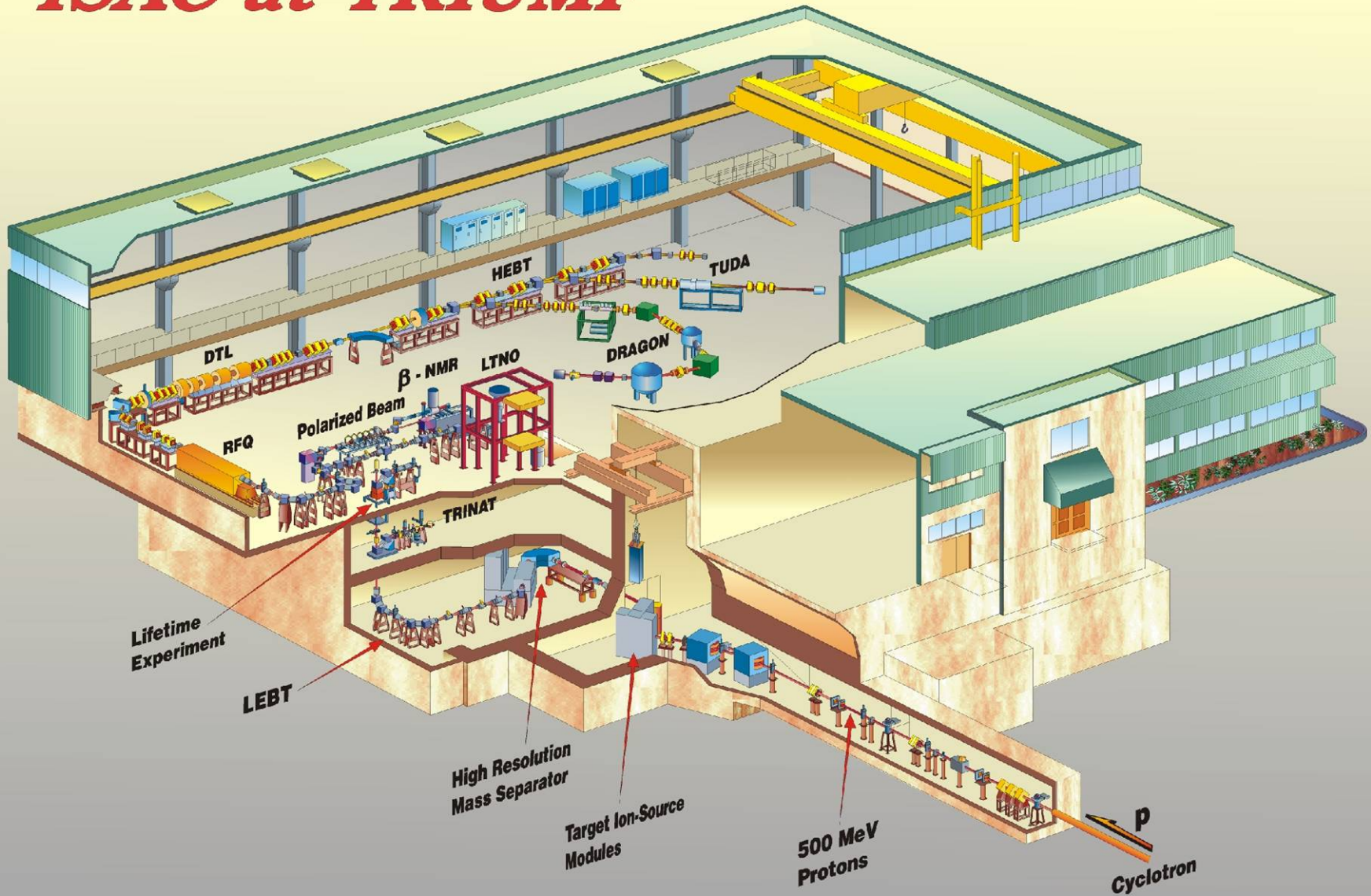
Routinely Accelerates 275 μA

Capable of 400 μA



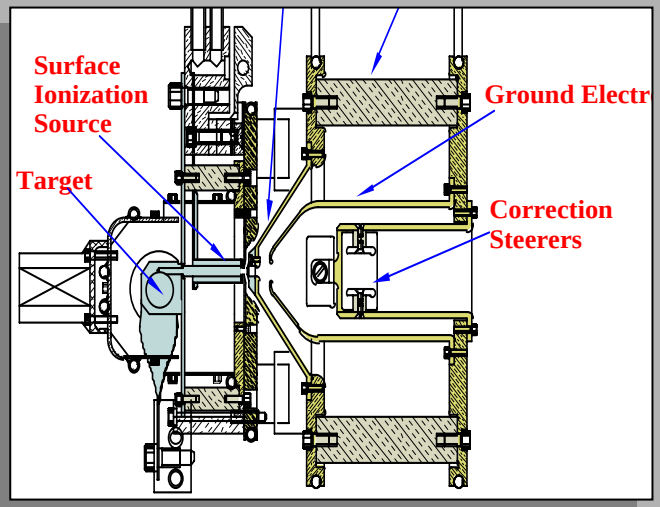
ISAC I

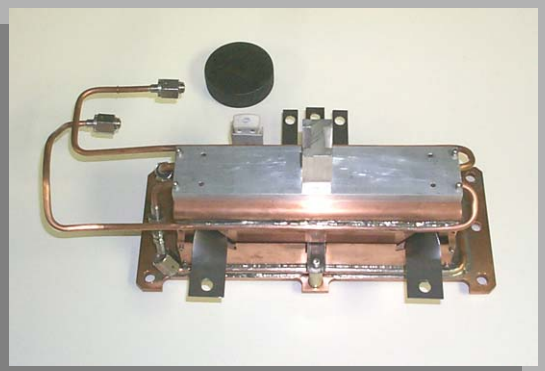
ISAC at TRIUMF



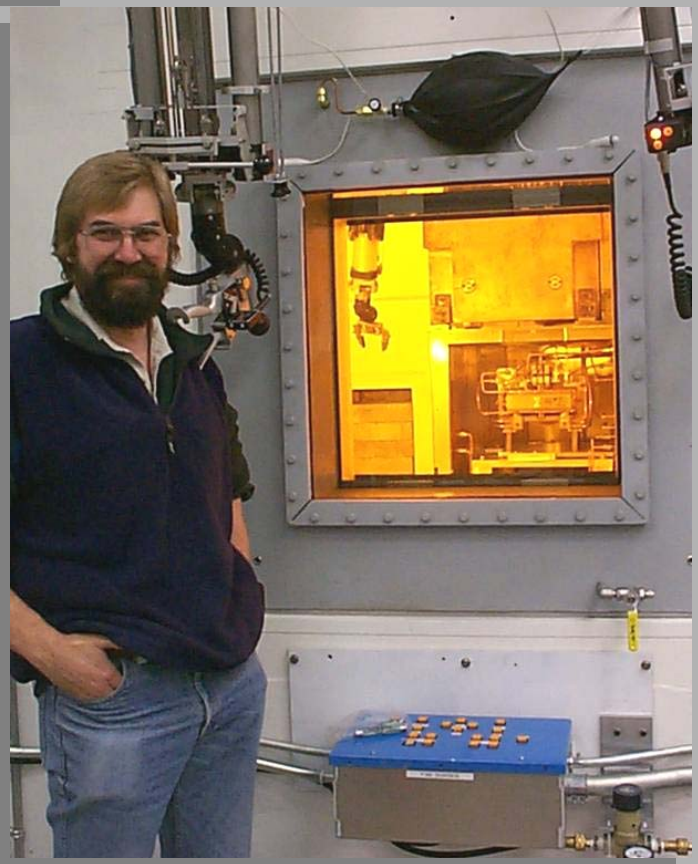
REMOTE HANDLING for ISAC TARGETS, ION SOURCES & MODULE COMPONENTS

HOT CELL AND REMOTE CRANE FOR MODULE & TARGET SERVICING





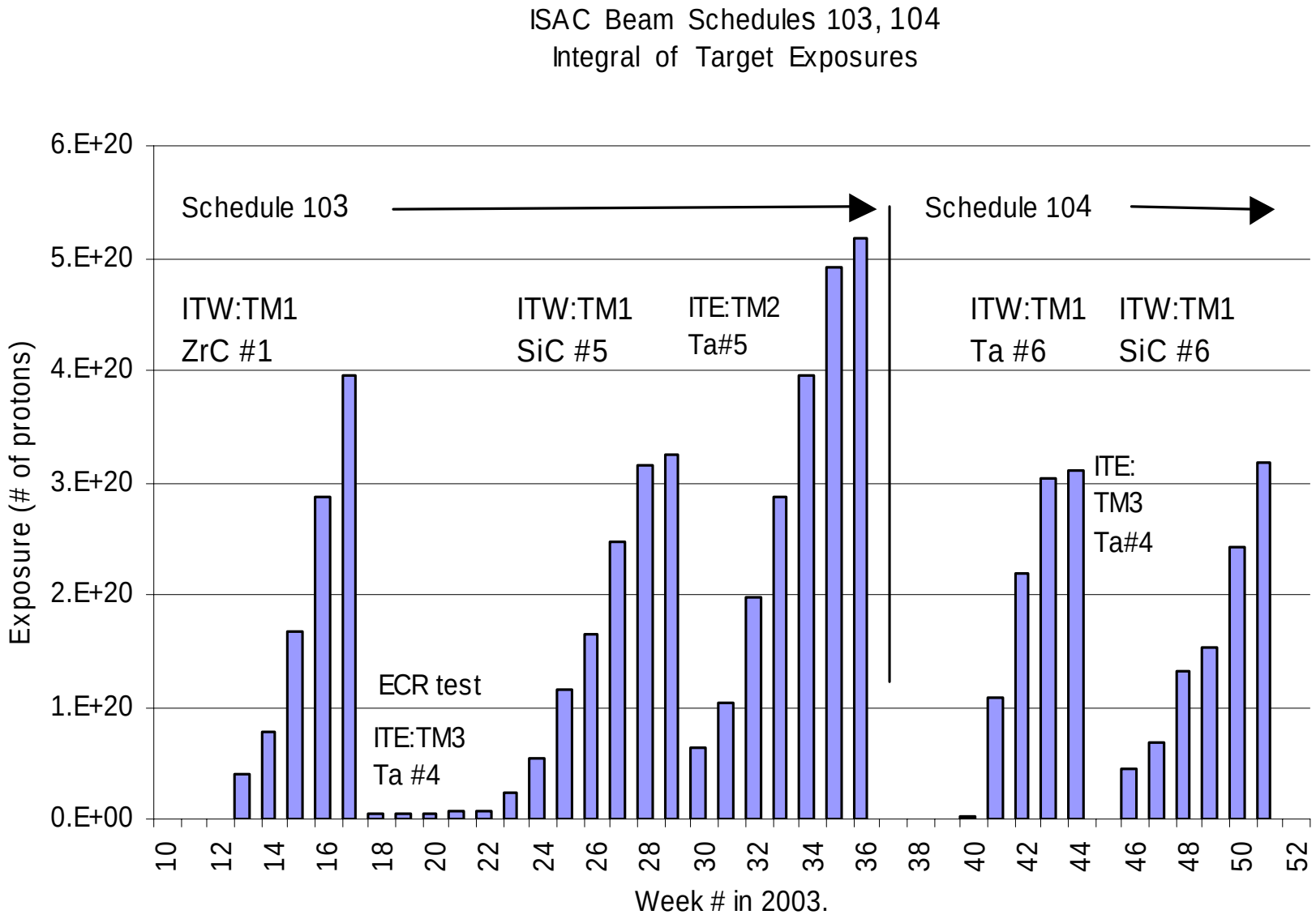
THERMAL ION SOURCE

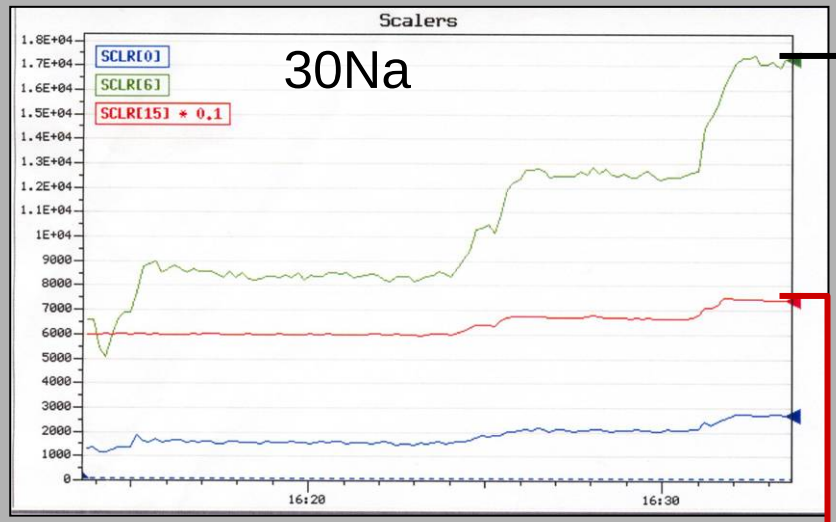


ISAC I TARGET DEVELOPMENT

- ISOL Target Area
  - **Shielded for 100 μA of 500 MeV Protons on Uranium**
  - **Dec 17, 1999 – 100 μA on Mo Target**
  - **May 25, 2001 - 40 μA on Nb Target**
  - **July 23, 2001 - 40 μA on Ta Target**
  - **Oct 18, 2001 – 15 μA on SiC Target**
  - **Sept 9, 2002 – 40 μA on TiC Target**
  - **Nov 11, 2002 – 45 μA on SiC Target**
  - **Fall 2005 – Actinide Target Tests**

