New Achievements at TRIUMF and Future Plans

P. W. Schmor & Accelerator TEAM
ISAC/TRIUMF

Cyclotrons 2007

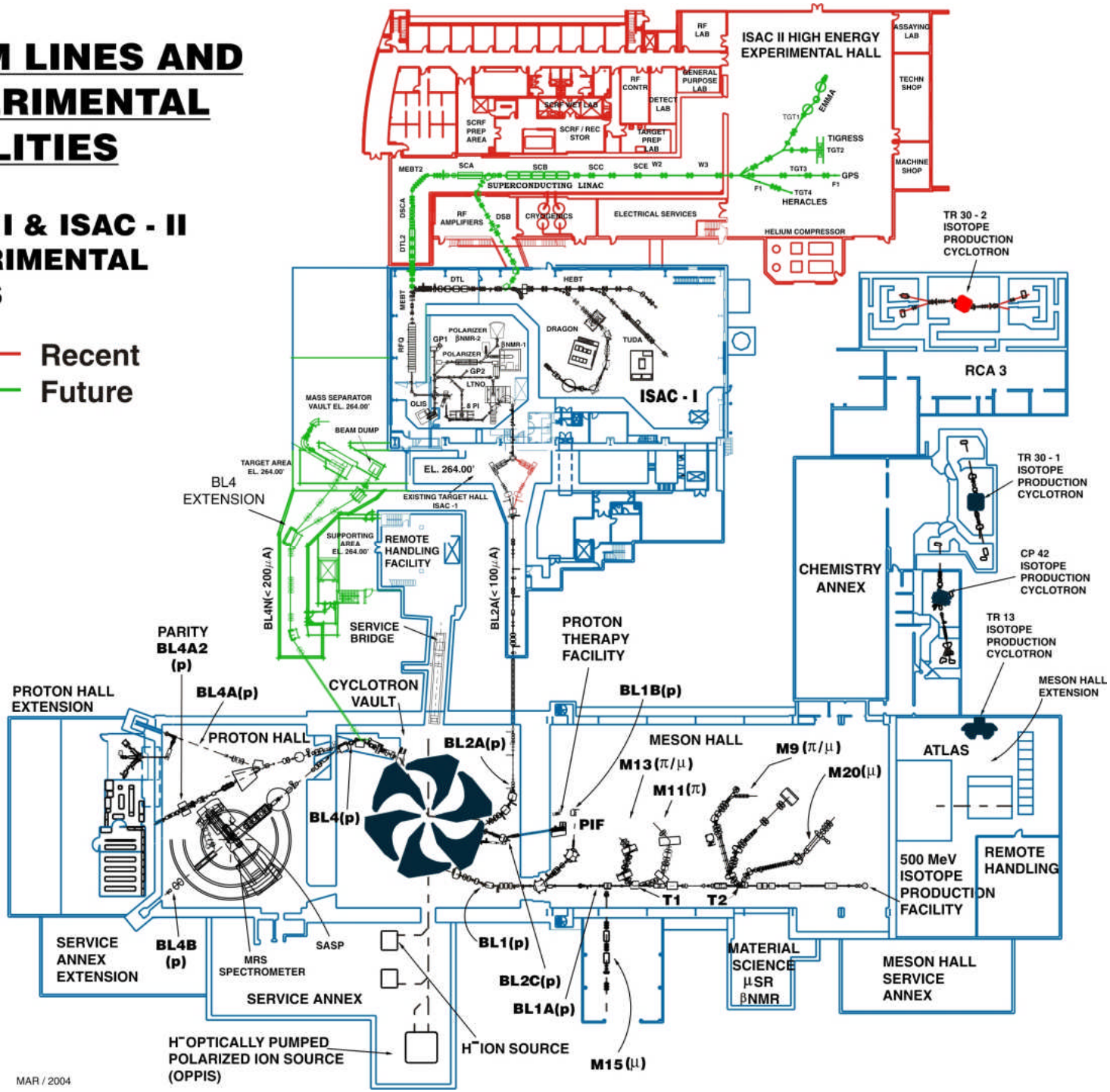

TRIUMF
ISAC
CYCLOTRON

BEAM LINES AND EXPERIMENTAL FACILITIES

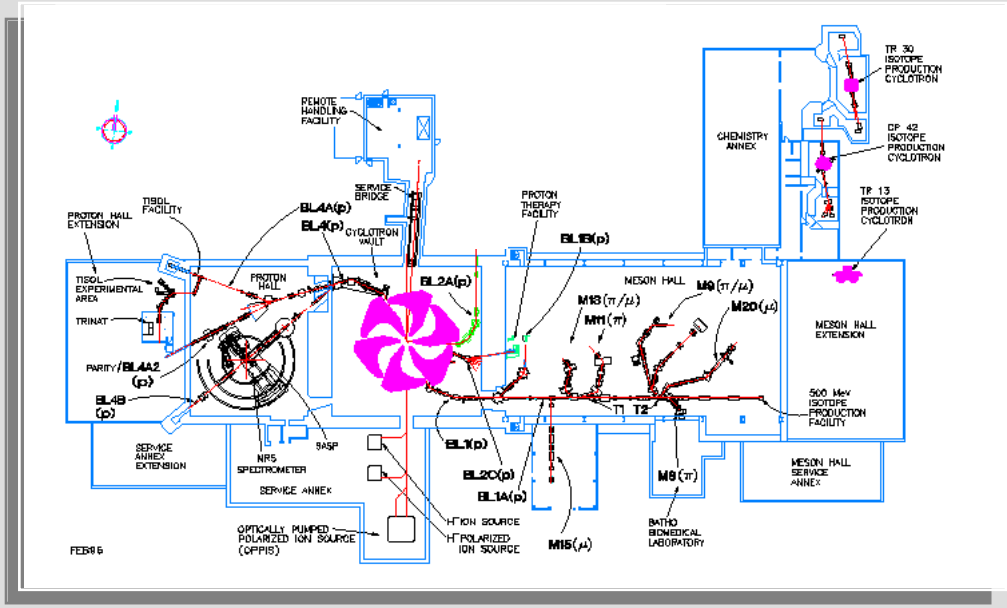
ISAC - I & ISAC - II EXPERIMENTAL HALLS

Recent

Future



MAR / 2004



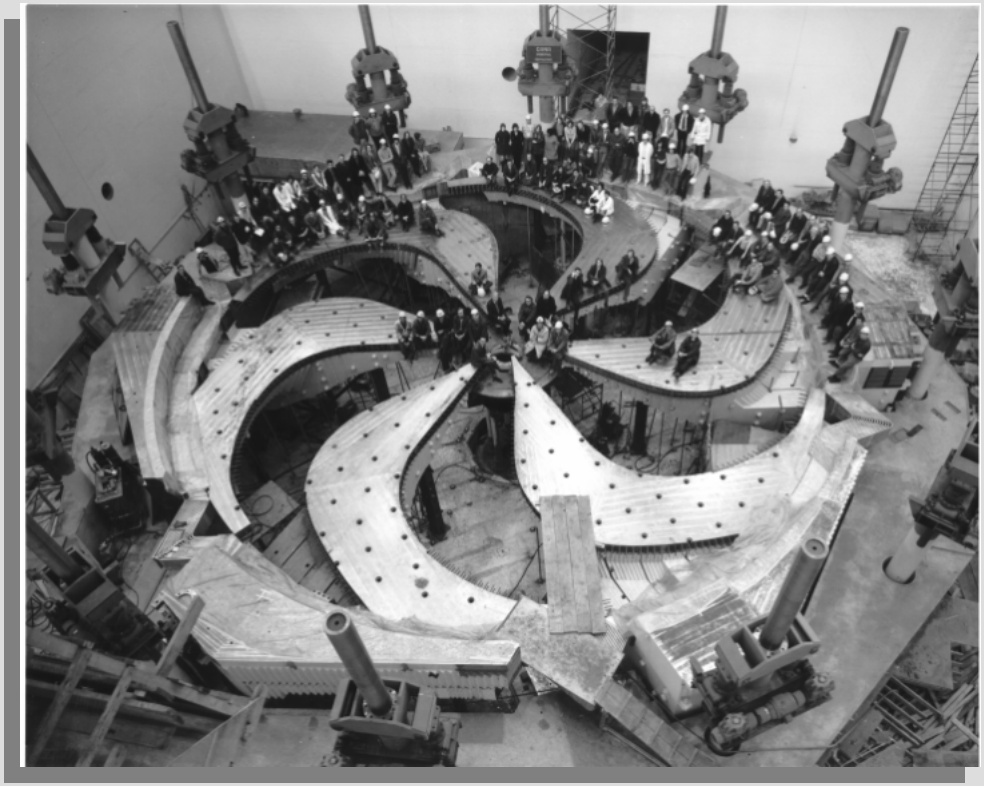
TRIUMF Driver

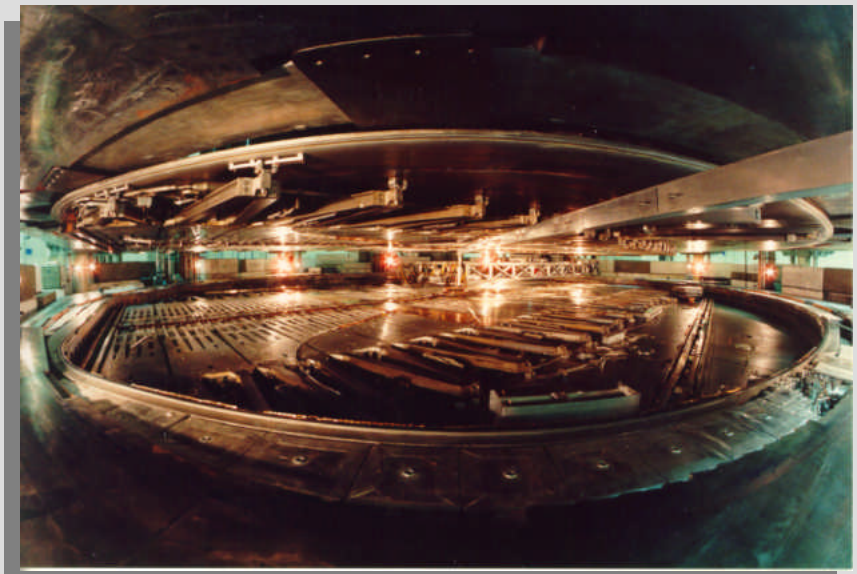
500 MeV H- Cyclotron

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

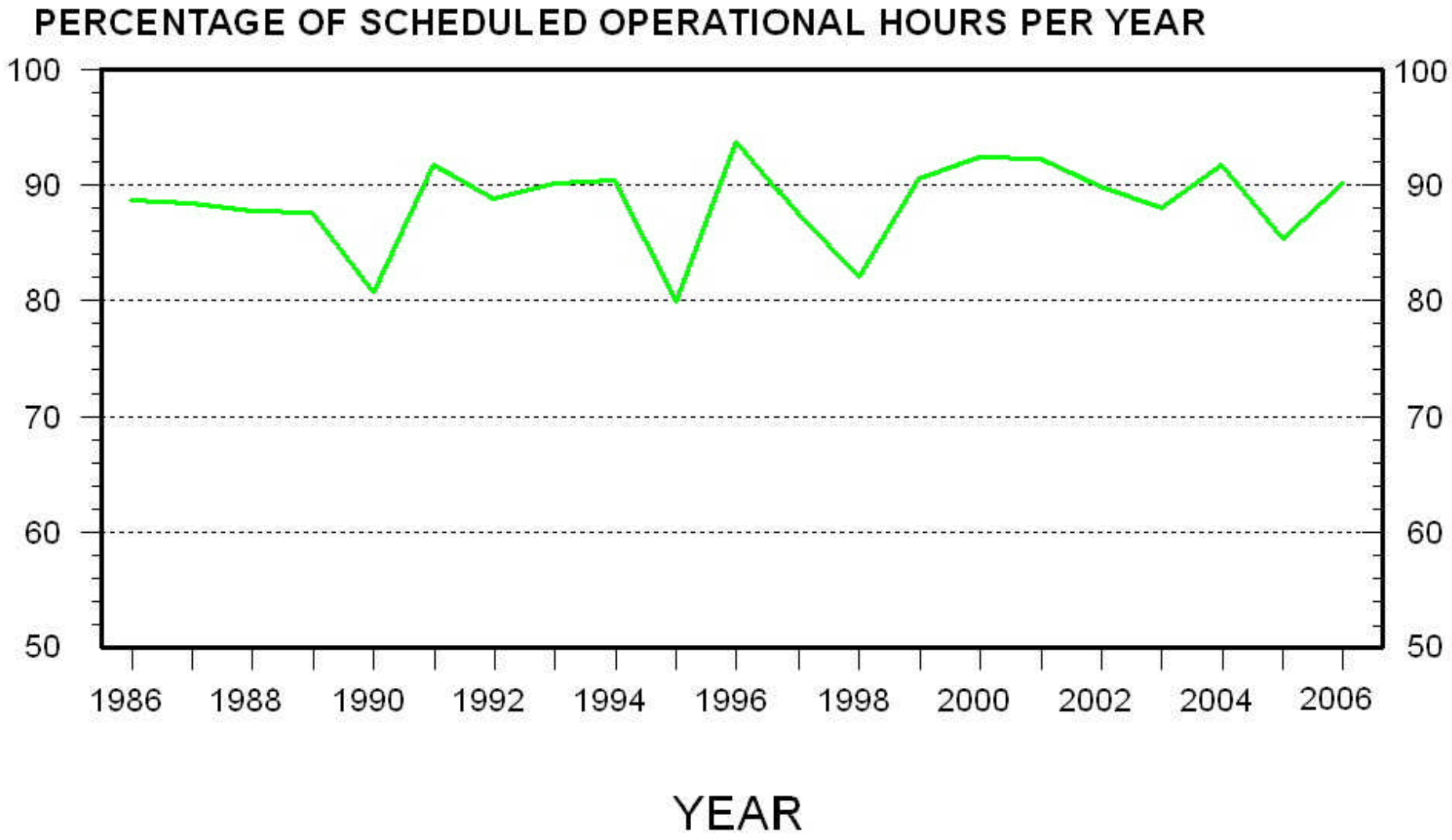
Routinely Accelerates 275 μA

Capable of 400 μA

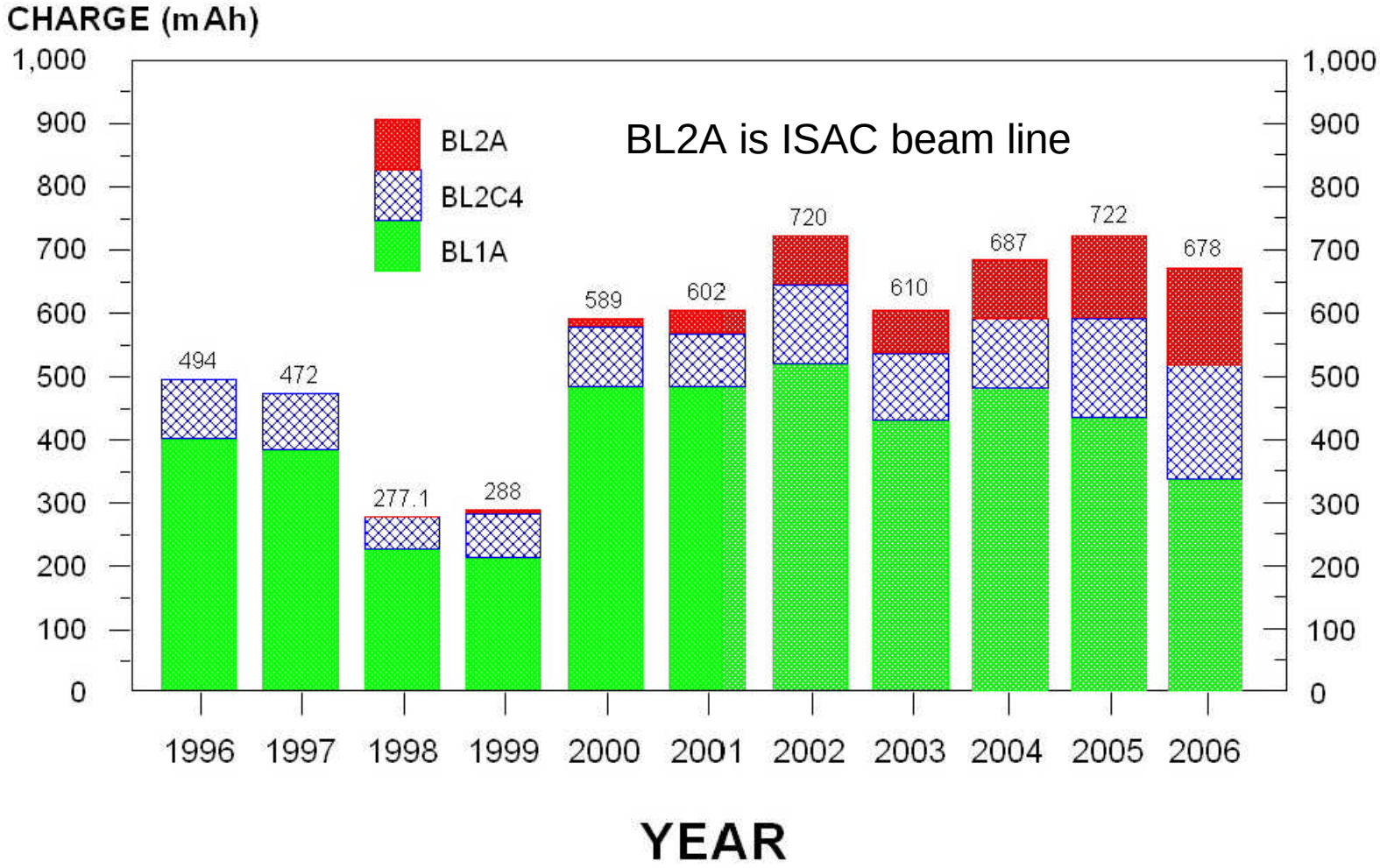


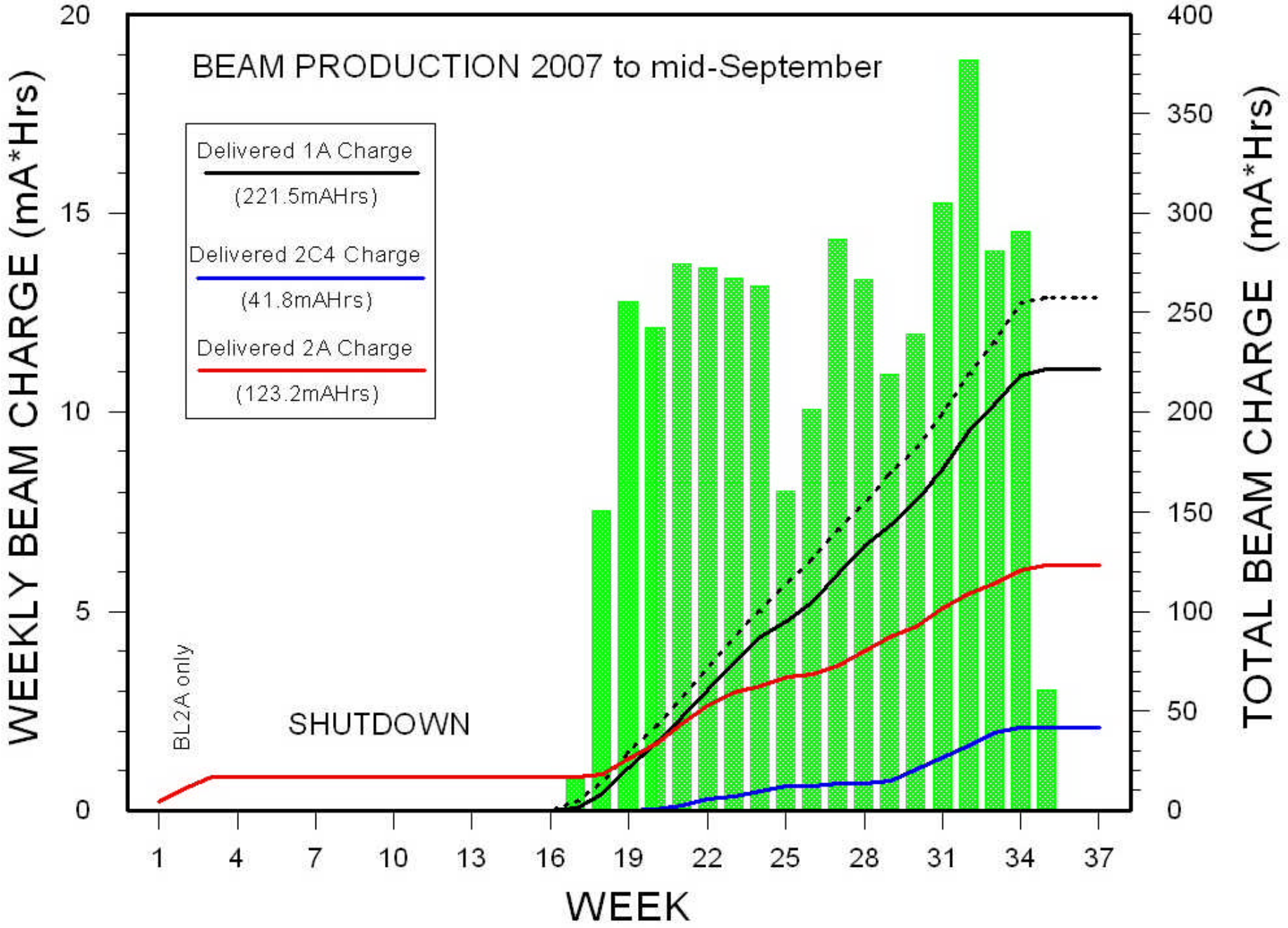


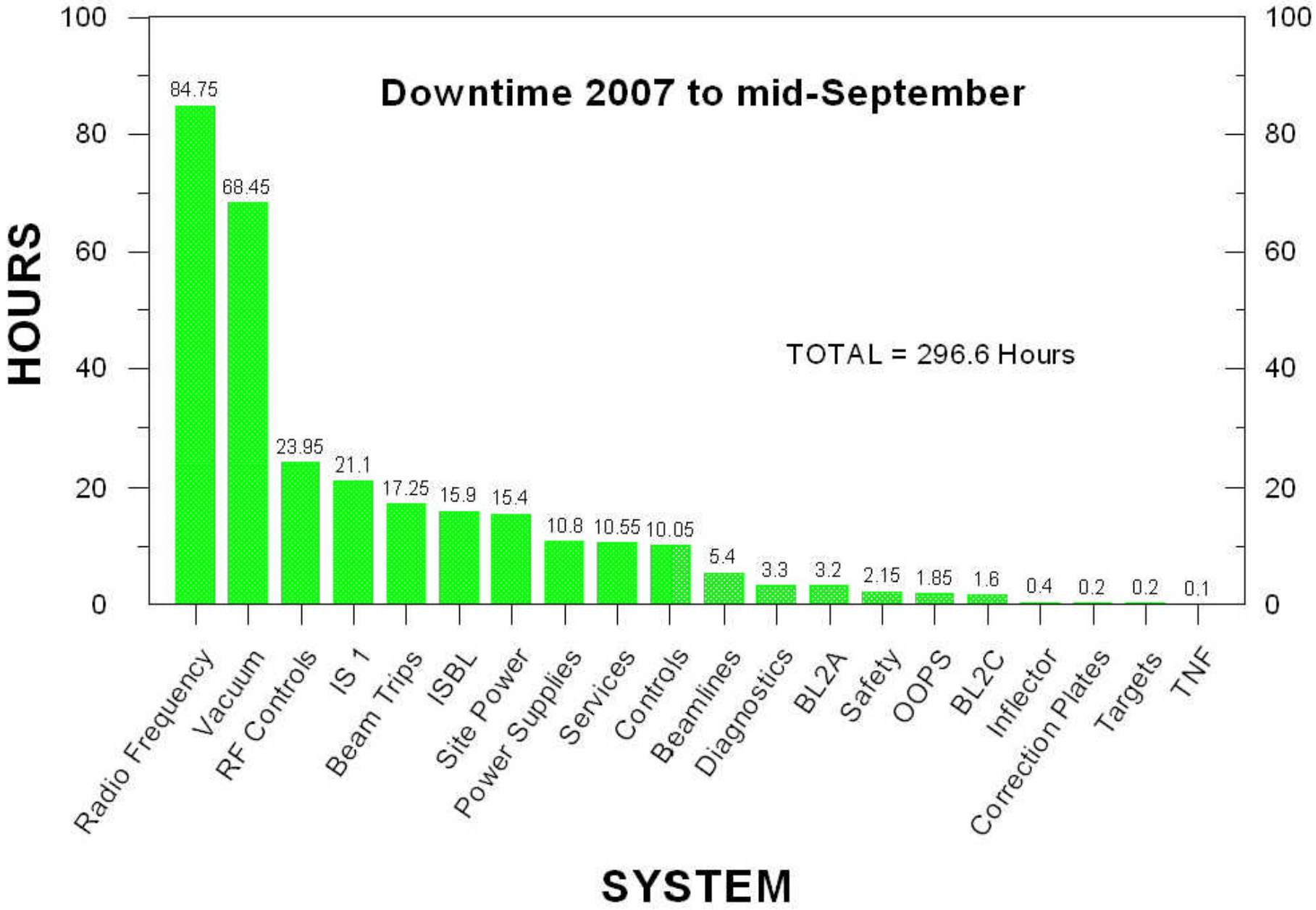
CYCLOTRON AVAILABILITY



ANNUAL TOTAL CHARGE DELIVERY



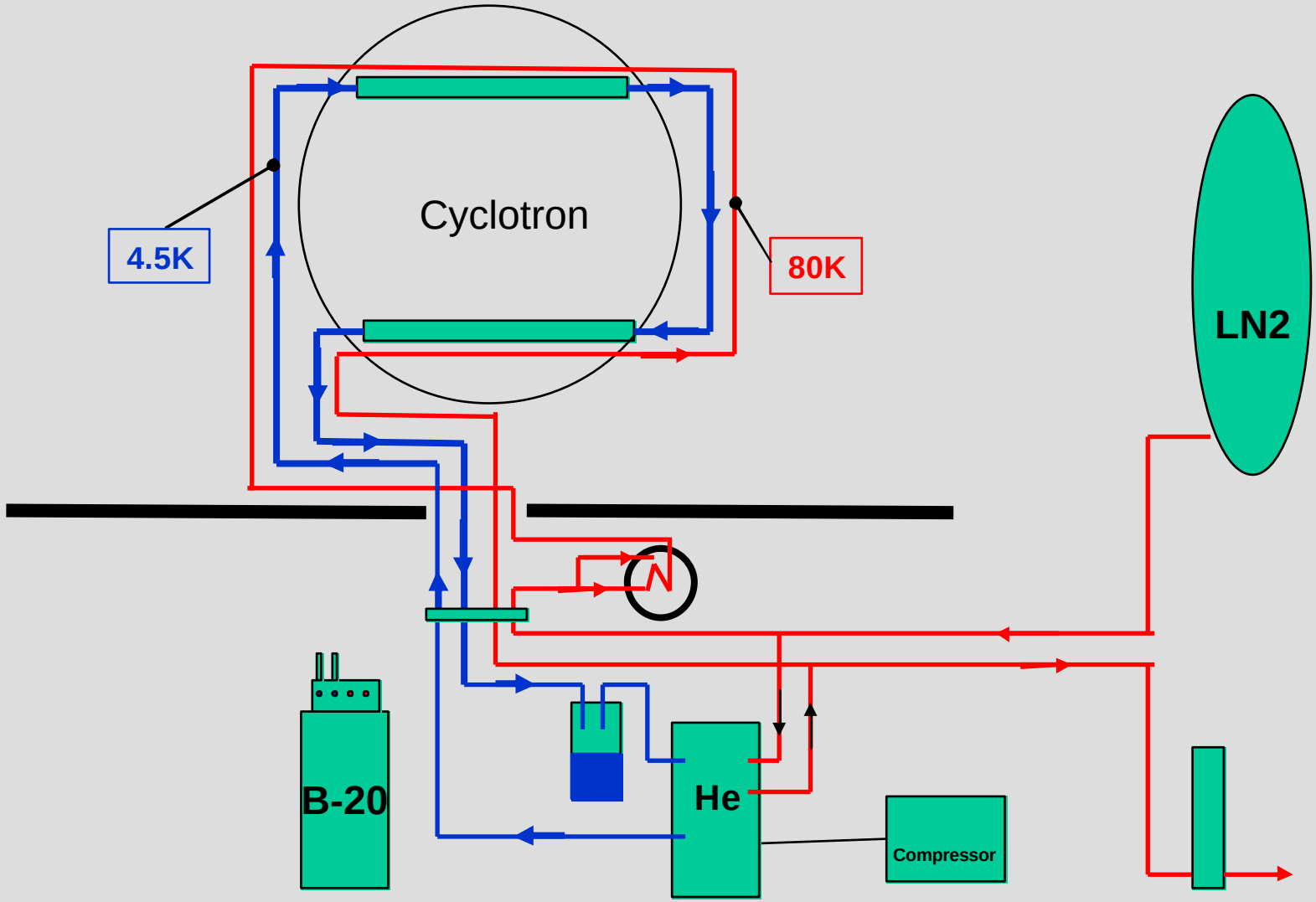

BEAM PRODUCTION 2007 to mid-September
Delivered 1A Charge
(221.5mAHrs)
Delivered 2C4 Charge
(41.8mAHrs)
Delivered 2A Charge
(123.2mAHrs)
BL2A only
SHUTDOWN
WEEKLY BEAM CHARGE (mA*Hrs)
TOTAL BEAM CHARGE (mA*Hrs)
WEEK
0
5
10
15
20
0
50
100
150
200
250
300
350
400
1
4
7
10
13
16
19
22
25
28
31
34
37


Downtime 2007 to mid-September
