

Targets and Ion Sources and the Five-Year Plan

Alexander Gottberg

Department Head, Targets and Ion Sources

Adjunct Professor, University of Victoria

July 21, 2022

TRIUMF Science Week 2022

Accelerator Science

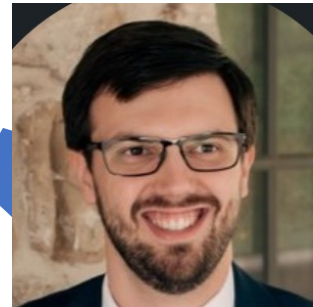


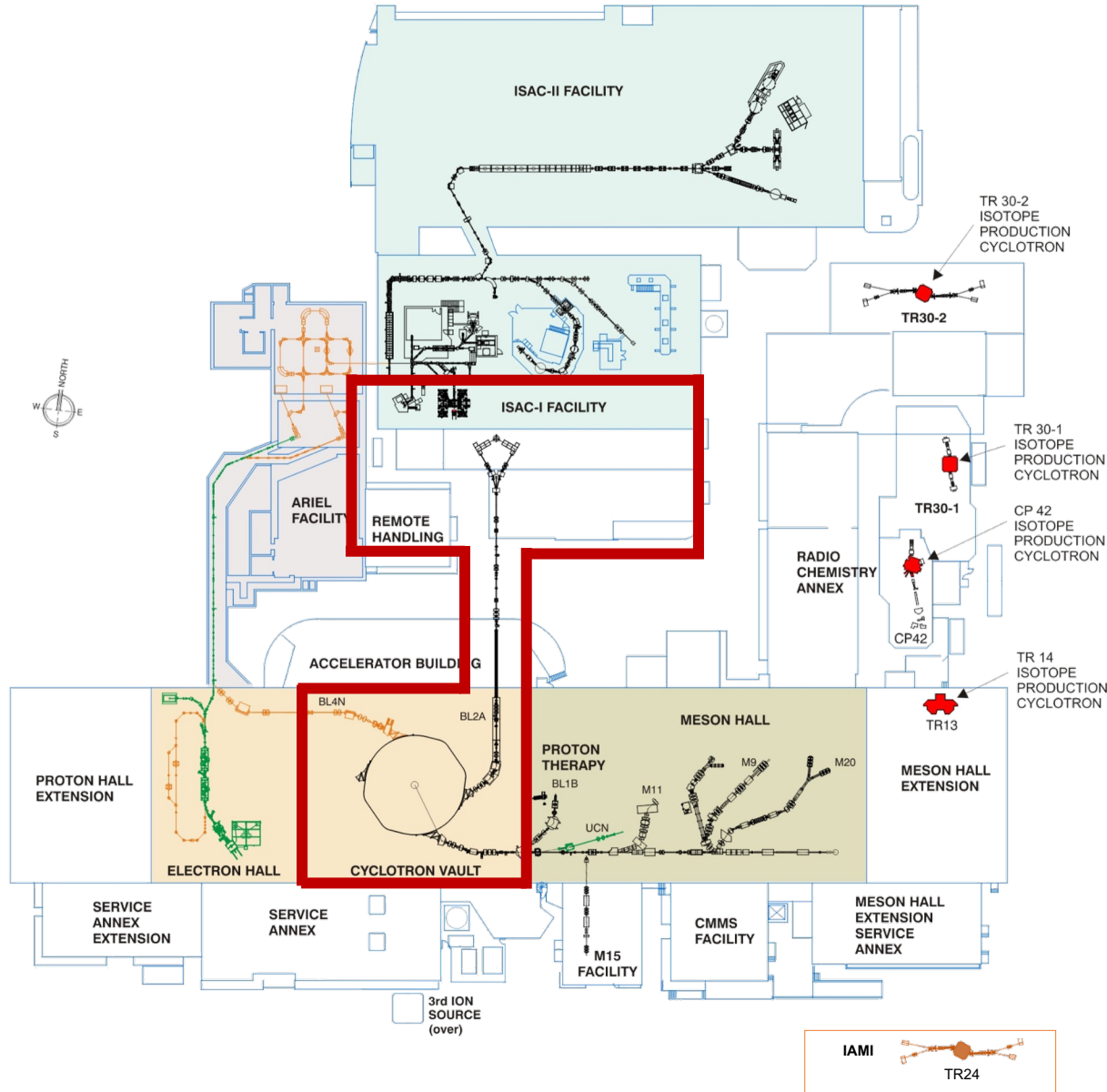
- The TRIUMF accelerator division safely operates the TRIUMF accelerator complex with high performance and availability. We develop and implement new accelerator facilities and related technologies to support world class science nationally and internationally.
- We lead accelerator physics research in 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.