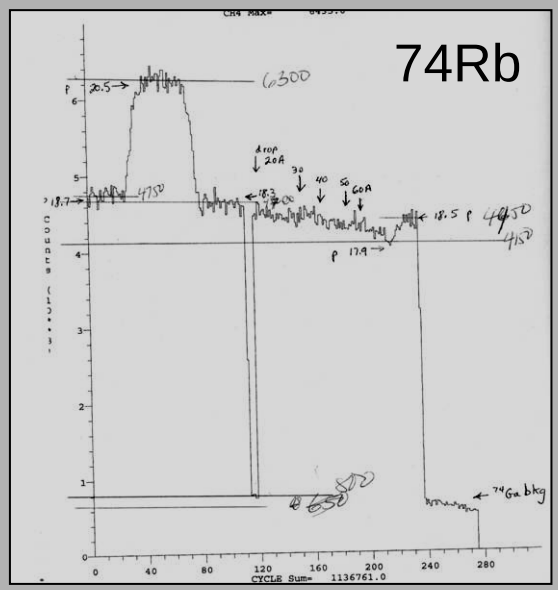
ISAC TARGET EXPOSURE 2003

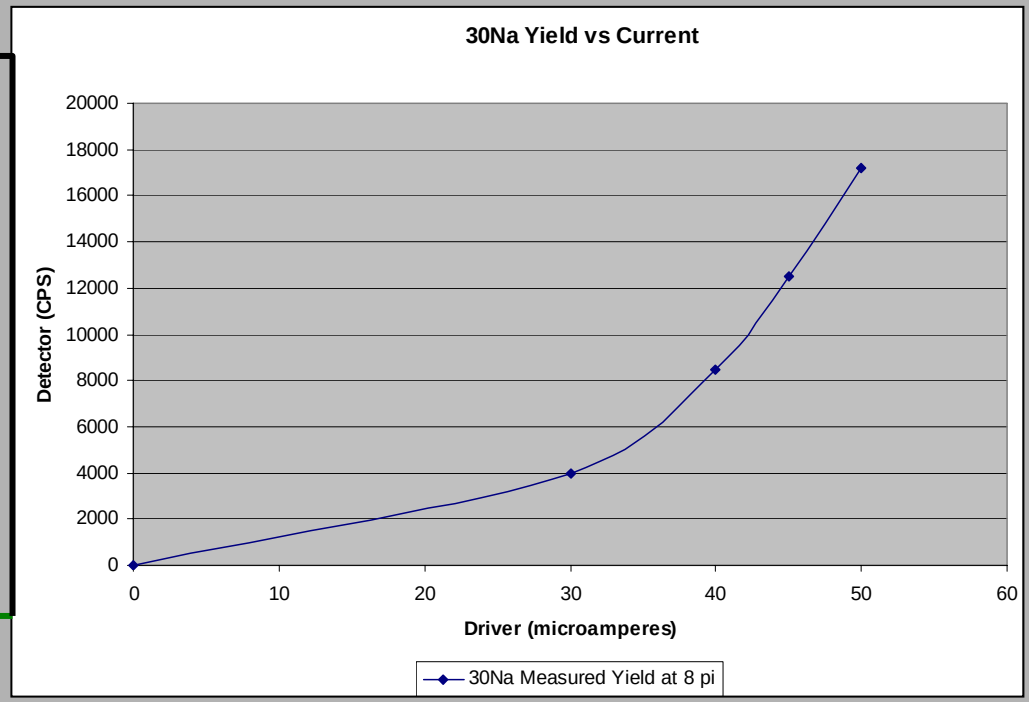


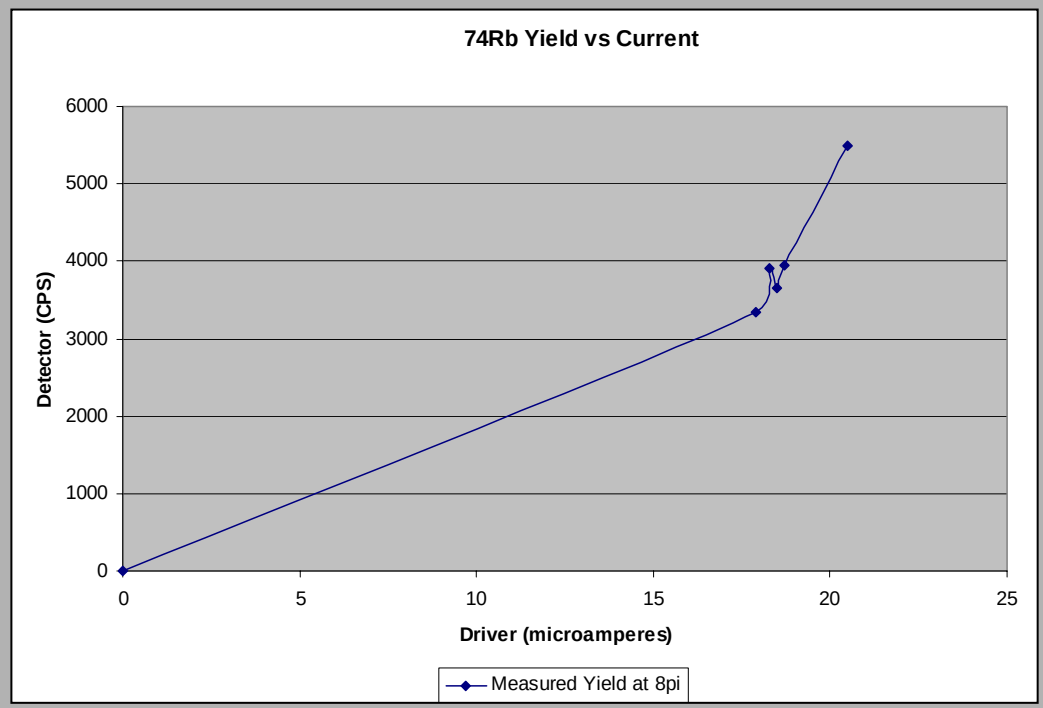


50 μA Protons

Yield Ratemeter



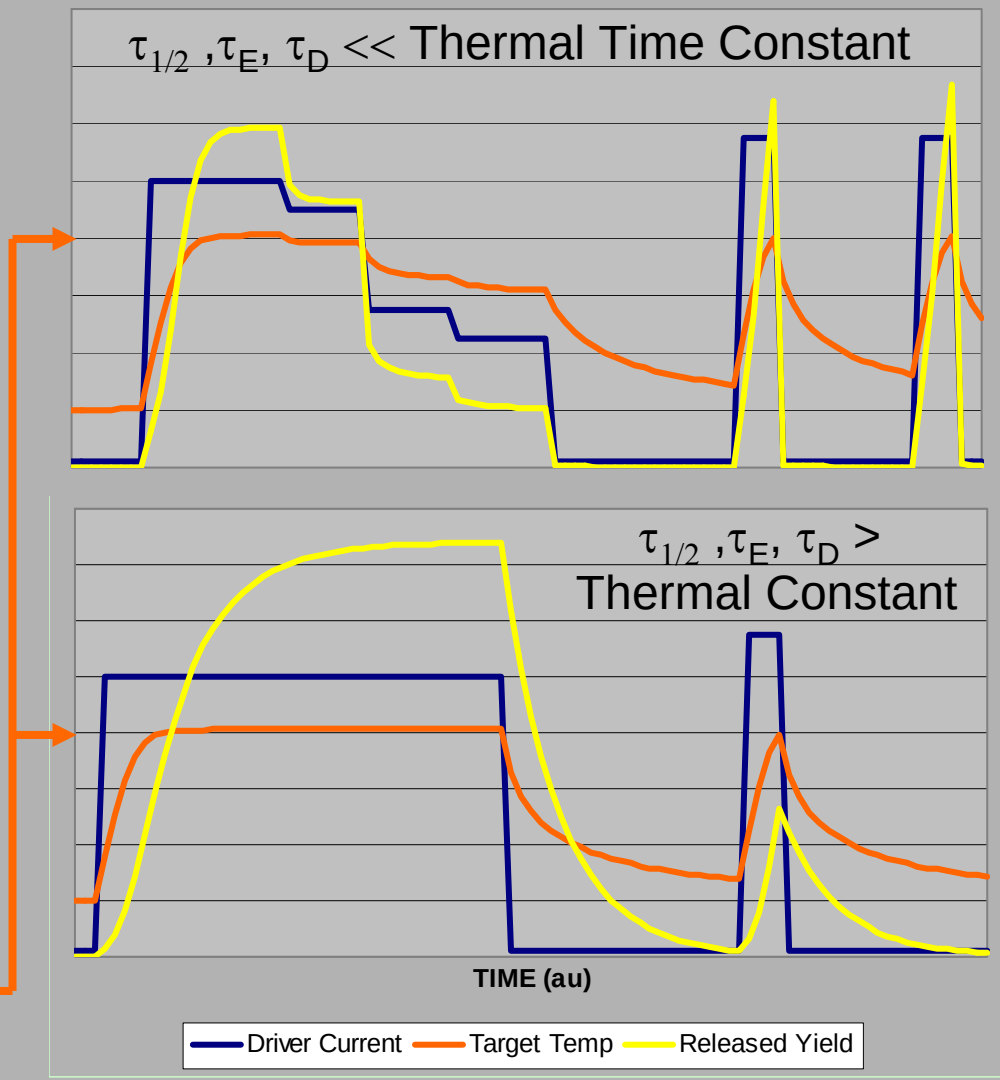




30Na & 74Rb Yield vs Driver Current

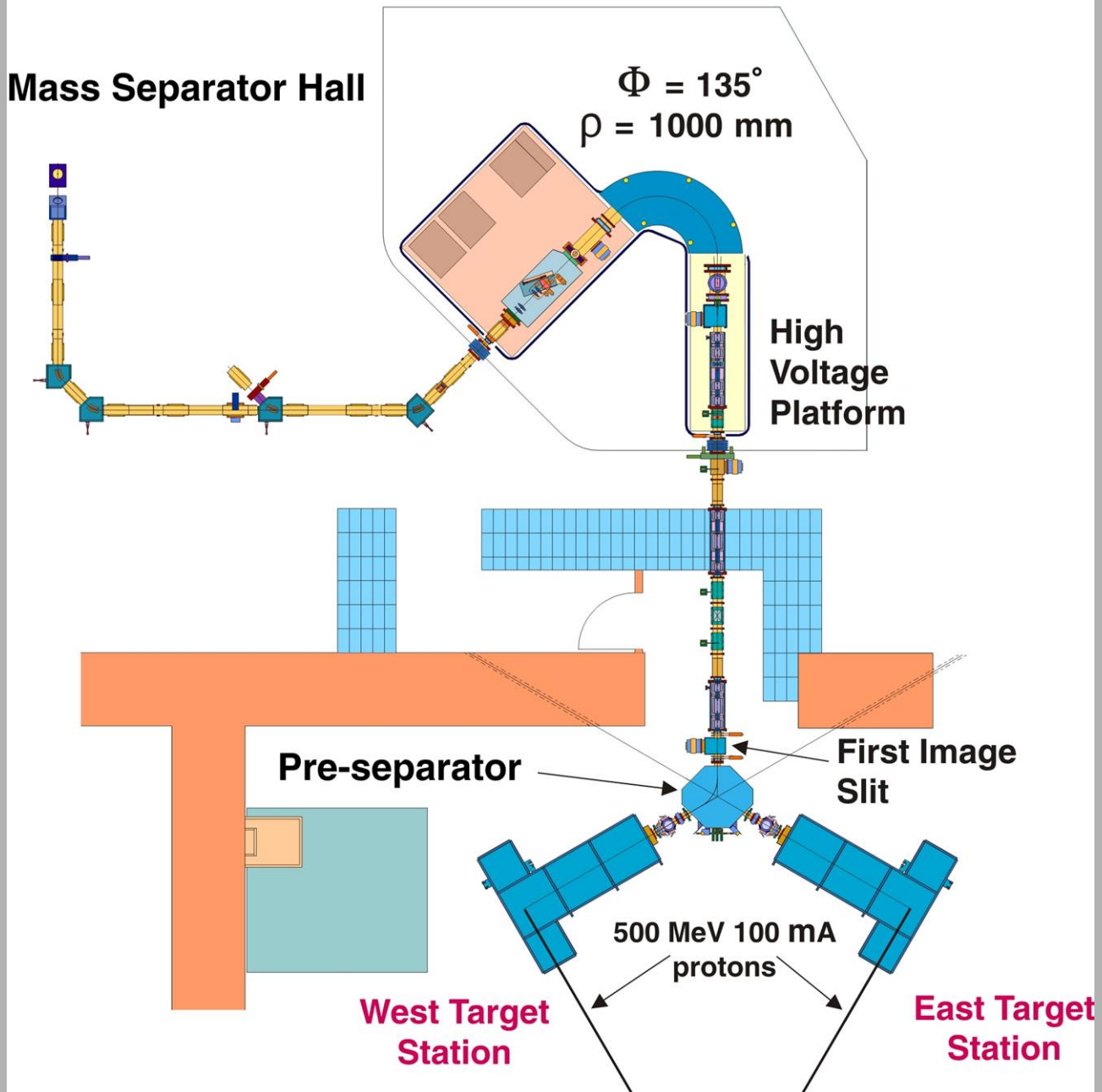
SCHEMATIC of TIME DEPENDENCE for DRIVER CURRENT with HIGH POWER, ISOL TARGET TEMP. & RELEASED YIELD

- Optimum Driver Current Pulse Lengths
  - >> Half-life, Diffusion & Effusion Times
  - >> Thermal Time Constants
    - Typically several minutes
- Driver Current Stability
  - Operating Temperature is Determined by Driver
    - Yield, Effusion, Diffusion Determined by the Driver Current
  - With Significant Beam Heating
    - $\Delta RIB/RIB > \Delta I/I$



Tmax

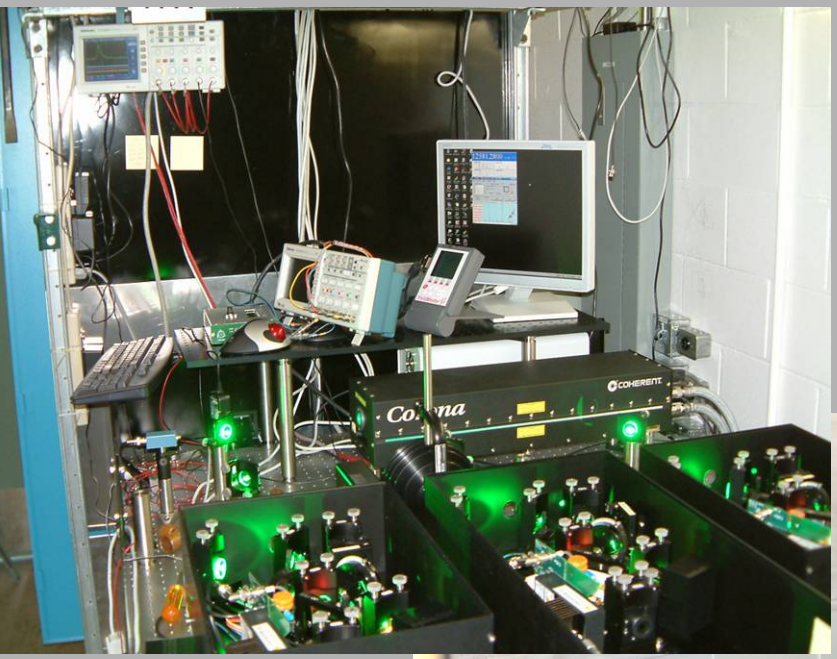
ISAC Mass Separator



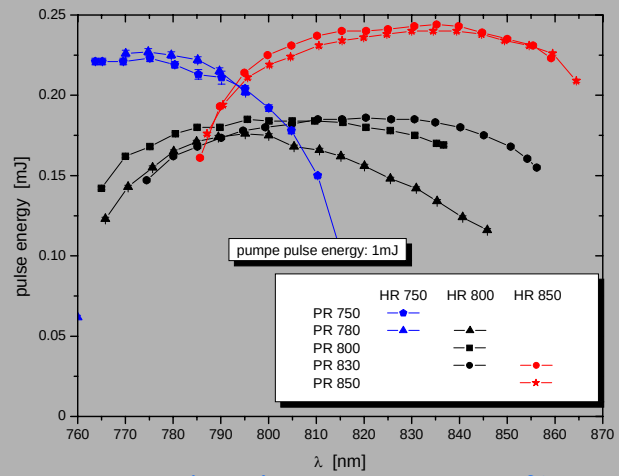
Ion Sources

- THERMAL
  - Primary Ion Source on 2 target modules
- RLIS (resonant laser ion source)