HOURS
SYSTEM
TOTAL = 296.6 Hours
0
20
40
60
80
100
84.75
68.45
23.95
21.1
17.25
15.9
15.4
10.8
10.55
10.05
5.4
3.3
3.2
2.15
1.85
1.6
0.4
0.2
0.2
0.1
Radio Frequency
Vacuum
RF Controls
IS 1
Beam Trips
ISBL
Site Power
Power Supplies
Services
Controls
Beamlines
Diagnostics
BL2A
Safety
OOPS
BL2C
Inflector
Correction Plates
Targets
TNF

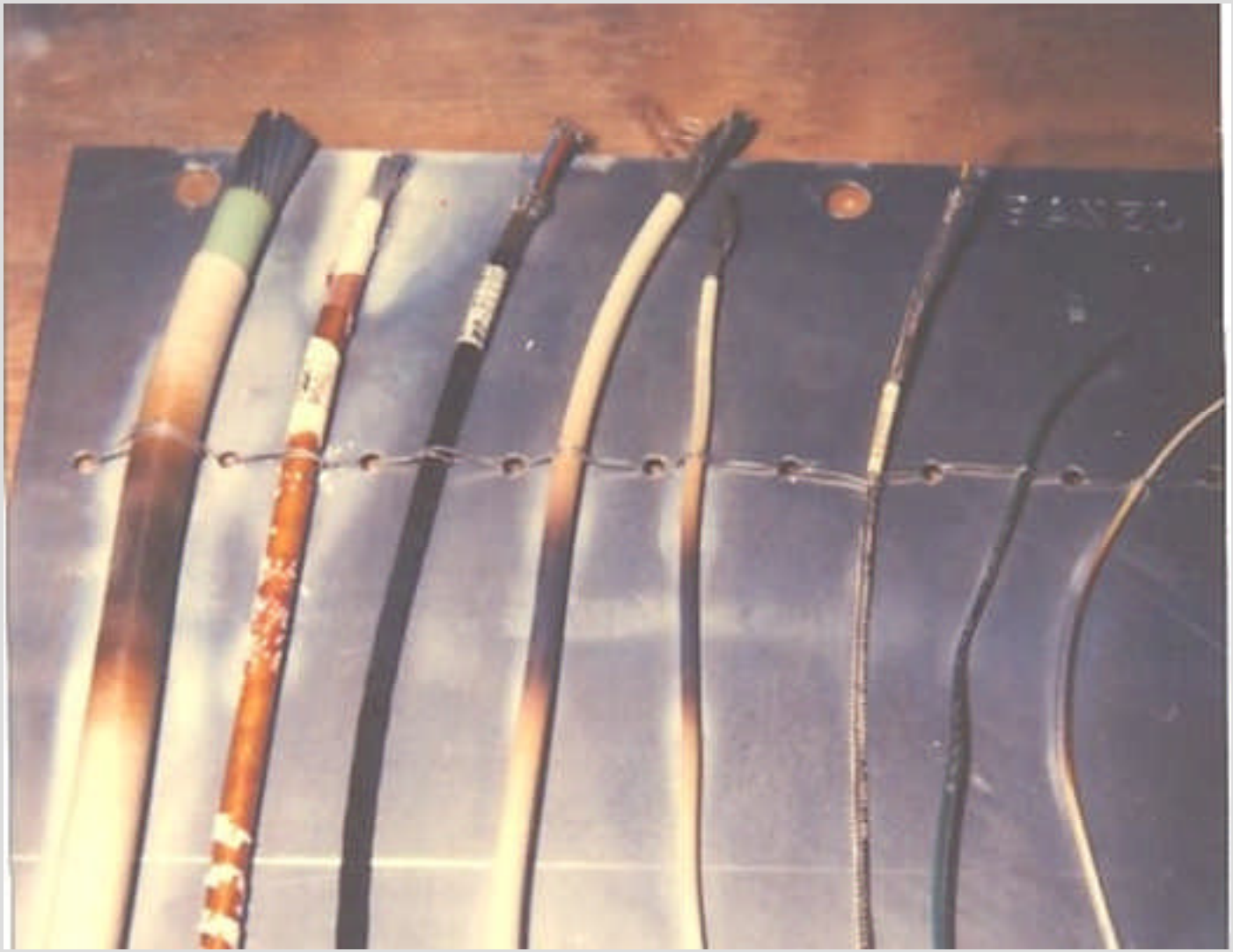
TRIUMF Upgrades/Refurbishment [MOPPRA05]

- CYCLOTRON
  - RF Systems (to reduce yearly down time)
  - Vacuum (to reduce yearly down time, improve vacuum & reduce residual radiation with increased current)
  - Solid Target Facility (to improve servicing & power handling capability)
  - Cabling (replace radiation damaged cables)
  - Ion Source & Injection System (Enhance high current ability)
  - Beam Improvements (Meet ISAC requirements of quality & stability)
- ISAC
  - Rotating proton beam on target
  - High Beta completion & experimental installation

4.5K and 80K Plumbing, Rev. 1

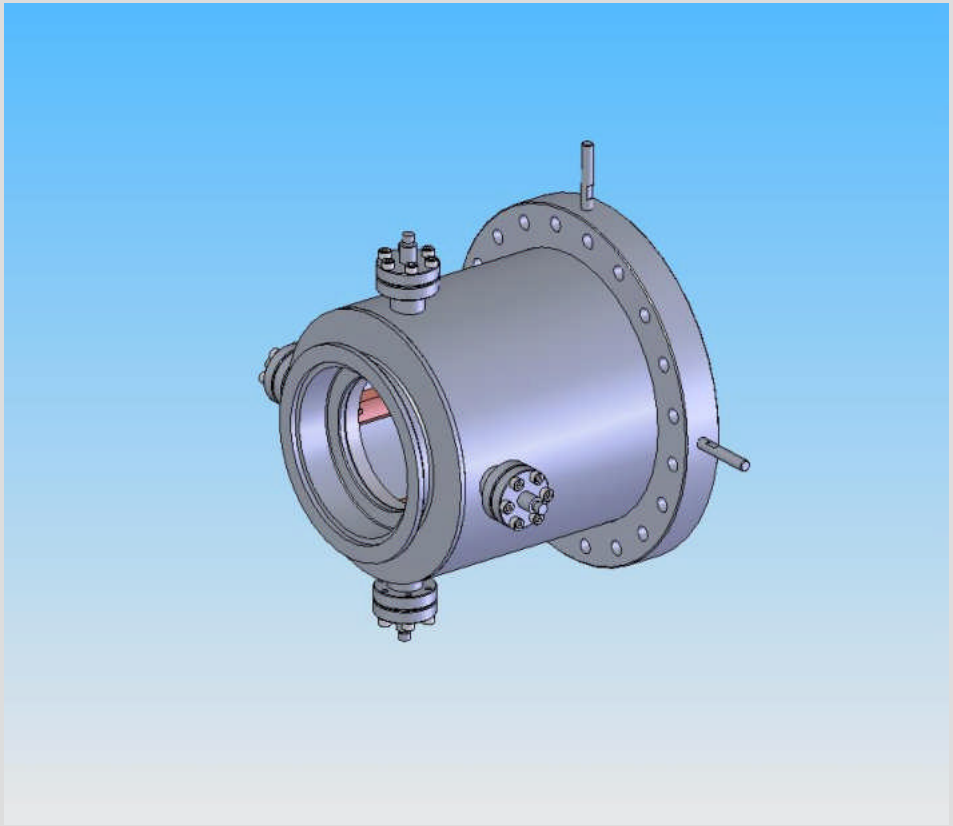


Many Vault Cables have Radiation damage & replacements must be carried out without moving other damaged cables