- 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.

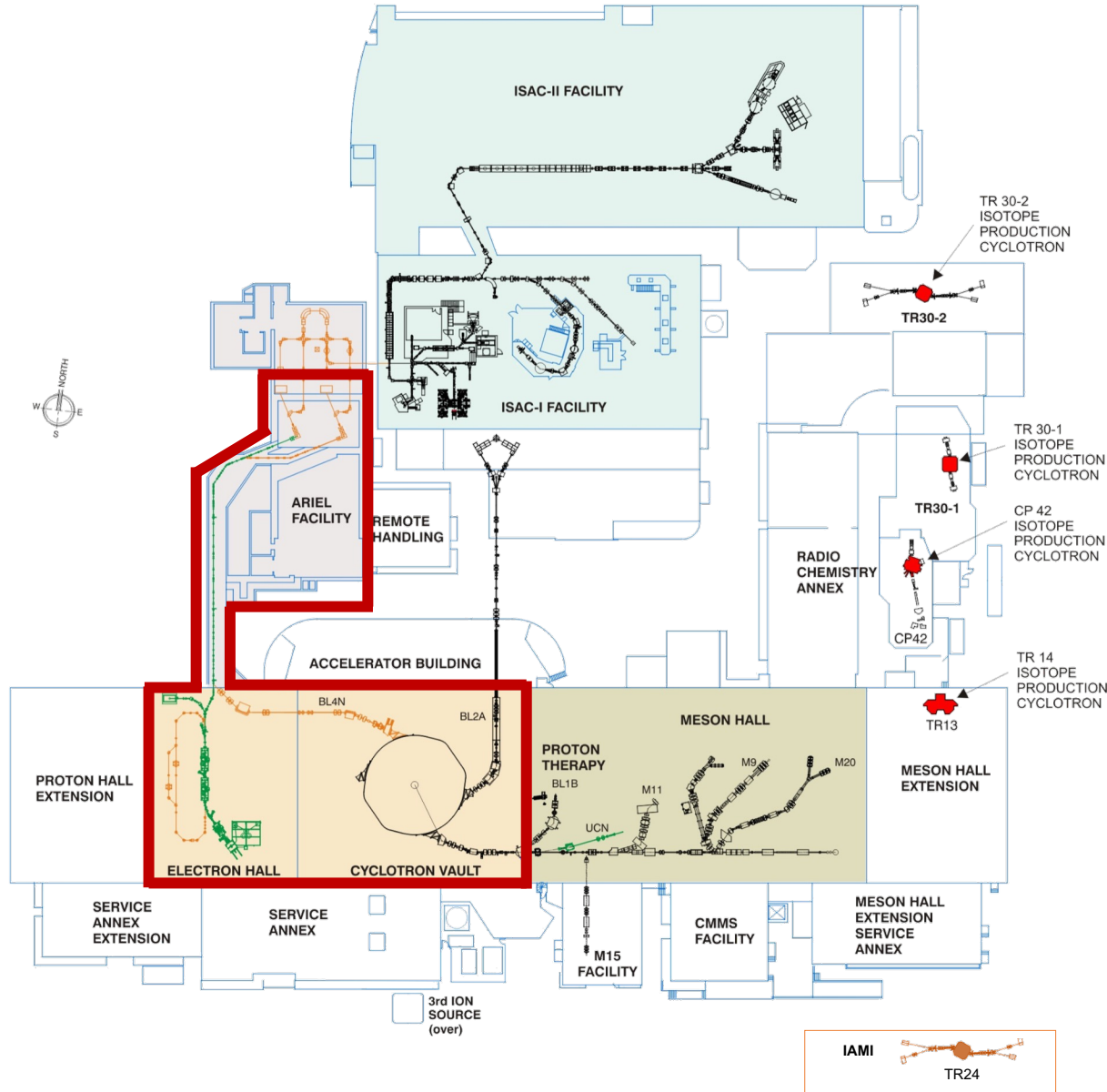
Synergy between operation, new facility development and research.
Accomplished by three expert groups.

