TRIUMF signature mark: High power ISOL Facility and Post Accelerators

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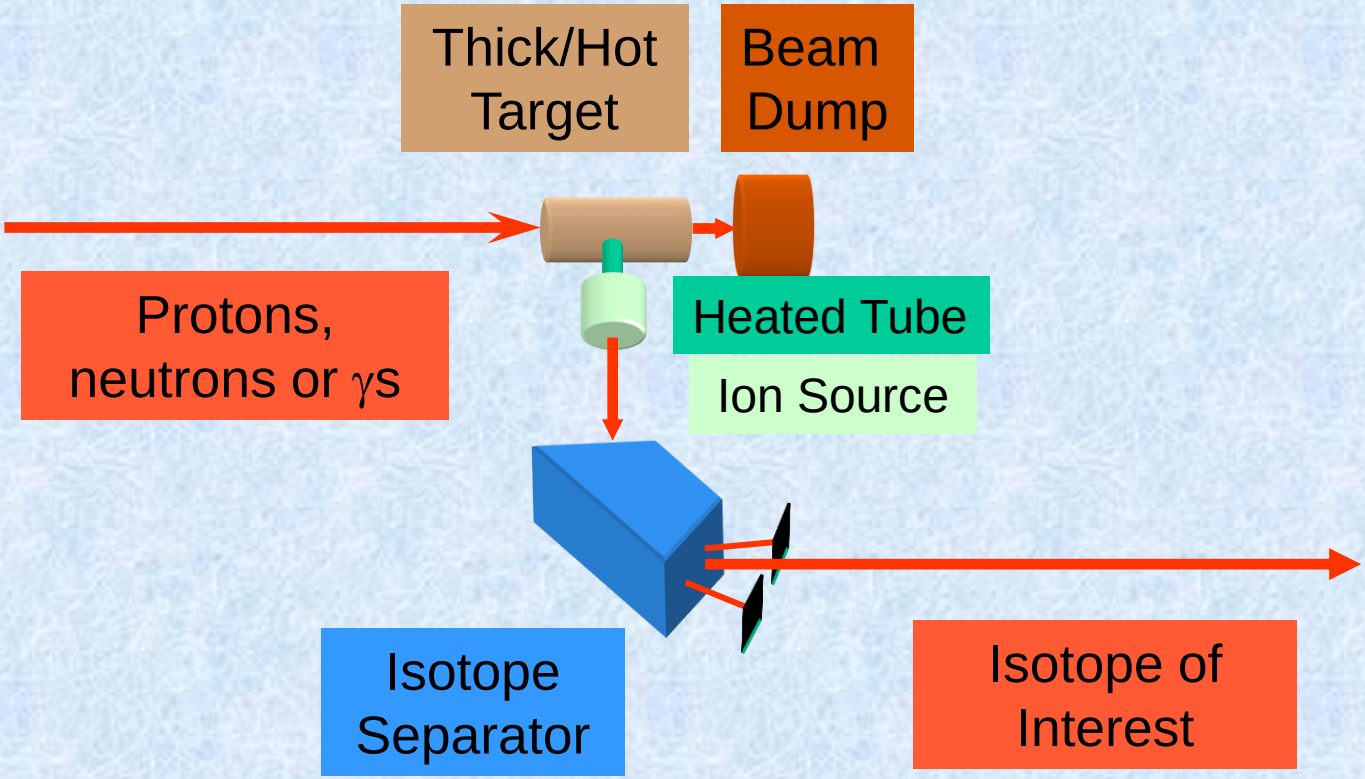
ISOL

{**I**sotope **S**eparation **O**n **L**ine}

{aka **I**on **S**ource **O**n **L**ine}

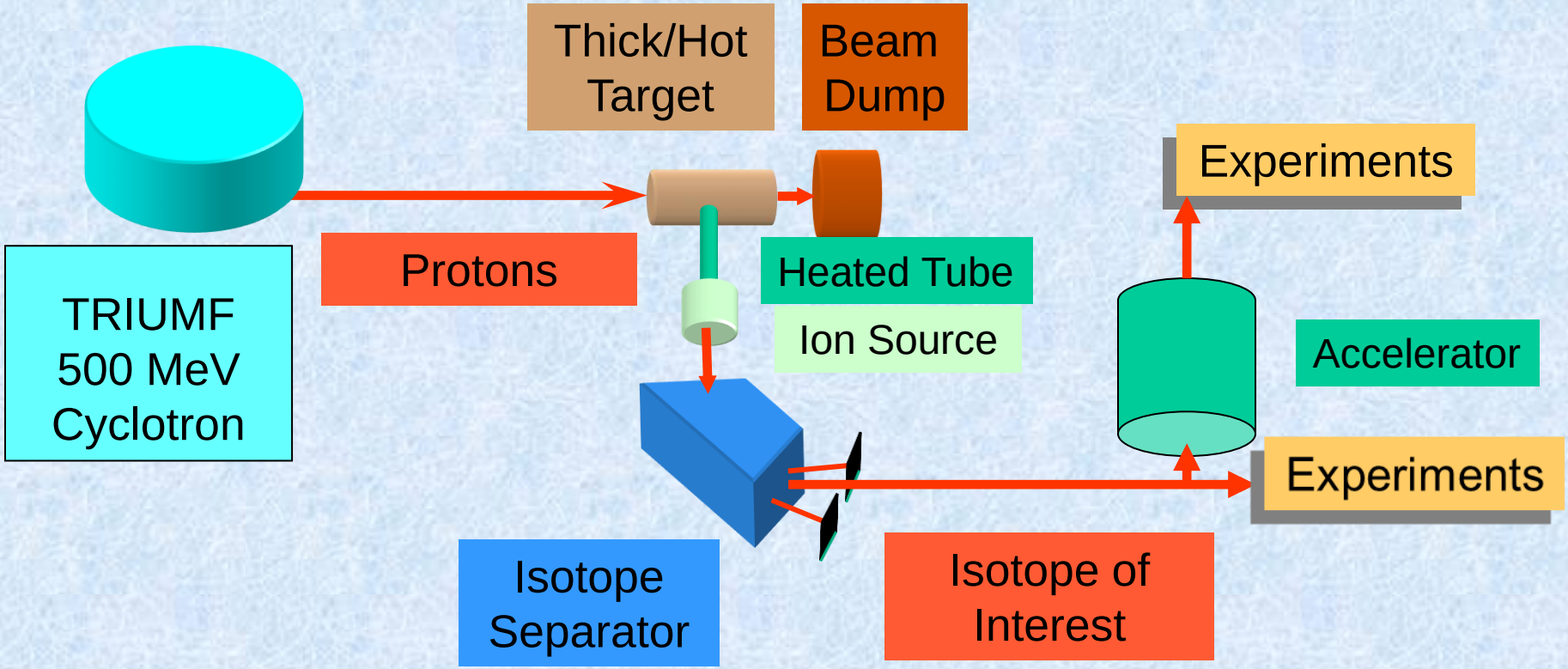
An Approach to Create & Study the Properties of Short-Lived Isotopes



Brief History of ISOL

- 1951 – First on-line ISOL (Niels Bohr Inst.)
- 1967 – present – ISOLDE/CERN
- 1960 – 1980s – Various Worldwide ISOL Facilities start
- 1986 – 1999 – TISOL – Test Facility at TRIUMF
- 1995 – ISAC Funded
  - Ambitiously Proposes to Increase Beam Power by Nearly an Order of Magnitude and Accelerate Radioactive Ion Beams
  - 2020 - 25th Anniversary
- 1998 – First ISAC RIB (^{38m}K)
  - 22 Years Ago

ISAC
{ISOL + ACcelerators}



The Proposal for a TRIUMF-ISOL Facility
June 1985

- 1985 ISAC Proposal
  - 35 years ago
  - Plan included a Post Accelerator
- This proposal was basis for funding announcement in June 1995
- Led to Funding of TISOL