Cable Tray System for Cyclotron Re-cabling Project

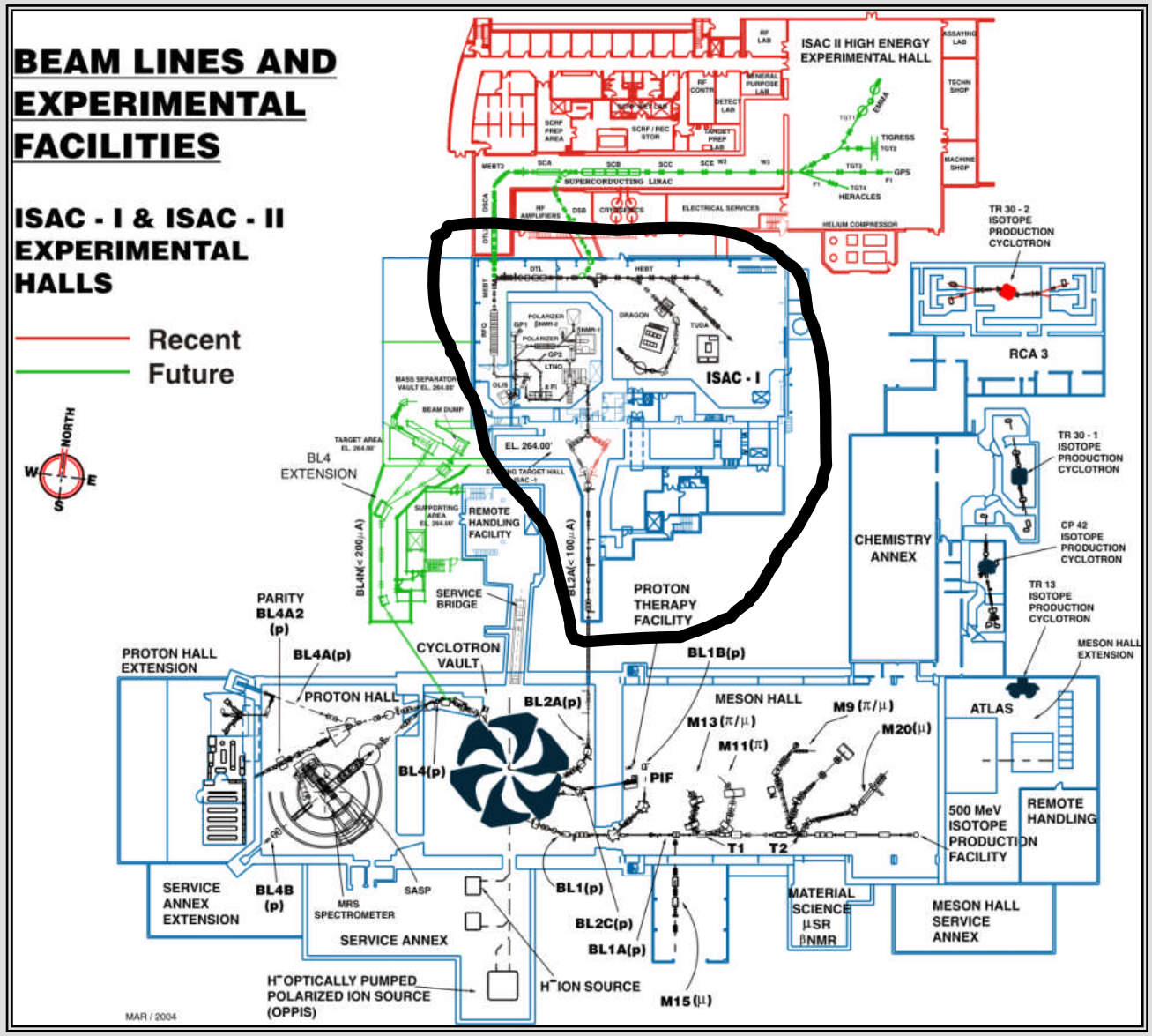
Inductive Beam Position Monitor [WEPPRB17]



- Proton current instabilities at the ISAC targets is magnified in observed isotope flux and is both a tuning & experimental rate concern
- This monitor is to achieve better control of beam size, position, and current on ISAC targets.
- Inductive loop beam position monitor. The monitor is built for high current operation. It is a non-intercepting device capable of measuring beam position with a 0.1mm relative resolution and 0.5mm absolute accuracy. It will be used for continuous monitoring of the high current beam profile and current. It is intended to be used for beam position feedback to ensure beam position stability on ISAC Targets.

ISAC Accelerators

ISAC I


BEAM LINES AND EXPERIMENTAL FACILITIES
ISAC - I & ISAC - II EXPERIMENTAL HALLS
Recent
Future
NORTH
W
E
S
ISAC II HIGH ENERGY EXPERIMENTAL HALL
SUPERCONDUCTING LINAC
ISAC - I
TR 30 - 2 ISOTOPE PRODUCTION CYCLOTRON
RCA 3
TR 30 - 1 ISOTOPE PRODUCTION CYCLOTRON
CP 42 ISOTOPE PRODUCTION CYCLOTRON
TR 13 ISOTOPE PRODUCTION CYCLOTRON
CHEMISTRY ANNEX
MESON HALL EXTENSION
ATLAS
BL4 EXTENSION
REMOTE HANDLING FACILITY
SERVICE BRIDGE
PROTON THERAPY FACILITY
PARITY BL4A2 (p)
BL4A(p)
PROTON HALL EXTENSION
CYCLOTRON VAULT
PROTON HALL
BL2A(p)
BL1B(p)
MESON HALL
M13(π/μ)
M9(π/μ)
M11(π)
M20(μ)
BL4(p)
PIF
T1
T2
500 MeV ISOTOPE PRODUCTION FACILITY
REMOTE HANDLING
SERVICE ANNEX EXTENSION
BL4B (p)
MRS SPECTROMETER
SASP
SERVICE ANNEX
BL1(p)
BL2C(p)
BL1A(p)
MATERIAL SCIENCE μSR βNMR
MESON HALL SERVICE ANNEX
H⁻ OPTICALLY PUMPED POLARIZED ION SOURCE (OPPIS)
H⁻ ION SOURCE
M15(μ)
MAR / 2004

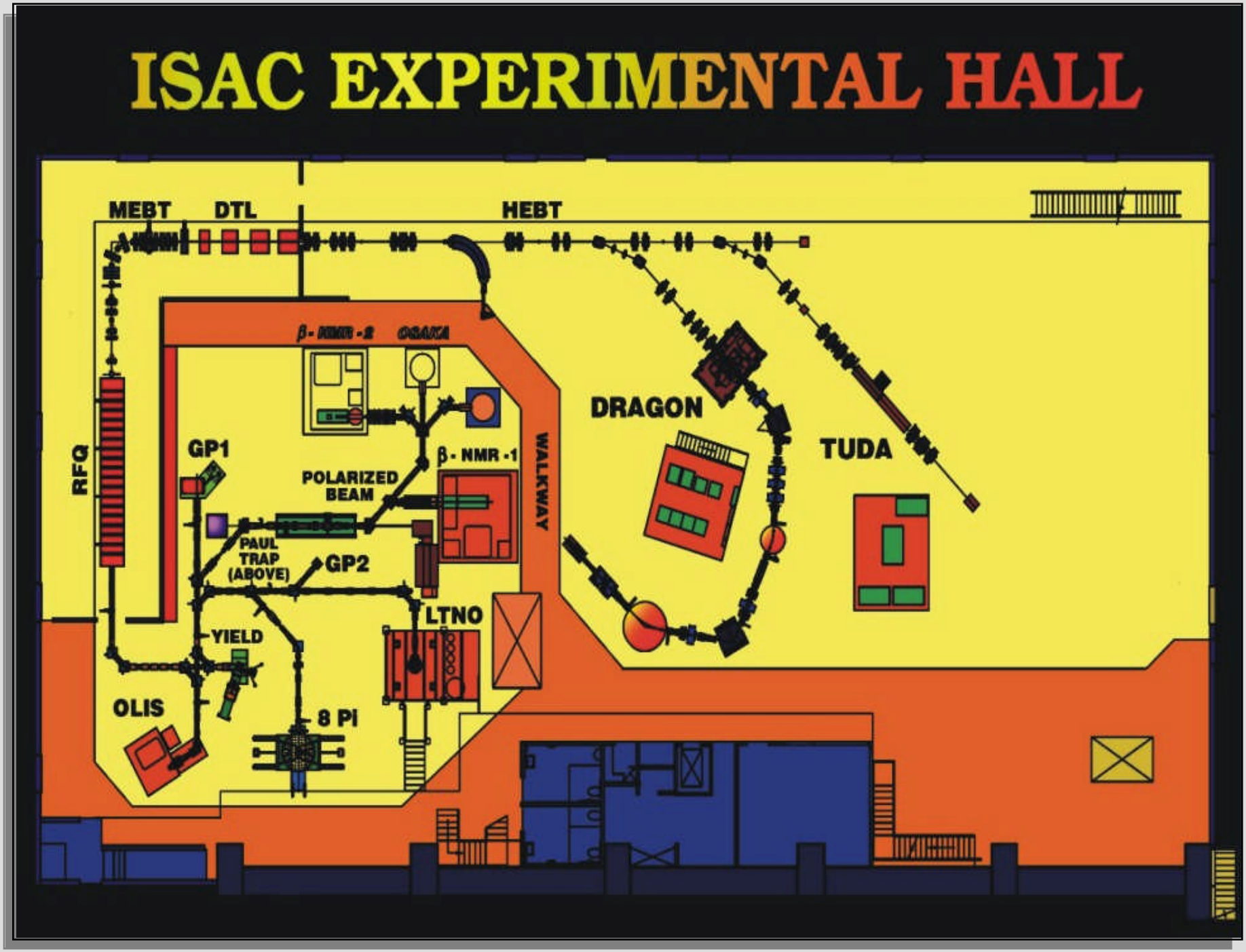
ISAC I & II

- **ISAC** (ISOL + ACCELERATORS)
  - **ISAC-I**
    - Funded in 1995 [1995-2000]
    - Low Energy
      - **E £ 60 keV & A_{max} » 240**
        - First RIB Experiment in November 1998
    - 'High' Energy (Accelerated with RFQ & DTL)
      - **Variable Energy from 0.15 to 1.8 MeV/u for q/A ³ 1/30**
        - First Beam in December 2000
  - **ISAC II**
    - Funded in April 2000 [2000-2005-2010]
      - **Variable Energy from 1.5 to 6.5 MeV/u for A £ 150**
        - First Beam December 2006 (4.3 MeV/u)
  - **Upgrades Proposed for 2010-2015**

ISAC Target & Ion Sources

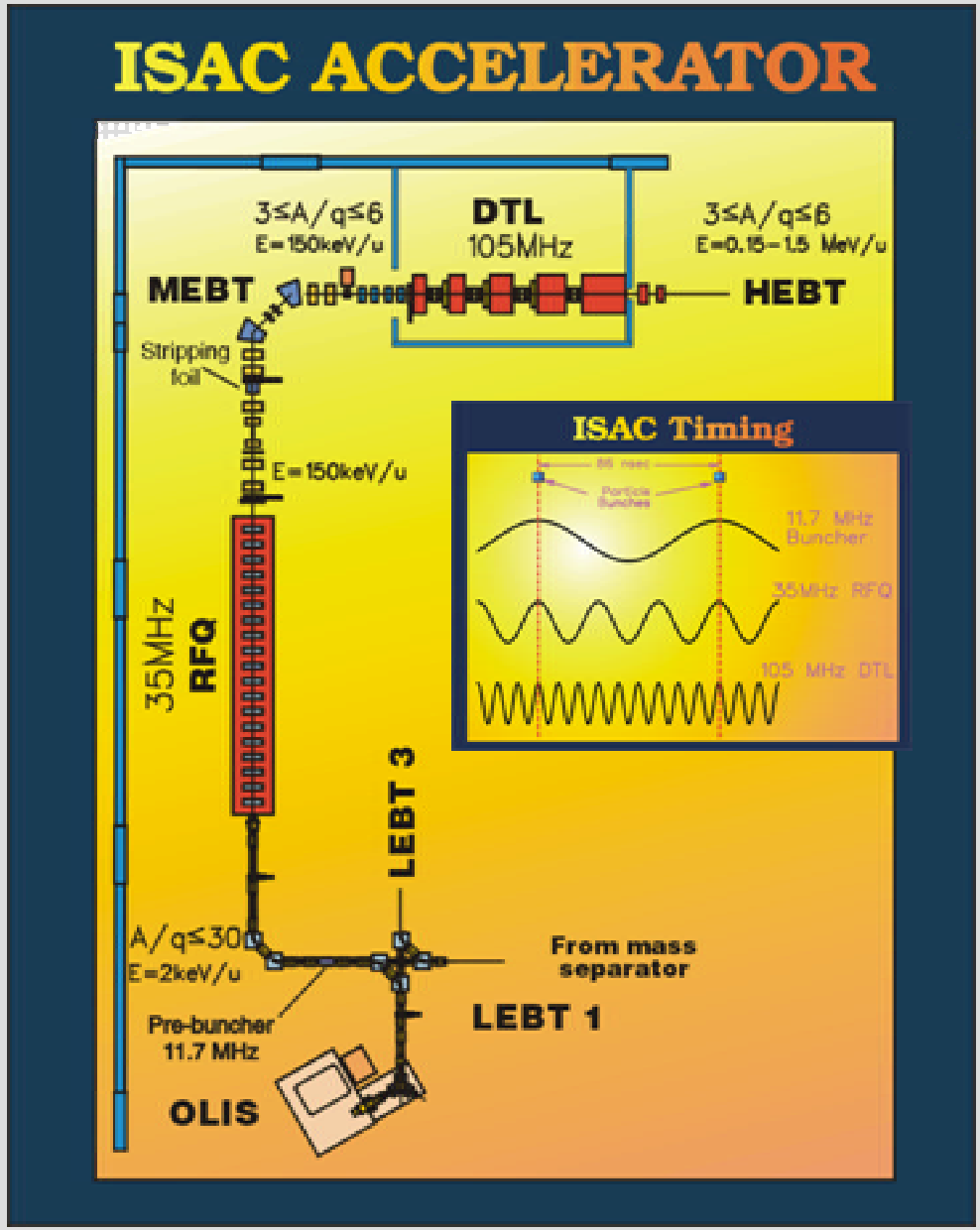
Pierre Bricault

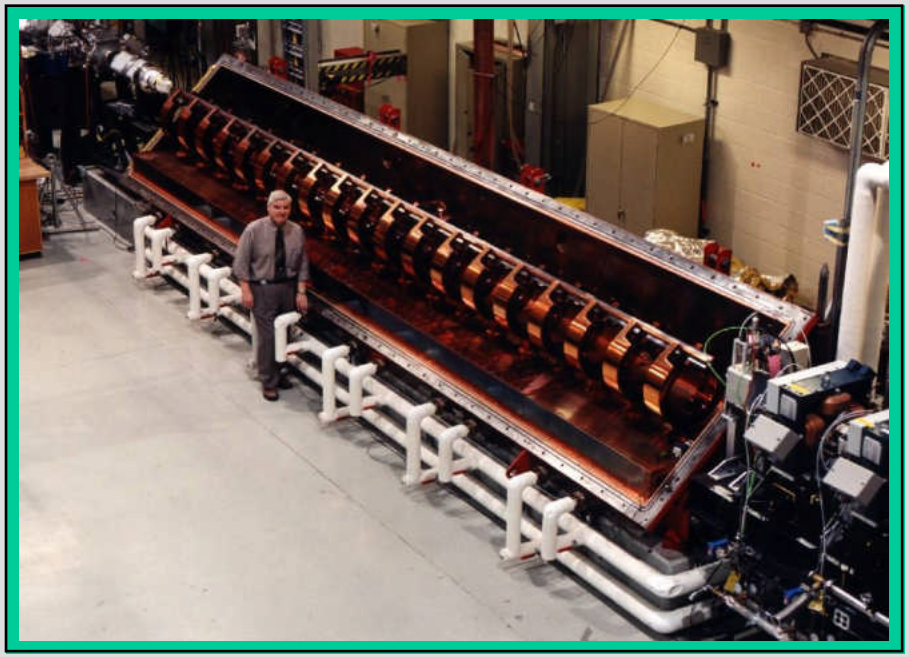
[MOZCR02]


ISAC EXPERIMENTAL HALL
MEBT
DTL
HEBT
β - NMR -2
OSAKA
RFQ
GP1
POLARIZED BEAM
β - NMR -1
WALKWAY
DRAGON
TUDA
PAUL TRAP (ABOVE)
GP2
LTNO
YIELD
OLIS
8 PI

ISAC-I Accelerator

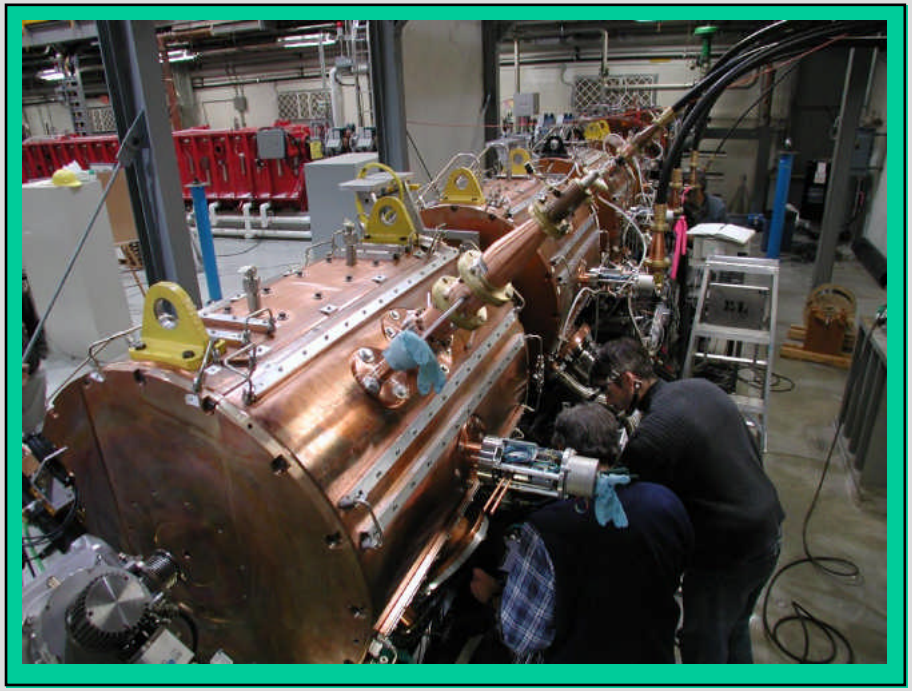
- OLIS
  - Stable beams
- LEBT
  - All-electrostatic (2 keV/u)
  - 11.8 MHz multi-harmonic pre-buncher
- 35 MHz cw RFQ
  - E=2 à 153 keV/u
  - A/q<=30
- MEBT
  - Stripping foil
  - 35 MHz rebuncher
- 105 MHz cw Variable Energy DTL
  - E=0.15-1.8 MeV/u
  - A/Q<=6
- HEBT
  - Diagnostic section
  - 11.8/35 MHz rebunchers