  - Initial online test scheduled for Sept. 2004
  - Initial user ^{62}Ga beam planned for Dec. 2004
- ECRIS (electron cyclotron resonance ion source)
  - Online & offline Commissioning of 2.45 GHz ECR
  - Online commissioning reproduces Ne ionization efficiency measured offline on ion source test stand
  - Initial experimental run with 8π & GPS in June 2004
  - Next experimental user scheduled for November 2004
- FEBIAD
  - Offline prototype nearly ready for testing
  - Online commissioning planned for Spring 2005
  - Goal is start experimental campaign in Summer 05
- OLIS [Off Line Ion Source for Stable Beams]
  - Microwave Ion Source for volatiles & metallic sputtering
  - Surface Ion Source Installed & Commissioned
  - Installation of heavy ion ECRIS under discussion

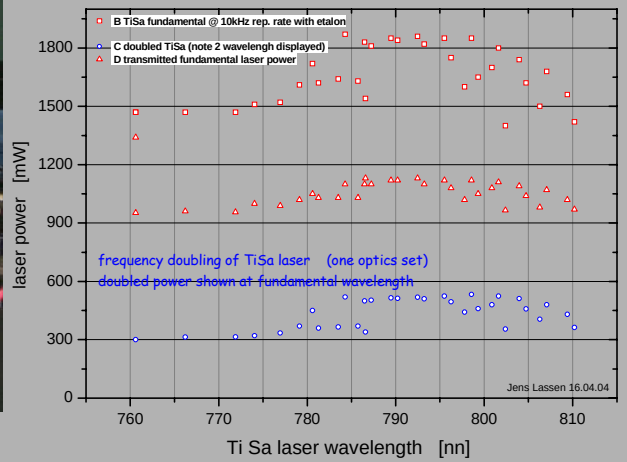
TRILIS - hardware development -



TiSa broadband tuning



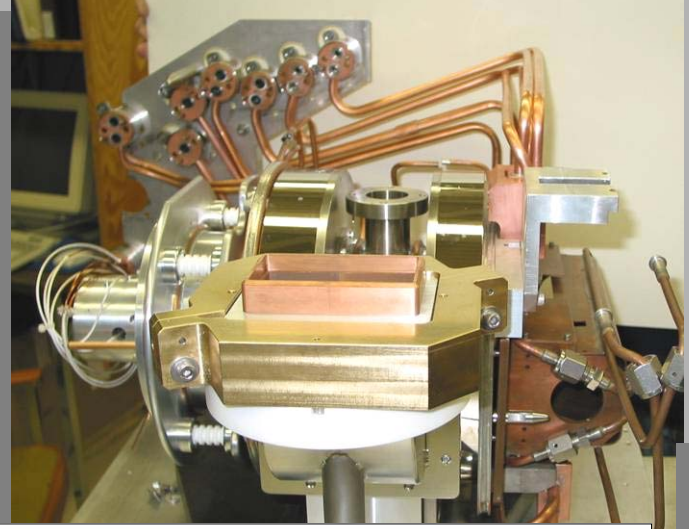
TiSa doubling ε up to 25%

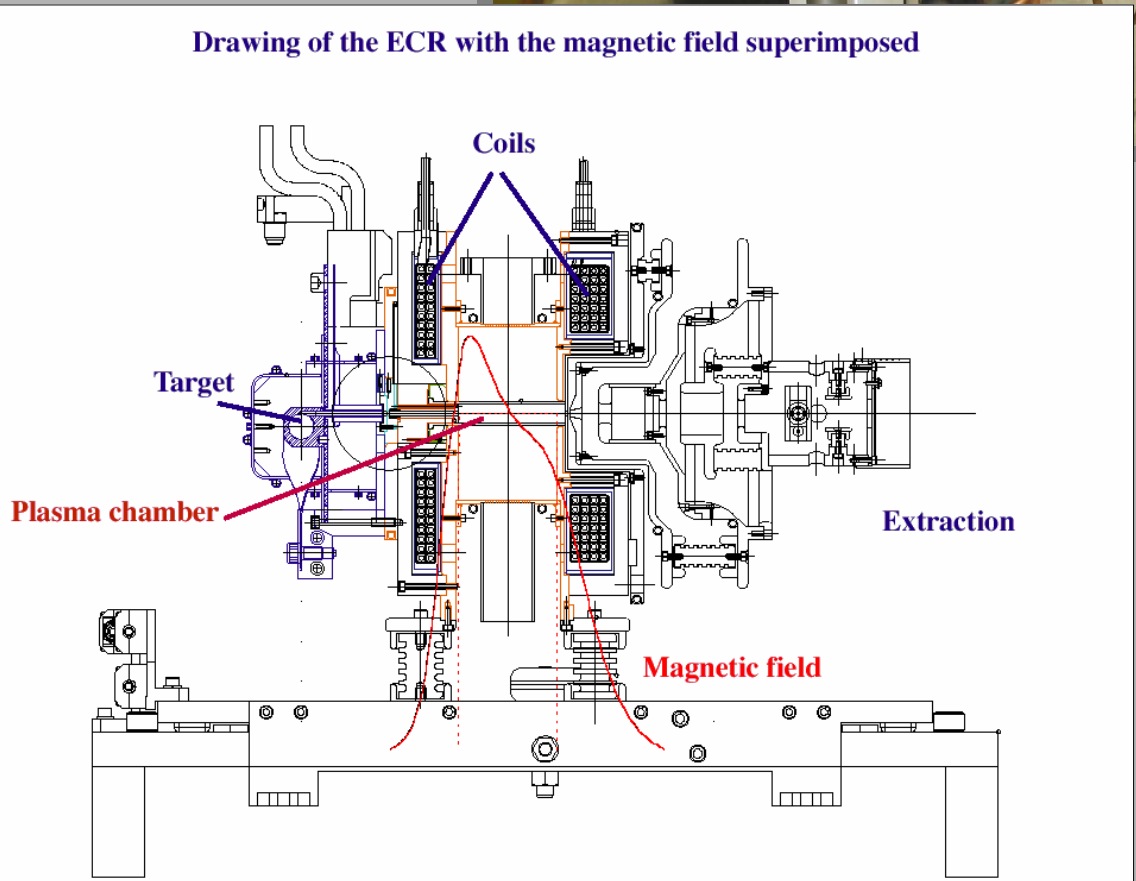


(status 04/2004)