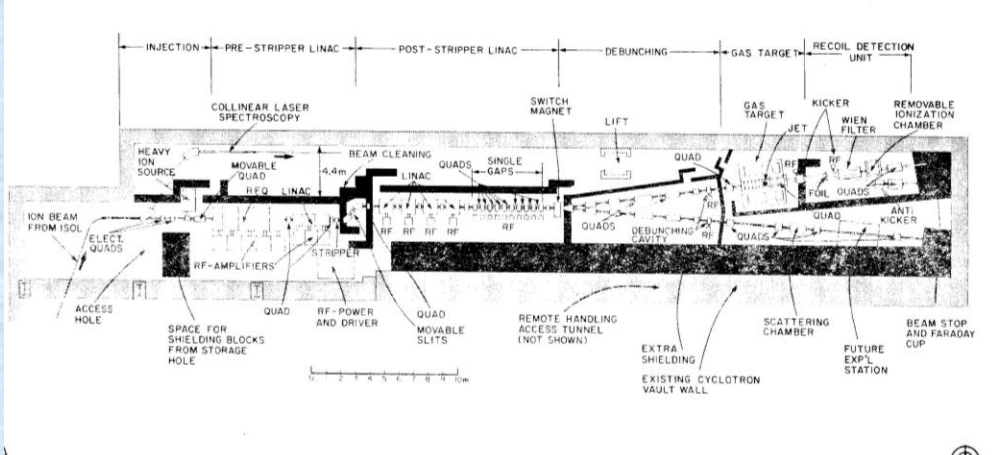
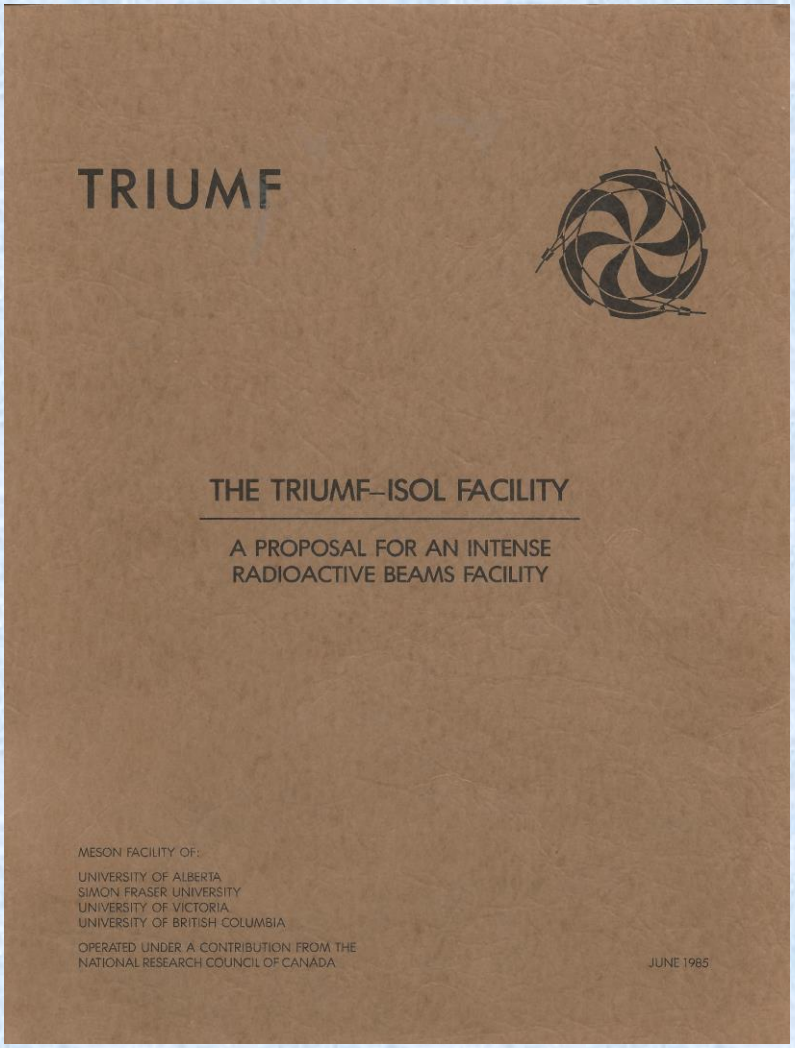
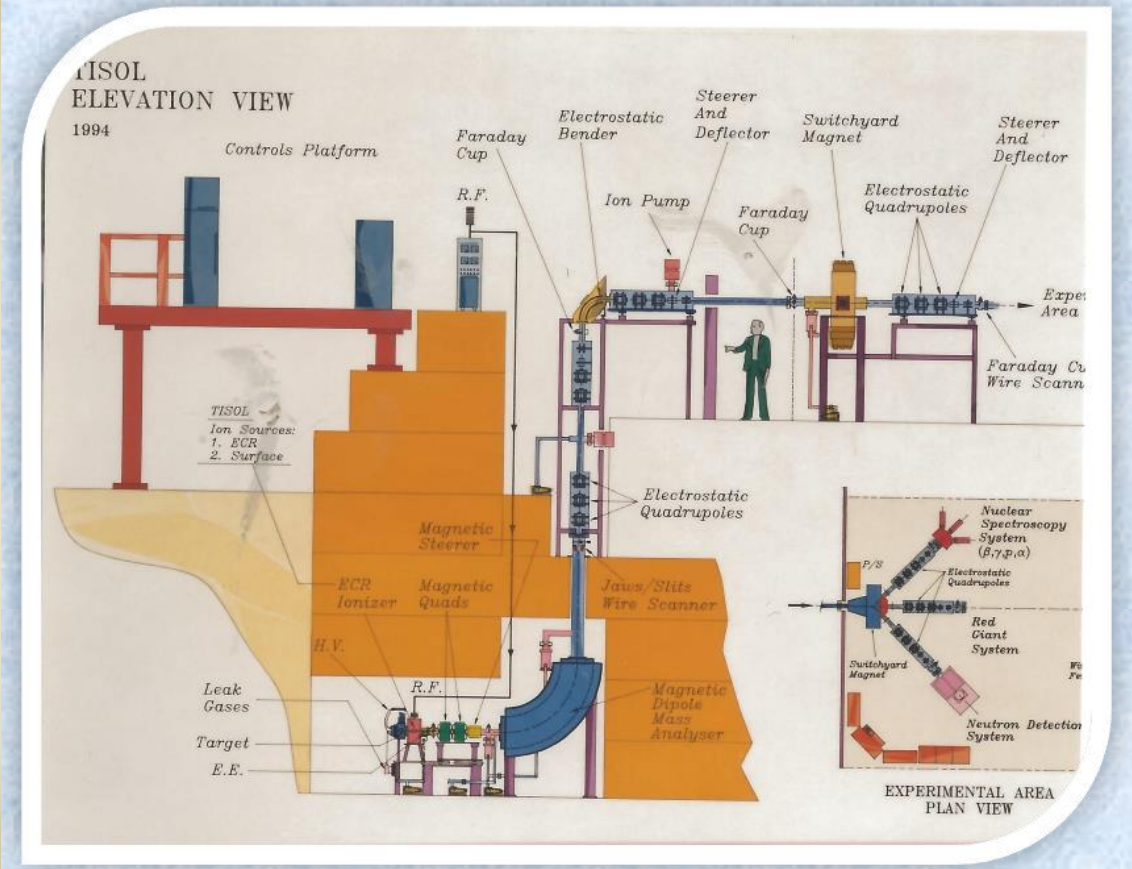


Fig. III.23. A schematic representation of a possible layout of an ISOL post-accelerator based upon suggestions of H. Klein [Kle 84].



TISOL (Test ISOL)
(Power on target ≤ 0.5 kW)

- 1985 – Design of TISOL begins
- 1987 – TISOL installed at TRIUMF
  - ♦ Operated until 1999
- 1st Nuclear Astrophysics Exp at TISOL yielded accurate estimates of ^{16}O production in massive stars



ISAC Funding was announced on June 1995

ISAC Proposal submitted Oct. 1995

(25 Years ago)

