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Targets and Ion Sources and the Five-Year Plan

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TRIUMF Science Week 2022

Accelerator Science

Discovery, accelerated

Accelerator Division Mission Statement

- The TRUMF accelerator division safely operates the TRIUMF accelerator complex with high performance and availability. We develop and implement new accelerator facilities and related technologies to support world class science nationally and internationally.
- We lead accelerator physics research in Canada and foster TRIUMF’s position at the forefront of accelerator science. We advance our core competencies and transfer our knowledge to industry for the benefit of society.
- We leverage infrastructure and expertise to provide world class training of HQP in accelerator physics and engineering.

TRIUMF Expertise and Accelerator Development and Research

- Accelerator science at TRIUMF provides Canada with a world-class platform in
  - beam physics and instrumentation
  - secondary particle production
  - SRF technologies.

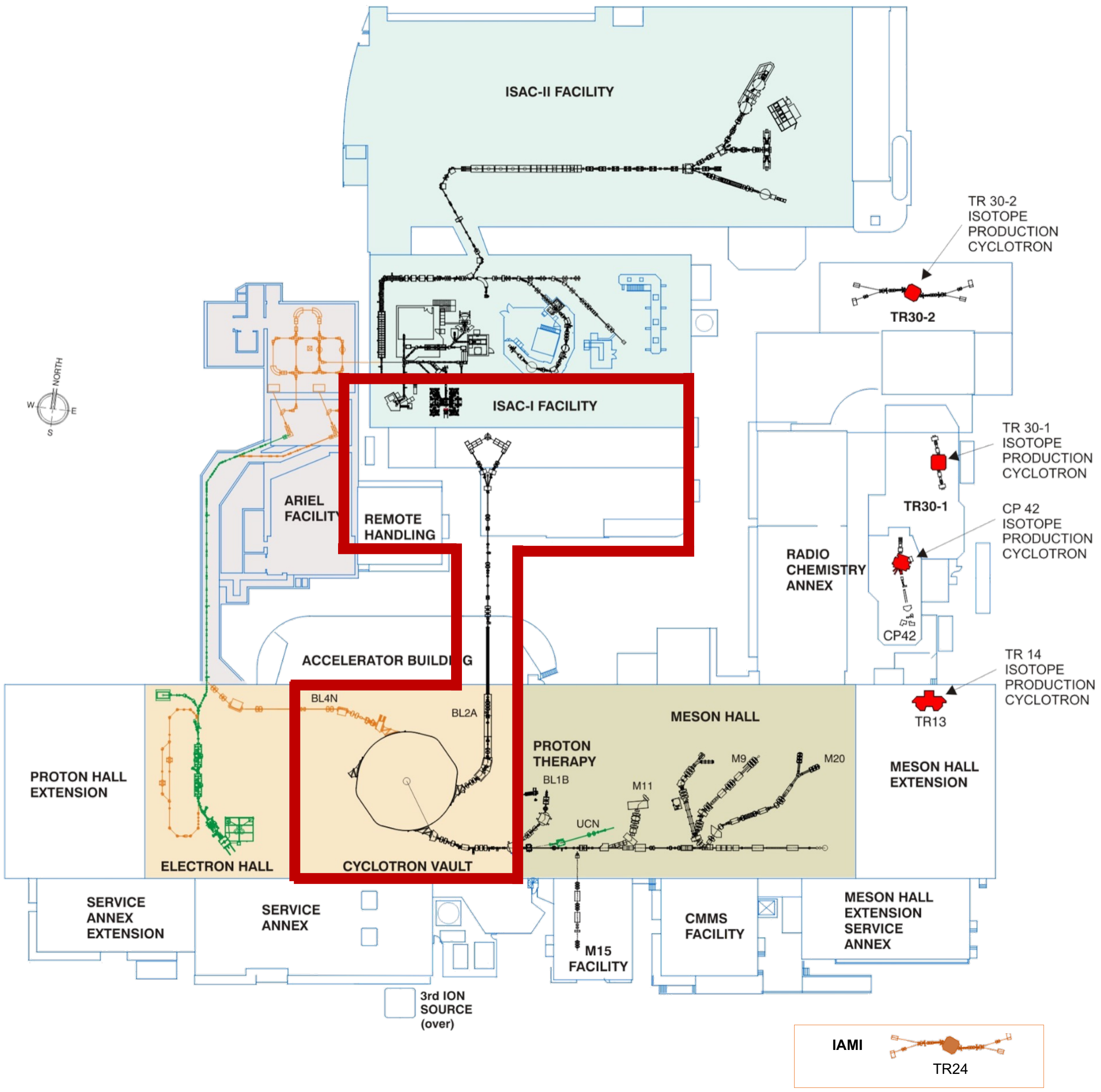
- Accelerator science supports the high performance and availability of TRIUMF's accelerator complex, including new facilities such as ARIEL and international projects such as HL-LHC.

Targets and Ion Sources Department

Synergy between operation, new facility development and research.
Accomplished by three expert groups.

- Remote Handling (Adam Newsome, P.Eng)
- RIB Target Production and Operation (Carla Babcock, PhD)
- RIB Target Research and Development (Thomas Day Goodacre, PhD)
- Laser Applications (Jens Lassen, PhD, BAE)

Support the ISAC RIB Program (since 1995)



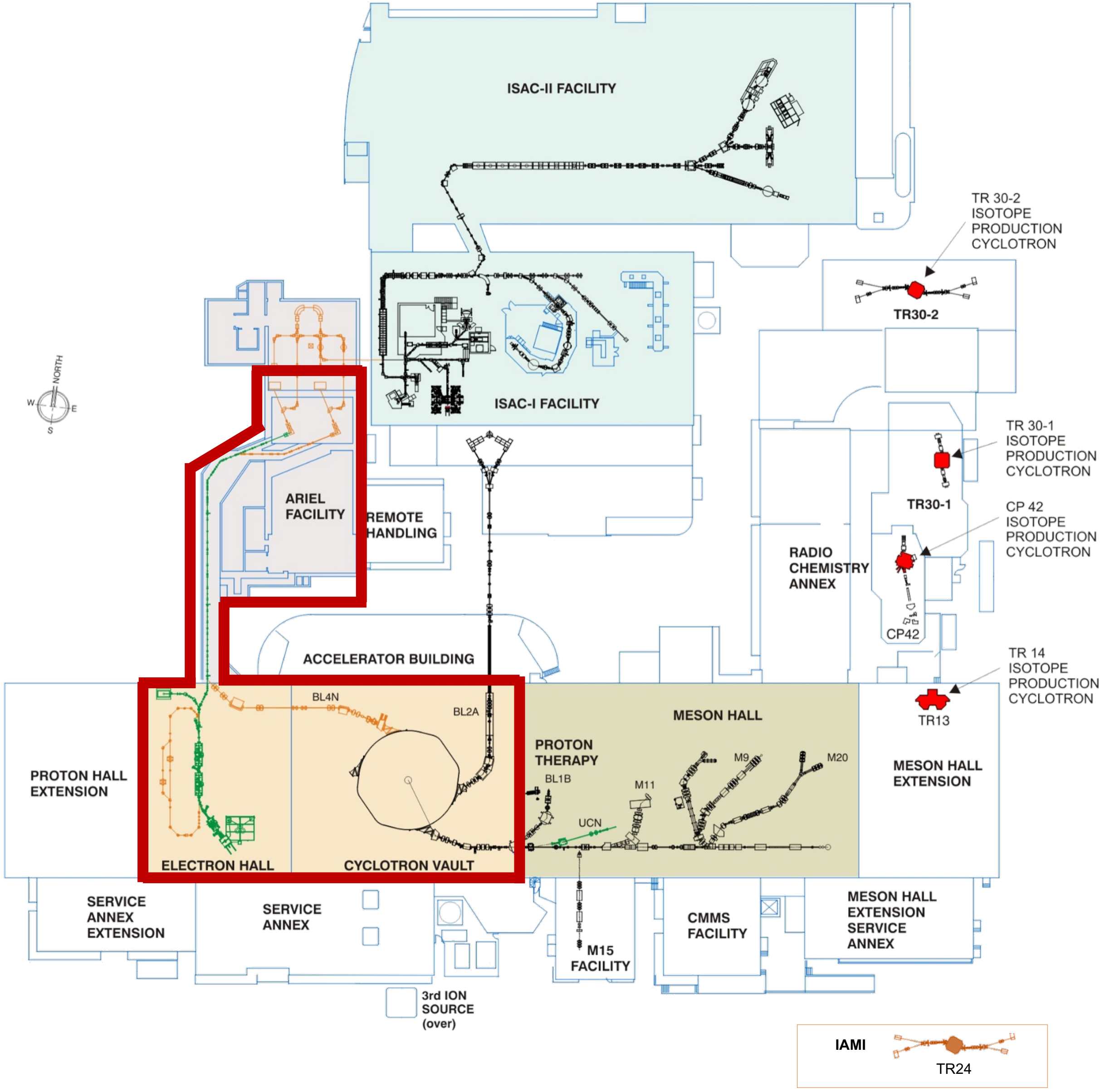
- Target production (10/y)
- Operation of 2 ISAC target stations and ancillary systems

- Resonant laser ionization
- Yield measurements
- Operation of RI implantation system
- Operation of nuclear spin-polarizer beamline

- Hot-cell based RIB target exchanges
- Target system refurbishment

- Research and development program: new target concepts, ion sources, target materials to meet evolving RI demand
driven by Beam Development Strategy (see C. Babcock's presentation tomorrow)

ARIEL Development and Installation (within a Matrixed Structure)