ISAC 35MHz Split-ring RFQ

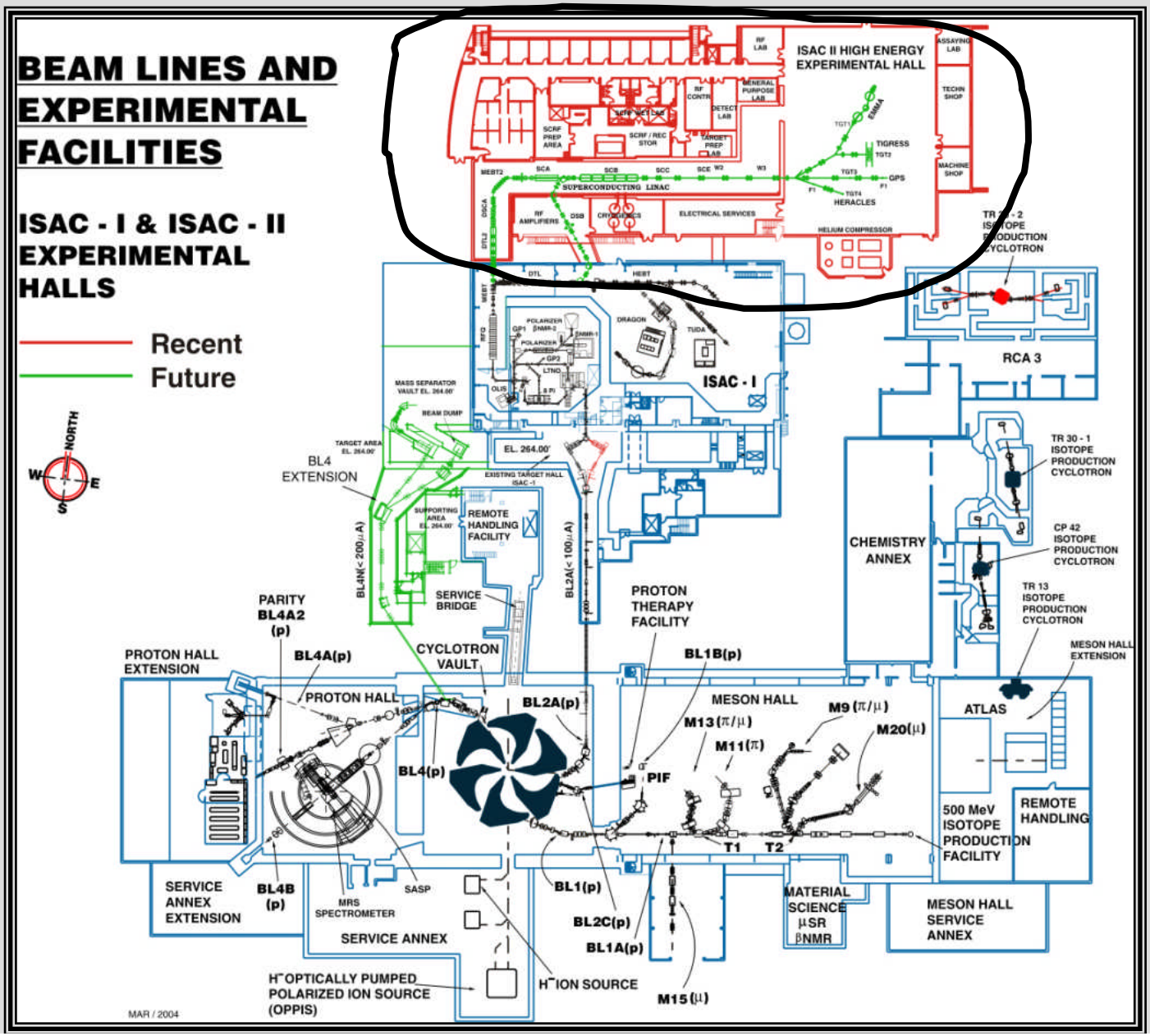
Accelerates ions with A/q<=30 from 2 keV/u to 150 keV/u



ISAC 106MHz Separated Function DTL

Accelerates ions with A/q<=6 to final energies fully variable from 0.15<E<1.8 MeV/u

ISAC II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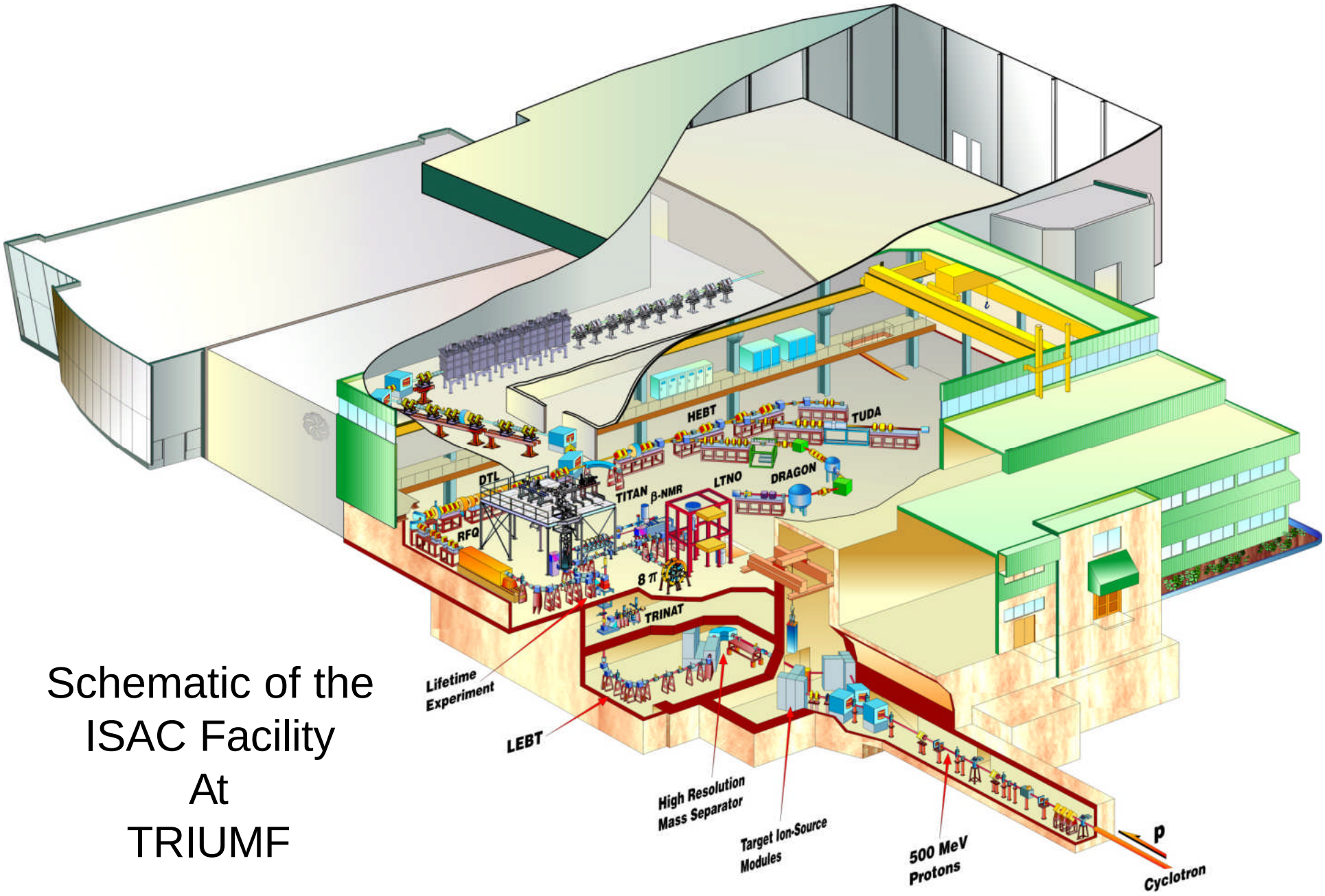
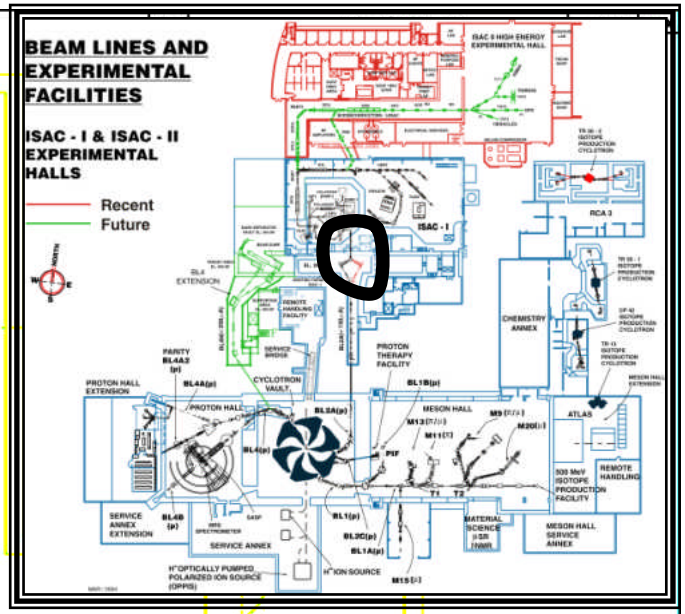
M15(μ)
MAR / 2004

ISAC I ® ISAC II
PHYSICS NEEDS HEAVIER MASSES

- Ion Source
  - Many $1 \leq A \geq 150$ are Ionized but with $q = 1$
- MASS SEPARATOR
  - Selects a Particular 1/A where $A \leq 240$ with energy ≤ 60 keV
- Accelerators
  - RFQ Requires $q/A \geq 1/30$
  - DTL & SC LINAC Requires $q/A \geq 1/6$
- CHARGE STATE BOOSTER (CSB)
  - Required to accelerate masses greater than A = 30
  - Boosts Isotope Charge from 1+ to n+
  - Goal is to efficiently achieve $q/A \approx 1/6$
  - Charge Boosting Time Should be Small Compared to Isotope Lifetime
  - Installation in 2008

Schematic of the
ISAC Facility
At
TRIUMF





Charge State Booster
& Mass Selector Location
In Mass Separator Cave

3	29-93		Preliminary optics corrected	Sa	RB
REV	DATE	LOC	REVISION DESCRIPTION	BY	APP'D

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

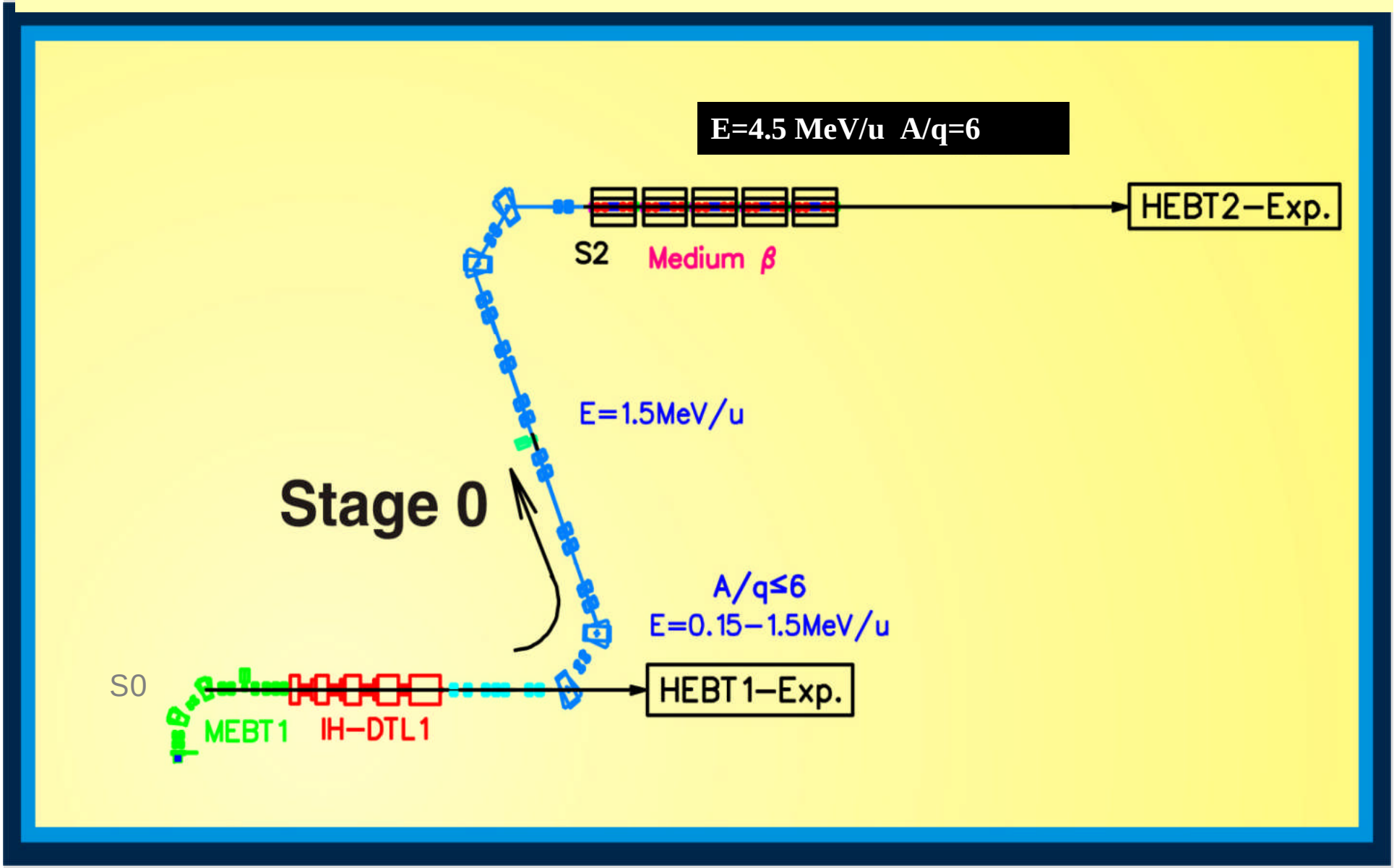
TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS ±
DECIMALS .XX ±
.XXX ±
ANGULAR ±
SURFACE FINISH µm

ALL DIMS IN INCHES

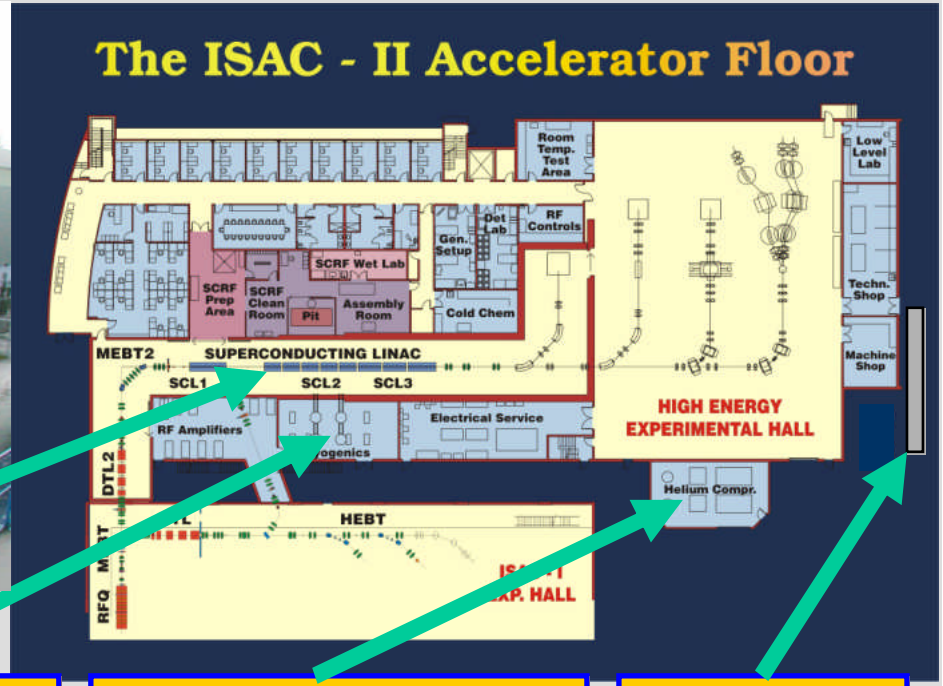
DESIGNED DL-
DRAWN
CHECKED
REF DWGS:

Proposal 3
CSB in Mass-sep hall
ISAC

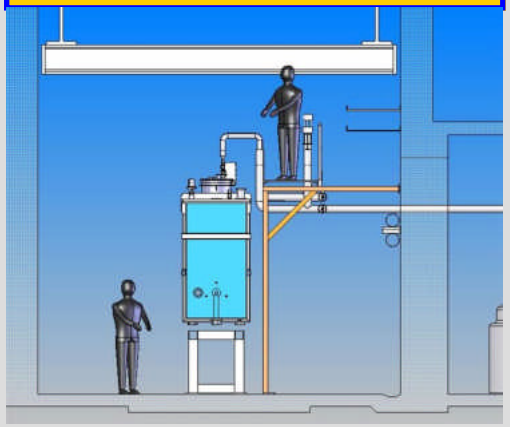
ISAC-II (Phase I - Medium Beta Section)
Commissioned in 2006