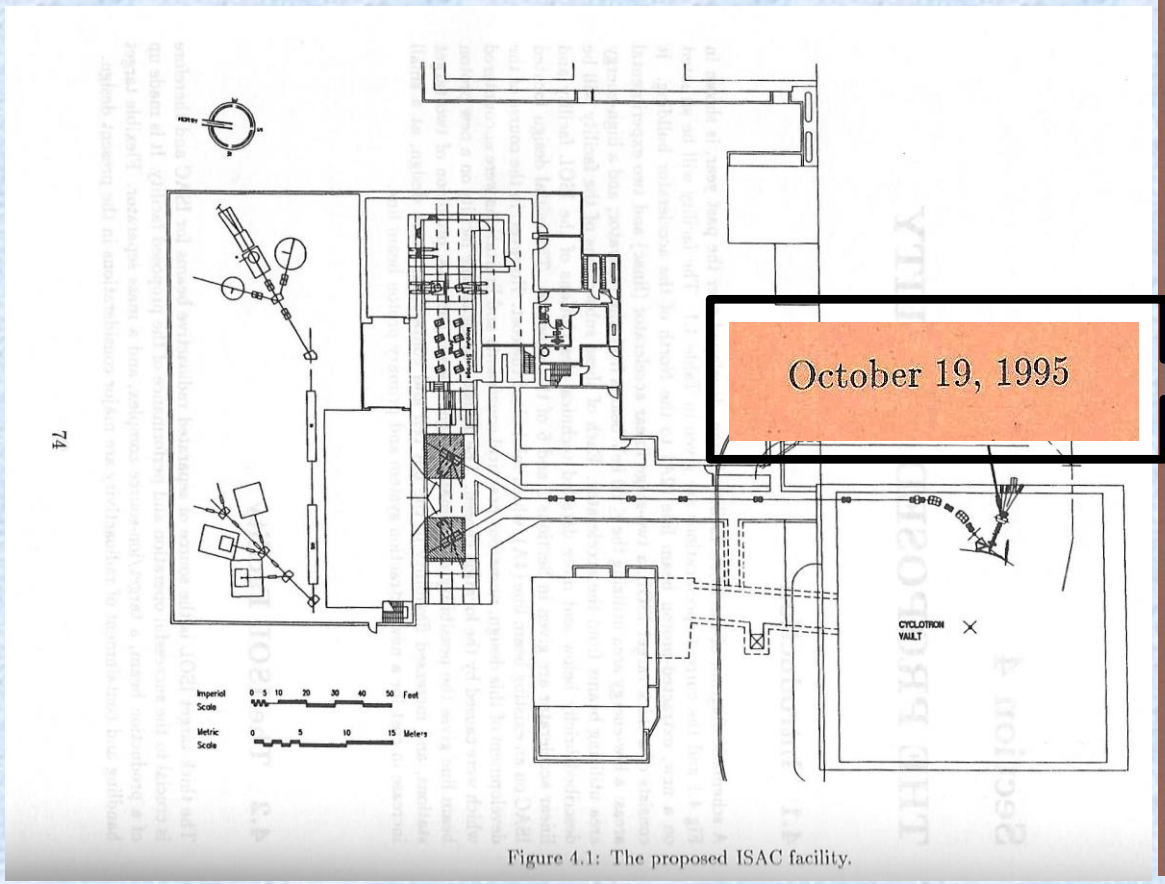
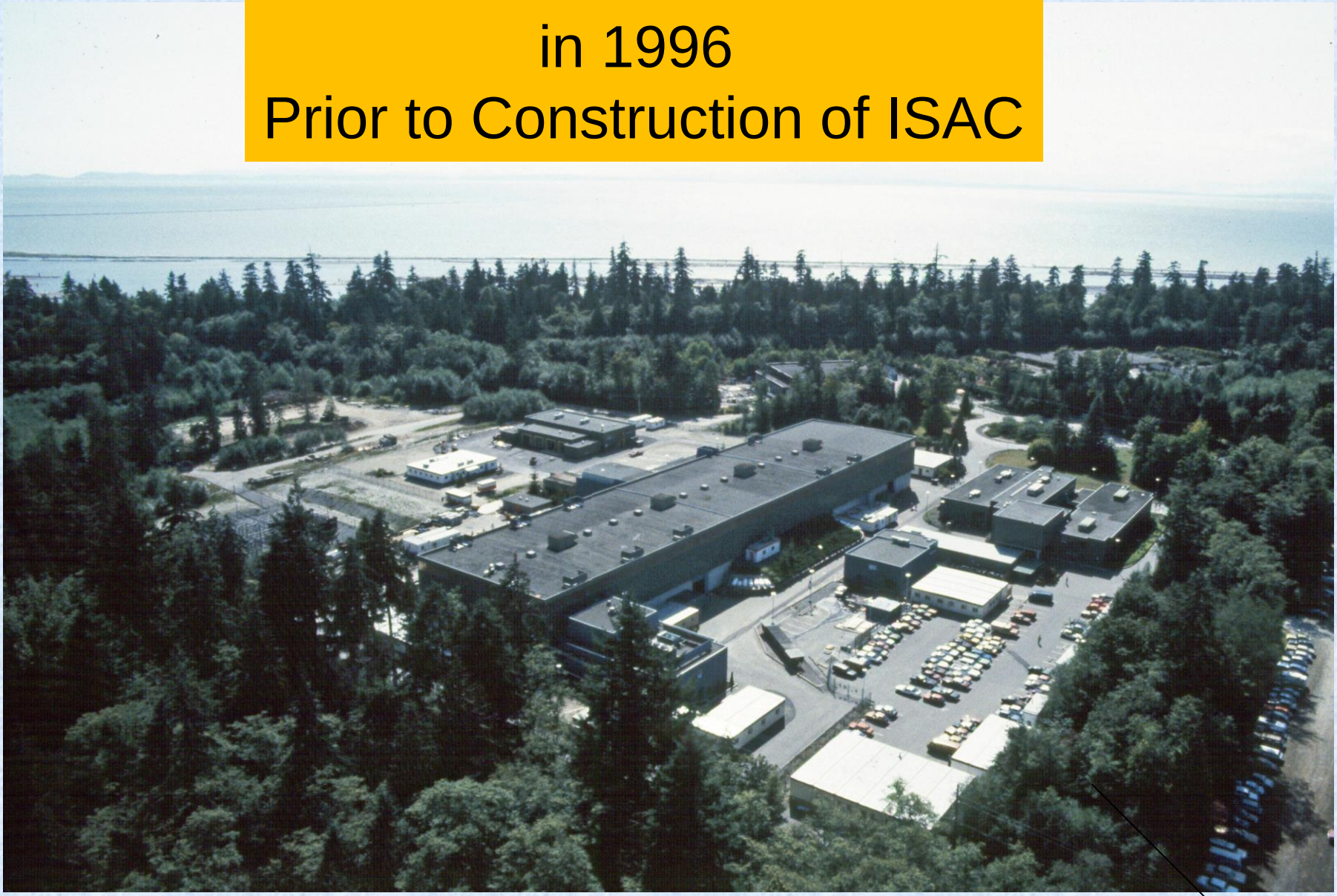


Figure 4.1: The proposed ISAC facility.