- 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)

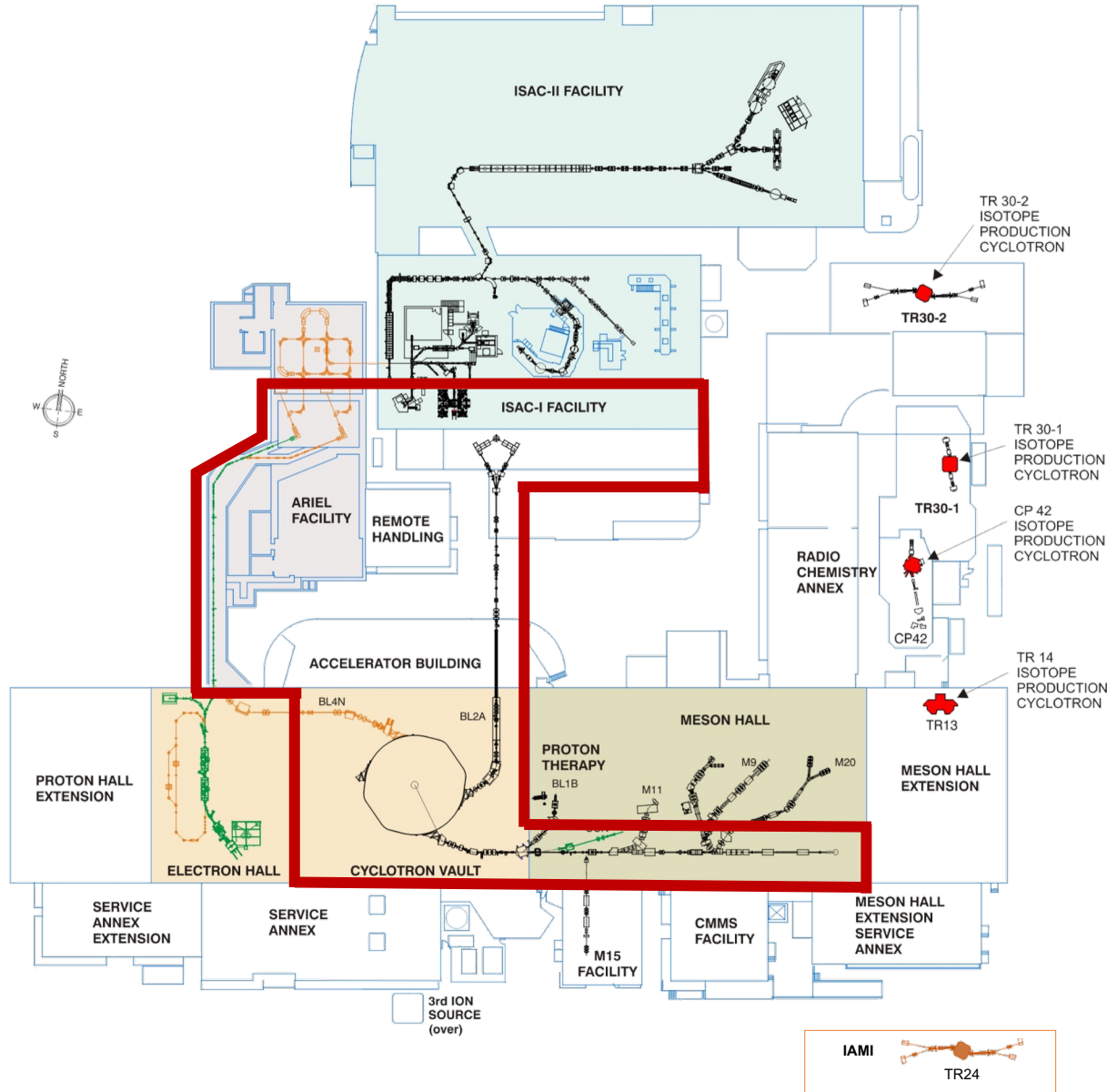




- Target production (10/y)
- Operation of 2 ISAC target stations and ancillary systems
- Resonant laser ionization
- Yield measurements
- Operation of RI implantation system
- Operation of nuclear spin-polarizer beamline
- Hot-cell based RIB target exchanges
- Target system refurbishment
- Research and 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)