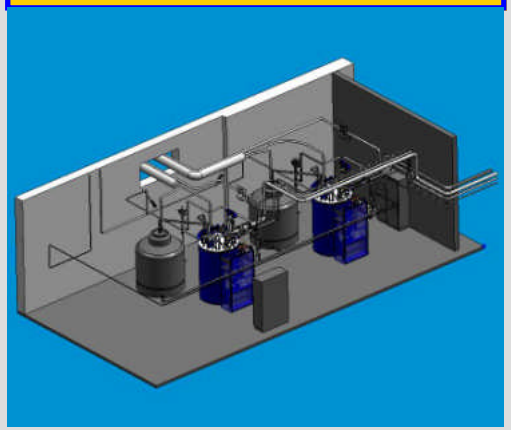
ISAC-II Building



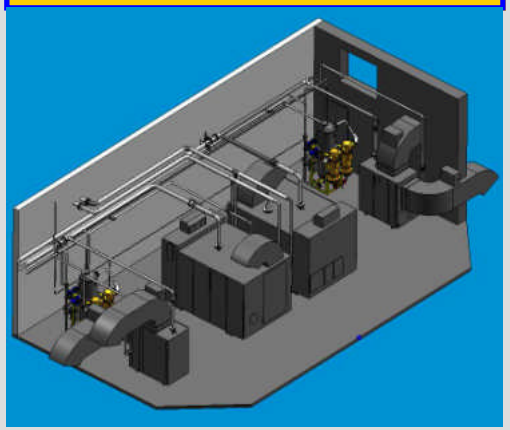
Linac Distribution



Refrigerator Room



Compressor Room



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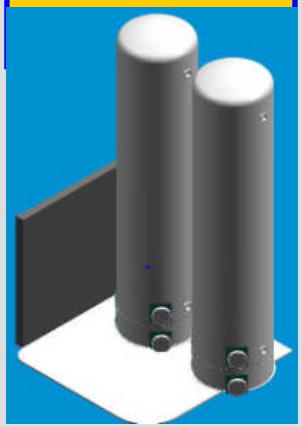
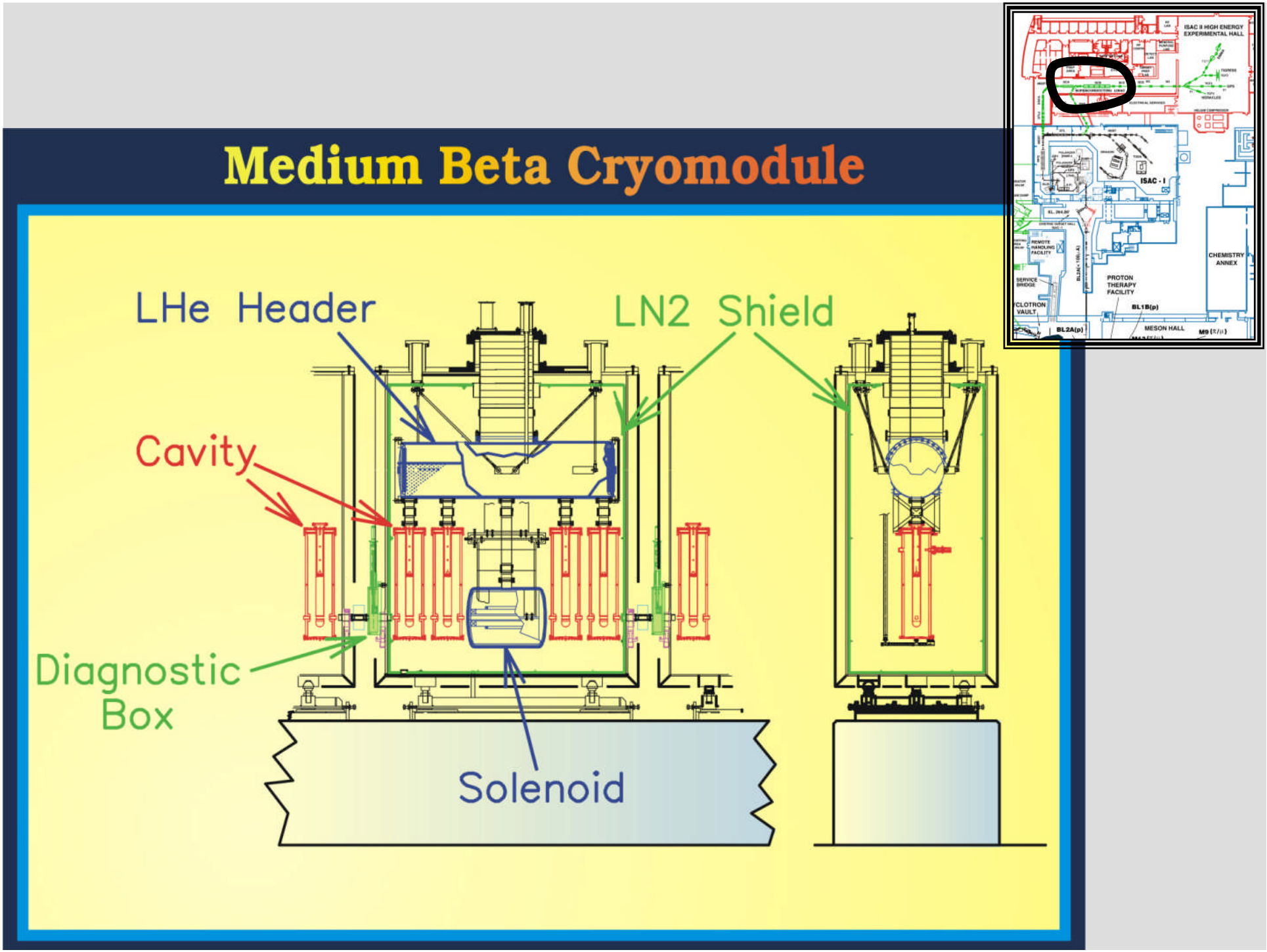
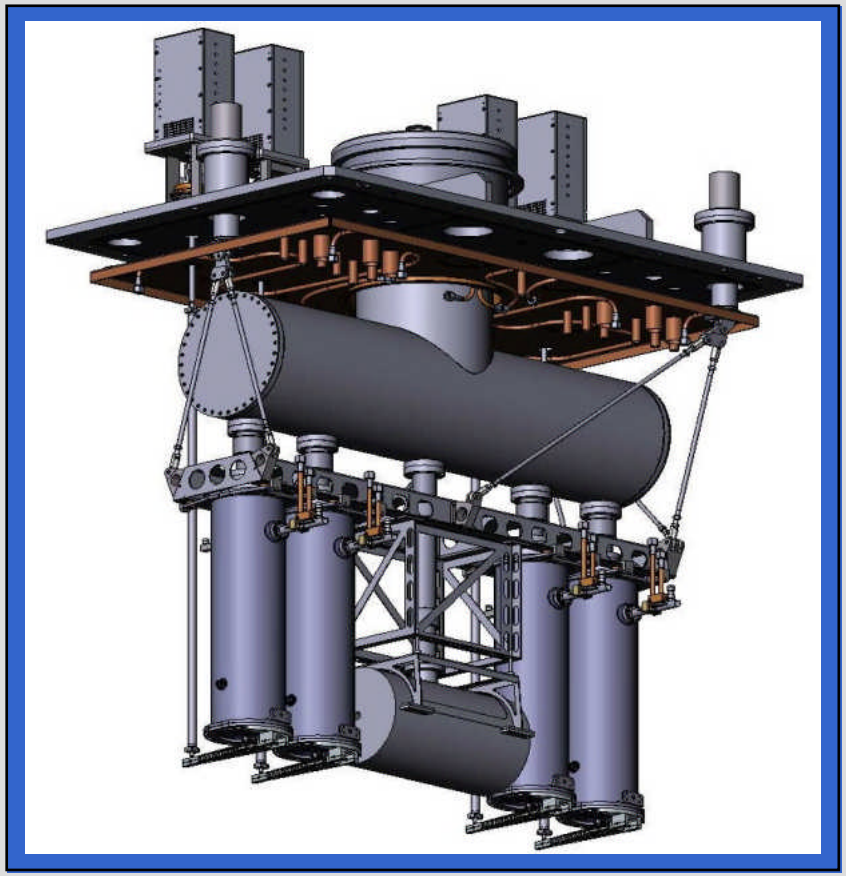
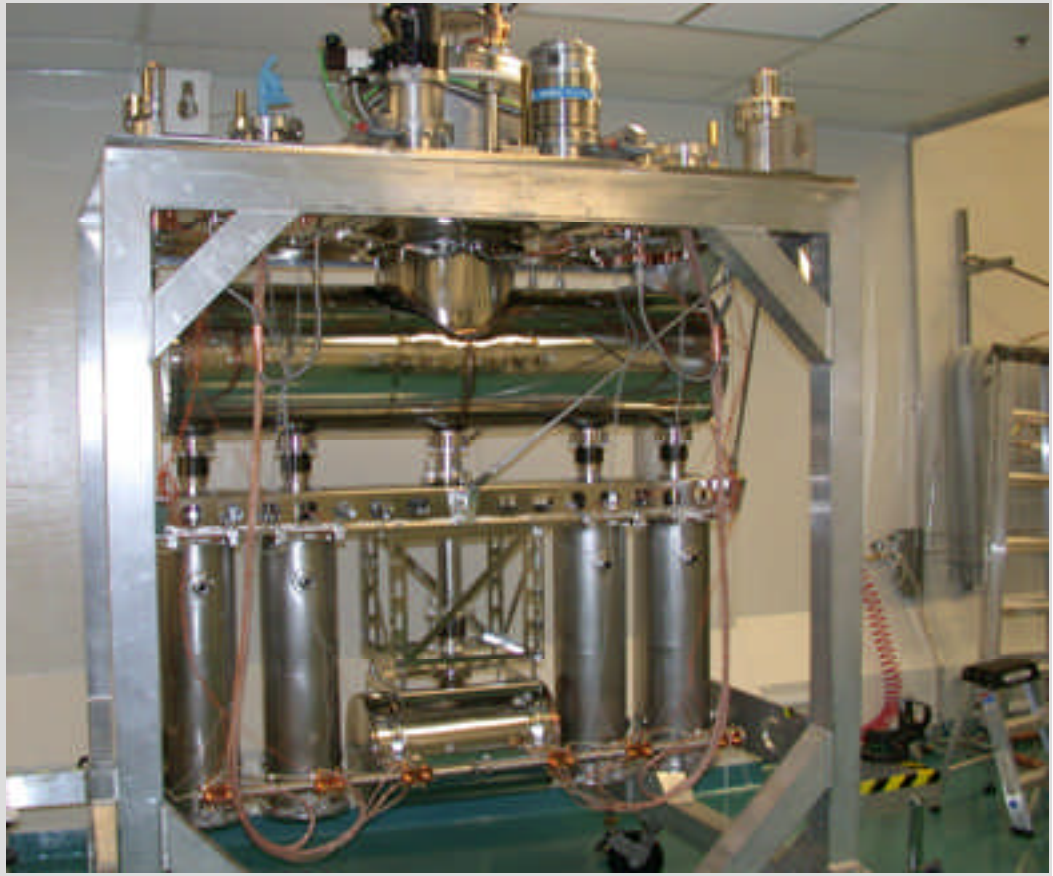


Medium Beta Cryomodule

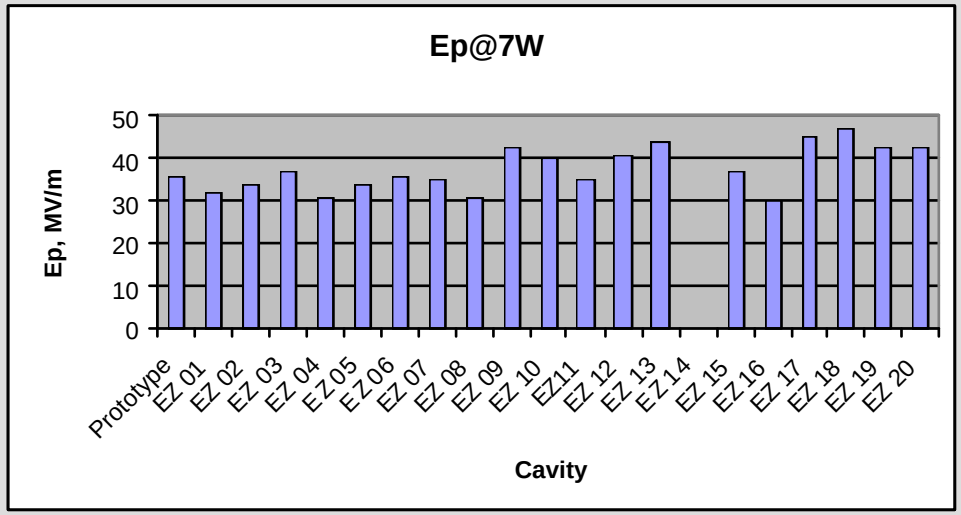


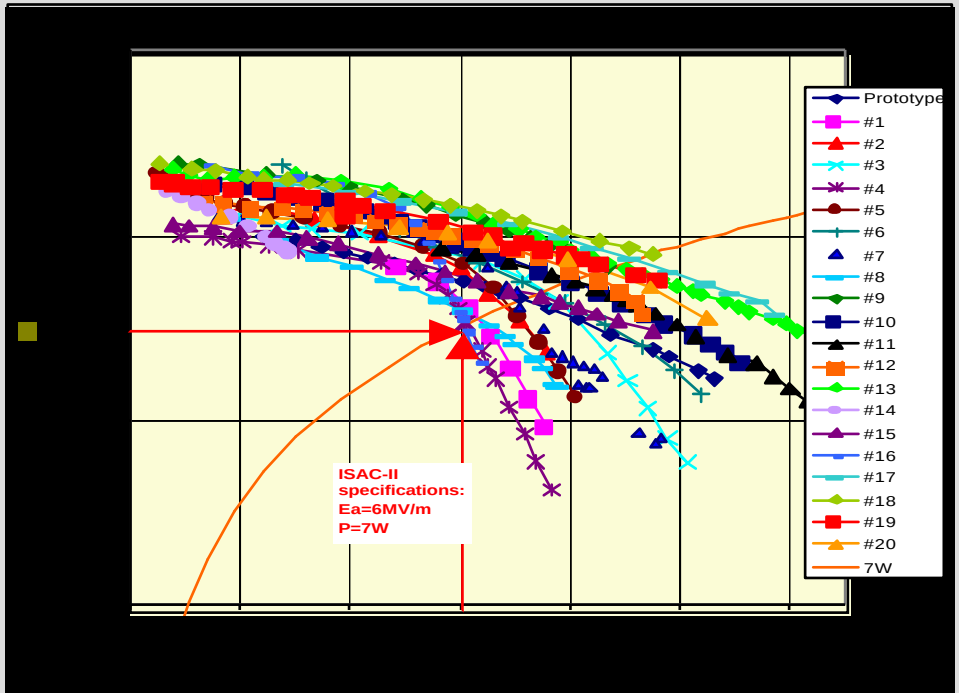
Medium Beta Cryomodules Assembly





Single Cavity Performance Summary





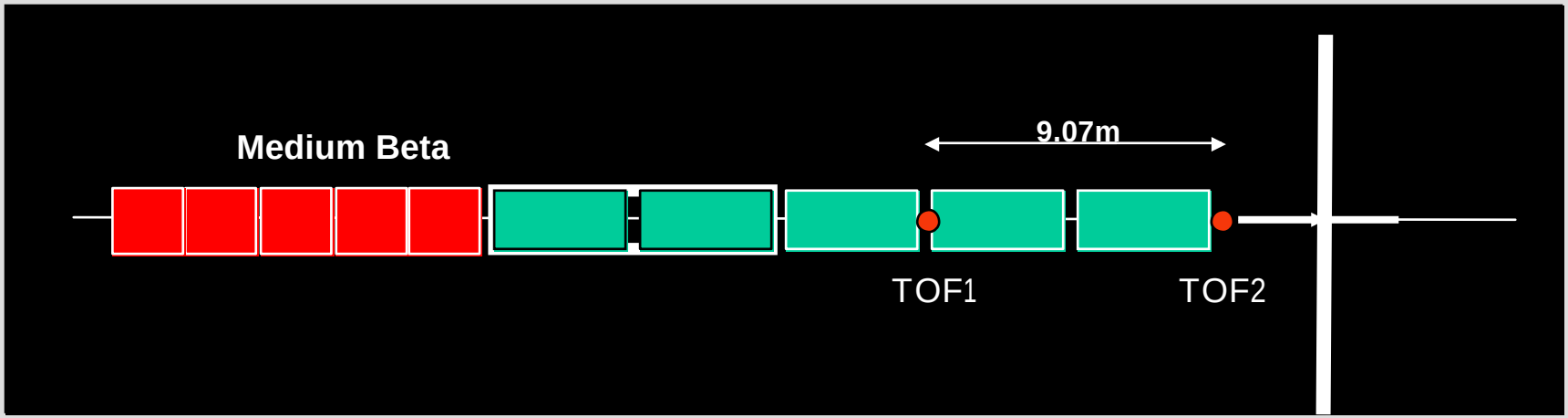
- Cavities tested initially in single cavity cryostat

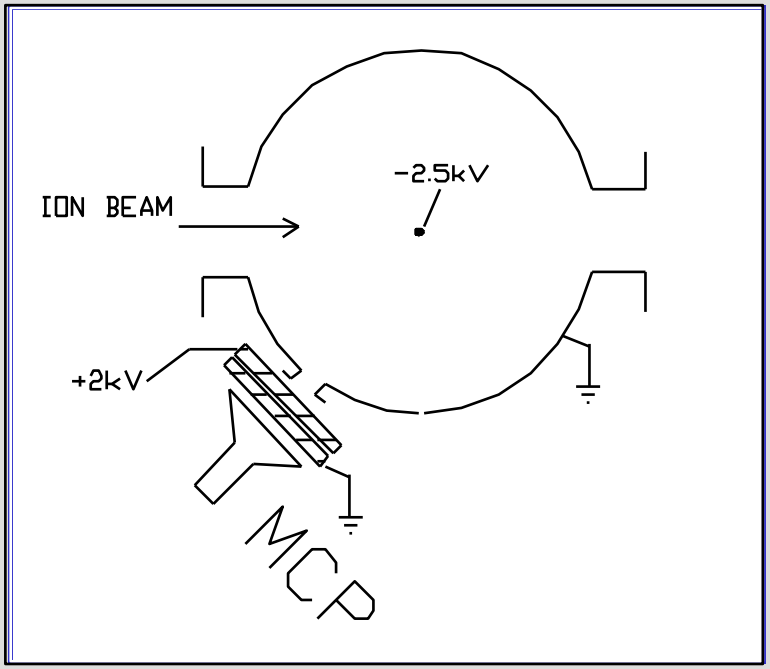
- Average peak surface field at operating power of 7W is now Ep=38MV/m corresponding to a voltage gain of 1.4MV/cavity and a magnetic field of Bp=75mT and a gradient Ea=7.5MV/m

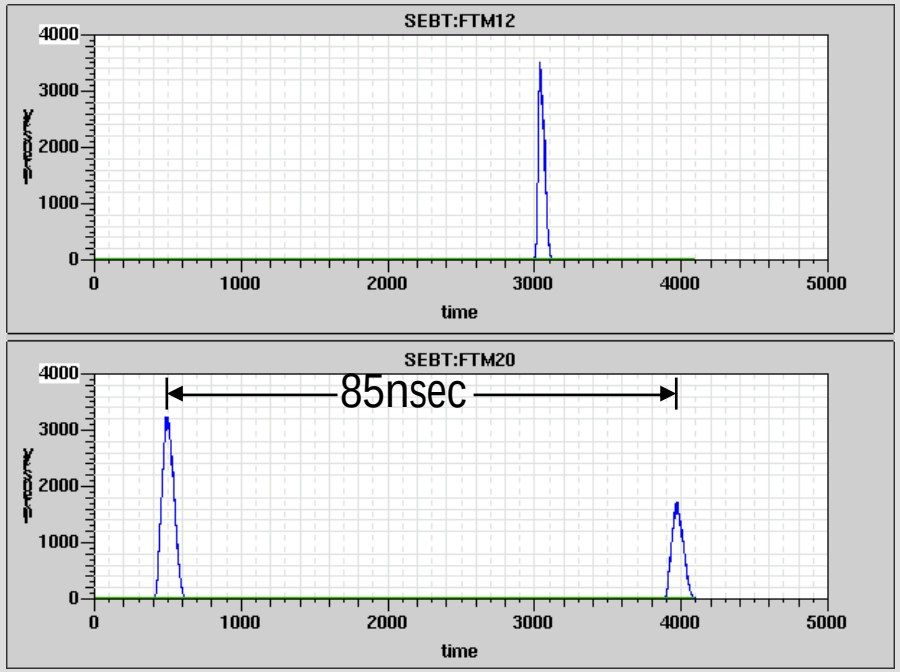
Superconducting LINAC

SEBT Beamline

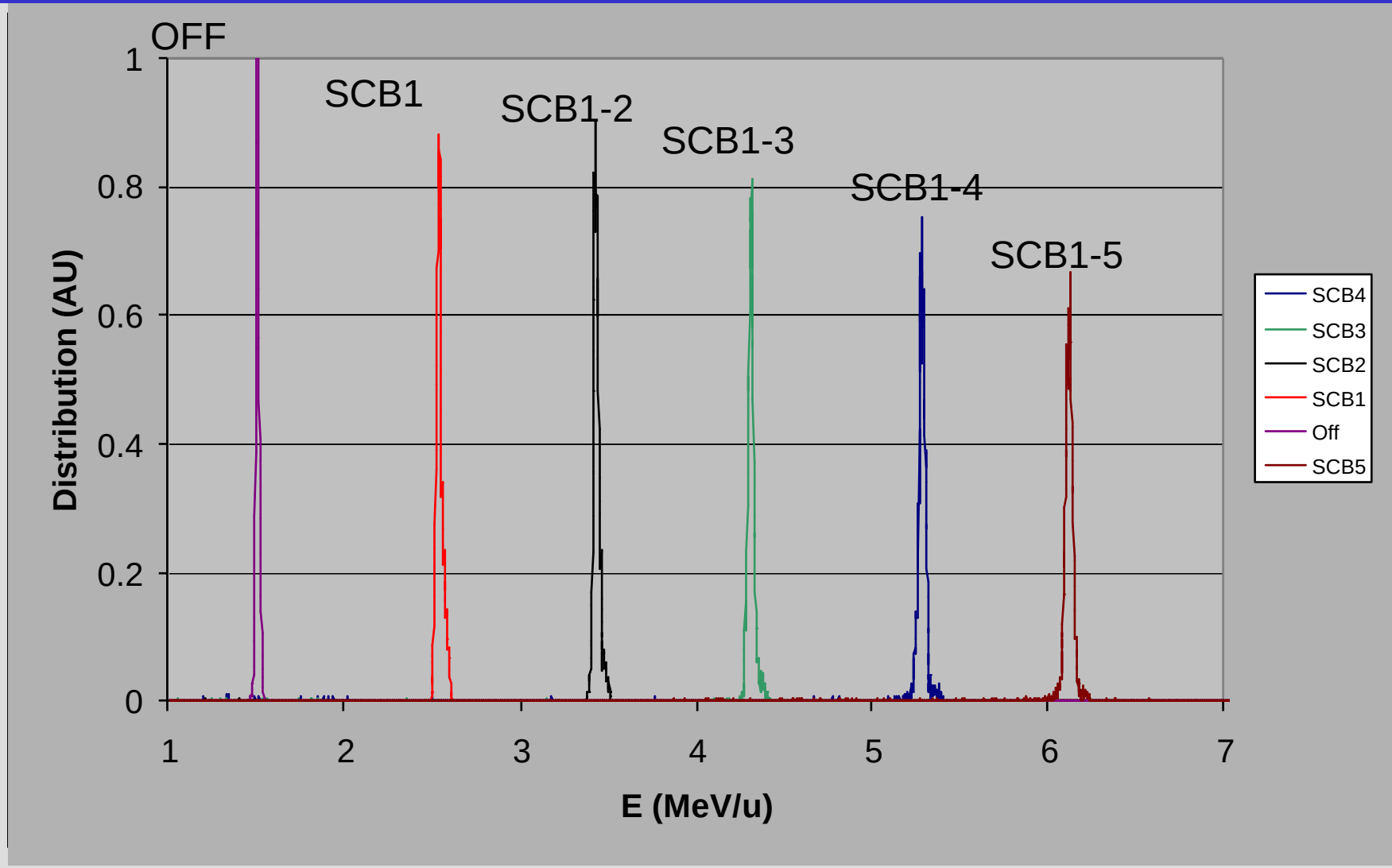
Energy Measurement – Time of Flight (TOF)