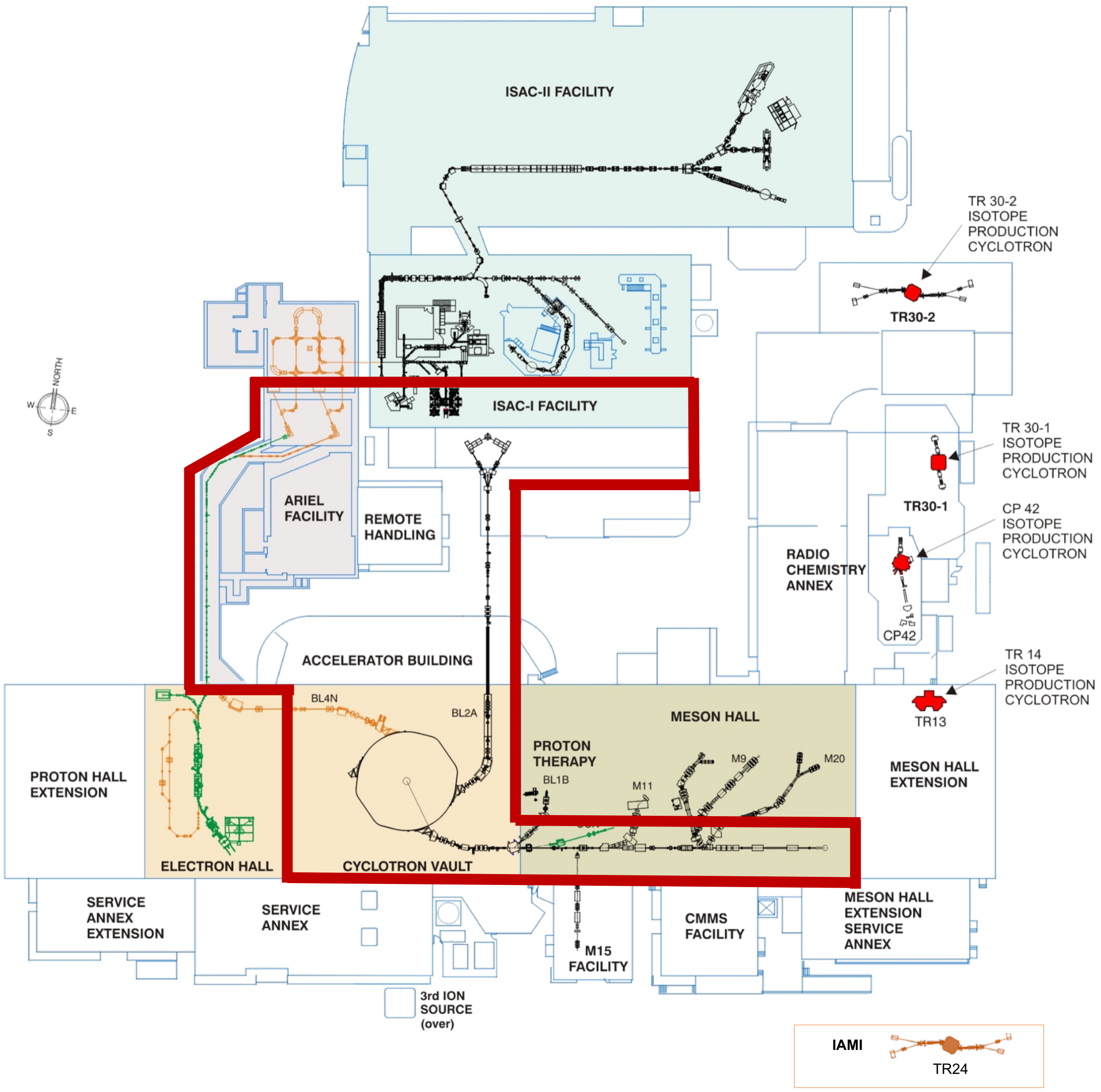


- First-of-a-kind high-power electron-driven ISOL target station (AETE)
- New proton target station (APTW) including a medical target irradiation and handling system

- Dedicated laser-ionization complex
- Target station shielding, mechanical and electrical services
- Target systems remote handling, including a new 3-workstation hot cell complex

- Additional yield measurement and implantation systems

Site-Wide Remote Handling



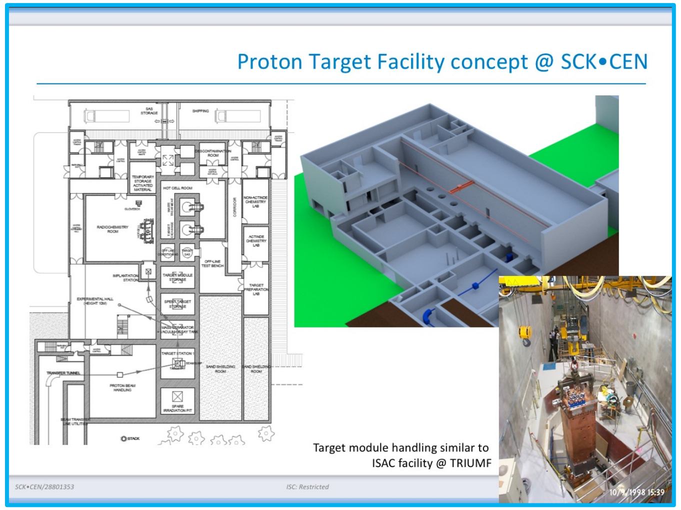
- Designing, building, maintaining, and operating equipment used site-wide to reduce radiation dose to personnel
- Remote handling and beamline infrastructure refurbishment
- Support of other TRIUMF groups by performing or assisting in work where standard approaches result in excessive radiological exposure
- 520 MeV cyclotron maintenance
- Target systems and waste handling within the Meson Hall, ISAC, and ARIEL facilities
- Primary beamlines and component handling

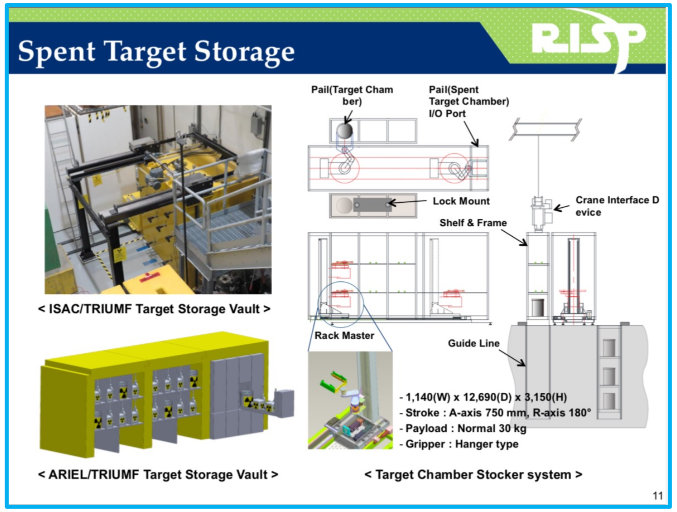
TRIUMF Remote Handling

TRIUMF is internationally recognized for its leading role in RH, hot cell design and operation and development of systems for operation in kGy – PGy dose fields.

- Mechatronics and robotics development
- Training programs on prototypes and hot cells
- International collaborations (T2K, CERN, SCK, VECC, RISP, etc)

SCK MYRRHA and IBS-RISP designs based on TRIUMF RH





RH robotics development

TRIUMF RH specialists assisting in T2K target repair

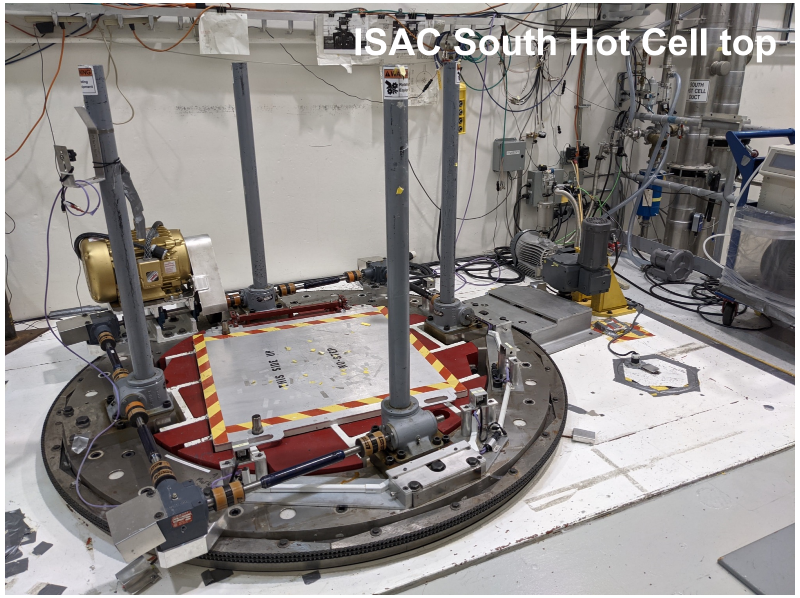
Remote Handling Refurbishment

Ongoing RH refurbishment projects, completion until 2025:

- 520 MeV Cyclotron RH mechatronics systems
- Cyclotron RH controls
- In-depth analysis of BL and all Meson Hall remote handling equipment
- Identify, characterize, prioritize and plan BL1A upgrade needs, experts are collecting requirements, 10 high-priority tasks identified

2025-2030

- Major BL1A refurbishments, based on priorities and available resources
- Continuation of RH controls refurbishment, including ISAC TH
- Meson hall RH systems refurb, including hot cell, T1/T2 target transfer flask
- Develop and install RH waste management reduction infrastructure