- 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

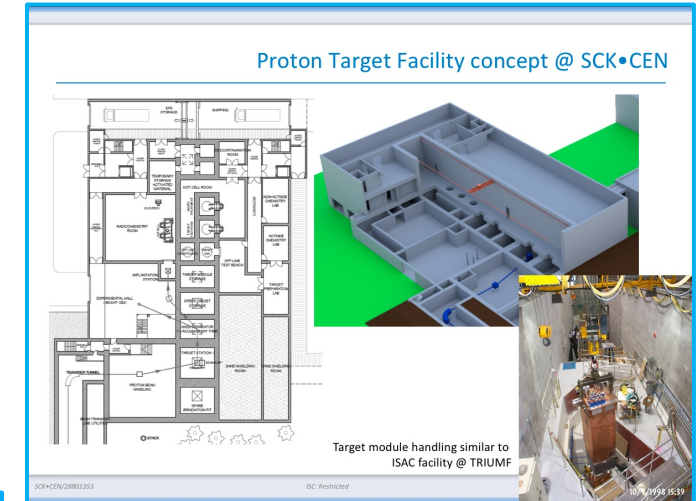


- Designing, building, maintaining, and operating equipment used site-wide to reduce radiation dose to personnel
- Remote handling and beamline infrastructure refurbishment
- Support of other TRIUMF groups by performing or assisting in work where standard approaches result in excessive radiological exposure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

TRIUMF 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)

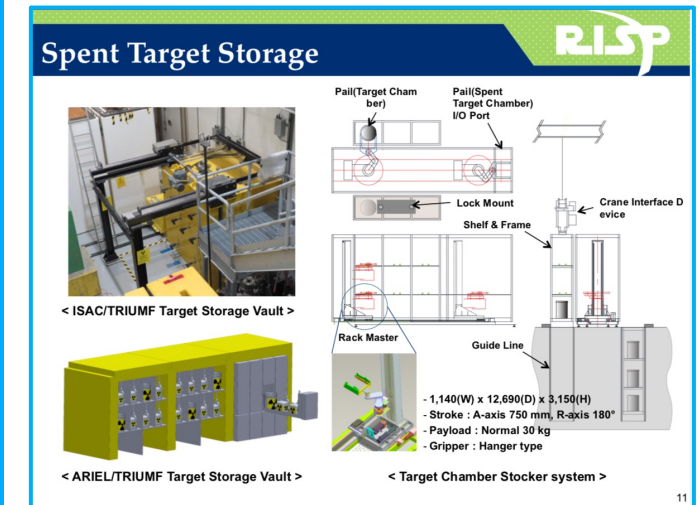
SCK MYRRHA and IBS-RISP designs based on TRIUMF RH



RH robotics development



TRIUMF RH specialists assisting in T2K target repair

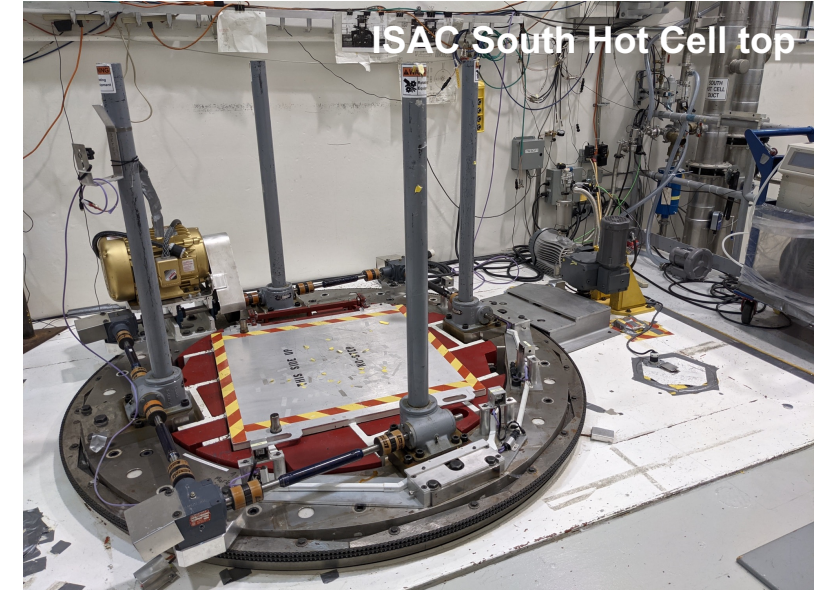


Ongoing RH refurbishment projects, completion until 2025:

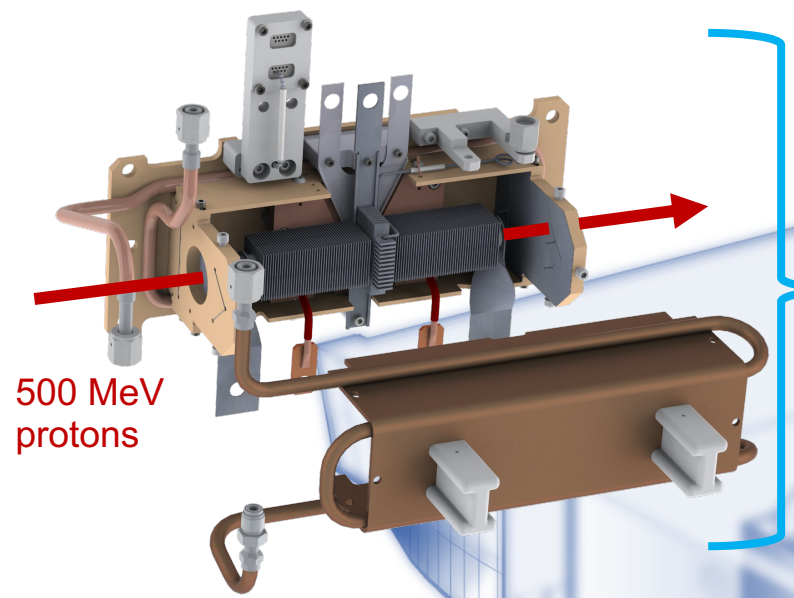
- 520 MeV Cyclotron RH mechatronics systems
- Cyclotron RH controls
- In-depth analysis of BL and all Meson Hall remote handling equipment
- Identify, characterize, prioritize and plan BL1A upgrade needs, experts are collecting requirements, 10 high-priority tasks identified

2025-2030

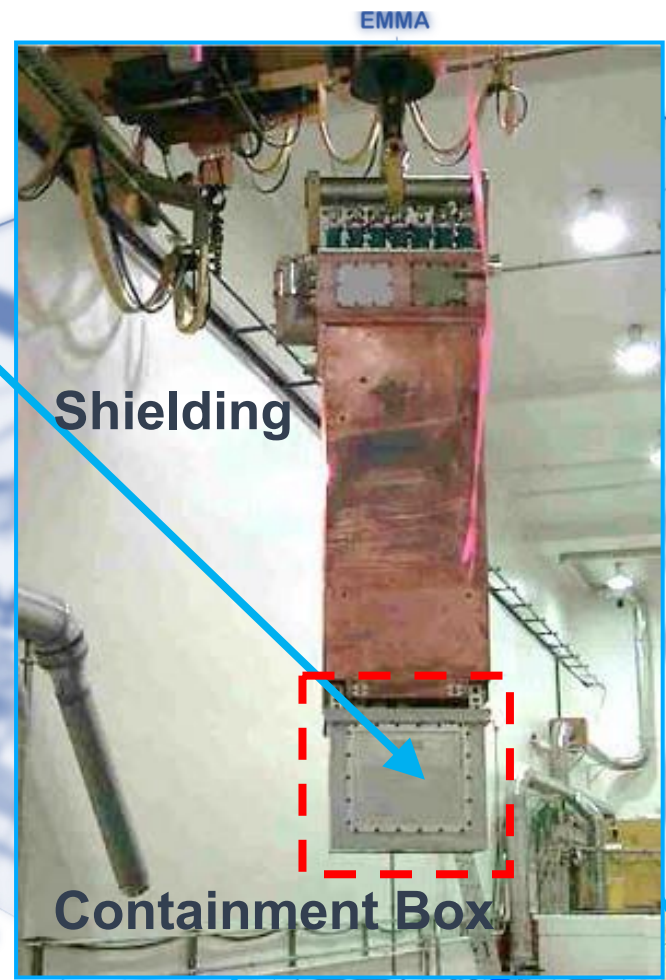
- Major BL1A refurbishments, based on priorities and available resources
- Continuation of RH controls refurbishment, including ISAC TH
- Meson hall RH systems refurb, including hot cell, T1/T2 target transfer flask
- Develop and install RH waste management reduction infrastructure