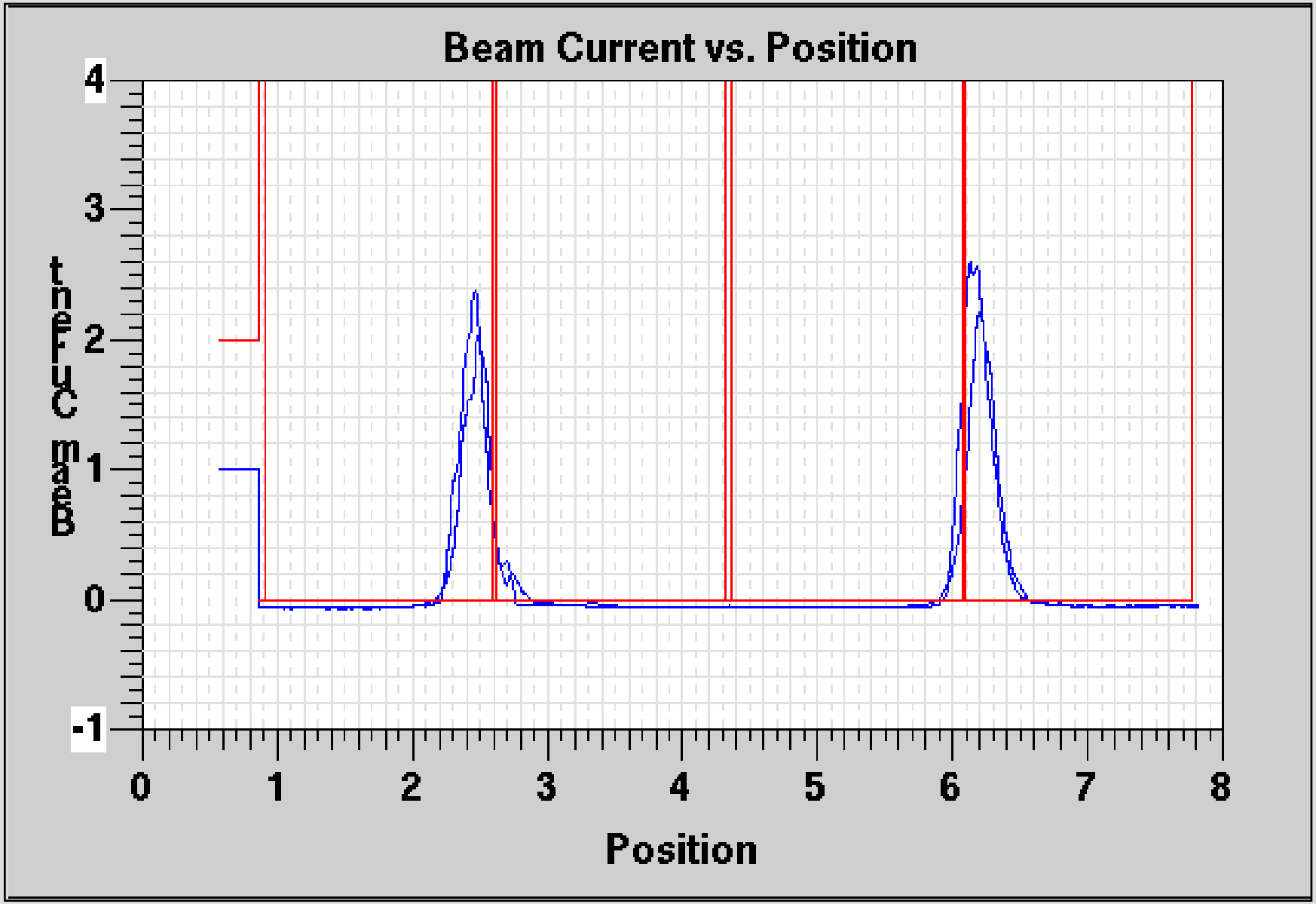


Milestone: Acceleration April 8, 2006



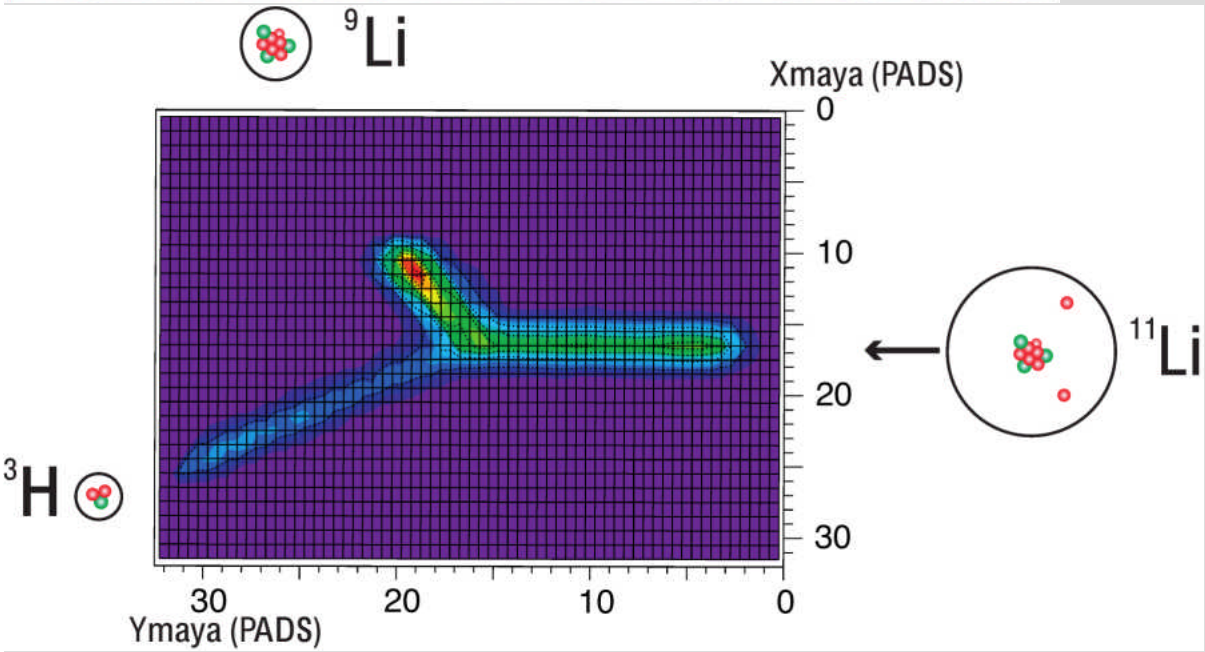
Energy after each cryomodule for C12(3+) with an injection energy of 1.5Mev/U.

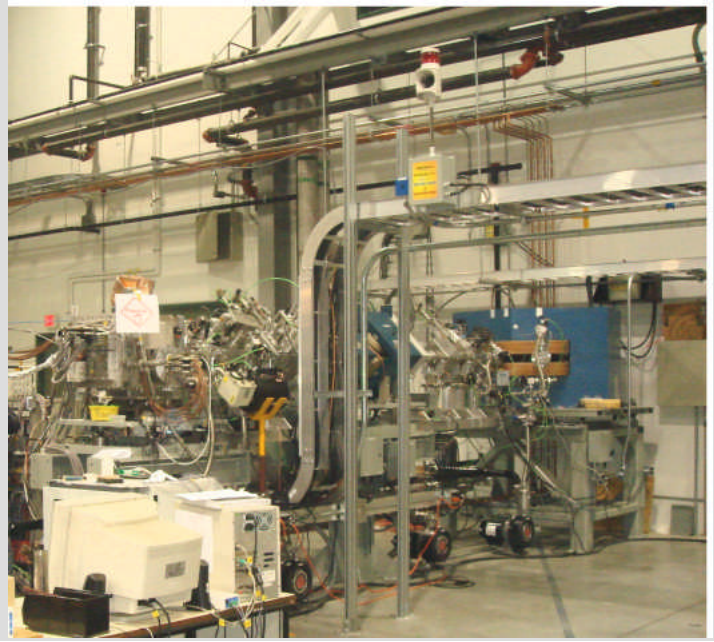
Beam Profile of full energy beam

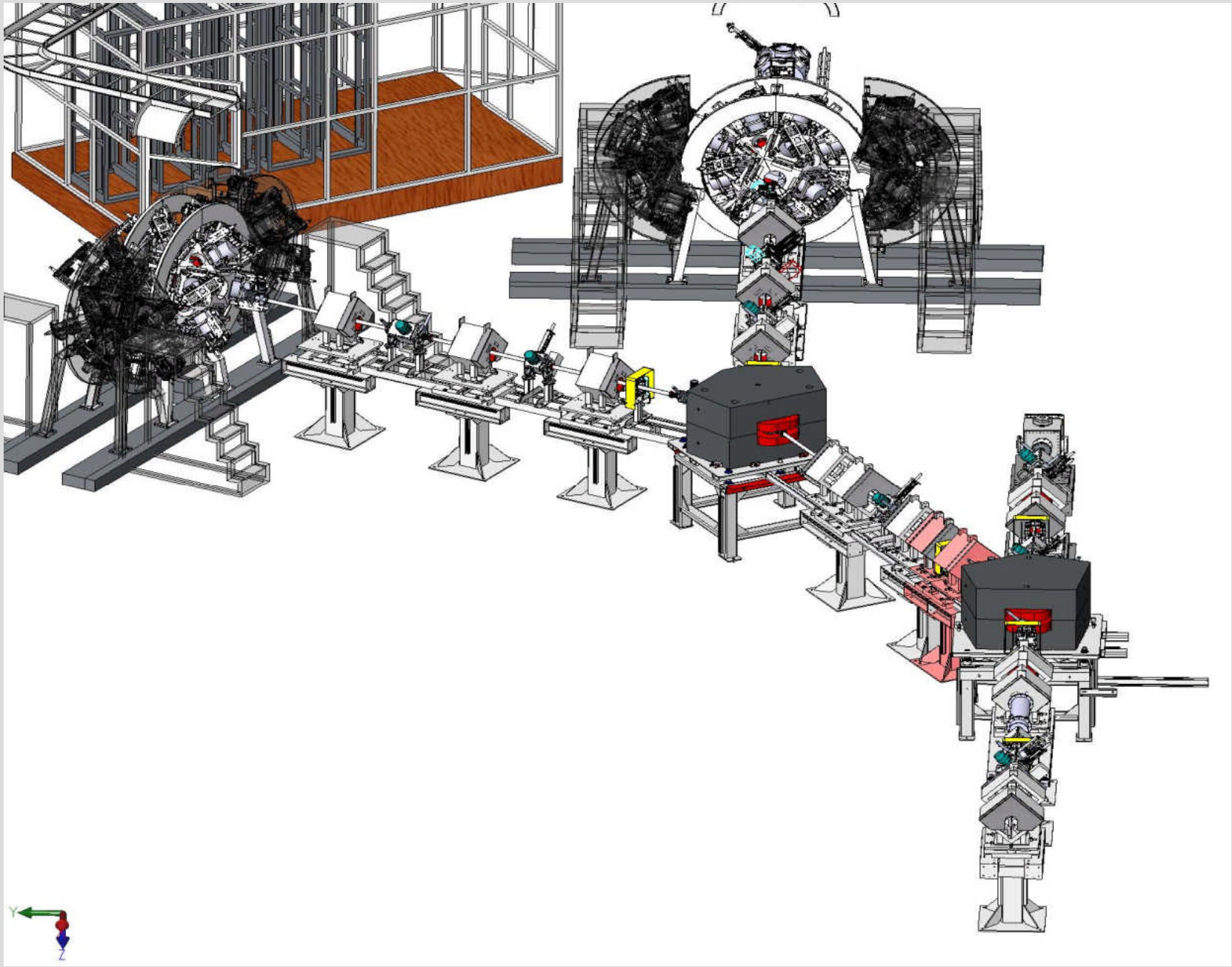


SEBT2 & SEBT3 Beamlines

January 05, 2007
First RIB in ISAC II



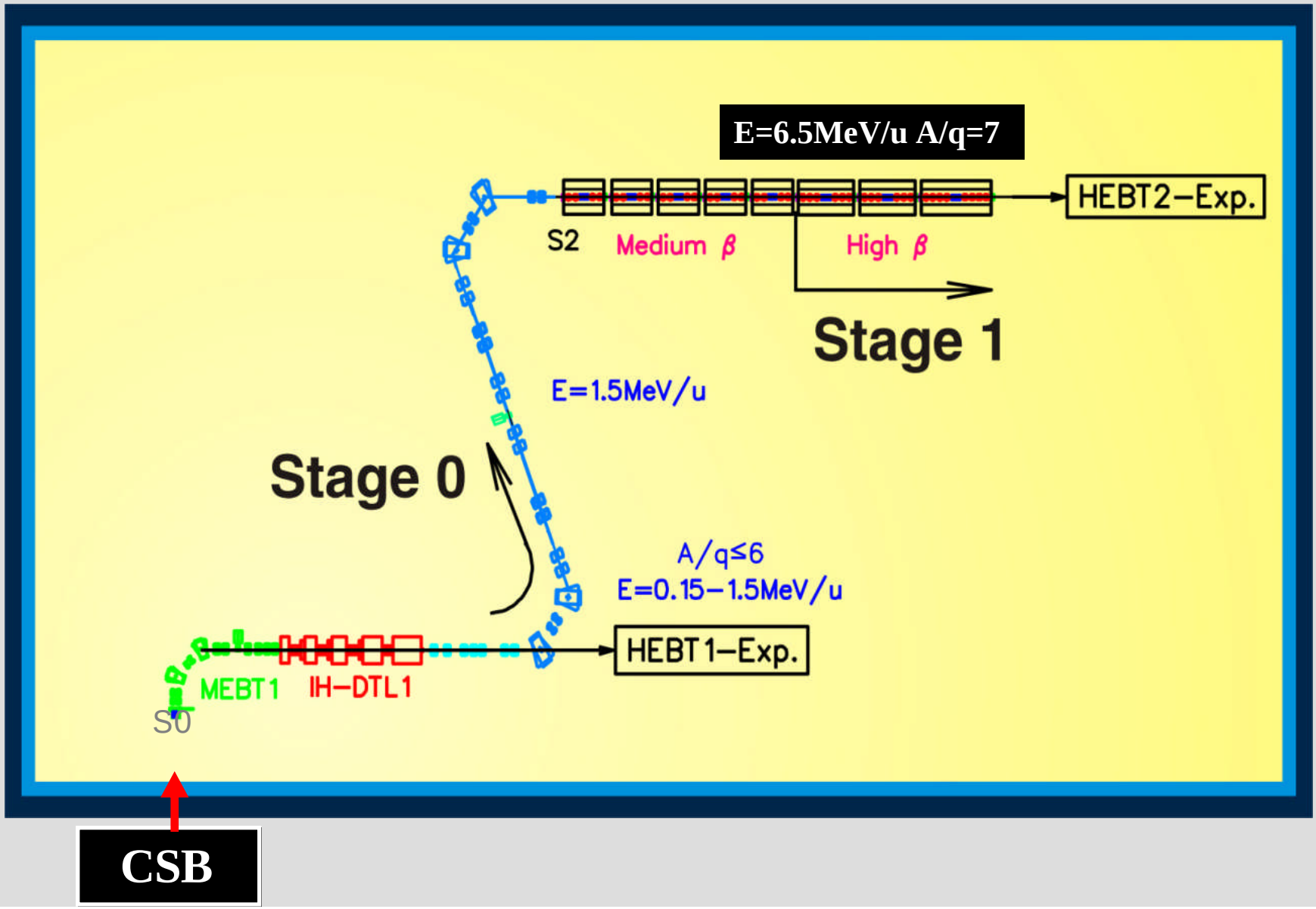




Near Term Plans for ISAC I & II

- Complete Installation of the ISAC II experimental stations & Beamlines
  - TIGRESS, EMMA, Heracles, ..
- Operation with Actinide Targets
  - Initial tests in 2008
  - Obtain fission produced neutron rich isotopes
- Completion of ISAC II Accelerators
  - High Beta cavities planned for 2009
  - To reach design energy of 6.5 MeV/u for all masses
- Installation of Charge State Booster in 2008
  - Heavier masses can be accelerated

Stage 1 - 2009


E=6.5MeV/u A/q=7
HEBT2–Exp.
S2
Medium β
High β
Stage 1
E=1.5MeV/u
Stage 0
A/q≤6
E=0.15–1.5MeV/u
HEBT1–Exp.
MEBT1
IH–DTL1
S0
CSB