Radioisotopes for Science and Innovation

Discovery,
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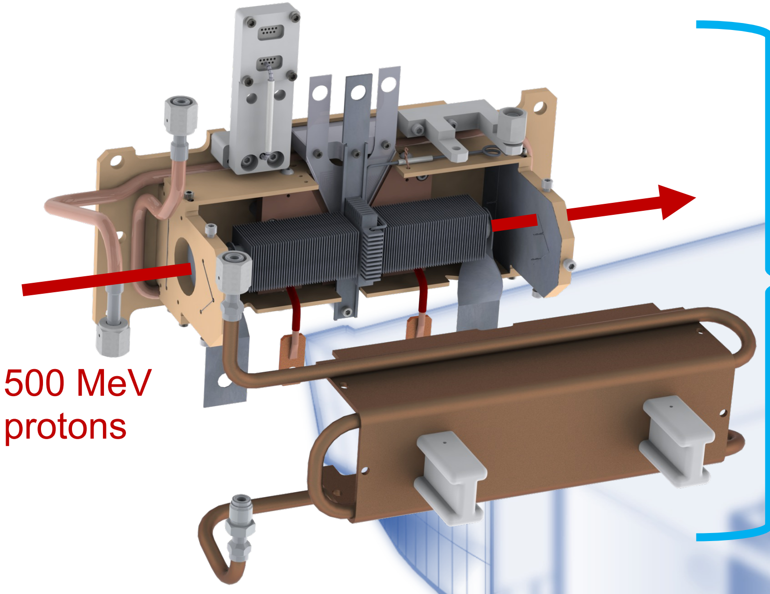
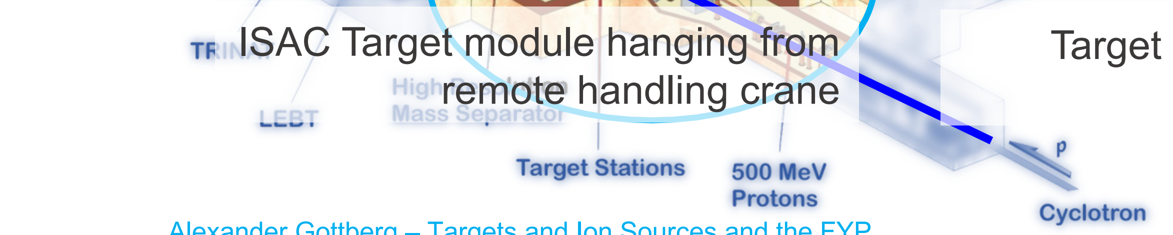
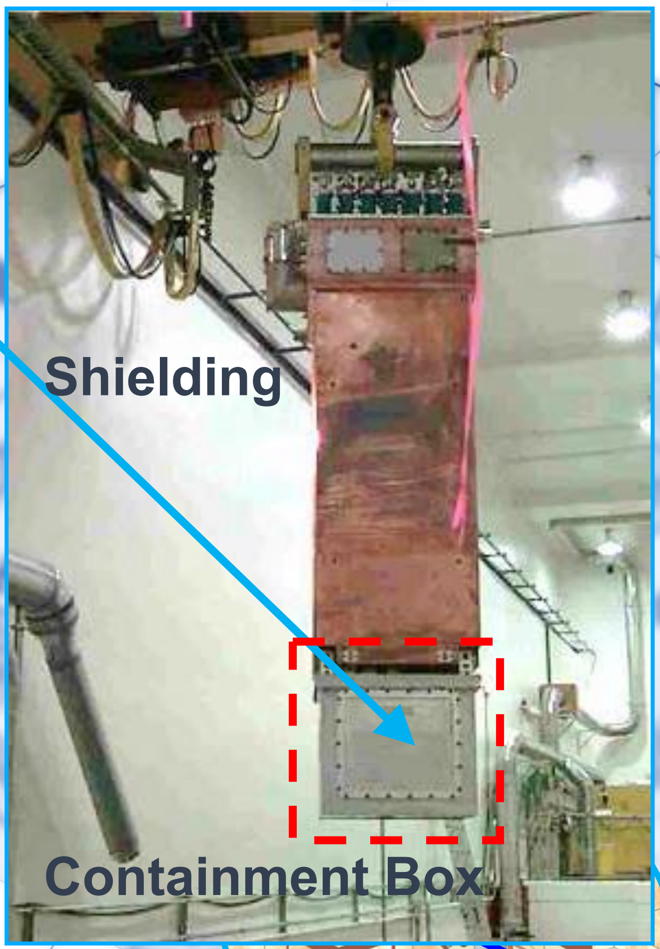
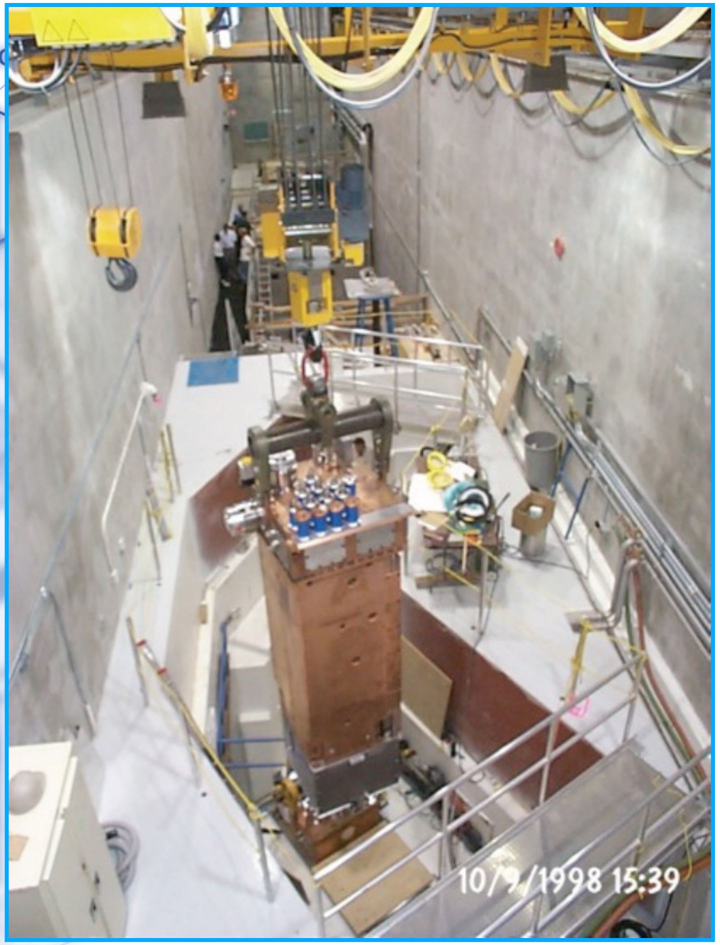
ISAC Radioisotope Beams Since 1998





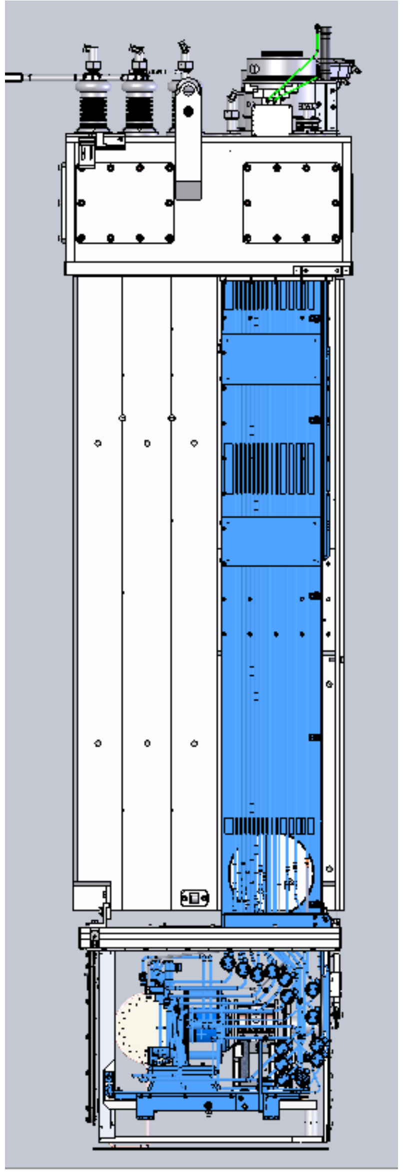


ISAC Target module hanging from remote handling crane



Target module transport to target station

ISAC Targets and Ion Sources Reliability Upgrades

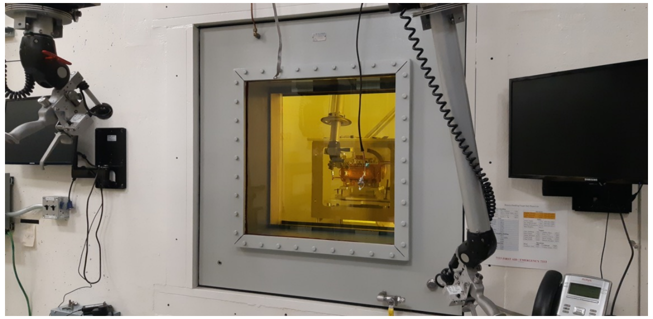


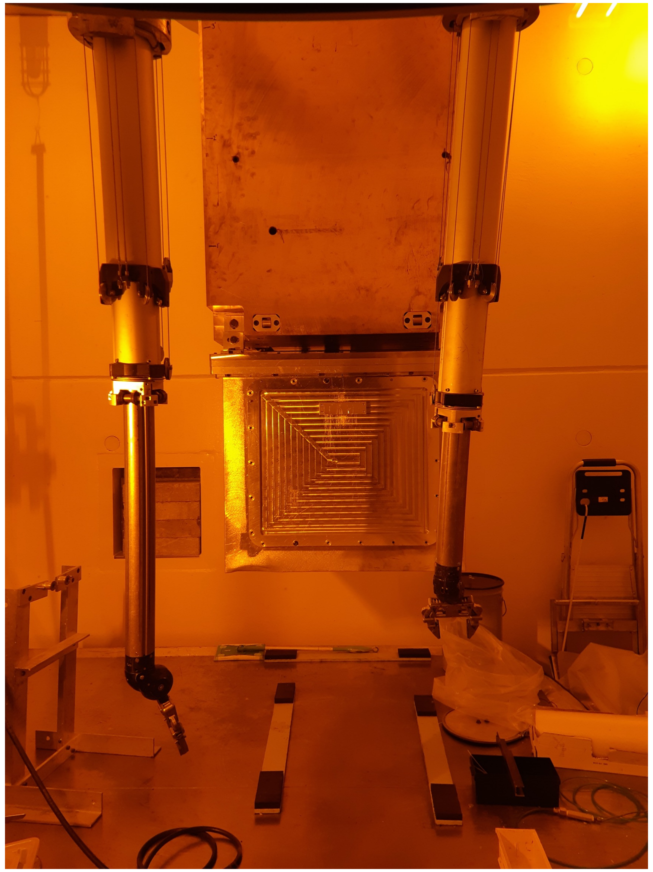
Recent infrastructure investments and refurbishments starting to pay off, examples:

- North hot cell complete
  South hot cell available for target and module maintenance, refurbishment and break fixes
- Safe Module Parking complete
  Required for regular Target Module refurbishment campaign
- Continuous HV tests and improvements
- Automation and additional diagnostics for reduced dose and proactive repairs

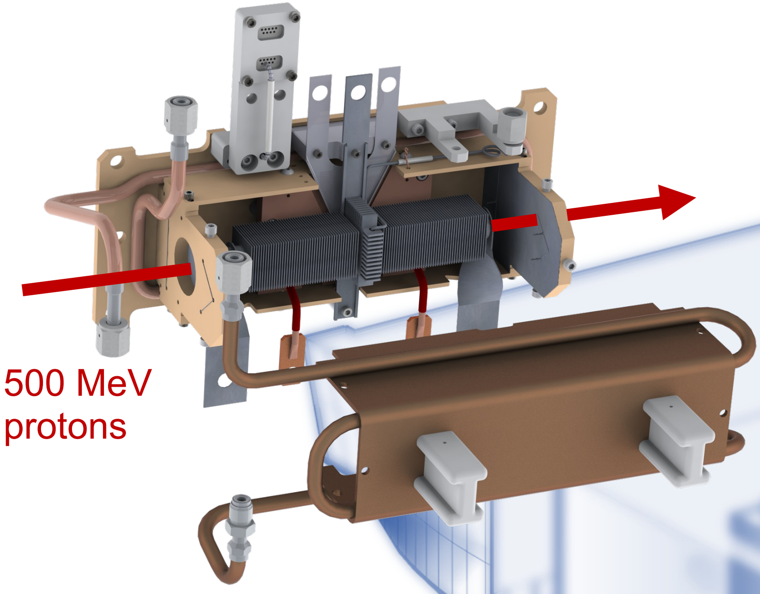
Target system consolidation will continue 2025-2030:

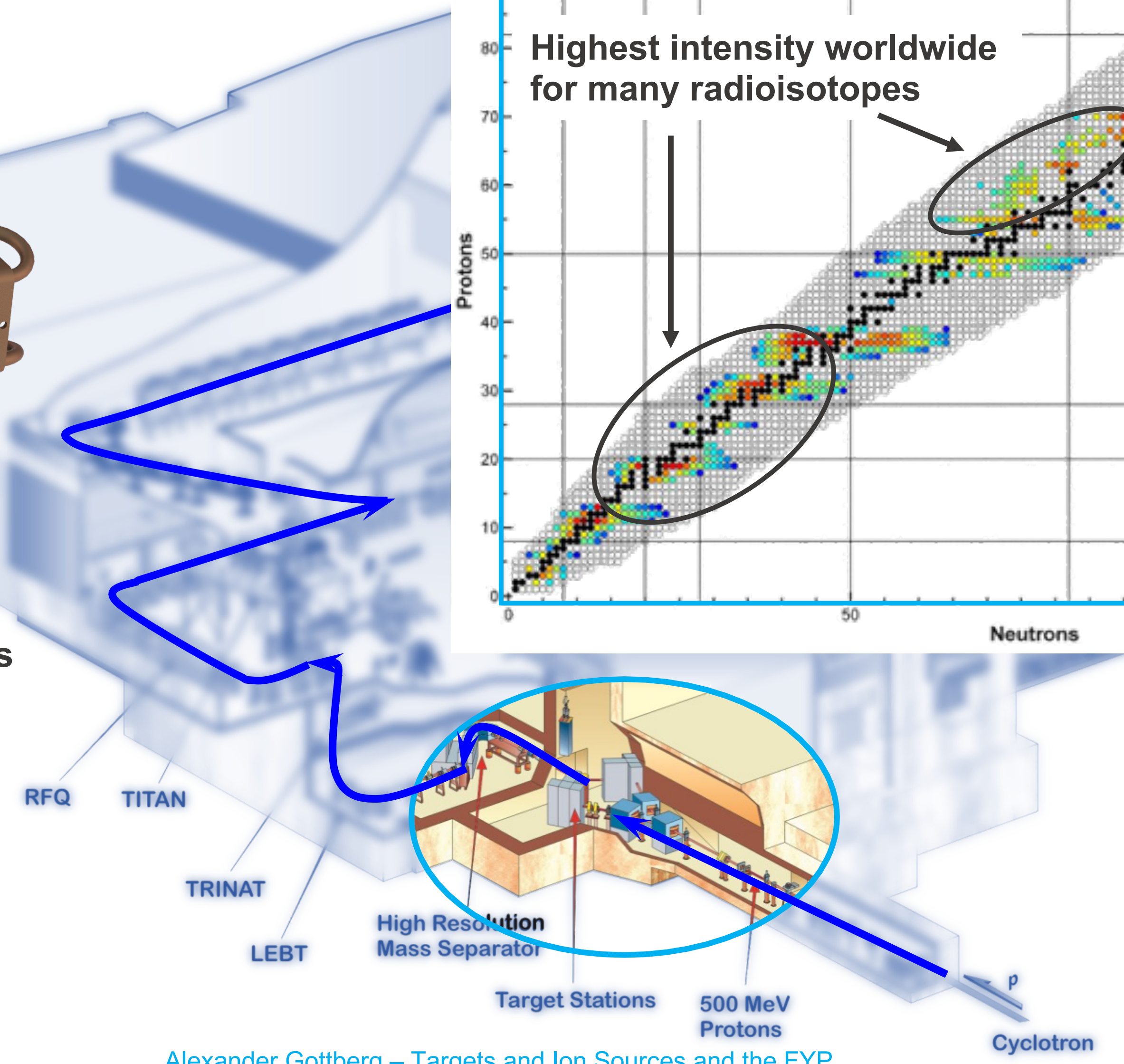
- Full roll-out of regular target module refurbishment program (all major components except shielding)
- Construction of an additional target module
- Target production and conditioning systems renewal
- Electrical and mechanical systems refurbishment and procurement of critical spares

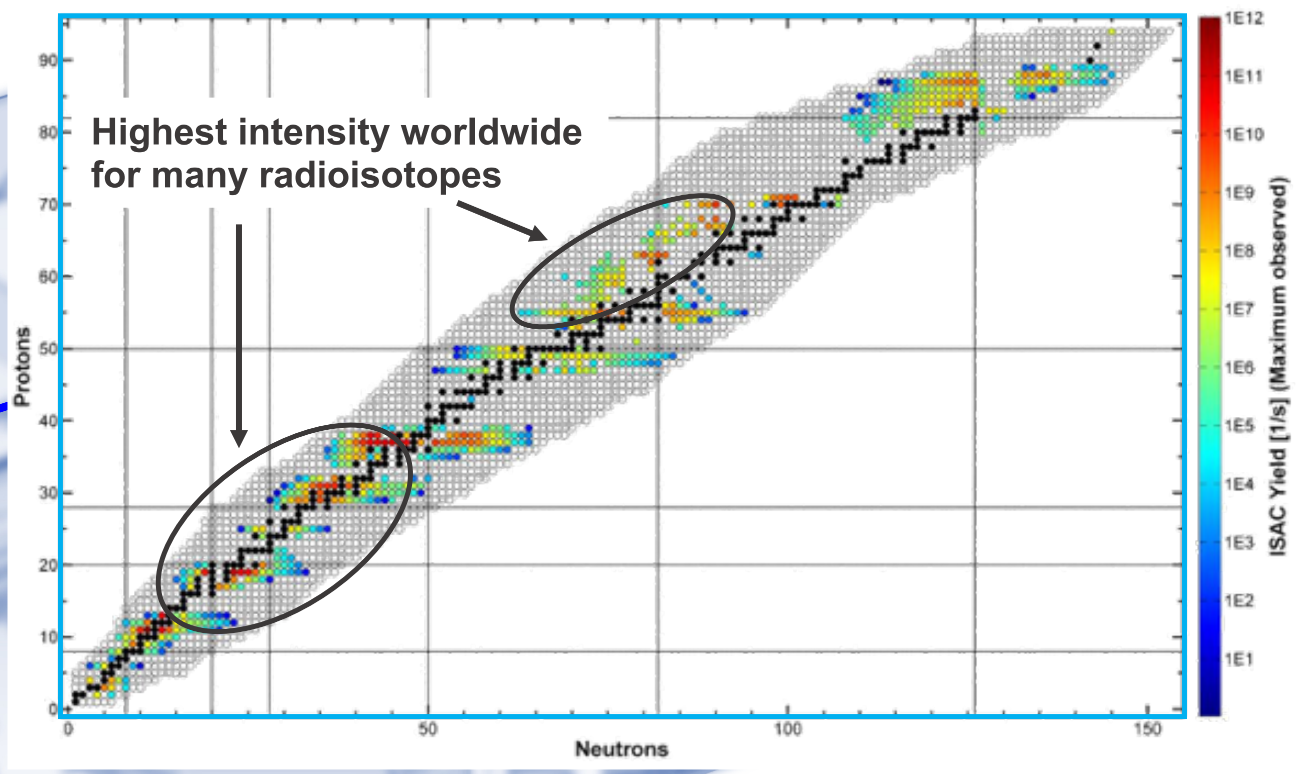




ISAC Radioisotope Beams Since 1998







Target materials:

- UC_x
- UO_2
- ThO
- Nb
- Ta
- TaC
- NiO
- ZrC
- TiC
- SiC

Variable beam power

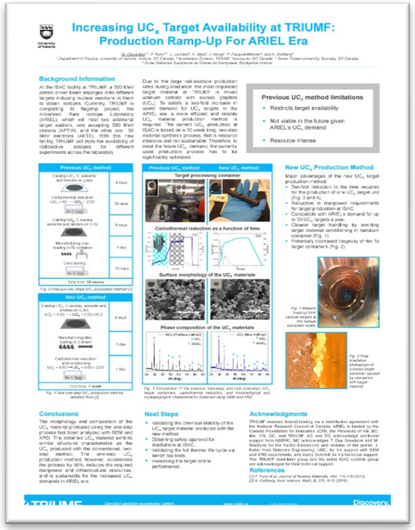
Variable transfer lines

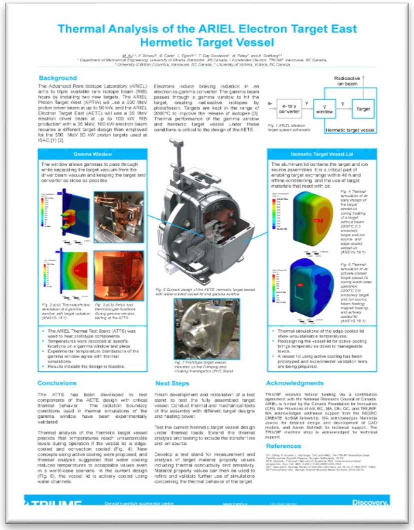
Ion sources:

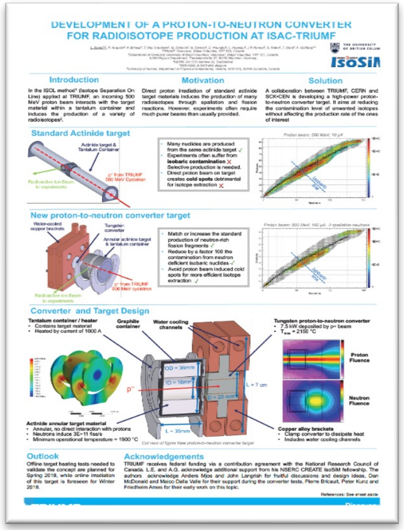
- surface
- resonant laser
- FEBIAD
- IG-LIS

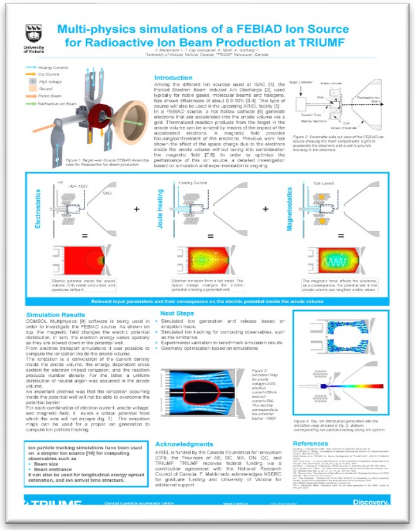
Maintaining RIB Competitiveness - Target/Ion Source Development

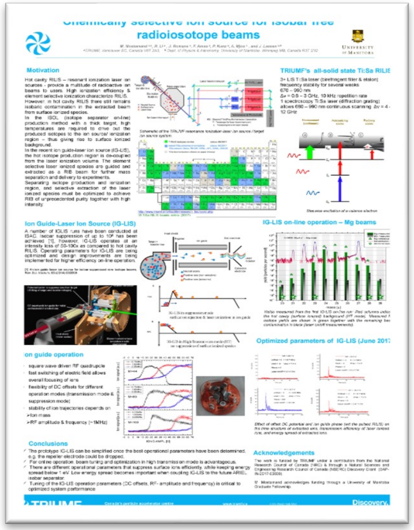
- ‘All’ beams are possible
- ARIEL capabilities will bring many development opportunities, more off / online development time
- Plenty of online and offline TISD projects ripe for picking. Missing: free energy outside of projects and operation
- Proven formula of success: close collaborations with RIB users, experimental infrastructure, universities / labs
- In TIS: 3 BAEs, 4 adjuncts, ~7 graduate students, ~15 publications per year

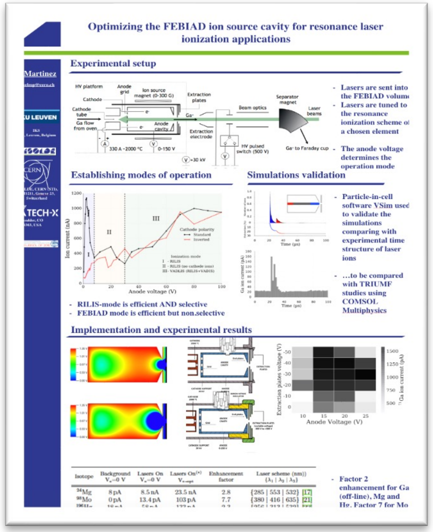






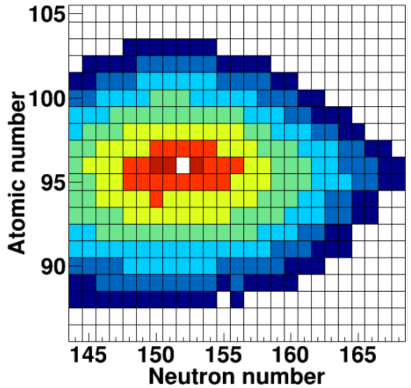






2025-2030:

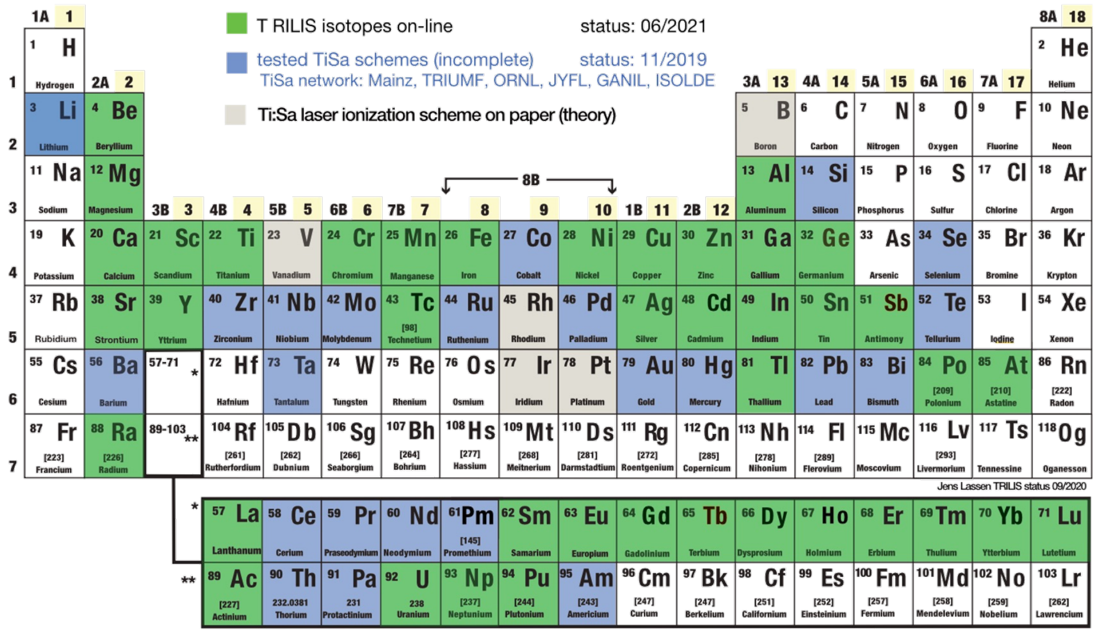
- Maintain a strong-student and post-doc led R&D program
- Harvest the development potential of ARIEL
- Continue to align TISD with evolving user RIB requirements
- Invest into dedicated mid-size R&D projects using non-NRC resources

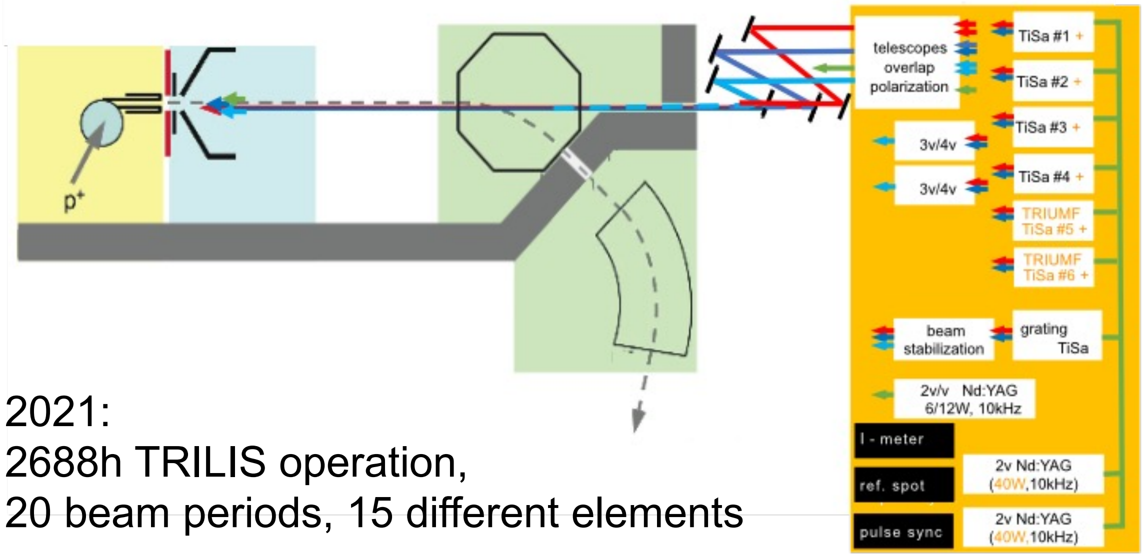


Production of heavy n-rich species through MNT reactions in secondary target station

https://indico.fys.kuleuven.be/event/58/contributions/1678/attachments/596/733/20190418_kuleuven_watanabe.pdf