October 19, 1995

TRIUMF SITE
in 1996
Prior to Construction of ISAC

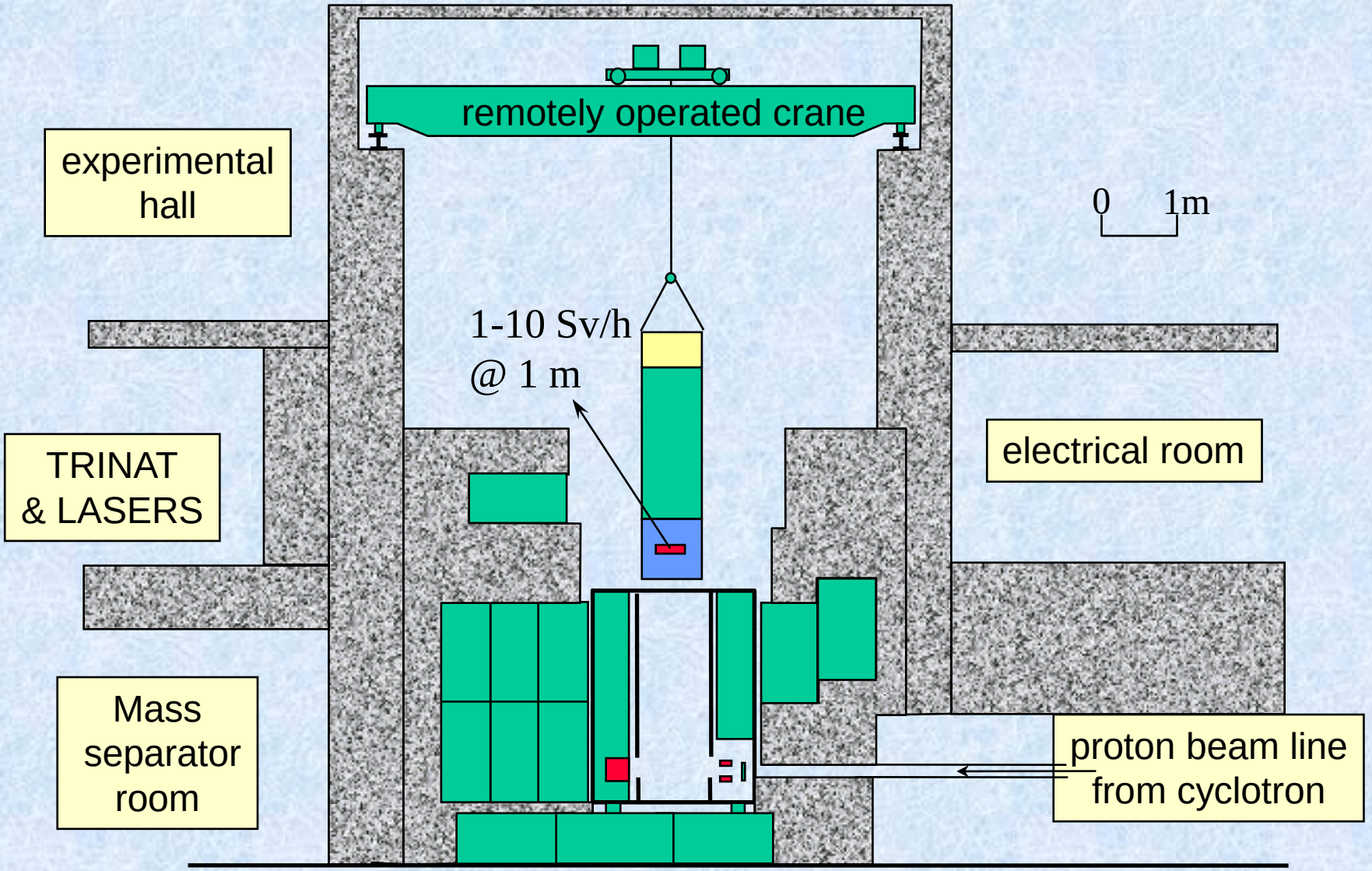


ISAC Construction

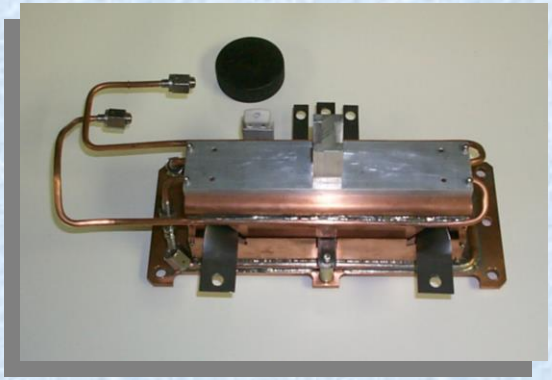
ISAC SPECIFICATIONS

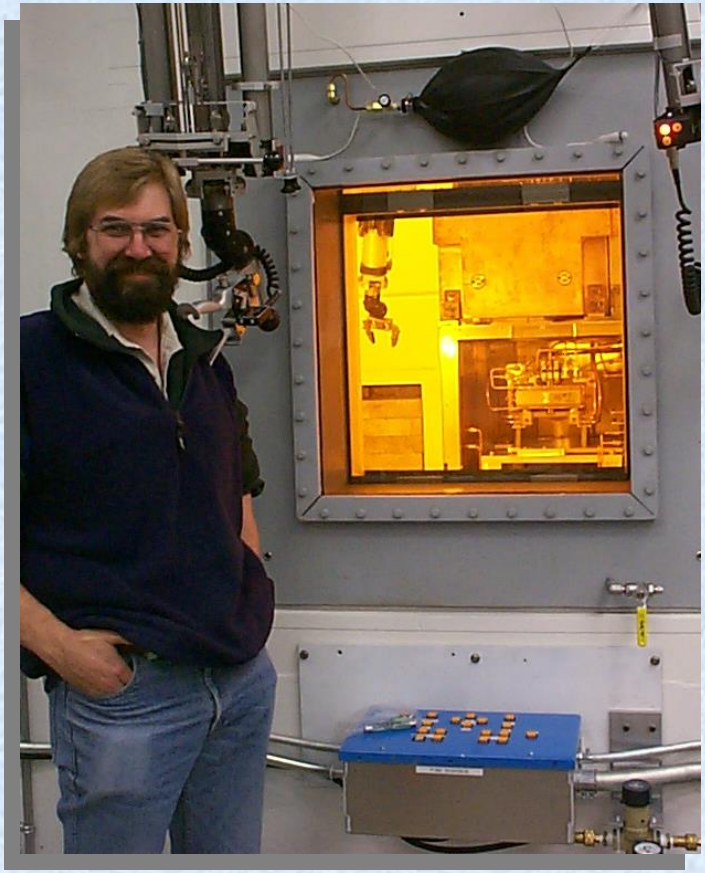
- DRIVER
  - 1 – 100 μA @ 500 MeV for ISAC
- ISAC (ISOL + ACCELERATORS)
  - ISOL Target Area
    - **Shielded for 100 μA of 500 MeV Protons on Uranium**
    - **Up to 50 kW on Target**
      - » **Achieved with Mo in Dec 1999 (21 years ago)**
  - ISAC
    - Low Energy
      - **E ≤ 60 keV**
      - **A_{max} ≈ 240**
        - **Achieved on Nov 1998 (22 Years ago)**
    - Accelerated Beams
      - **Variable Energy**
        - **0.15 to 1.5 MeV/u**
        - **1st full energy beam in Dec 2000 (20 years ago)**
      - **Charge/mass = q/A ≥ 1/30**

ISAC TARGET SERVICING

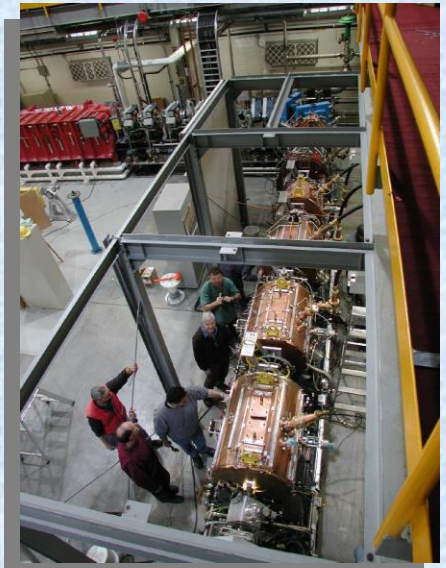


REMOTE HANDLING for ISAC TARGETS, ION SOURCES & MODULE COMPONENTS



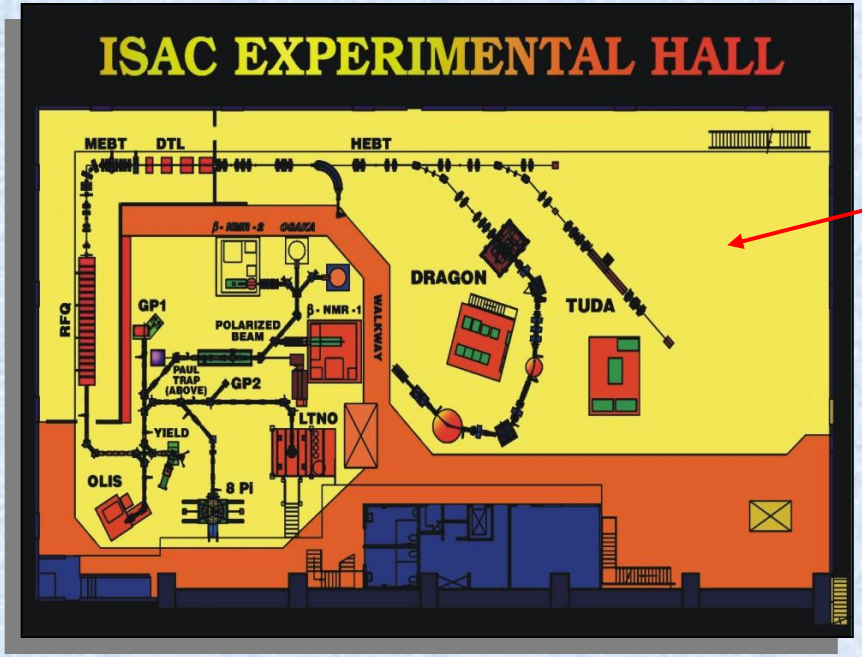


ACCELERATOR TECHNOLOGY for ISAC

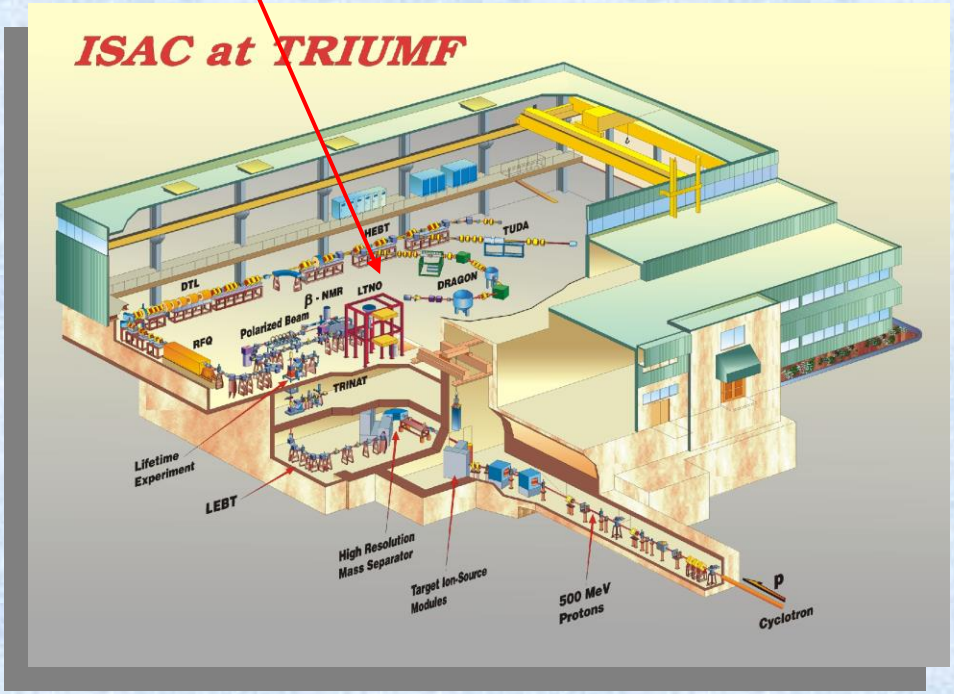


Copper Plating Facility
Cloverdale

- ISAC (ISOL + ACCELERATORS) Achieved Milestones
  - ISAC-I
    - Low Energy (First RIB Experiment in November 1998)
      - **$E \leq 60$ keV & $A_{max} \approx 240$**
      - **Nov 30, 1998 – First Radioactive Beam to TRINAT**
    - High Energy (First Accelerated Beam in December 2000)
      - **Variable Energy from 0.15 to 1.5 MeV/u for $q/A \geq 1/30$**
      - **Dec 21, 2000 - First Full Energy Stable Beam**
      - **July 25, 2001 - Accelerated RIB (^{8}Li to TOJA)**
      - **Oct 05, 2001- ^{21}Na to TUDA**
      - **Oct 17, 2001 - ^{21}Na to DRAGON**
  - ISOL Target Area
      - **Shielded for 100 μA of 500 MeV Protons on Uranium**
      - **Dec 17, 1999 – 100 μA on Mo Target**



Layout of ISAC Experimental Facilities (1999)