3 TiSa lasers, 2 frequency doubling units in operation
beamtransport into ICB completed, off-line LIS start

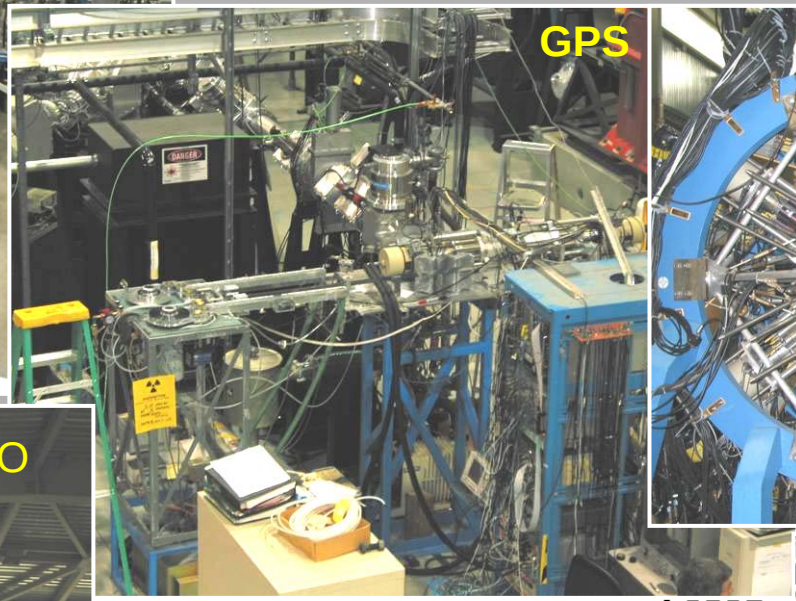
ECR1 & TARGET MODULE

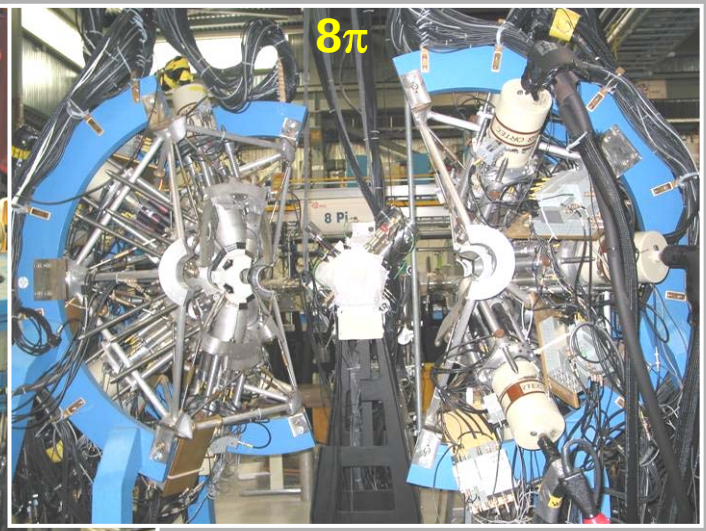


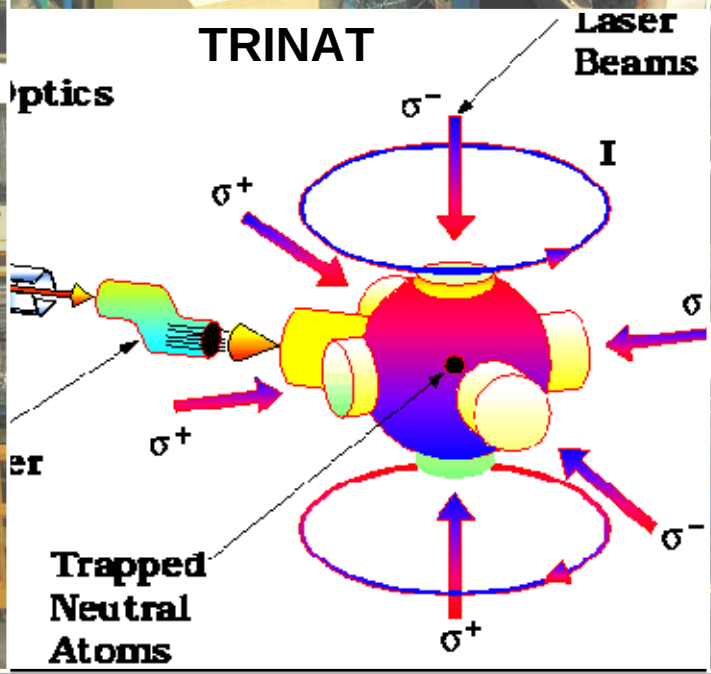


ISAC EXPERIMENTAL HALL

LOW ENERGY STATIONS

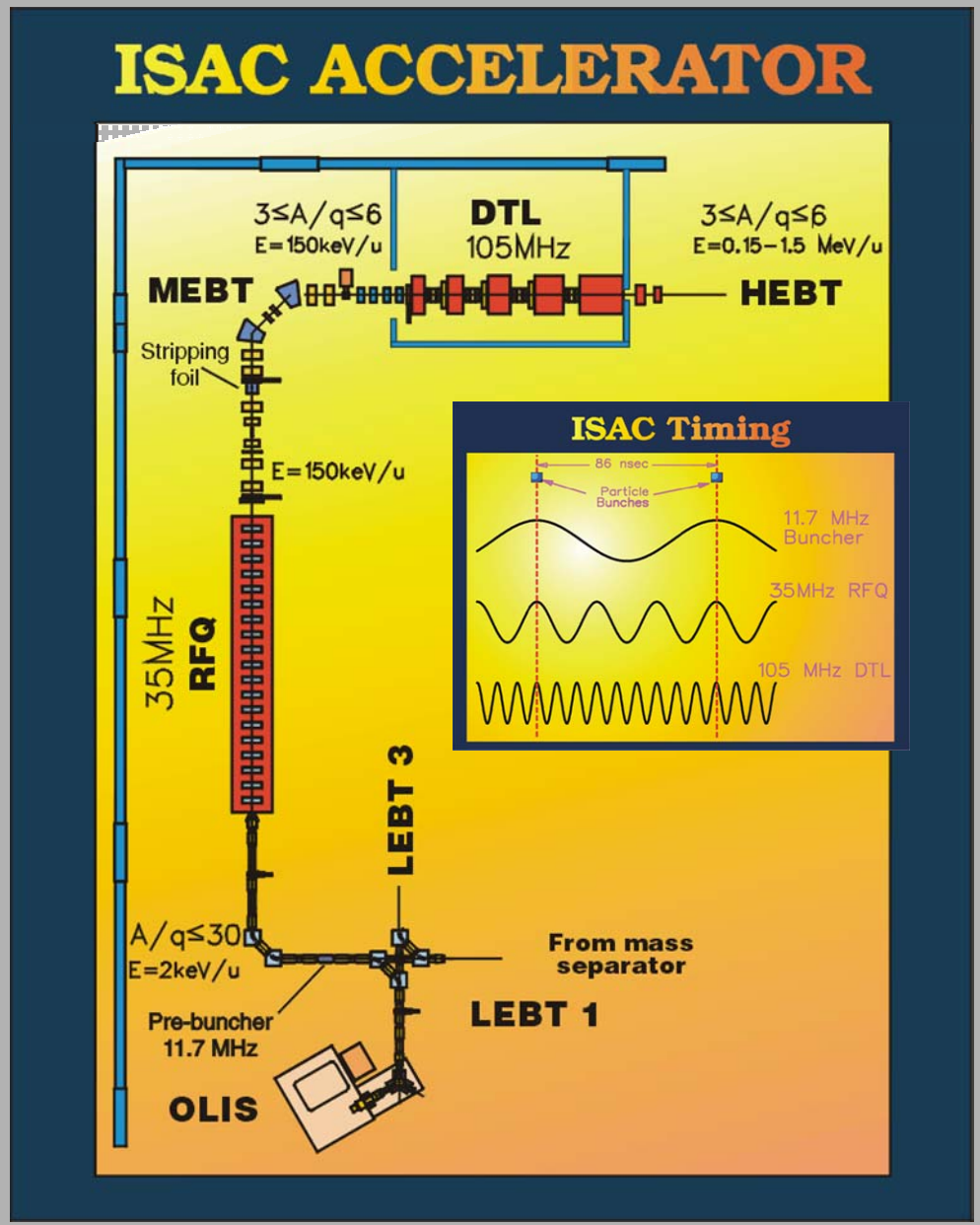






ISAC-I Accelerator

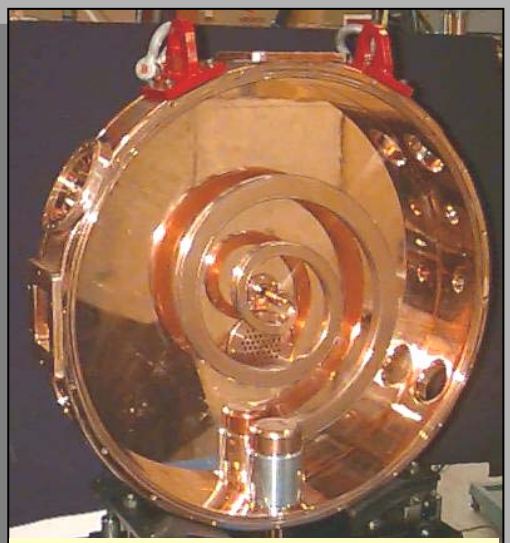
- OLIS
  - Stable beams
- LEBT
  - All-electrostatic (2 keV/u)
  - 11.8 MHz multi-harmonic pre-buncher
- 35 MHz cw RFQ
  - E=2→153 keV/u
  - A/q<=30
- MEBT
  - Stripping foil
  - 35 MHz rebuncher
- 105 MHz cw Variable Energy DTL
  - E=0.15-1.53 MeV/u
  - A/Q<=6
- HEBT
  - Diagnostic section
  - 11.8/35 MHz rebunchers