TRIUMF/ISAC

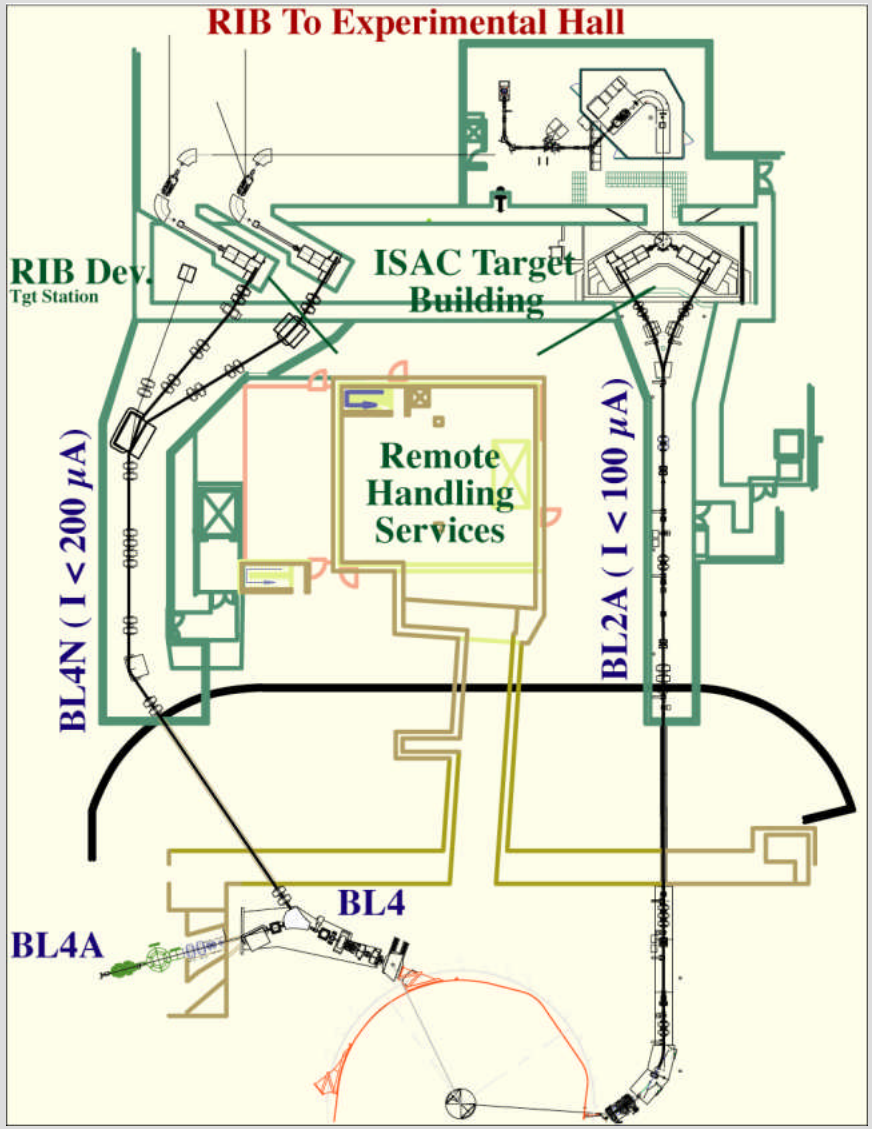
Beyond ISAC II $\rightarrow$ ISAC III

(2010 -2015)

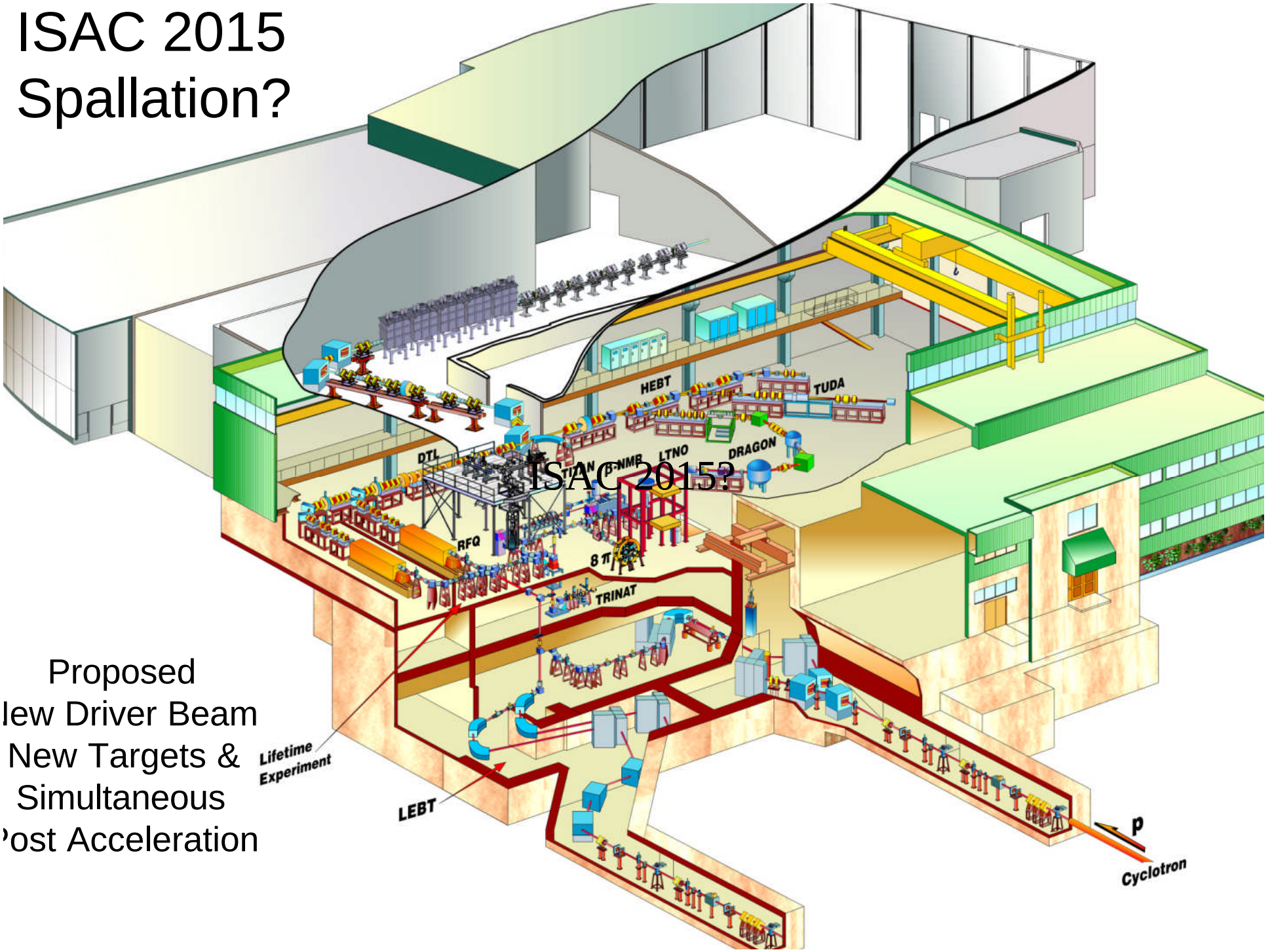
Proposals & Plans

ISAC Future Plan/Proposal

- The TRIUMF cyclotron driver could provide another proton beam (~ 200 μA) from a presently unused beam line (BL4AN) to new target stations,
- These target stations would then provide a place to perform systematic development of exotic beams,
  - Ion Source development,
  - Characterization of new targets
- An additional Radioactive Nuclear Beam could be simultaneously accelerated from these new target stations for experiment

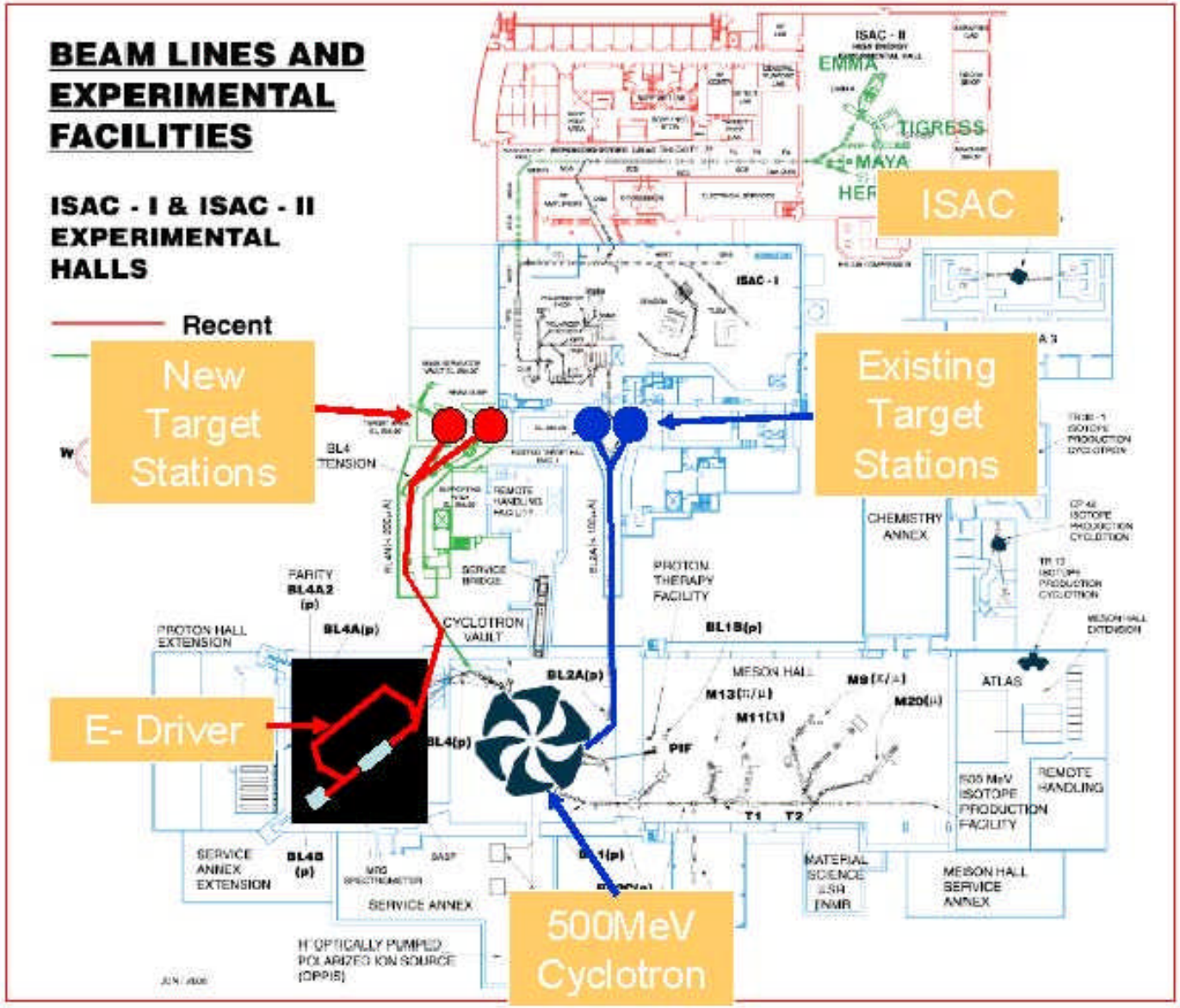


ISAC 2015 Spallation?



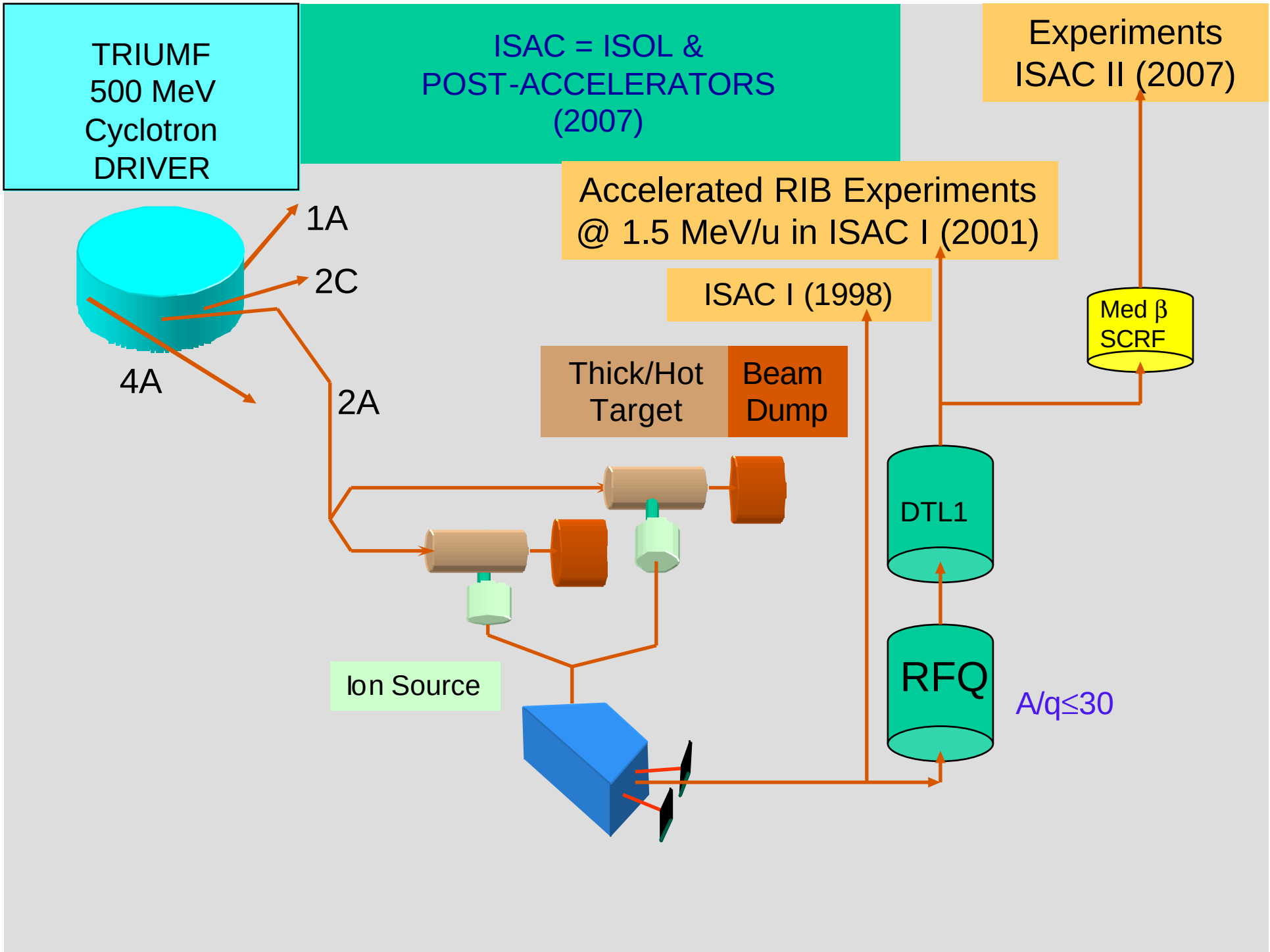
Proposed
lew Driver Beam
New Targets &
Simultaneous
ost Acceleration