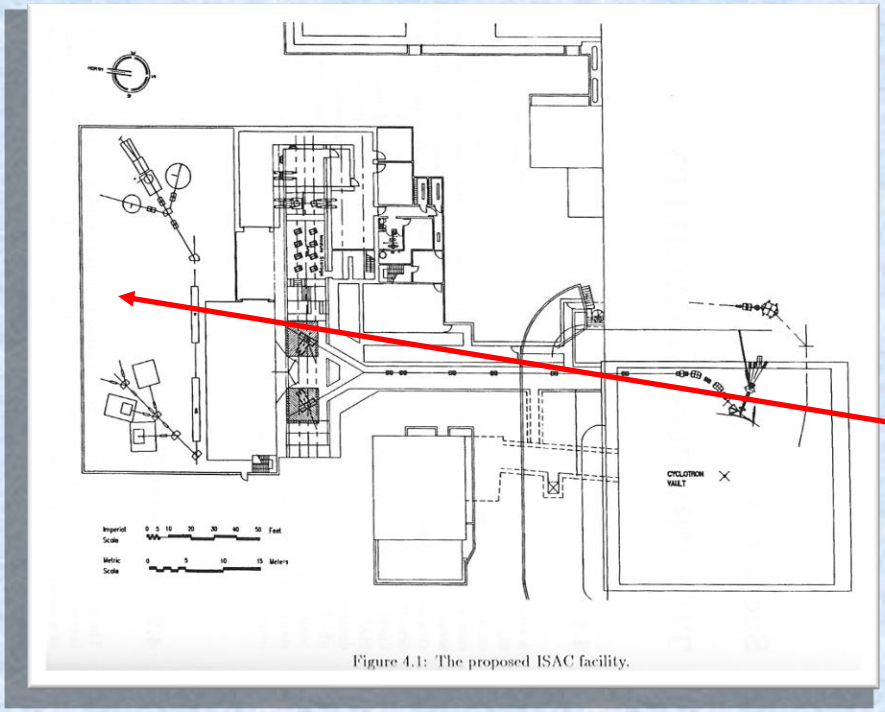
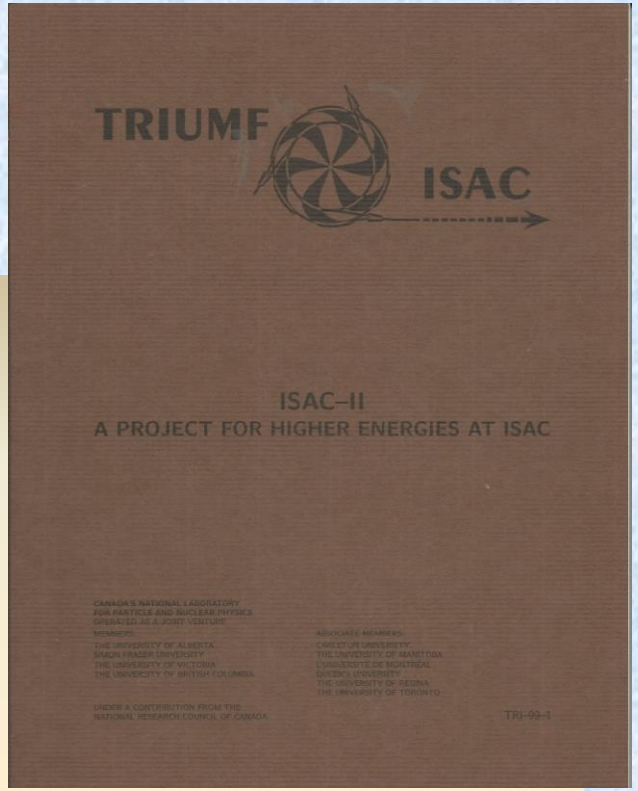


Figure 4.1: The proposed ISAC facility.

Proposed Layout of ISAC Experimental Facilities (1995)

ISAC I → ISAC II

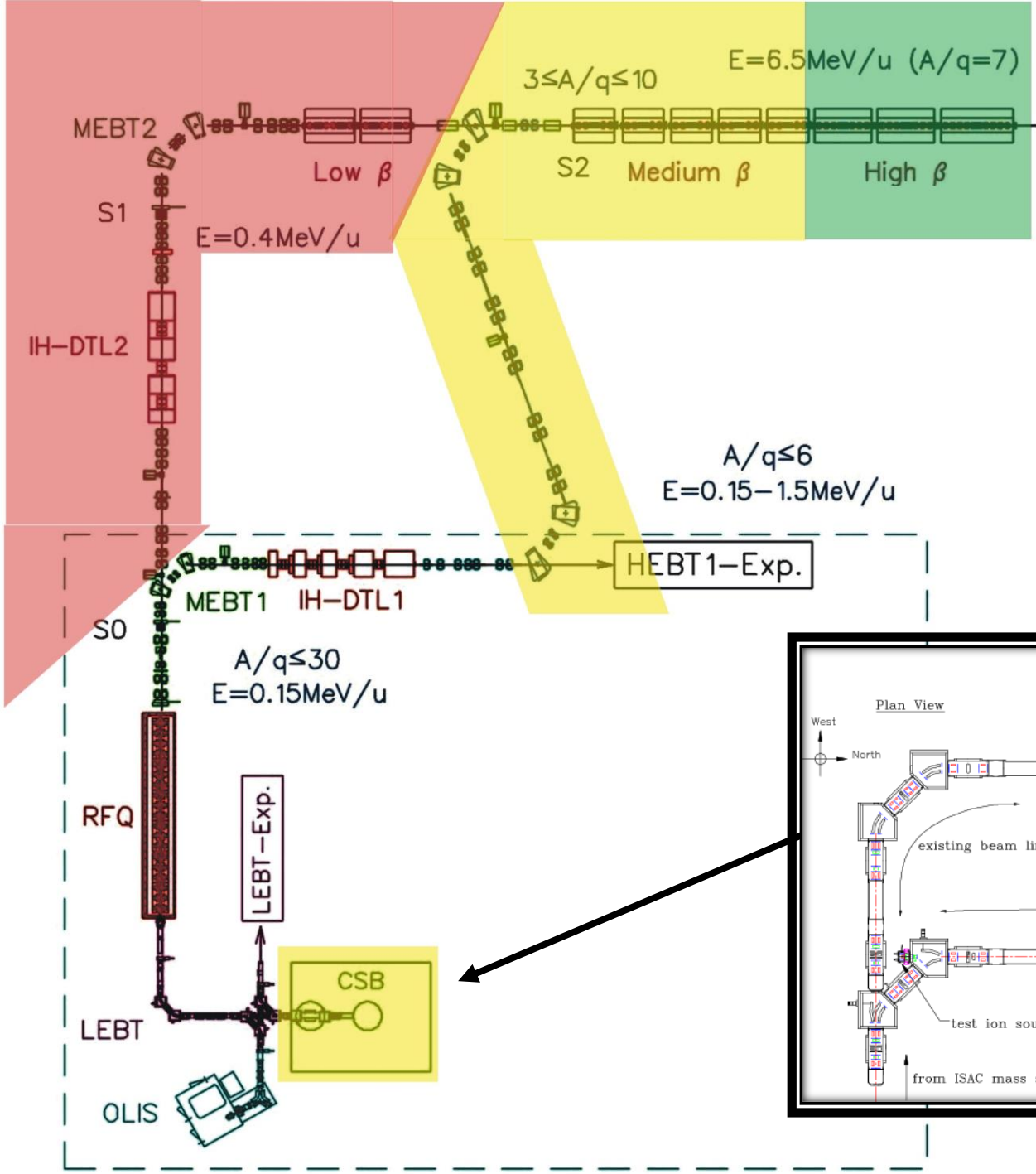
ISAC II Timeline



- Spring 1998
  - ♦ Workshops at Dunsmuir & McMaster
    - Defined basic ISAC II parameters
- August 1999
  - ♦ ISAC-II proposal submitted
- April 2000 - Funding Announcement
  - ♦ Canadian Gov. approves a reduced 5 year plan
  - ♦ 20 Years Ago
- Project Scope Reduced
- Project Dates Delayed

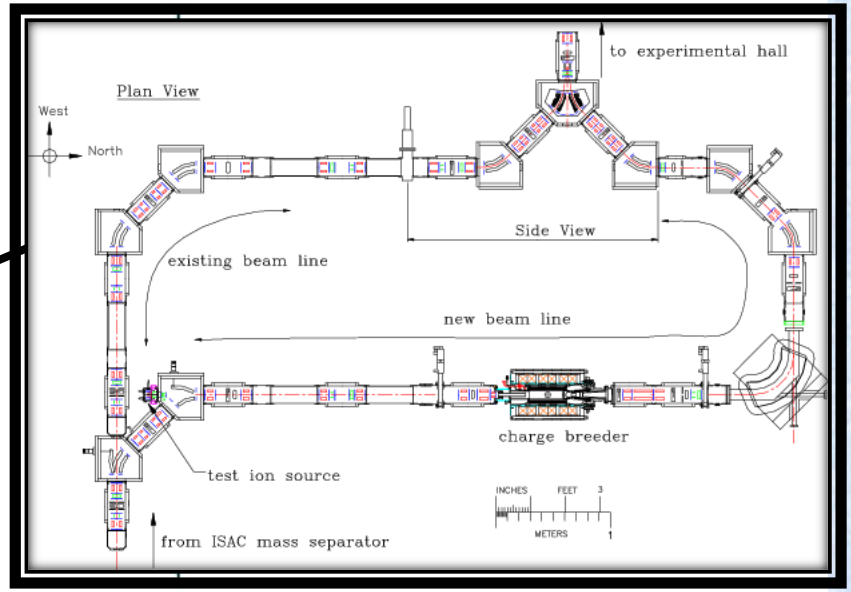
ISAC II Parameters & Project Revised with Reduced Funding (2000 – 2005)

- ENERGY
  - E_{MAX} = 5.8 MeV/amu for stripping to A/q = 6 **(2005)**
  - E_{MAX} = 6.5 MeV/amu for stripping to A/q = 7 **(2005 +)**
  - E_{MAX} = 15 MeV/amu for stripping to A/q = 3 **(2005+)**
- MASS
  - A_{MAX} = 60 **(2005)**
  - A_{MAX} = 150 **(2005+)**