ACCELERATOR TECHNOLOGY

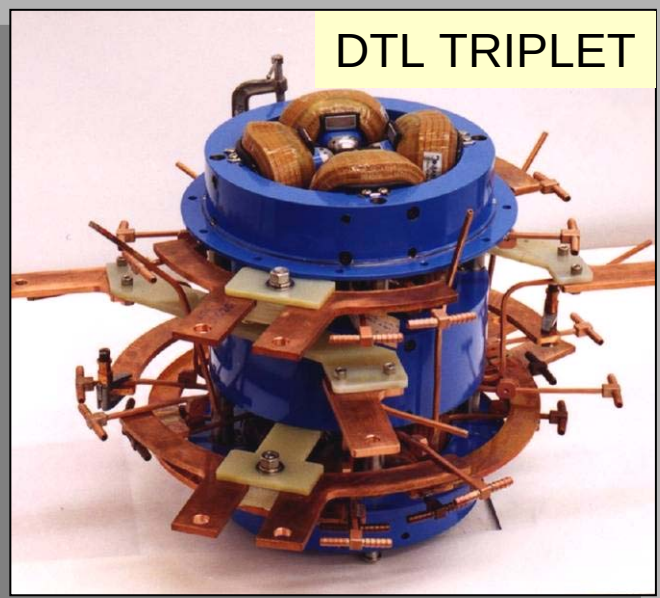
DTL TANK 2

RFQ



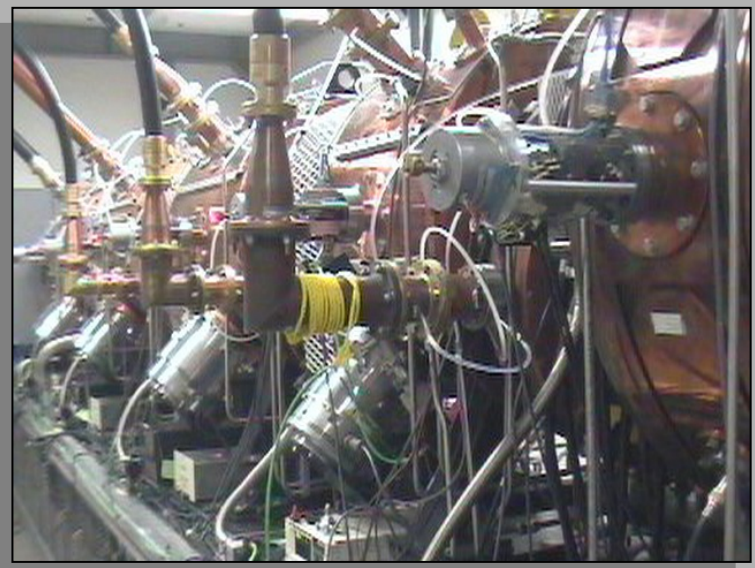
MEBT REBUNCHER

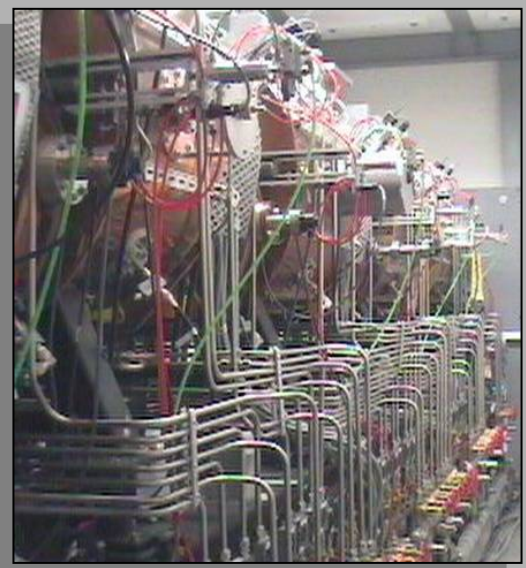
DTL TRIPLET



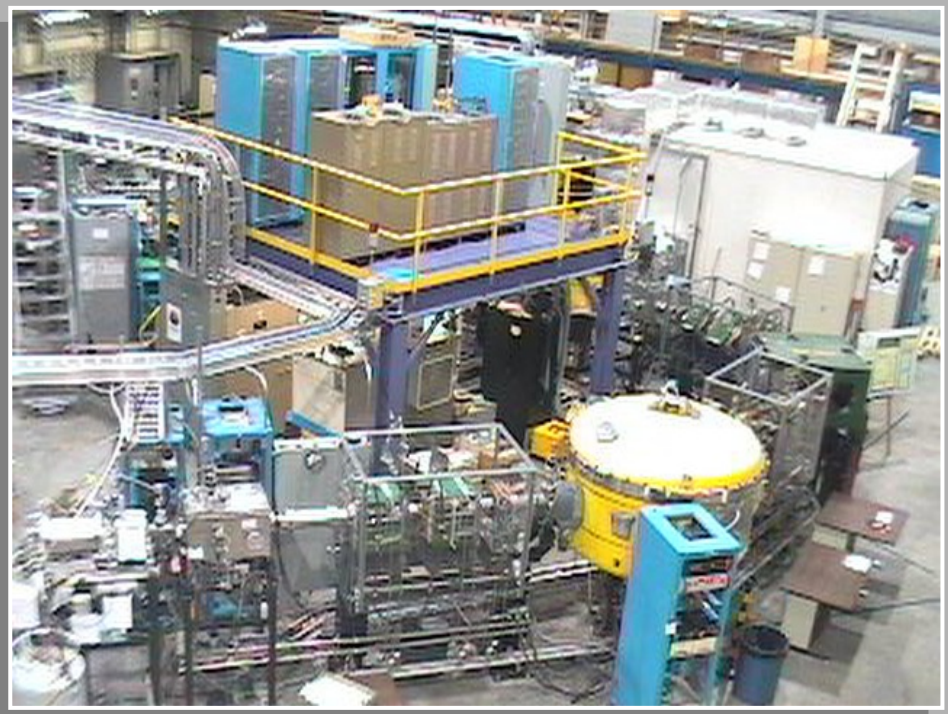
INR BUNCH ROTATOR

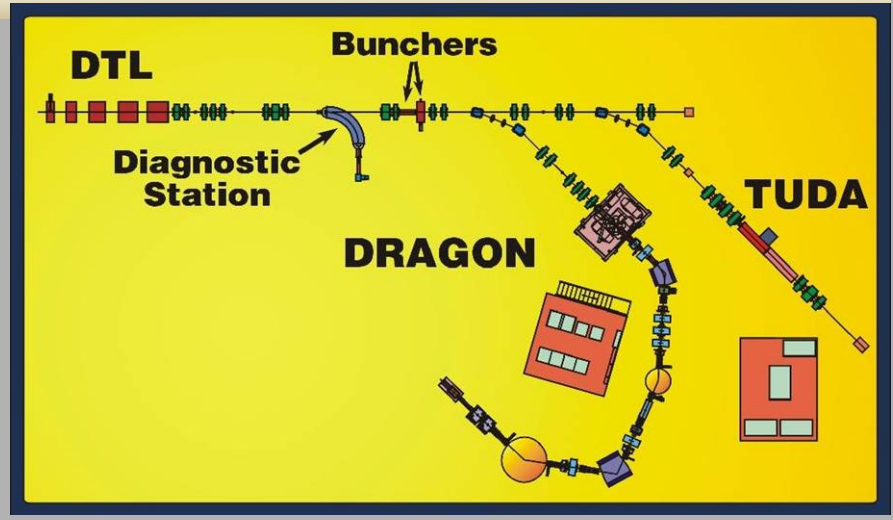
COMPLETED DRIFT TUBE LINAC

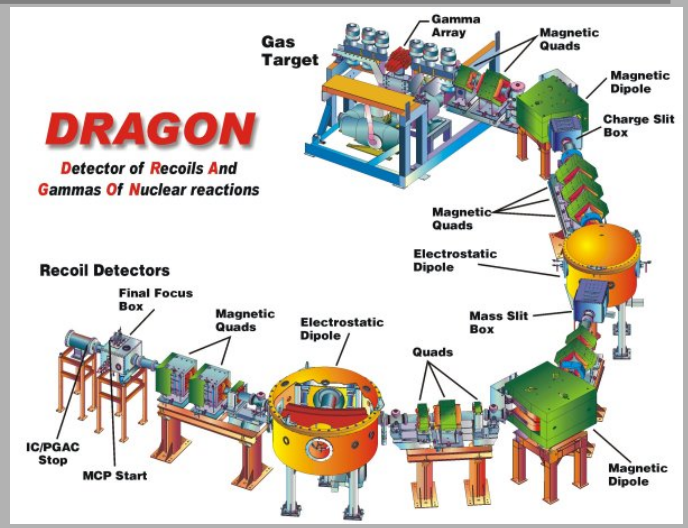


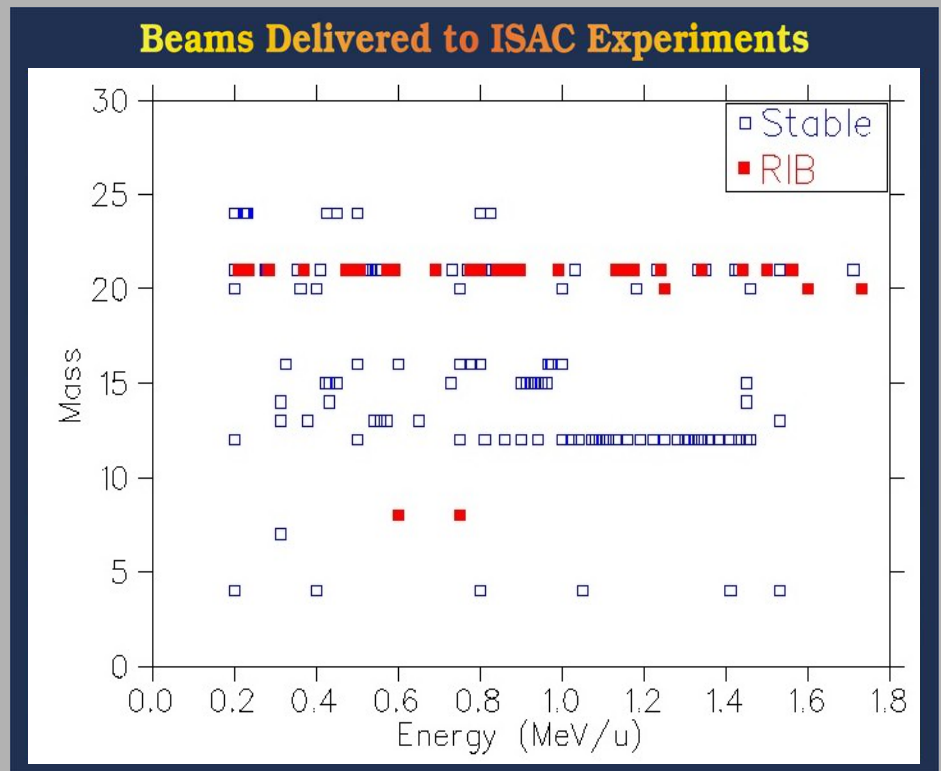


Nuclear Astrophysics Experimental Stations



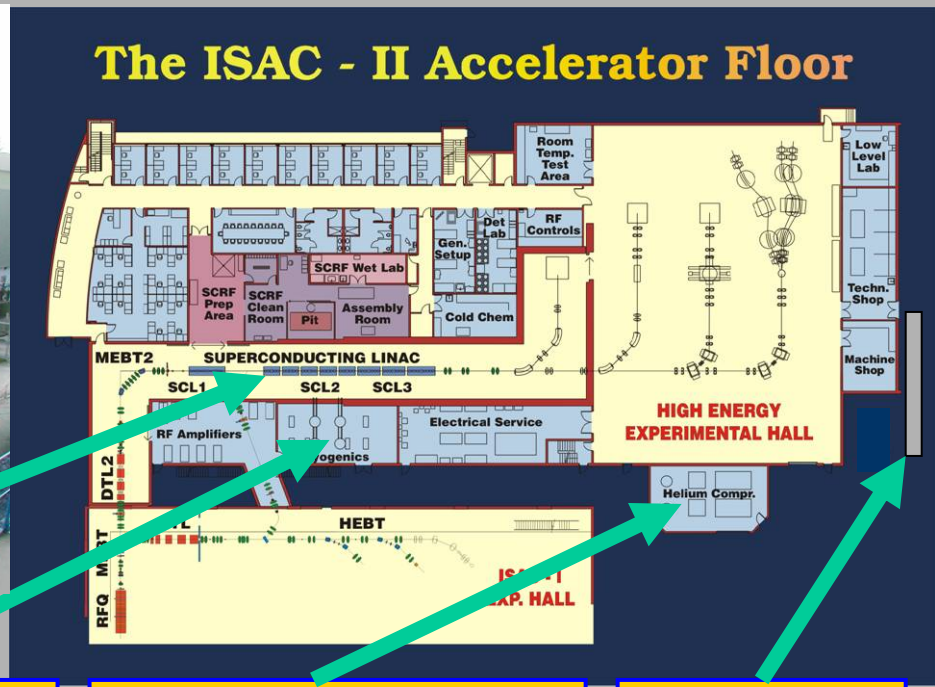




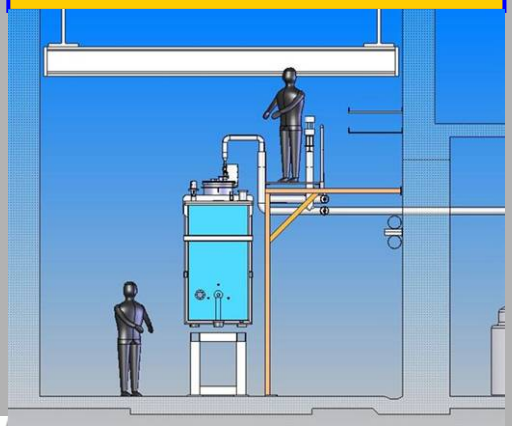


ISAC II

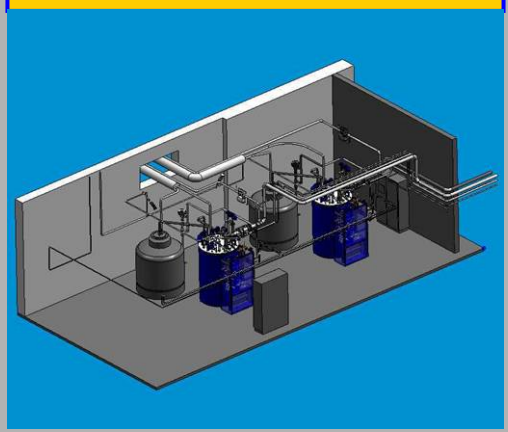
ISAC-II Building



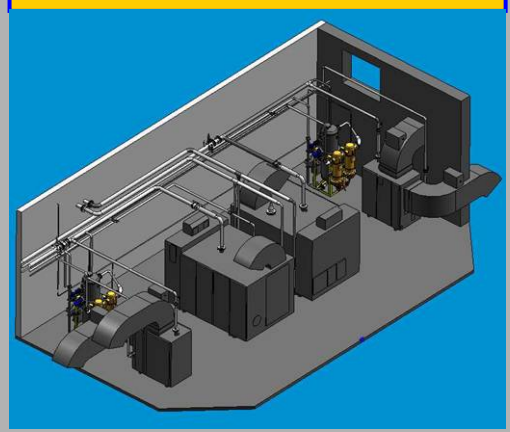
Linac Distribution



Refrigerator Room



Compressor Room



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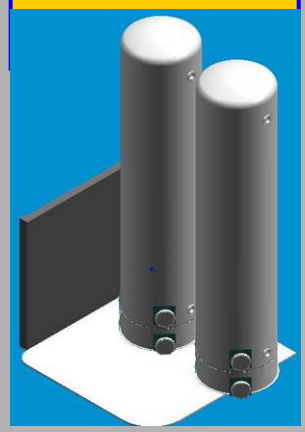
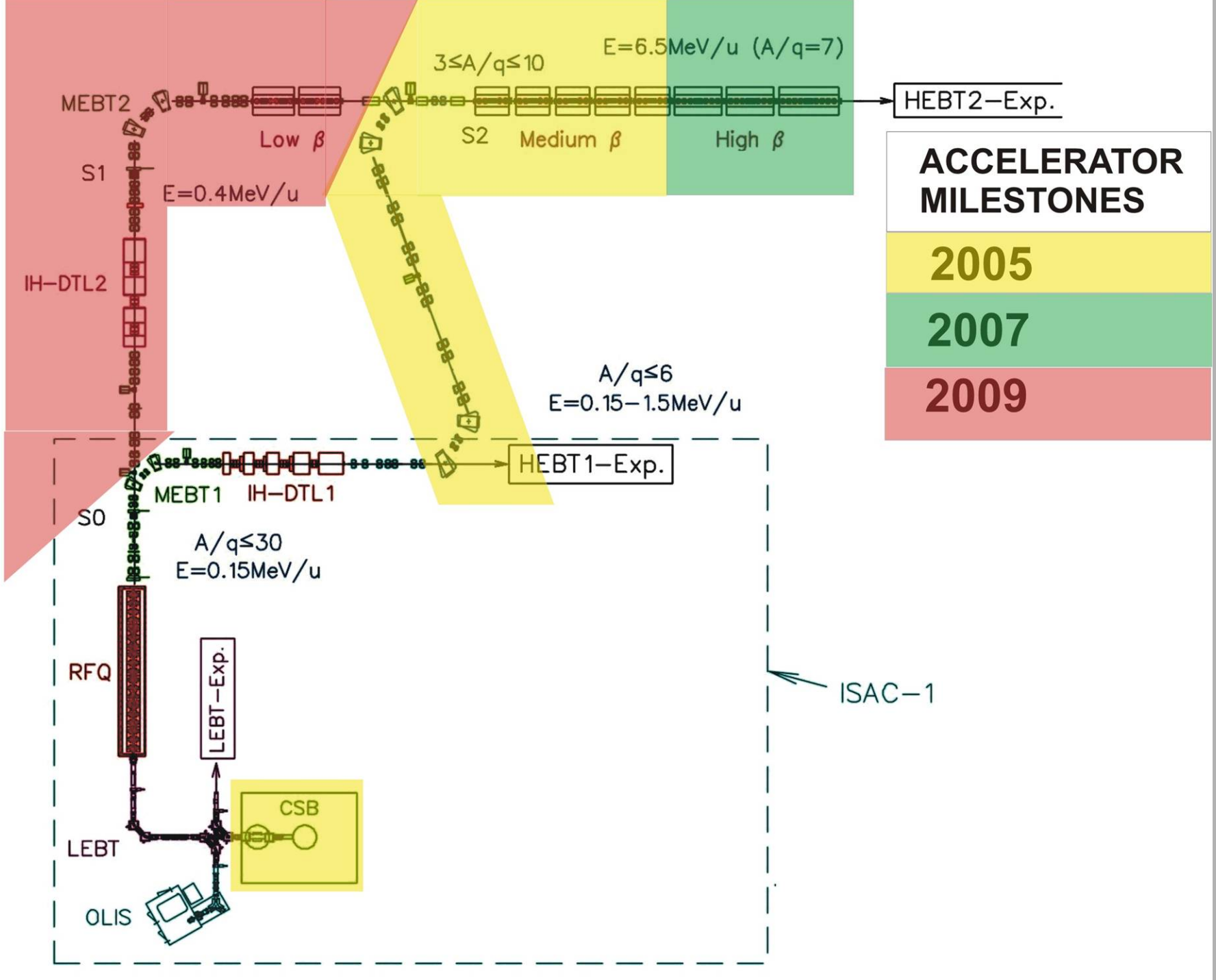


ISAC II Components

- CSB [ECR based Charge State Booster]
  - Operating on Ion Source Test Stand with 1+ injection
- “S” Bend HEBT
  - 4 Dipoles in Magnet Measuring Lab
- He Liquifier
  - Ordered Compressors & liquifier system
  - Installation & Commissioning this Fall
- Cryogenic Distribution System
  - Warm system tendered
  - Cold System being Specified
- Experimental Hall HEBT
  - Concept not finalized
- Accelerator
  - First cryomodule cooled to LHe