T RILIS Resonant Ionization Laser Ion Source in the ARIEL Era





2021:
2688h TRILIS operation,
20 beam periods, 15 different elements

Beam Delivery:

- Status: 41 elements
- Multiple laser-ionized species
- Increased user control

Beam Development:

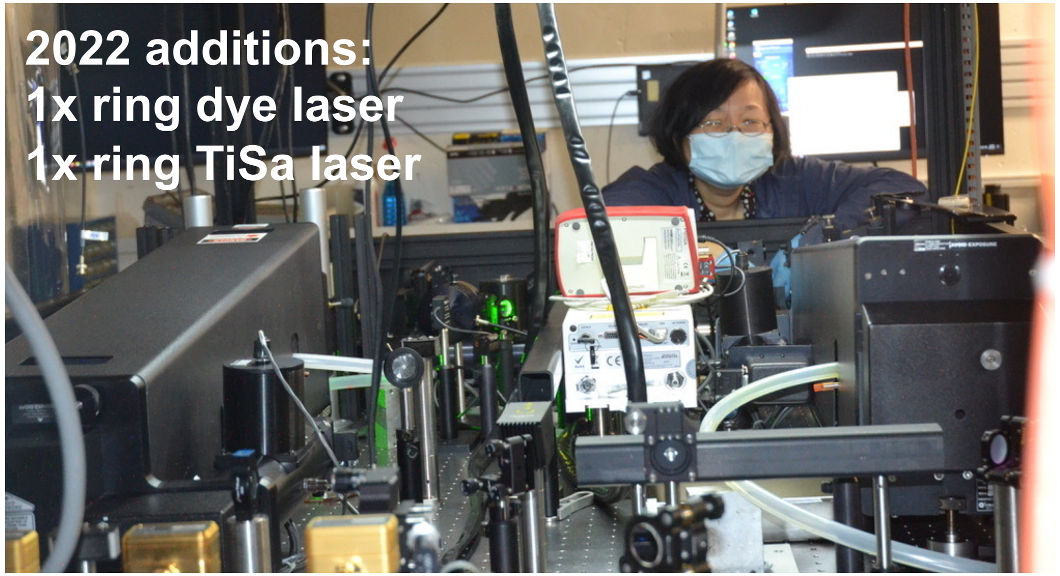
- Target: 2 elements/y (increasingly difficult)

Upgrades:

- Allow for more complex setups
- Allow ALIS & TRILIS parallel operation

ARIEL startup

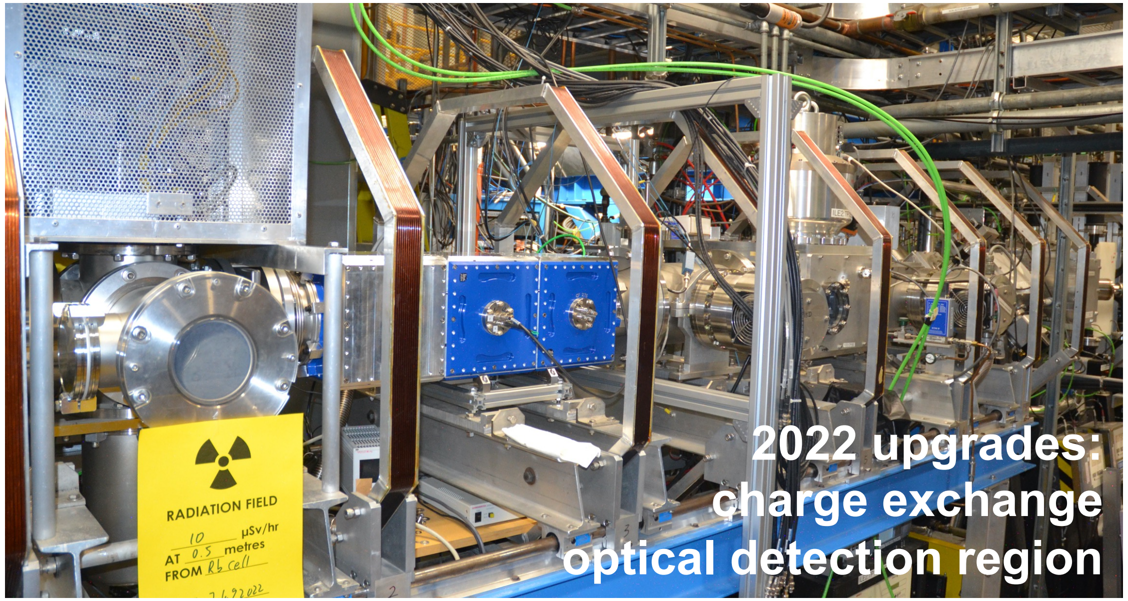
Polarizer in the ARIEL Era: Multi-Element Spin Polarized Beams



- Continue infrastructure refurbishment
- Develop spin-polarized beams as part of POLARIS project & nuclear structure

→ Install off-line source for polarizer
→ Off-line polarization R&D

- Operate upgraded polarized beams to OSAKA
- Add beamline junction polarizer → GRIFFIN & bio β-NMR



Discovery, accelerated

Advanced Radioisotope Laboratory
(ARIEL)