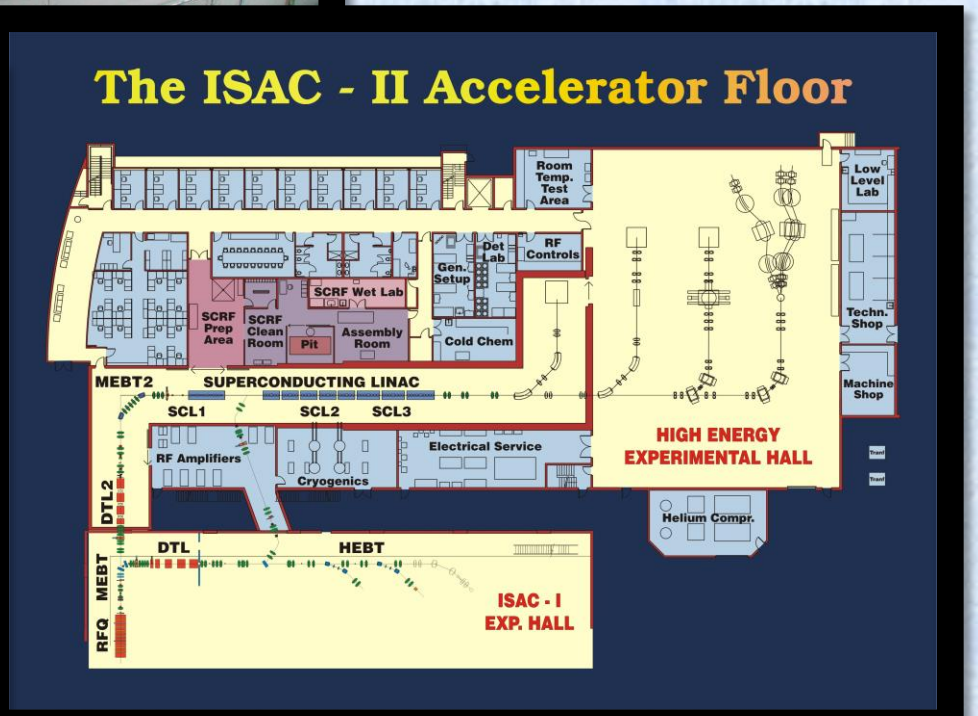
ACCELERATOR MILESTONES

- 2005
- 2007 ~~7~~ 8
- ~~2009~~

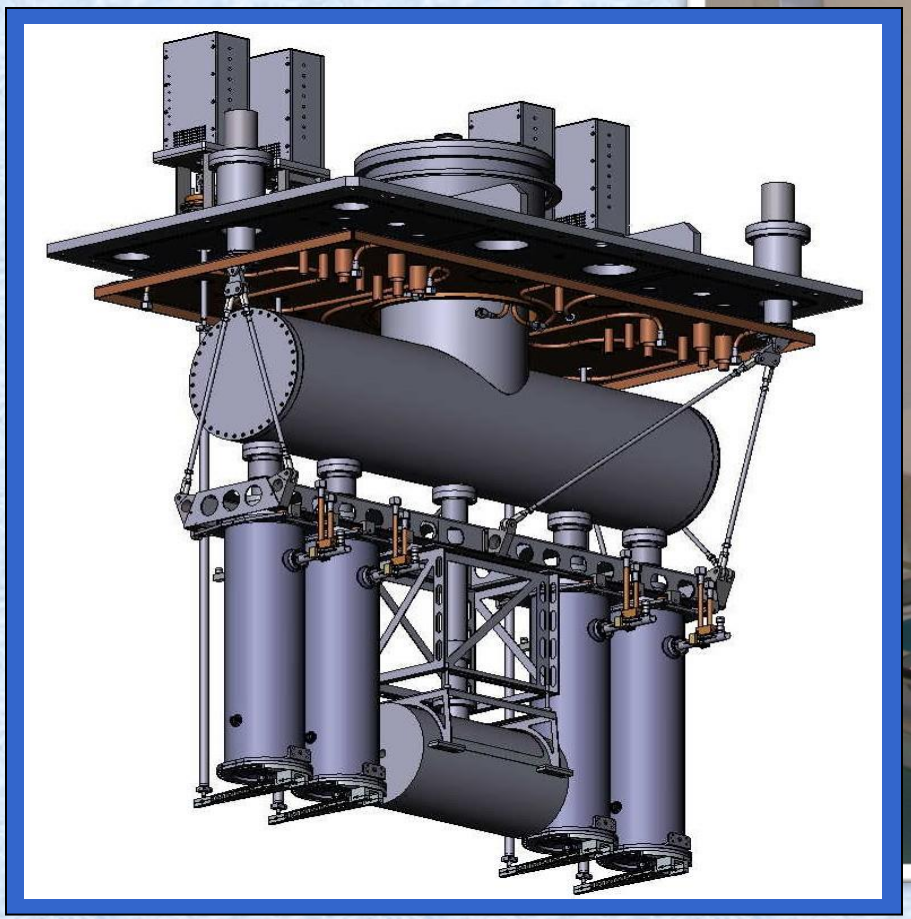


ISAC-II Building

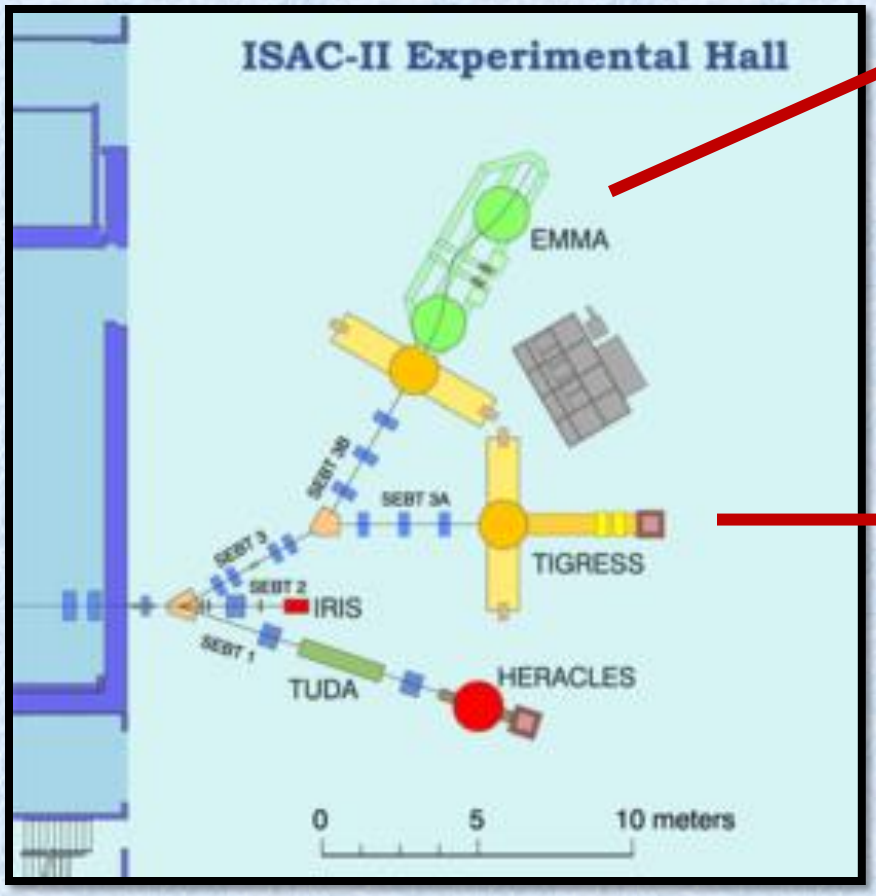
2003
UBC Gives
Temporary
Occupancy
Permit