  - Two additional cryomodules in fabrication
  - All 20 medium beta cavities fabricated


E=6.5MeV/u (A/q=7)
3≤A/q≤10
MEBT2
HEBT2–Exp.
Low β
S2
Medium β
High β
S1
E=0.4MeV/u
IH–DTL2
A/q≤6
E=0.15–1.5MeV/u
HEBT1–Exp.
MEBT1
IH–DTL1
S0
A/q≤30
E=0.15MeV/u
RFQ
LEBT–Exp.
ISAC–1
CSB
LEBT
OLIS
ACCELERATOR MILESTONES
2005
2007
2009

Charge State Booster & Mass Selector Location In Mass Separator Cave

ITEM	REF No./DESCRIPTION	MATERIAL	QUAN

REV	DATE	LOC	REVISION DESCRIPTION	BY	APP'D
3	20-03		Preliminary optics corrected	Sa	RB

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS ±
DECIMALS .XX ±
.XXX ±
ANGULAR ±
SURFACE FINISH µin

ALL DIMS IN INCHES

DESIGNED DL-
DRAWN
CHECKED
REF DWGS:

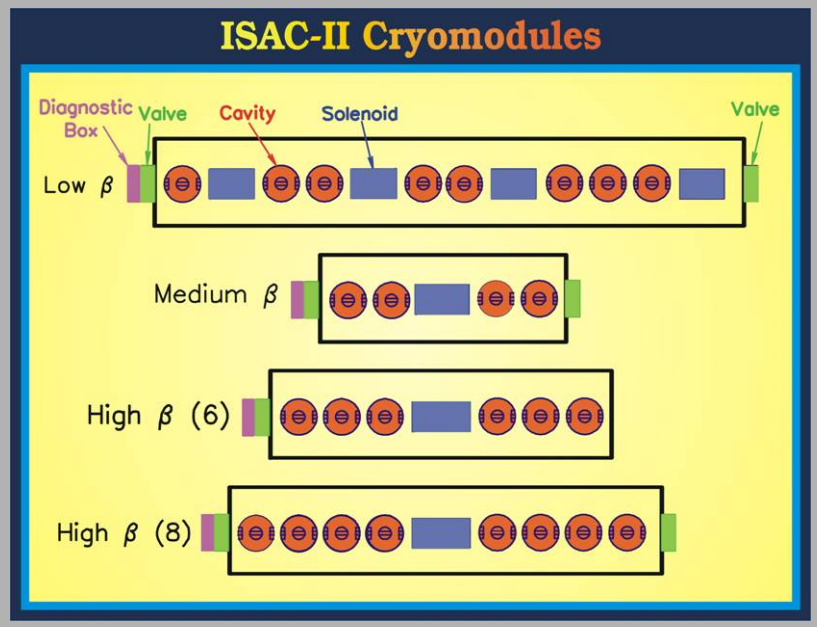
TRIUMF 4004 WESBROOK MALL VANCOUVER, BRITISH COLUMBIA CANADA V6T-2A3 CANADA'S NATIONAL MESON FACILITY

Proposal 3
CSB in Mass-sep hall
ISAC

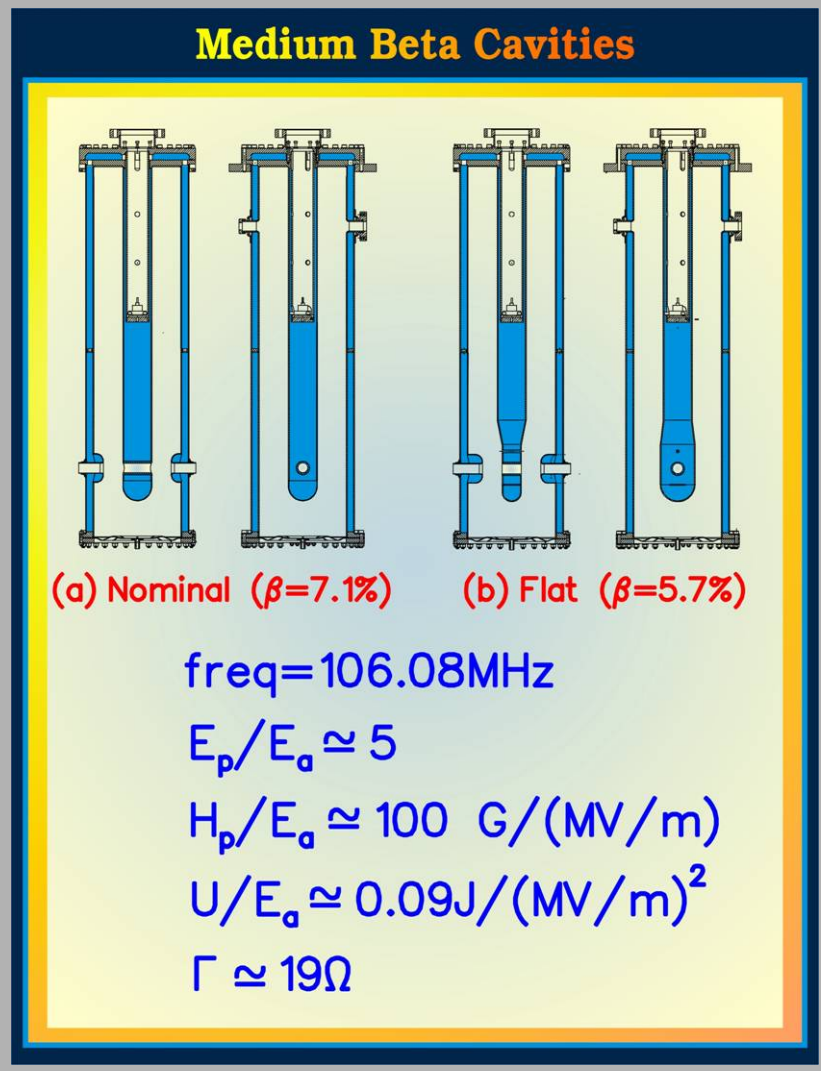
CSB Status

- CSB is producing highly charged ions on ion source test stand
  - Ar7+ & 8+ observed
  - Transmission losses due to background gas observed
    - Improvements to vacuum pumping planned
- ECR2 installed as 1+ injector
- Initial final optics installation scheduled for winter 2005 shutdown
- Final installation of CSB scheduled for winter 2006
- Commissioning planned for spring 2006