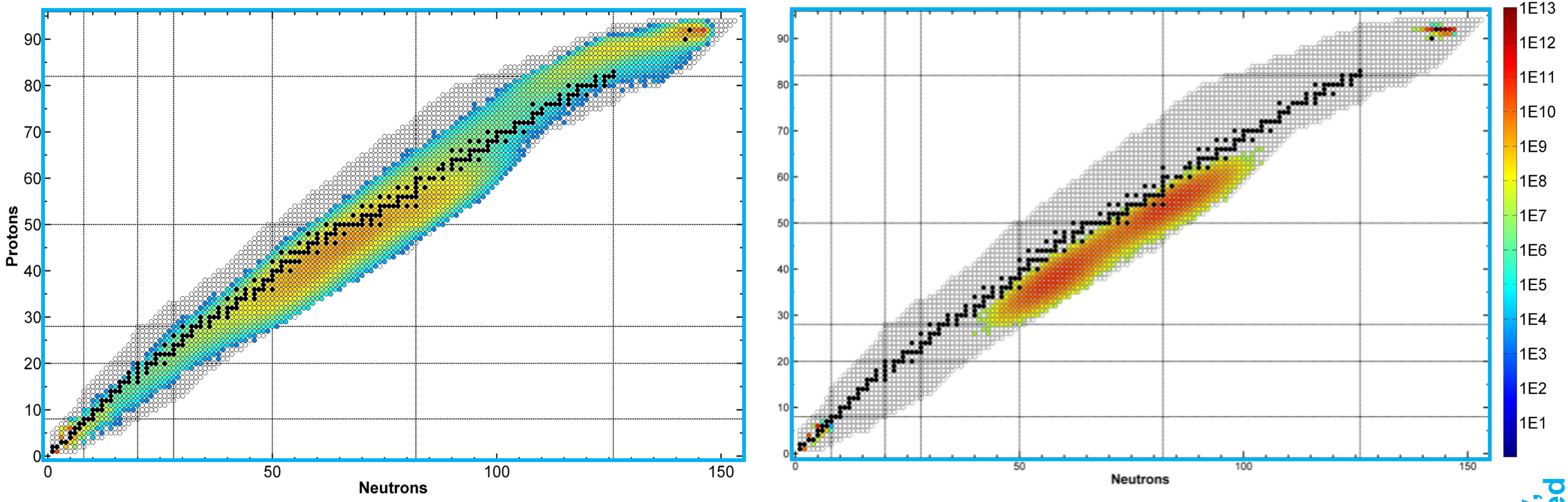
Discovery,
accelerated

An Independent Driver for TRIUMF's Rare Isotope Program

Production rates from $^{238}UC_x$

500 MeV x 10 µA protons [1/s]

35 MeV x 10 mA electrons [1/s]

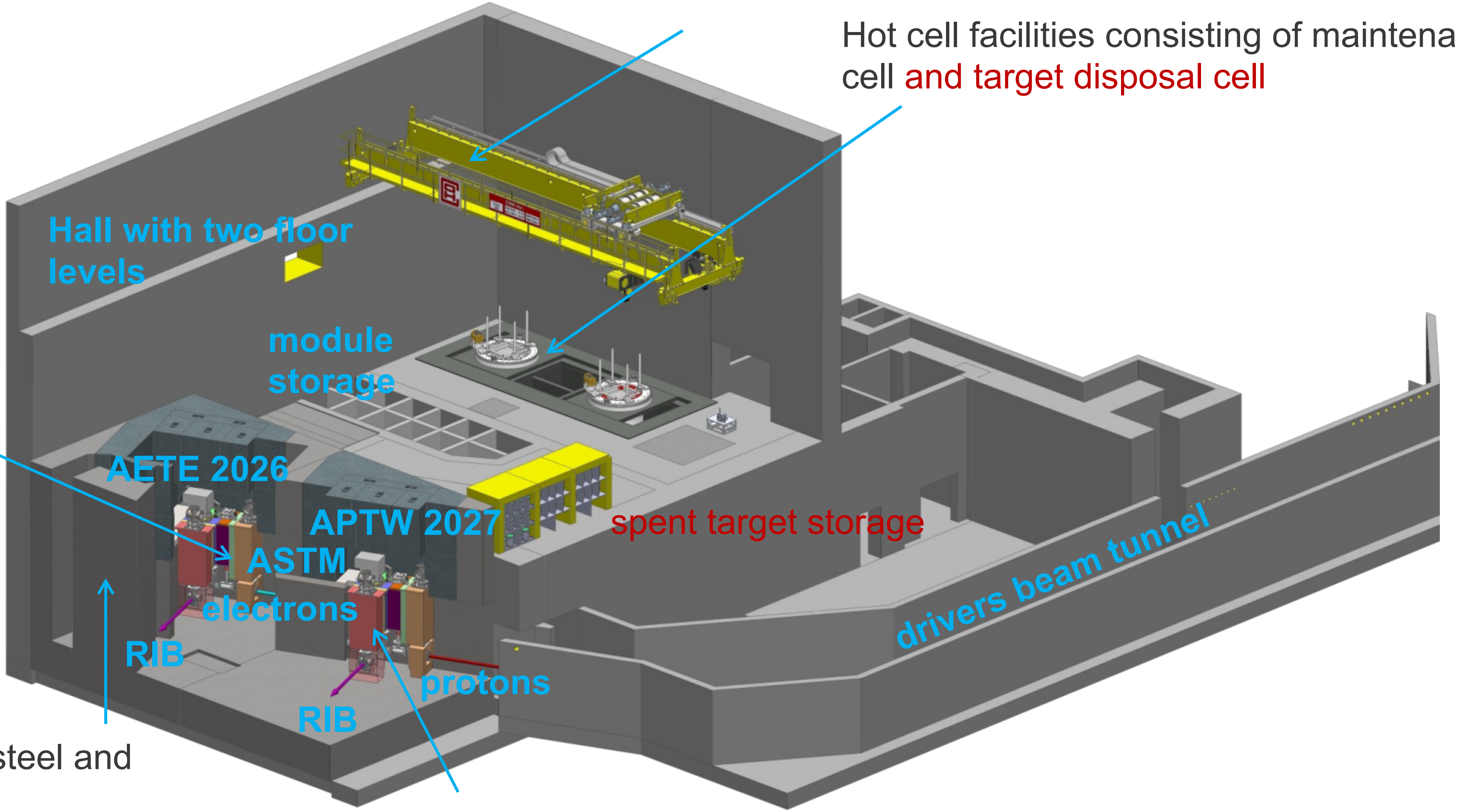


Advanced Radioisotope Laboratory (ARIEL)

Remote-controlled crane

Hot cell facilities consisting of maintenance cell and target disposal cell

Symbiotic medical target in APTW beam dump



2000 t of steel and concrete

Modular RH high-power infrastructure

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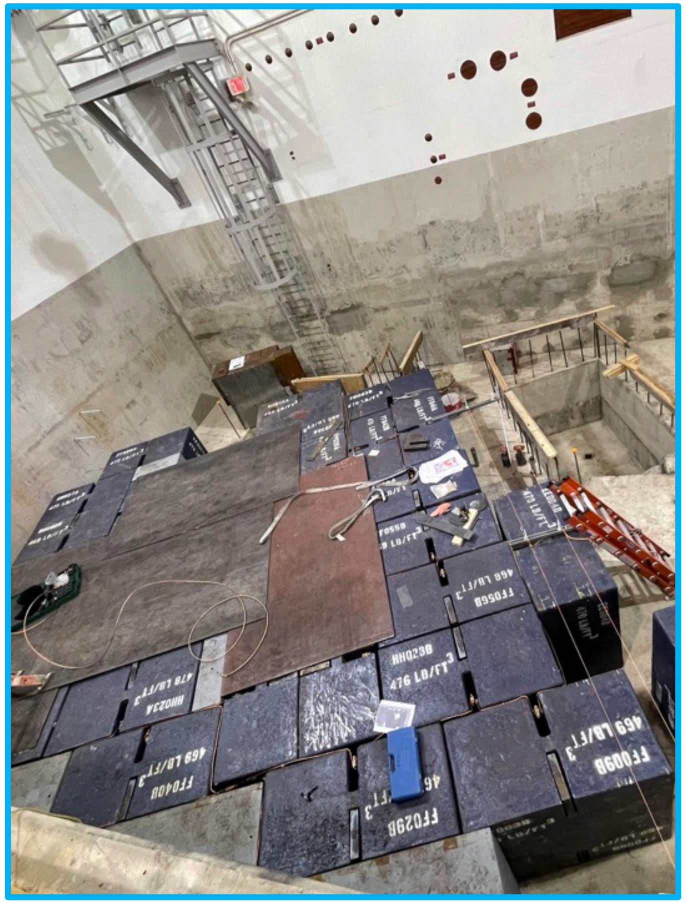
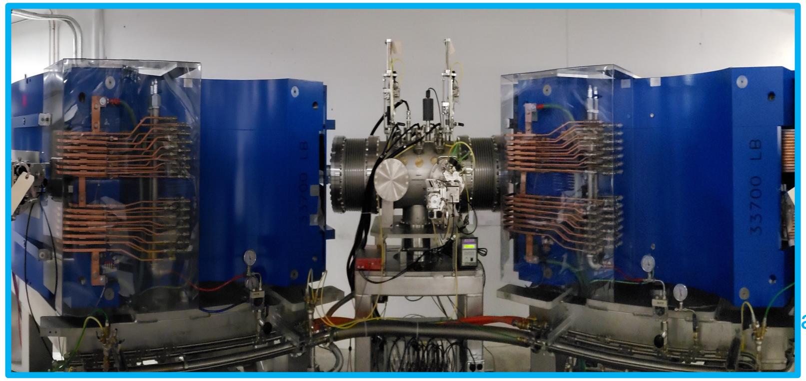
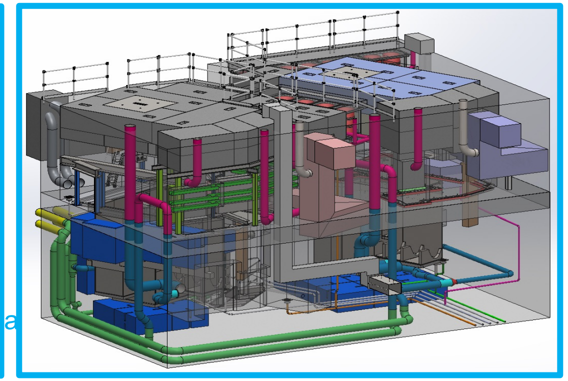
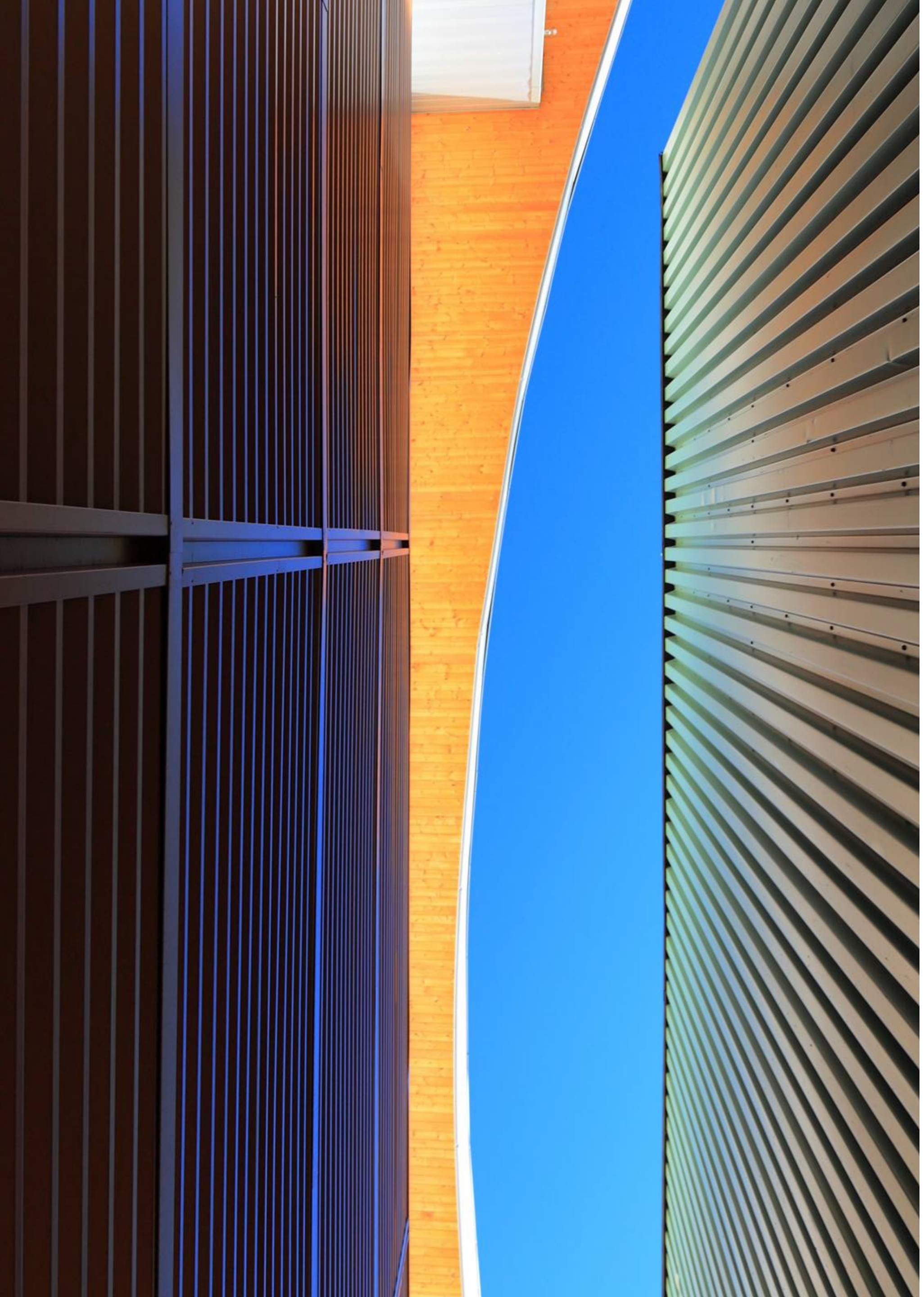
ARIEL Installation Progressing









Completing ARIEL

With ARIEL, TRIUMF will host the world's largest RIB production complex.