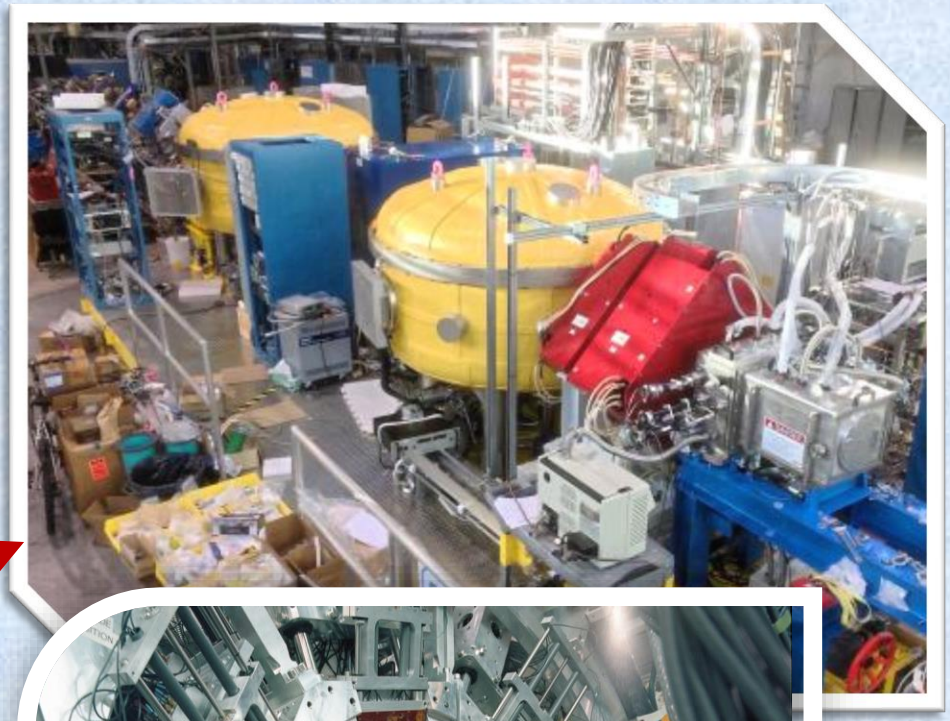


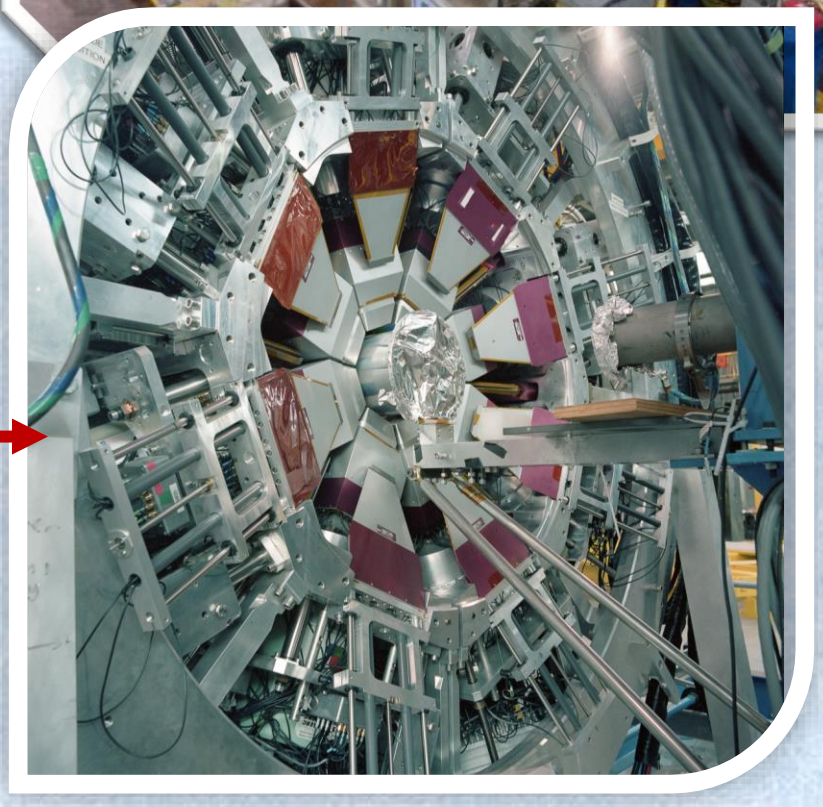
Medium Beta Cryomodule



ISAC II Experiments



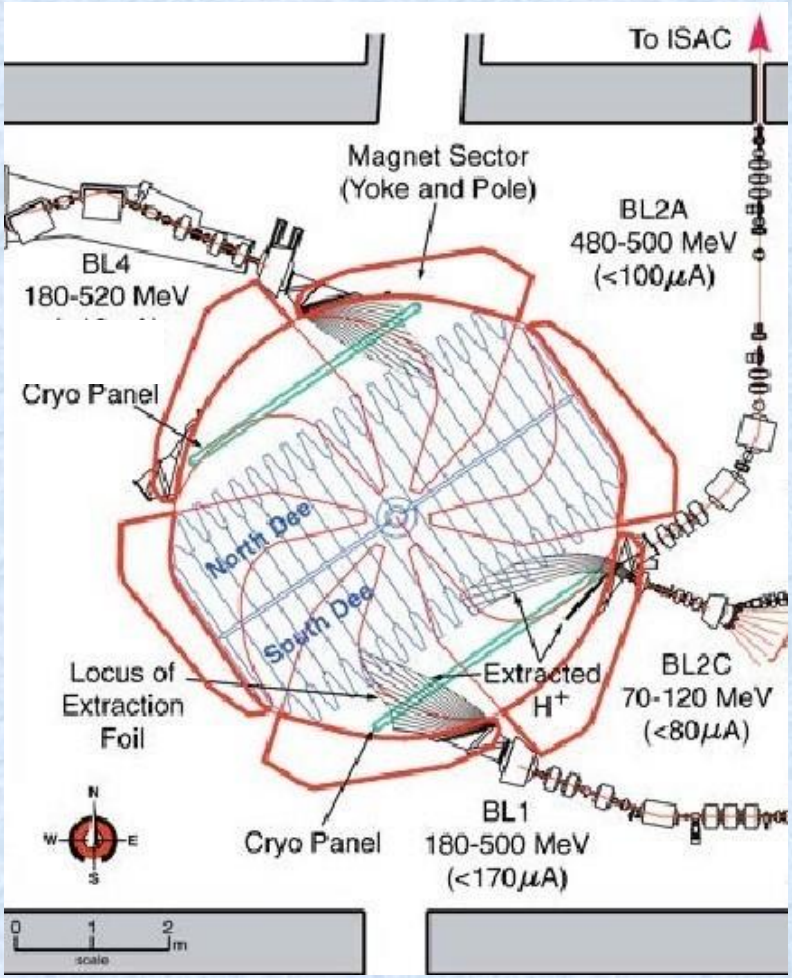




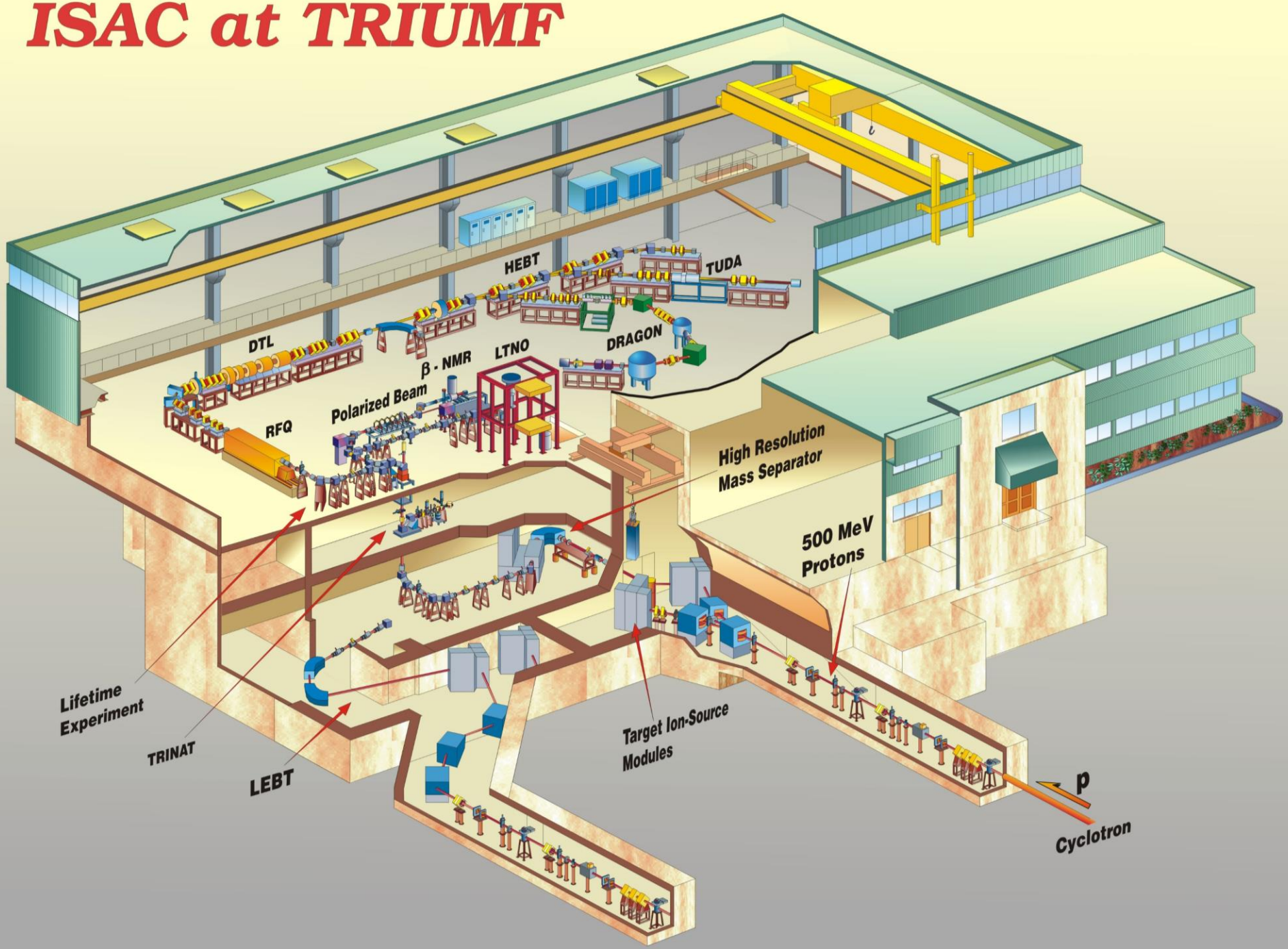
ISAC NEEDS MULTIPLE SIMULTANEOUS RIBs

- MAY 2002 – PRESENTATION TO ACOT NOTED
  - ♦ USER DEMAND (ALREADY) EXCEEDS ISAC CAPABILITY
    - NEED FOR MORE EXOTIC BEAM TIME
      - * INCREASED HOURS PER YEAR
      - * MULTIPLE DRIVER BEAMS
      - * MULTIPLE TARGET STATIONS
      - * MULTIPLE MASS SEPARATORS
      - * DUAL ACCELERATOR SYSTEMS
- UNLIKE THE TRIUMF CYCLOTRON, ISAC CANNOT SIMULTANEOUSLY GIVE BEAMS TO MULTIPLE EXERIMENTS

TRIUMF Cyclotron Can Simultaneously Extract Multiple Proton Beams



ISAC at TRIUMF



ISAC PRIORITIES as SUBMITTED in 2005-10 PLAN

- OPERATE ISAC I & II
- DEVELOP NEW TARGETS, BEAMS & ION SOURCES
- COMPLETE ISAC II
  - ACHIEVE DESIGN SPECIFICATIONS
  - PROVIDE HEBT TO FUNDED TARGET STATIONS
- CONSTRUCT 2nd DRIVER BEAM & TARGET STATIONS
  - PROVIDE MULTIPLE SIMULTANEOUS EXOTIC BEAMS
  - INSTALL TARGET DEVELOPMENT STATION