ISAC-II SC Linac

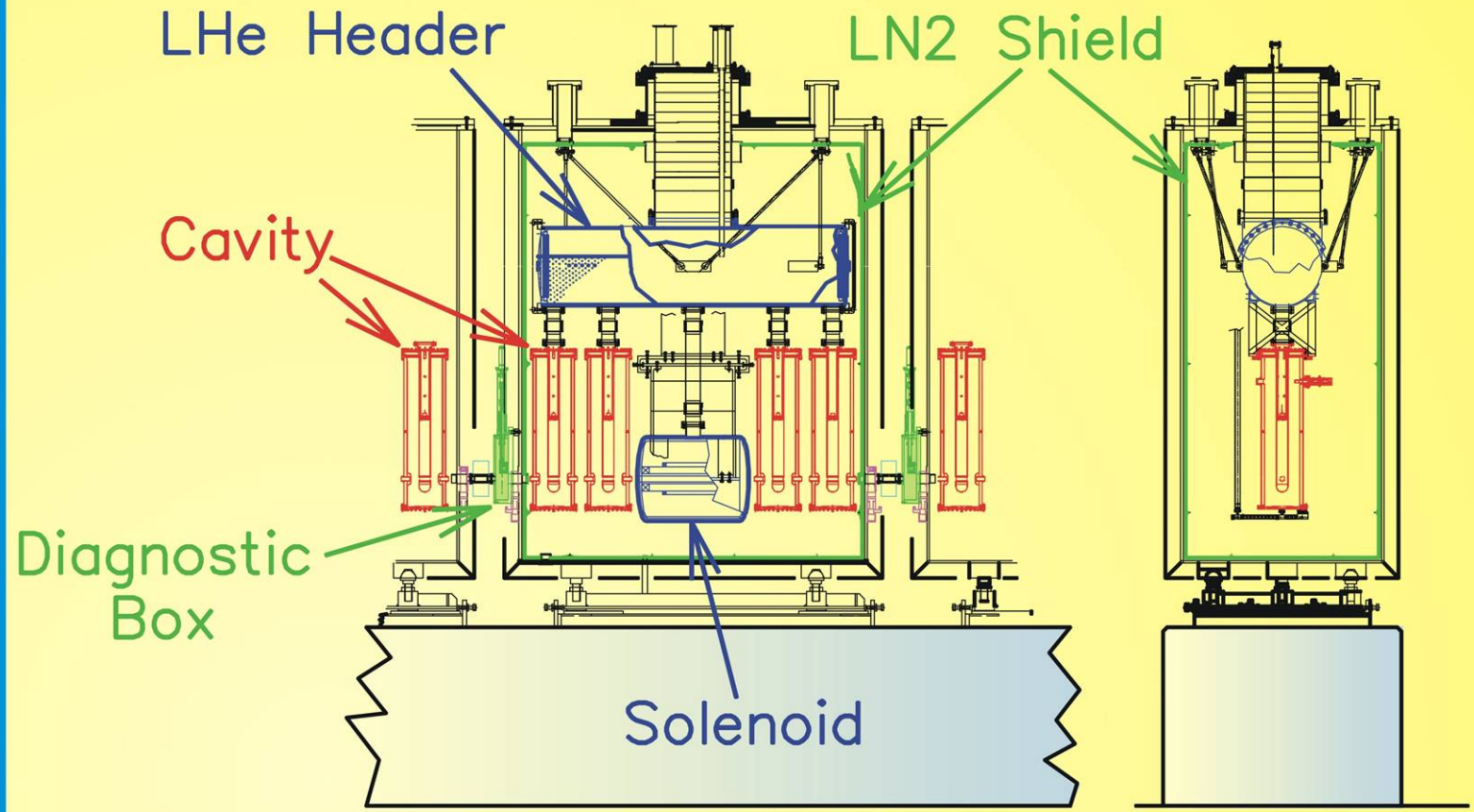


Section	β_0 (%)	f_{RF} (MHz)	No.	E_a (MV/m)
Low β	4.2	70.7	8	5
Med β	5.7	106	8	6
	7.1	106	12	6
High β	10.4	141	20	6



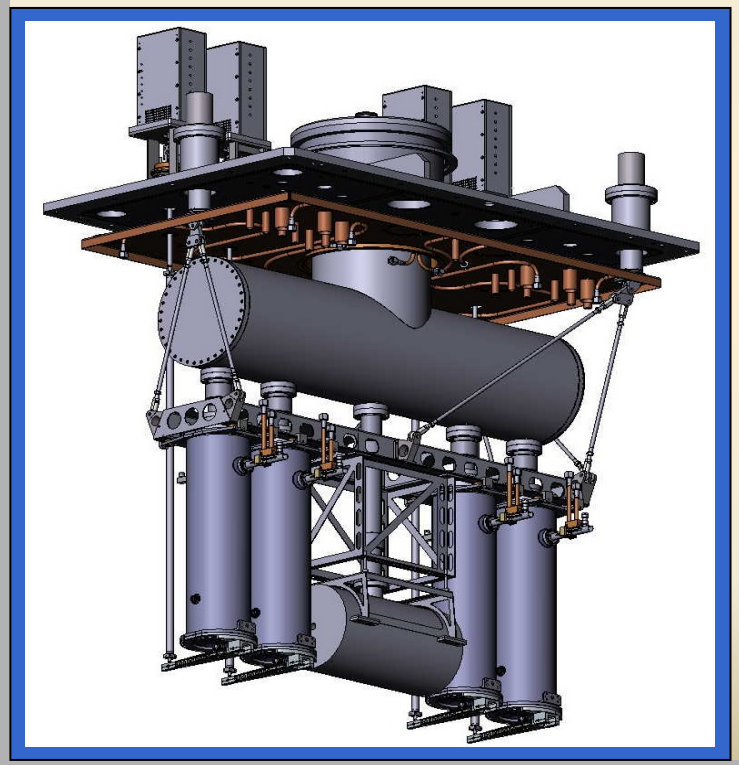
High Beta Frequency Optimization [THP14]

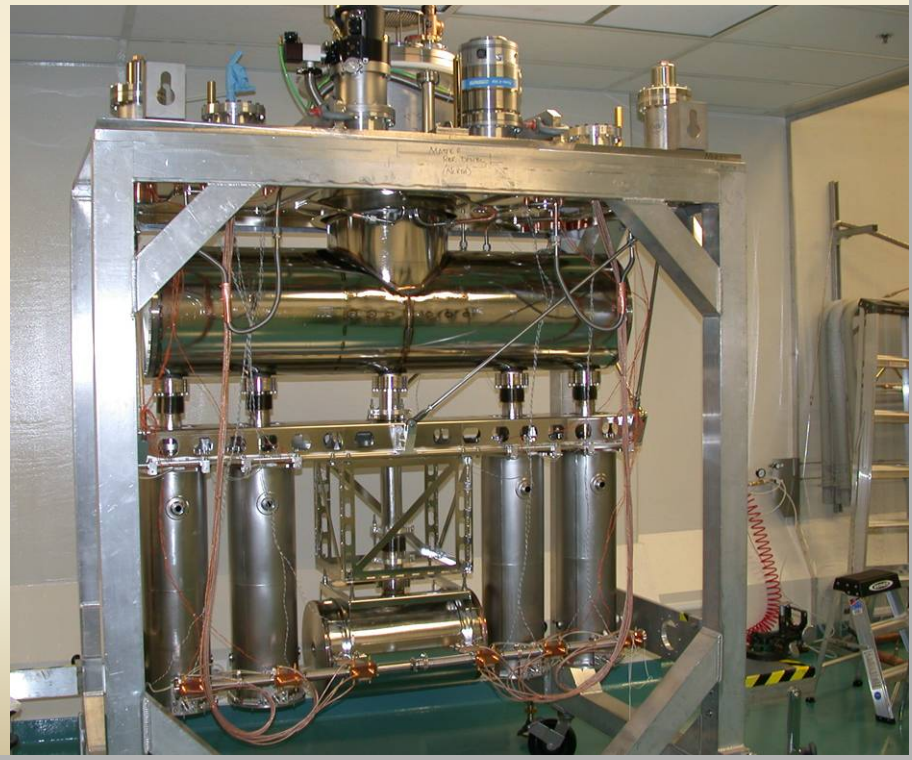
Medium Beta Cryomodule



Medium Beta Cryomodules Assembly

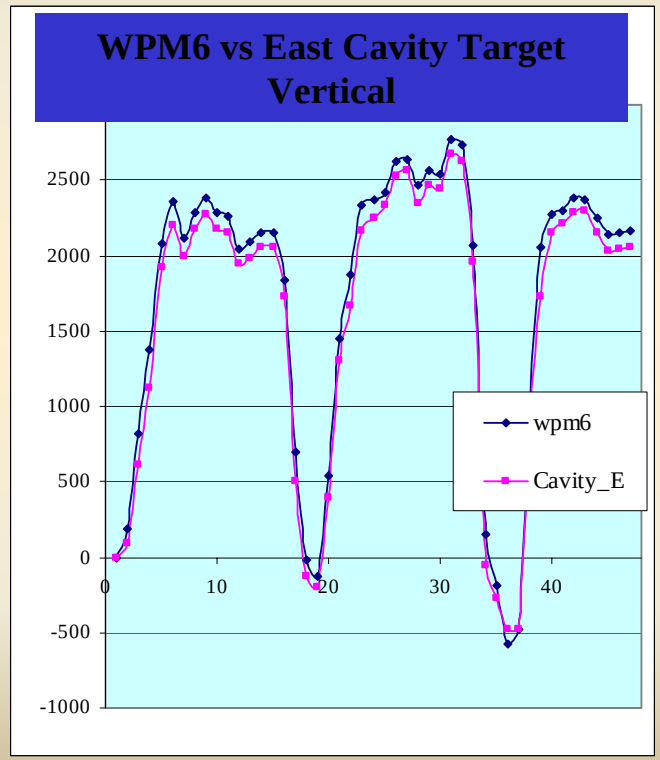
- First (3rd in dtl line) Assembled & Successfully Cold Tested with rf Power, tuners, rf control system & Solenoid [MOP86]

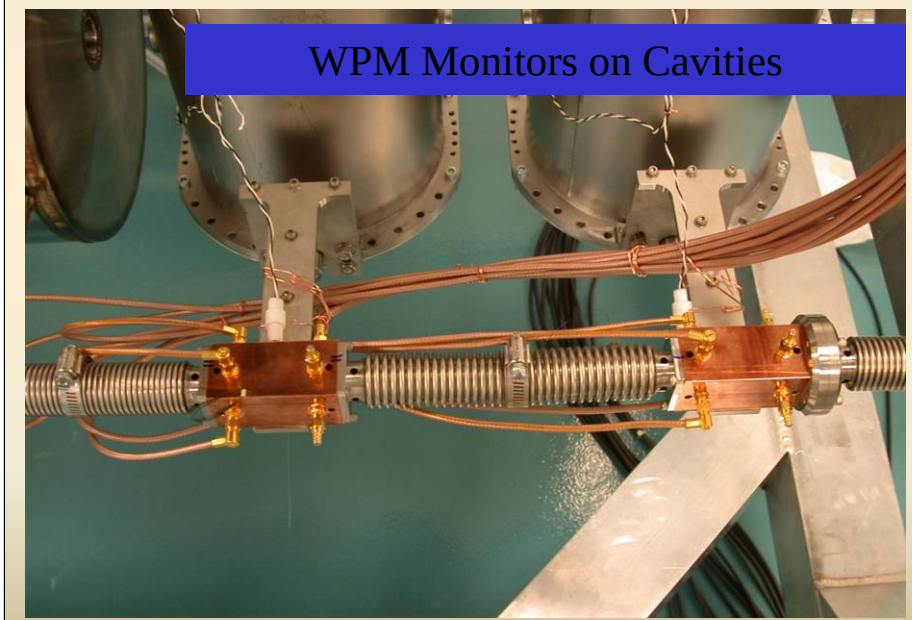




Medium Beta Cryomodules Alignment

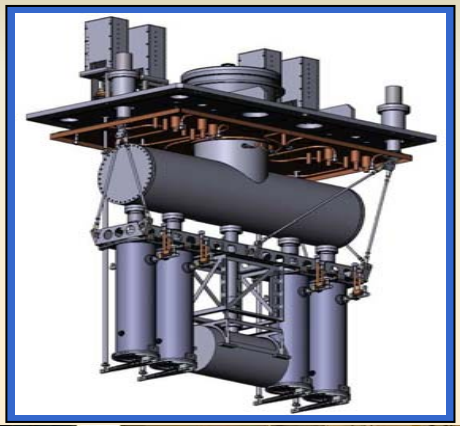
- Alignment Movement During Temperature cycling Measured with Wire Position Monitoring System & Telescope [MOP89]