Still required within TIS to take full advantage of ARIEL, i.e., 9000+ hours, 3 simultaneous exotic RIBs:

- Offline target acceptance stand
- Target production laboratories
- Full electrical infrastructure for simultaneous APTW and AETE operation.
- Target disposal hot cell
- Target decay storage vault
- Resonant laser ion source for proton target station
- APTW proton beam raster system
- High-power target ramp-up

Discovery, accelerated

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Targets and Ion Sources 2025-2030 Plan Summary

- Unleash the full potential of ISAC/ARIEL
  - Investments to reach full ARIEL capabilities and capacity
  - R&D for ramping up driver beam power, number of targets (10/y to 40/y), RIB production (2300h/y to 9000 h/y)
- Consolidating and refurbishing of ageing targetry and RH infrastructure
- Maintaining a strong research program with national and international involvement, train HQP, continue to deliver new isotopes, purer and stronger beams
- Thriving for international excellence in secondary particle production and RH by leading and participating in internal and external research projects.

A list of 18 major TIS initiatives to support this plan have been identified and will help to quantify resource requirements to be brought forward for the 5YP 2025-2030

Thank you
Merci

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Discovery, accelerated

Beamlines

- At this time the exact scope of the remote handling BL1A refurbishment work is not known, however relevant parties have recently been meeting to identify important issues to be resolved. It is unknown whether some of these would be resolved prior to 2025, or which of these would be classified under a different project. The following is a brief summary of expected work:

Task	Approx. Cost	Human Resources
Collimator B vacuum leak – remove Col B and replace indium ring	$10-20k	1 RH mech eng, 1 RH mech tech, 1 design office, potential 1 RH ctrls eng
Triplet magnet downstream of Col B needs replacing	$3M ballpark	TBD – magnet design and manufacturing largely outsourced
M15 permanent quad is demagnetized, requires replacement	TBD	1 RH mech eng/tech
M9 solenoid disposal	TBD	2-3 “waste disposal techs”
T2 monument stability – investigate cause of misalignment over the years	TBD	1 RH mech tech, 1 beamlines tech (or eng)

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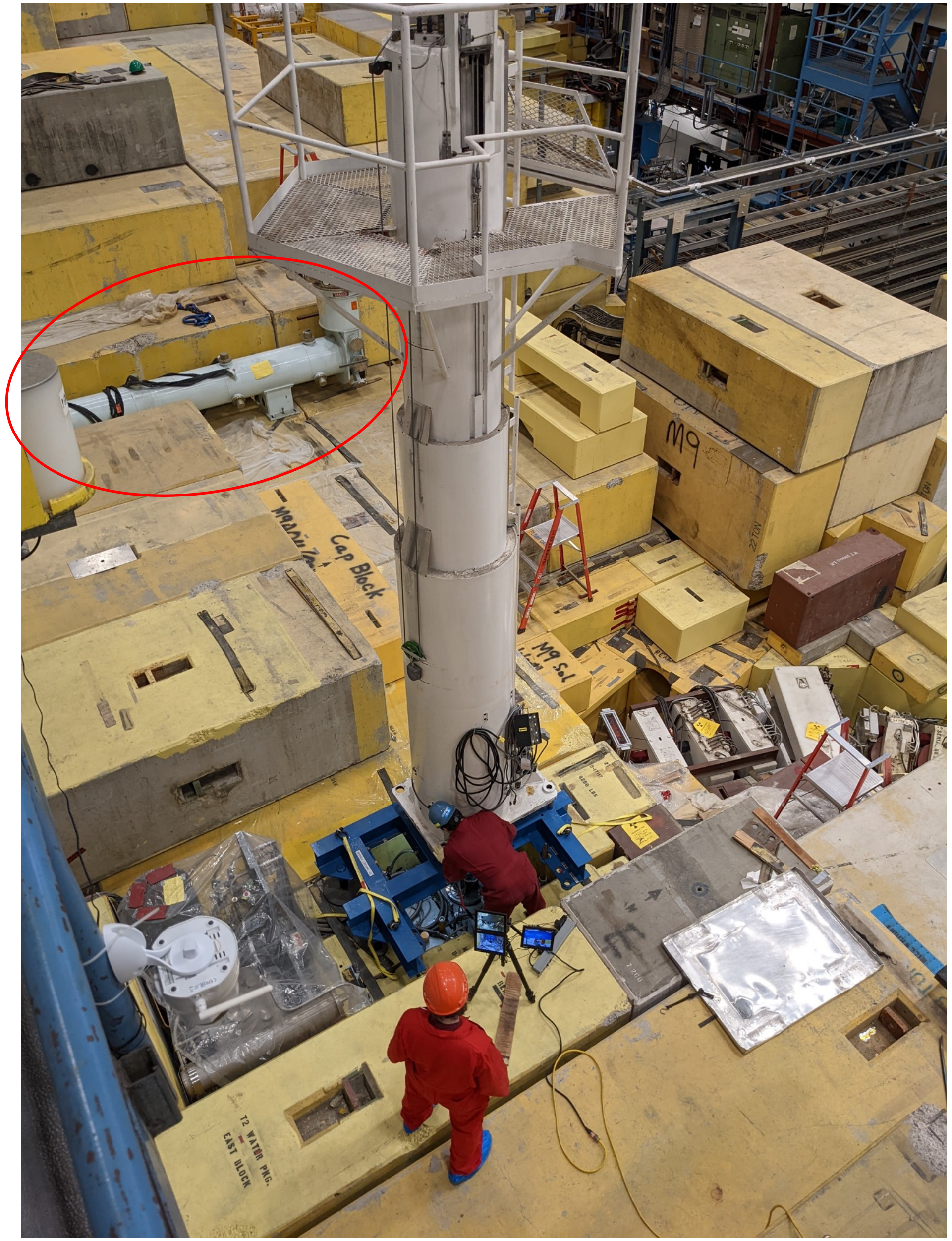
Beamlines (cont.)

Task	Approx. Cost	Human Resources
Beamline is no longer straight – investigate	TBD	TBD
Cabling, waterline, and airline overhaul	TBD	TBD
Water leak detector installation at key points	TBD	TBD
Shielding block modifications to improve serviceability	TBD	TBD
Misc. support equipment upgrades	$5-15k per year, ongoing	1 RH mech tech, 1 manufacturing, 1 potential designer

Beamline example highlighting magnets, cabling, etc.

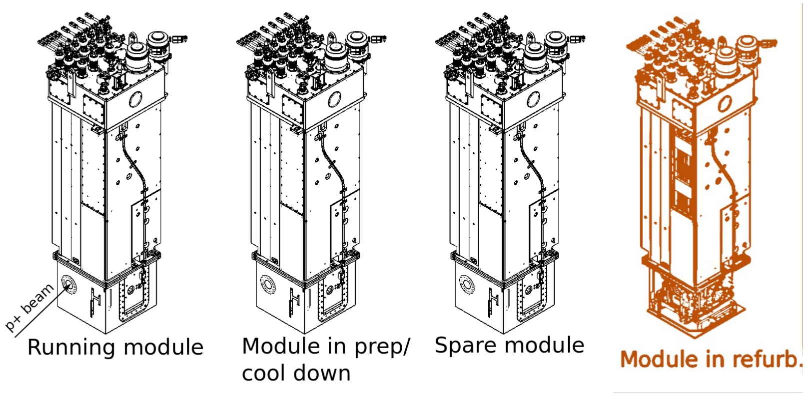


M9 currently resting on blocks, awaiting disposal

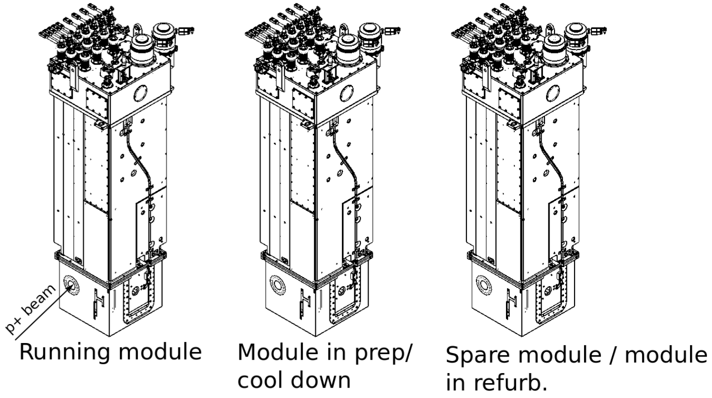
Discovery, accelerated

Major vulnerability: Number of target modules in circulation

- Optimal running situation: 4 modules
  A 4th module will be added to ensure reliability and consistent operation in ARIEL mode



- Reliable intermediate running situation: 3 modules as of 2023



- Our current running situation: 2 modules