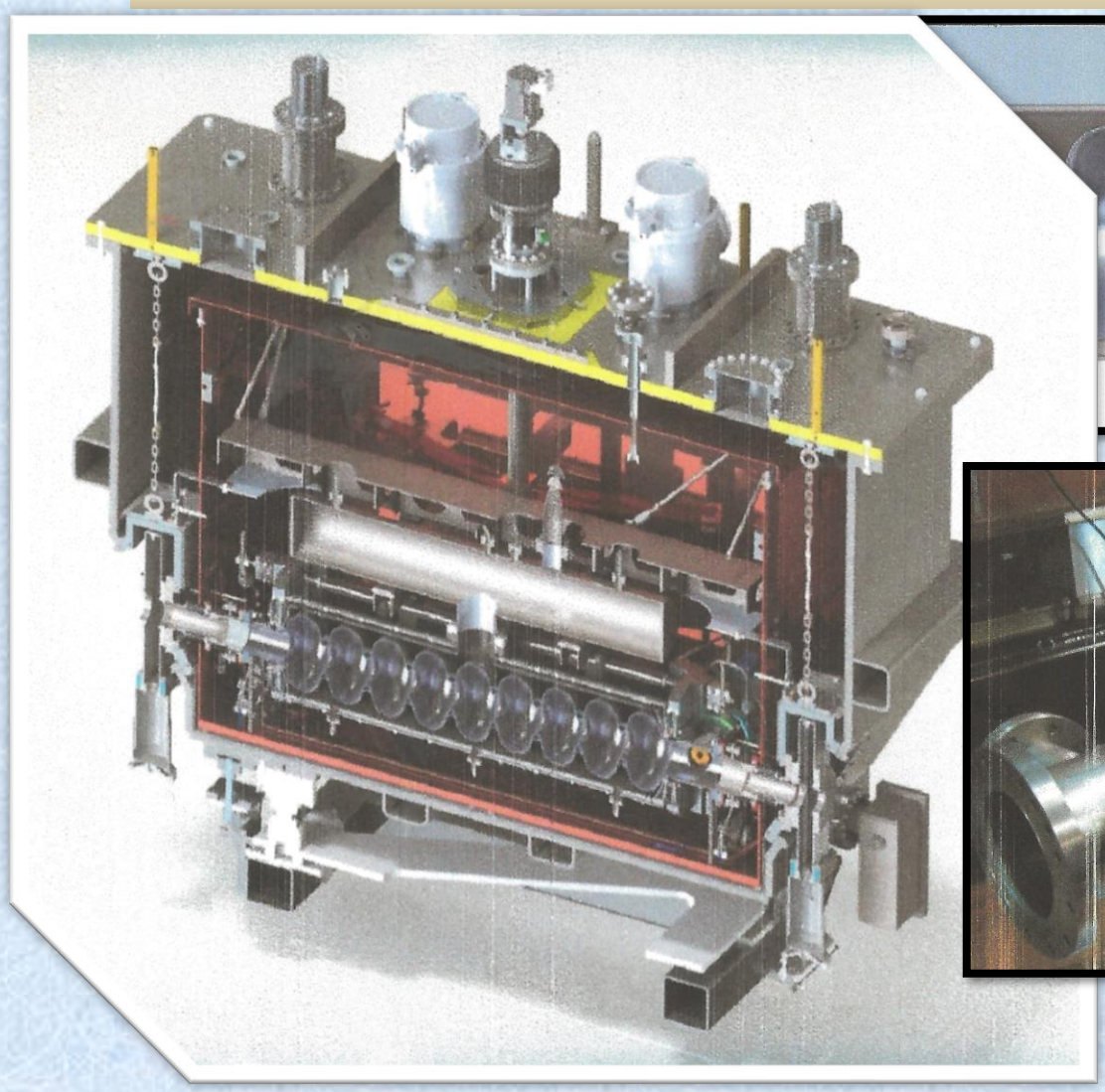
AVANCED **R**ARE **I**SOTOP**E** **L**ABORATORY

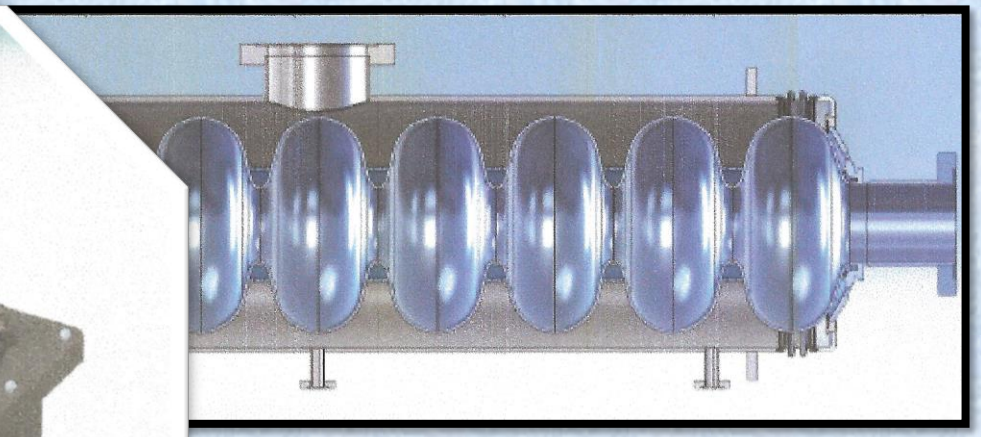
(2010 – 2023)

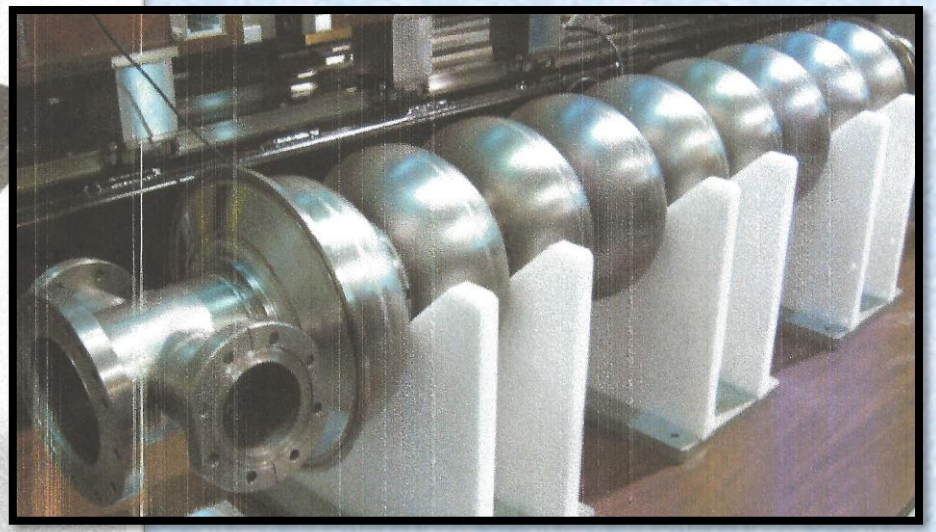
ARIEL Building Completed 2013

- ISAC I utilized one driver beam at 500 MeV and 50 kW to create RIBs for ISAC (#1 driver)
- ARIEL will allow two more driver beams (a total of three simultaneous RIB beams)
  - Adds e-Linac to create RIBs via photofission (#2 driver)
  - Adds a second beam from the cyclotron (#3 driver)
  - Includes Additional Target Stations & Mass Separators

ARIEL ACCELERATOR TECHNOLOGY
Injector Cryomodule







ISOL YIELD ~ $\Phi \sigma \chi \varepsilon_R \varepsilon_A \varepsilon_i$

- Φ = INCIDENT PROTON BEAM INTENSITY
- σ = ISOTOPE PRODUCTION CROSS SECTION
- χ = TARGET THICKNESS
- ε_R = DIFFUSION EFFICIENCY ~ F(TARGET TEMP)
- ε_A = EFFUSION EFFICIENCY ~ F(TARGET TEMP)
- ε_i = IONIZATION EFFICIENCY

- HIGHEST YIELD at HIGH TEMPERATURES
  - ♦ OFTEN OPERATING NEAR TARGET MELTING

MAXIMIZE YIELDS OF RARE ISOTOPES

- MAXIMIZE CURRENT ON TARGET
  - MINIMIZE PROTONS HITTING TARGET SHELL
  - KEEP CURRENT STABLE
  - KEEP BEAM PROFILE STABLE
  - AVOID HOT SPOTS ON TARGET
- RAISE TEMPERATURE OF TARGET TO NEAR MAXIMUM
  - AVOID MELTING TARGET
- RAISE TEMPERATURE OF TARGET SHELL
  - AVOID MELTING TARGET SHELL

Some of Gerardo Dutto's Major Contributions to ISAC's Success

- Provided Cyclotron Resources to ISAC
  - Postponed Numerous Cyclotron Planned Upgrades
  - Cyc. Funds Diverted to & Personnel Seconded for ISAC Construction
- Arranged for International Accelerator Collaborations
  - Expertise in Linear Accelerator Technology Brought to TRIUMF
- CUSP ION SOURCE
  - Brought Dr. Pioscxyk & Karlsruhe H^- technology to TRIUMF
- 100 μA Task Force
  - Developed Ability to Stably Accelerate & Extract up to 420 μA
    - 2 Simultaneous 50 kW Beams for ISAC & ≤ 50 kW for Meson Hall
- Ion Source pulsed beam
  - Introduced System to Protect Cyclotron Beam Systems
  - Turned out to be Essential to Safely Increase Beam on ISAC Targets - Avoids Thermal Shocks to Target
    - Improved Target Lifetime & RIB Availability
- Developed Cyclotron Schemes to Stabilize Current Extracted to ISAC

THANK YOU GERARDO

In Memoriam

Gerardo Dutto

1938 - 2020