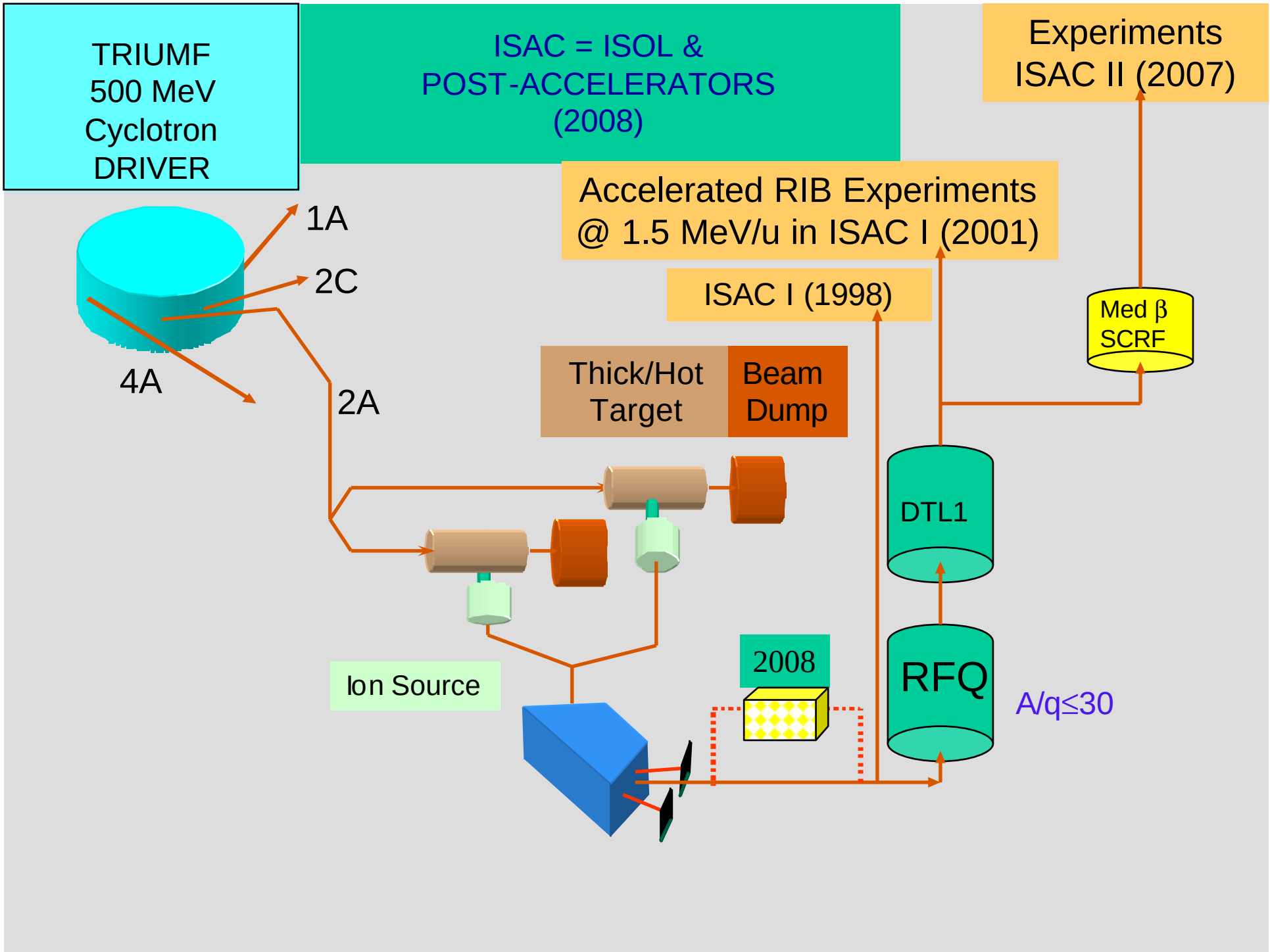
The proposed new facility for TRIUMF

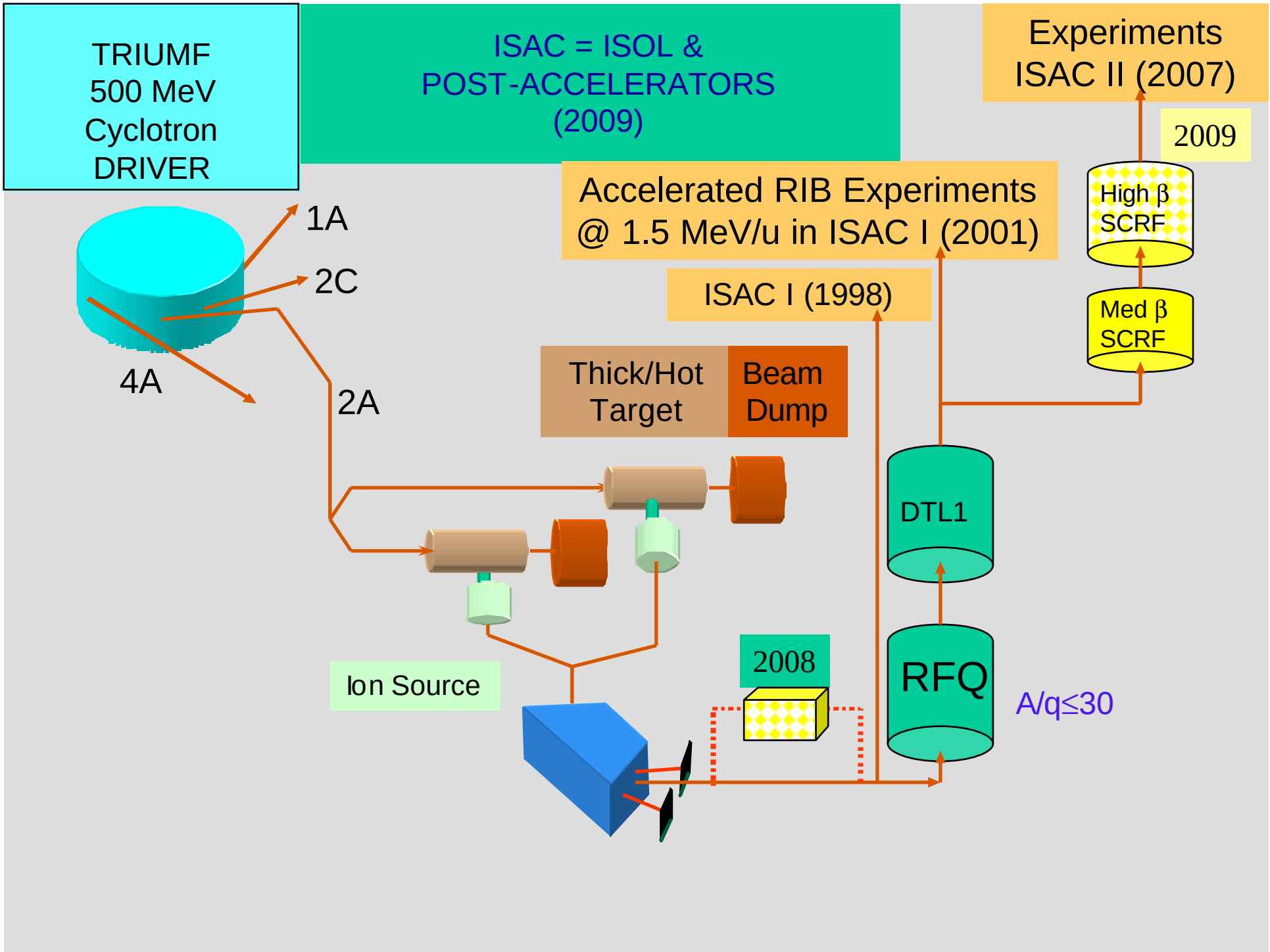


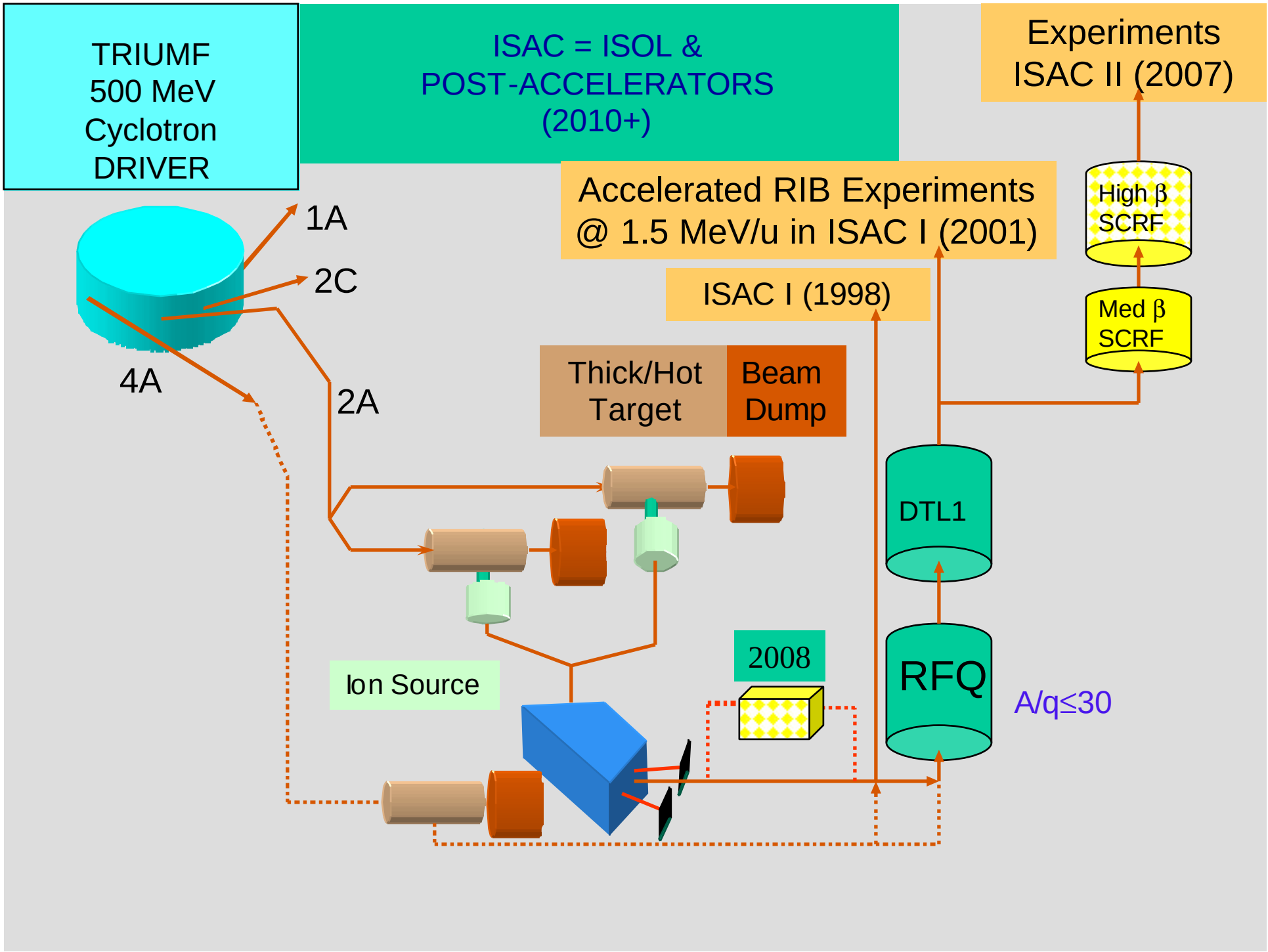
Proposal:

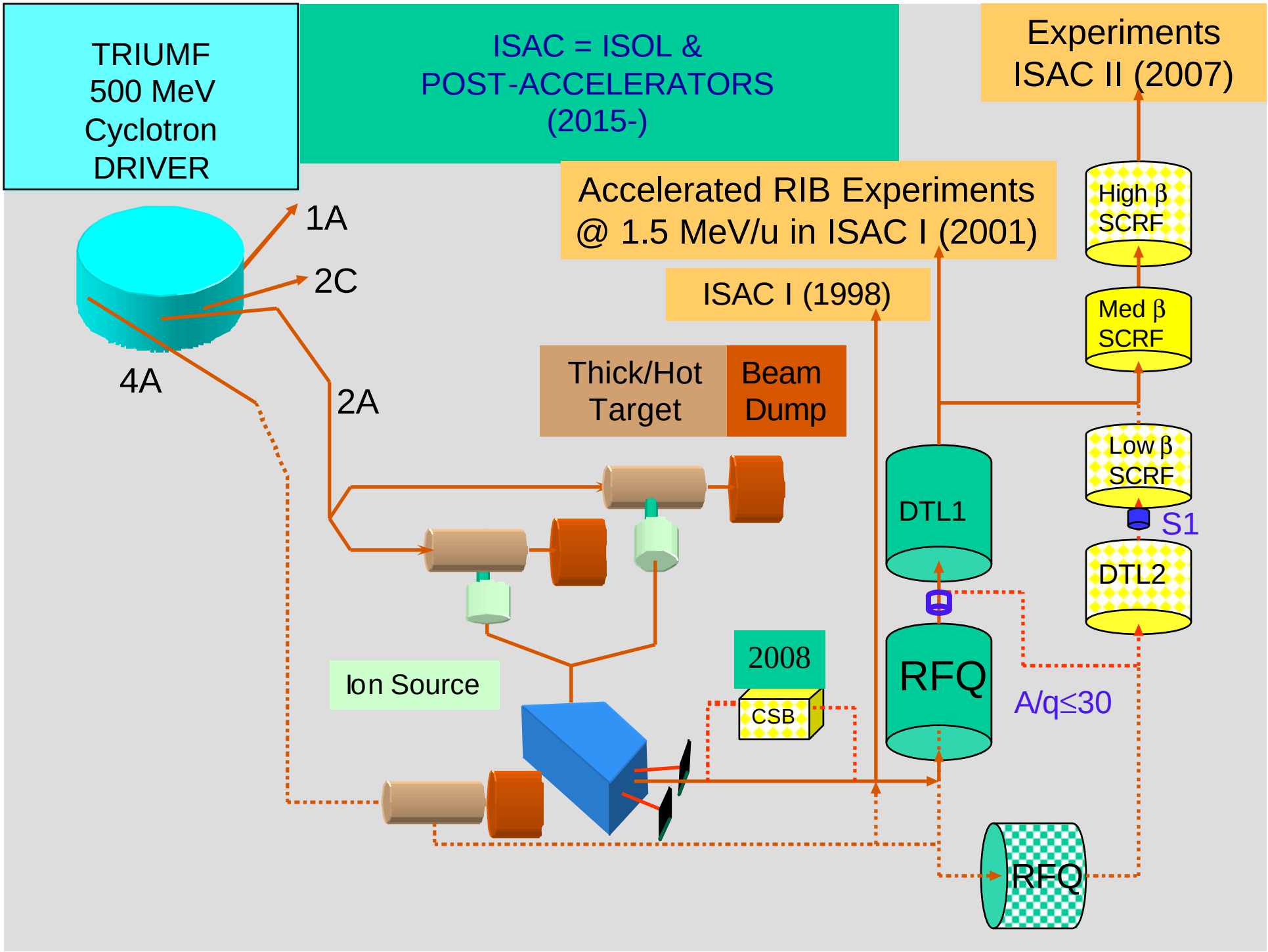
- A new electron accelerator produces 50 MeV electrons
- Electrons impinge on converter and photos are generated
- Photons hit target and photo-fission occures
- New, very exotic, neutron rich isotopes are produced
- Isotopes are delivered to existing state-of-the-art ISAC complex and experimenal facilities

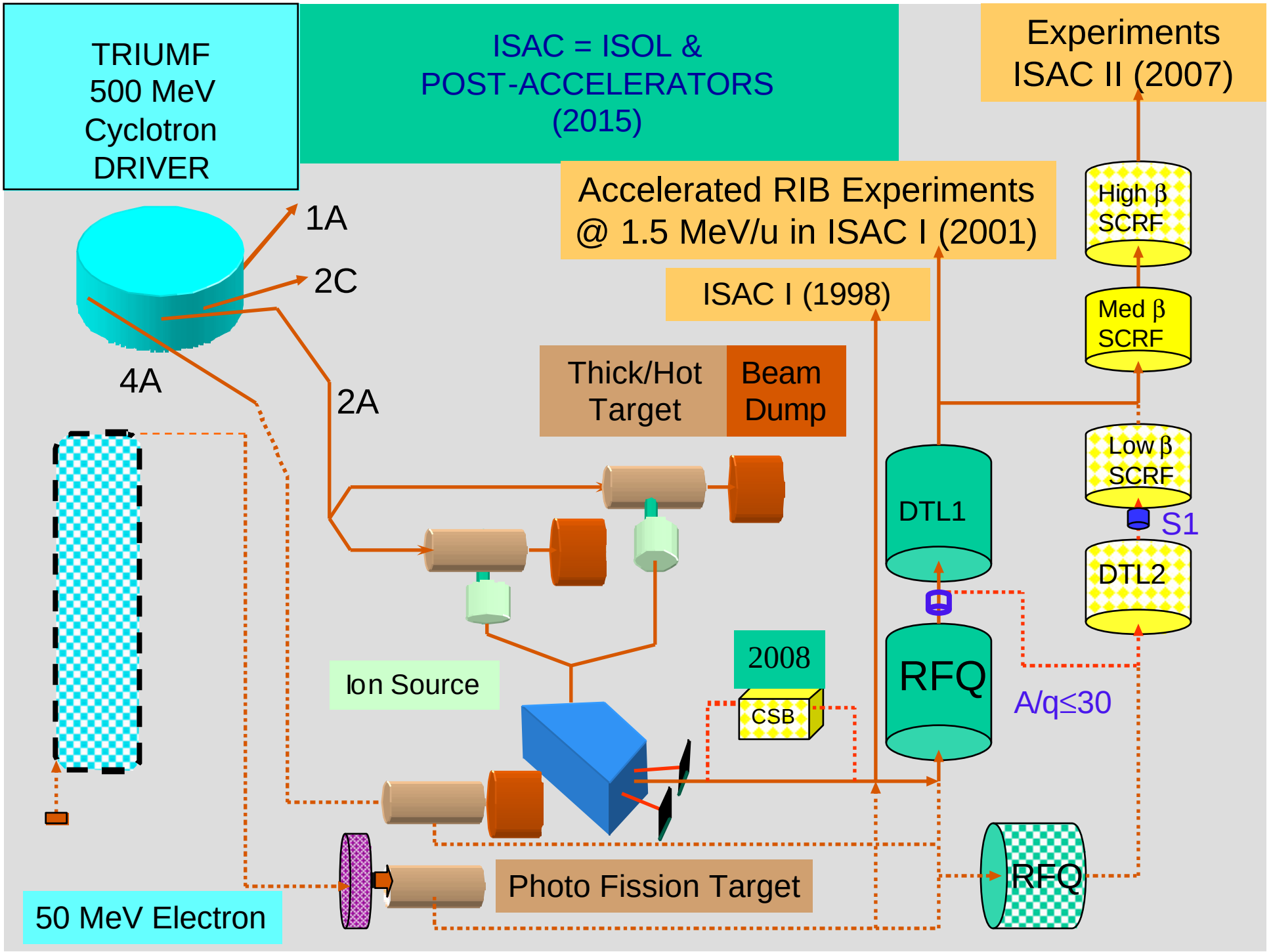

TRIUMF
500 MeV
Cyclotron
DRIVER
ISAC = ISOL &
POST-ACCELERATORS
(2007)
Experiments
ISAC II (2007)
Accelerated RIB Experiments
@ 1.5 MeV/u in ISAC I (2001)
ISAC I (1998)
1A
2C
4A
2A
Thick/Hot
Target
Beam
Dump
Med β
SCRF
DTL1
RFQ
A/q≤30
Ion Source


TRIUMF
500 MeV
Cyclotron
DRIVER
ISAC = ISOL &
POST-ACCELERATORS
(2008)
Experiments
ISAC II (2007)
Accelerated RIB Experiments
@ 1.5 MeV/u in ISAC I (2001)
ISAC I (1998)
1A
2C
4A
2A
Thick/Hot
Target
Beam
Dump
Med β
SCRF
DTL1
RFQ
A/q≤30
2008
Ion Source


TRIUMF
500 MeV
Cyclotron
DRIVER
ISAC = ISOL &
POST-ACCELERATORS
(2009)
Experiments
ISAC II (2007)
2009
Accelerated RIB Experiments
@ 1.5 MeV/u in ISAC I (2001)
High β
SCRF
Med β
SCRF
ISAC I (1998)
1A
2C
4A
2A
Thick/Hot
Target
Beam
Dump
DTL1
2008
RFQ
A/q≤30
Ion Source


TRIUMF
500 MeV
Cyclotron
DRIVER
ISAC = ISOL &
POST-ACCELERATORS
(2010+)
Experiments
ISAC II (2007)
Accelerated RIB Experiments
@ 1.5 MeV/u in ISAC I (2001)
ISAC I (1998)
High β
SCRF
Med β
SCRF
1A
2C
4A
2A
Thick/Hot
Target
Beam
Dump
DTL1
RFQ
A/q≤30
2008
Ion Source


TRIUMF
500 MeV
Cyclotron
DRIVER
ISAC = ISOL &
POST-ACCELERATORS
(2015-)
Experiments
ISAC II (2007)
Accelerated RIB Experiments
@ 1.5 MeV/u in ISAC I (2001)
ISAC I (1998)
1A
2C
4A
2A
Thick/Hot
Target
Beam
Dump
High β
SCRF
Med β
SCRF
Low β
SCRF
S1
DTL1
DTL2
RFQ
A/q≤30
2008
CSB
Ion Source
RFQ


TRIUMF
500 MeV
Cyclotron
DRIVER
ISAC = ISOL &
POST-ACCELERATORS
(2015)
Experiments
ISAC II (2007)
Accelerated RIB Experiments
@ 1.5 MeV/u in ISAC I (2001)
ISAC I (1998)
1A
2C
4A
2A
Thick/Hot
Target
Beam
Dump
High β
SCRF
Med β
SCRF
Low β
SCRF
S1
DTL1
DTL2
RFQ
A/q≤30
2008
CSB
Ion Source
Photo Fission Target
RFQ
50 MeV Electron

SUMMARY

- CYCLOTRON DRIVER
  - PROVIDES MULTIPLE BEAMS FOR MESON PRODUCTION, MEDICAL ISOTOPE PRODUCTION, PROTON IRRADIATION FACILITY & ISAC
    - REFURBISHMENT PROGRAMME IN PLACE TO ENSURE THE CYCLOTRON REMAINS RELIABLE & CAPABLE OF HIGH CURRENT OPERATIONAL DEMANDS
  - CAPABLE OF PROVIDING SIMULTANEOUS, VARIABLE INTENSITY, STABLE, MULTIPLE HIGH POWER BEAMS TO ISOL TARGETS
    - EXTRACTION BY STRIPPING PERMITS EASY ADJUSTMENT OF PRIMARY BEAM POWER TO MEET TARGET REQUIREMENTS
- ISAC
  - ISAC I & II IN OPERATION
    - ISAC II OPERATIONAL AT 4.3 MeV/u NOW & 6.5 MeV/u IN 2009
  - 3 SIMULTANEOUS INDEPENENT RIBs PROPOSED FOR FUTURE
- ELECTRON DRIVER FOR PHOTOFISSION PROPOSED
  - 3rd SOURCE OF RIB FOR ISAC
  - COMPLIMENTARY TO SPALLATION PRODUCED RIBs