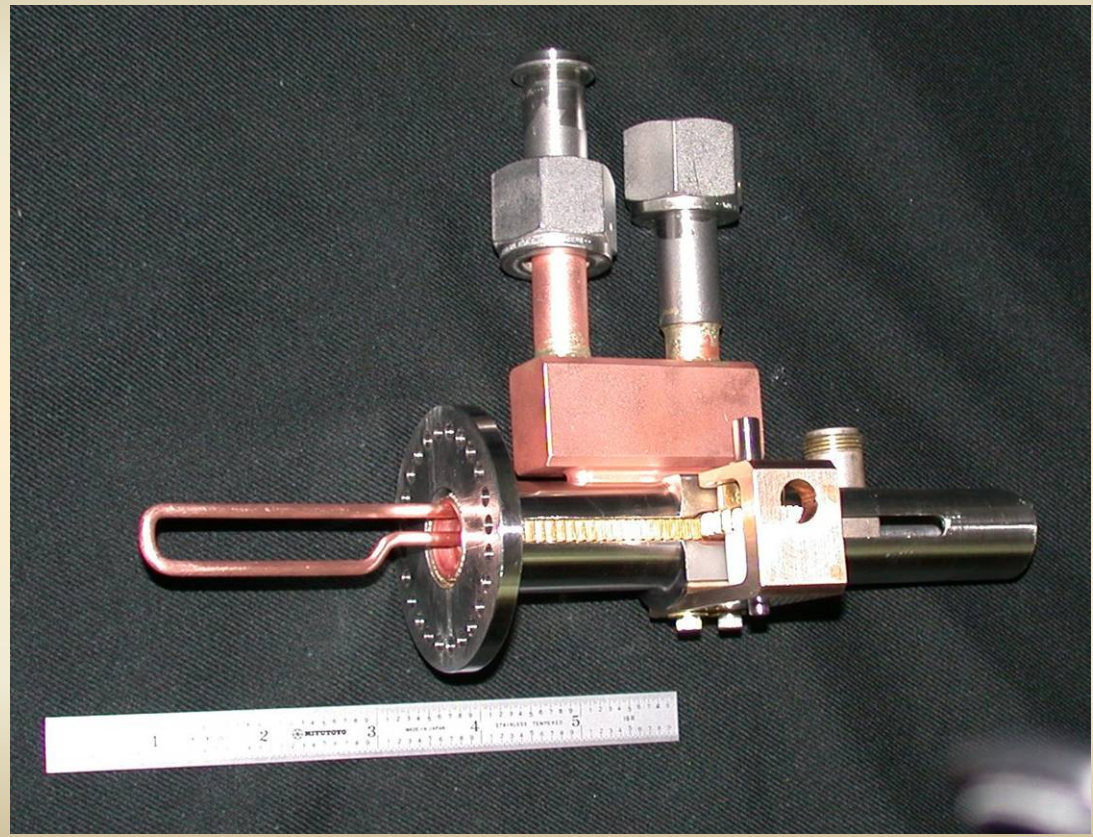
Medium Beta Cryomodules
RF Tuning

RF Tuning Successfully Commissioned [MOP86, THP16, TUP77]



Medium Beta Cryomodules
RF Coupling

- RF Coupler Successfully Commissioned [MOP92, MOP88]



LINAC, Cryomodules & Cryogenics Status

- LINAC
  - First medium beta Cryomodule being Cold Tested
  - Liquid Helium test confirmed heat load estimates
  - Wire Position Monitor meets requirements
  - Solenoid field does not impact cavity performance
  - Rf frequency could be ‘locked’ with control system
- Cryomodules
  - #2 [1] & #3 [2] are being fabricated & assembled
- Cryogenics
  - Compressors & Liquifiers ordered
    - Commissioning scheduled for Fall 2004
  - Warm Distribution System Contract let
  - Cold Distribution System
    - Initial system will be installed in 2005

2005 -2010

ISAC Issues

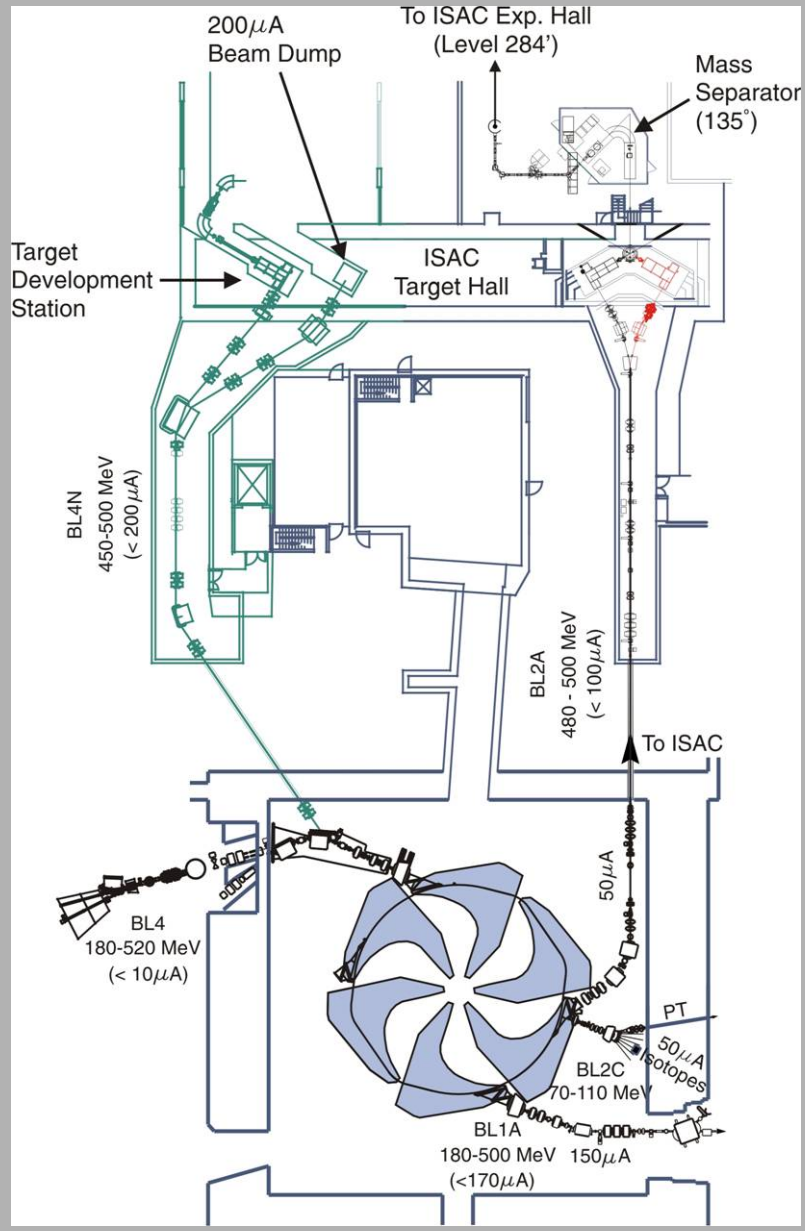
- Cyclotron Stability & Sparking requires Improvement
  - RIB production requires stable driver beam
  - Cyclotron Refurbishing Planned
- Target Development Incompatible with Production & Science Program
  - High Power Target Development Facility Required
  - Must Be Independent of Experimental Program
- OLIS [off line ion source for stable beams]
  - Initially installed for commissioning & tuning accelerators
  - Has become essential to science program
  - Needs to have a more universal ion source
- 5 Year Proposal Submitted to Canadian Federal Government
  - Endorsed by Government Appointed Peer Review
  - Decision Expected in Feb 2005

ISAC PROPOSAL FOR NEXT 5 YEAR PLAN

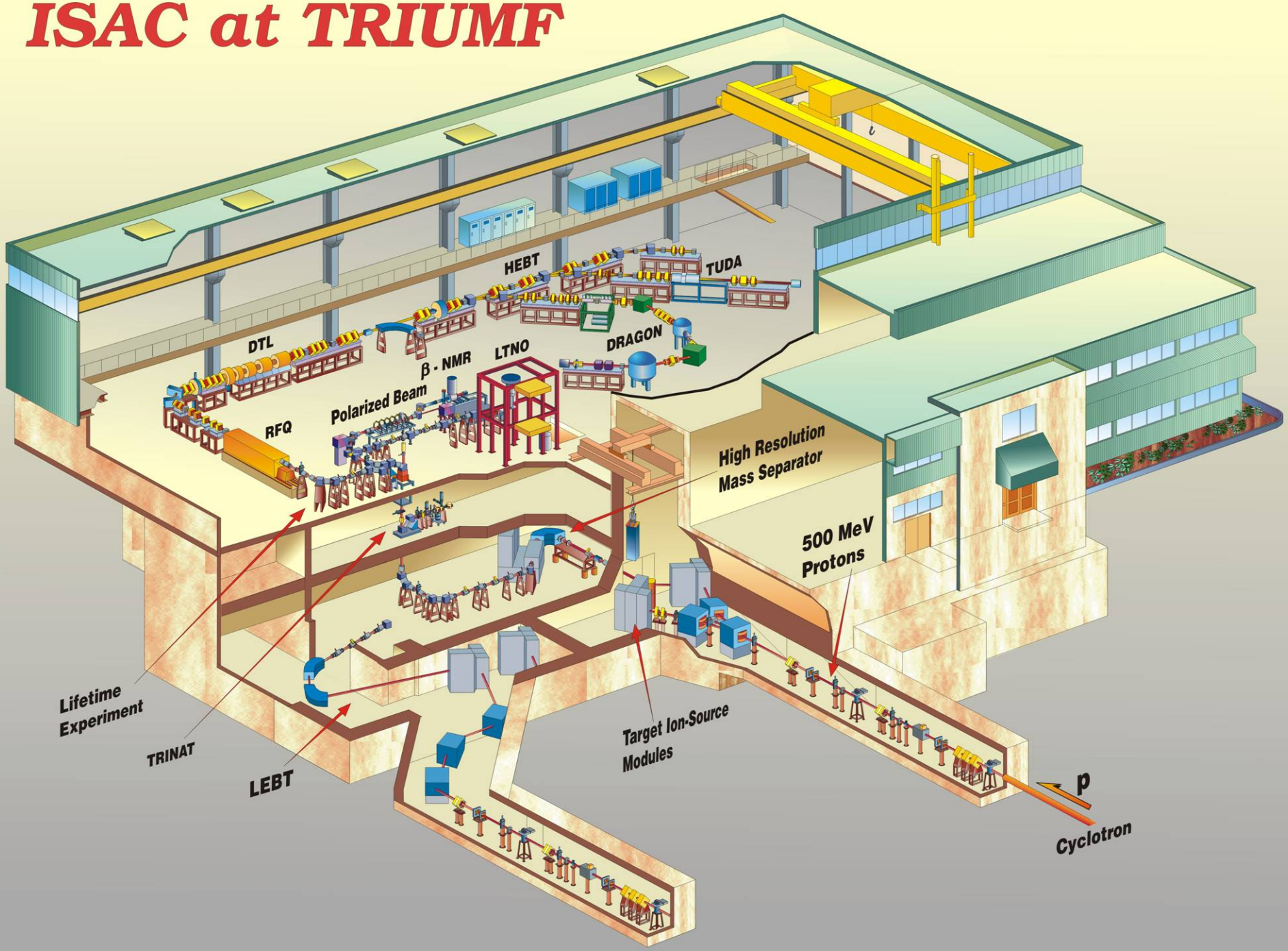
- OPERATE ISAC I & II
- DEVELOP NEW TARGETS, BEAMS & ION SOURCES
- COMPLETE ISAC II
  - ♦ ACHIEVE DESIGN SPECIFICATIONS
    - Medium Beta Section Completed by end of 2005
      - ∗ 4.3 MeV/u (Initial Experiments Begin)
    - CSB Commission early in 2006
      - ∗ Extends Mass Range for Isotopes with q/a = 1/7
    - High Beta Section Completed in late 2007
      - ∗ 6.5 Mev/u (3 Operating Experimental Stations & Beam Lines)
    - Low Beta & DTL2 Completed in late 2009
      - ∗ CSB only required to provide q/a = 1/30 for difficult isotopes
      - ∗ Provides full Mass Range & Multiple Charge Acceleration
- 2nd DRIVER BEAM & TARGET STATIONS
  - ♦ INSTALL TARGET/ION SOURCE DEVELOPMENT STATION
  - ♦ PERMITS FUTURE MULTIPLE SIMULTANEOUS EXOTIC BEAMS
- MULTIPLE SEPARATOR STATION CAPABILITY
  - ♦ SEPARATED RIBs TO MULTIPLE SIMULTANEOUS EXPERIMENTS
- ALLOW FOR FUTURE DOUBLE ACCELERATOR CHAIN

High Power Target Development

- Beam line 4 Extraction Front End Upgraded for 200 μA Operation
- New Underground Beam line to ISAC.
- ISAC Target Hall Extended to North
  1. High Power Target Station
     - Target Development
     - Mass Separator & Yield Station
  2. High Power Beam Dump
     - Used for tuning Cyclotron for High Current Operation



ISAC at TRIUMF



ISAC Beyond 2010?