Radioisotopes for Science and Innovation

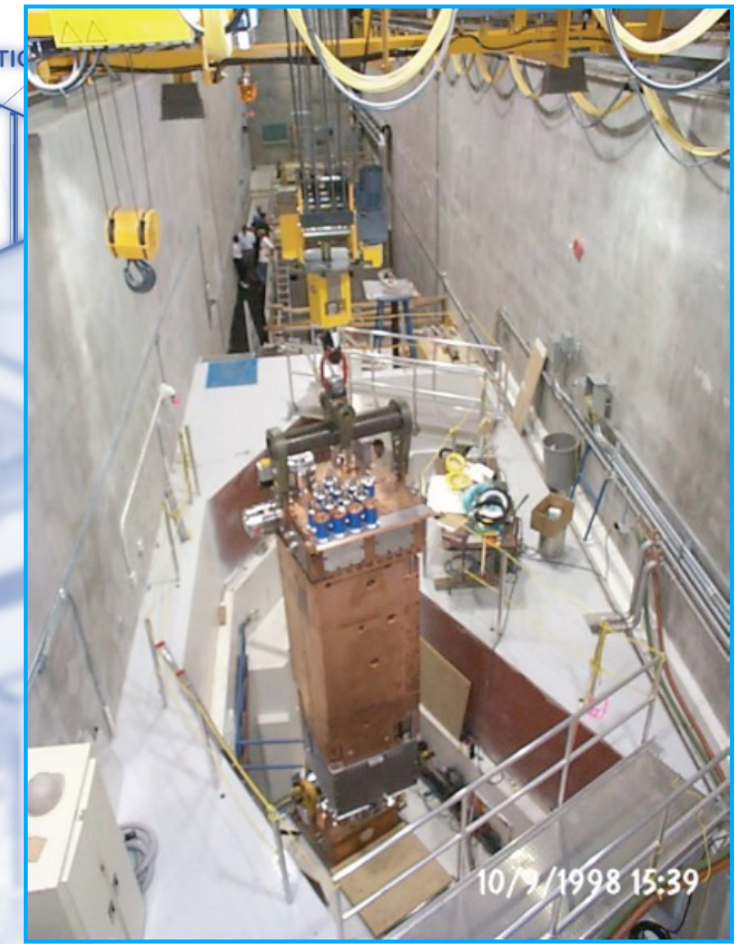


500 MeV protons



Shielding

Containment Box



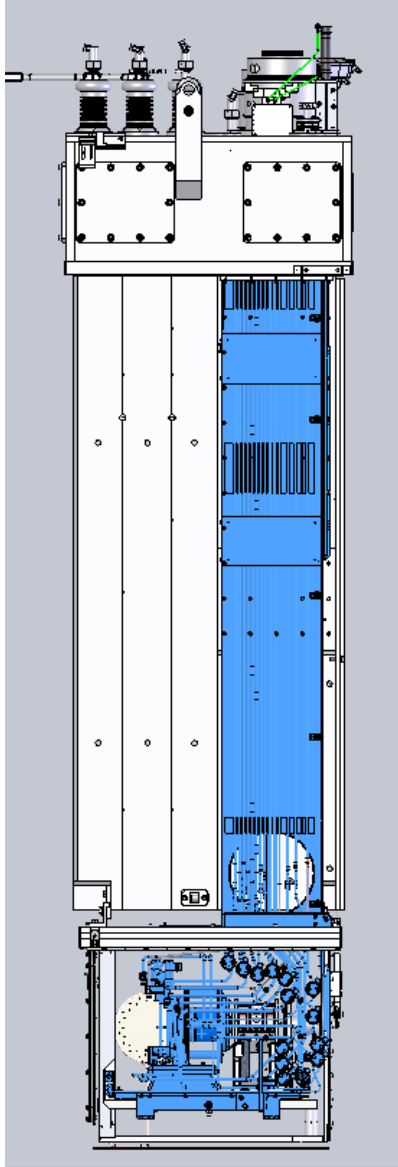
Target module transport to target station

RFQ TITAN

ISAC Target module hanging from remote handling crane

TRIN LEBS High Voltage Mass Separator Target Stations 500 MeV Protons

Cyclotron

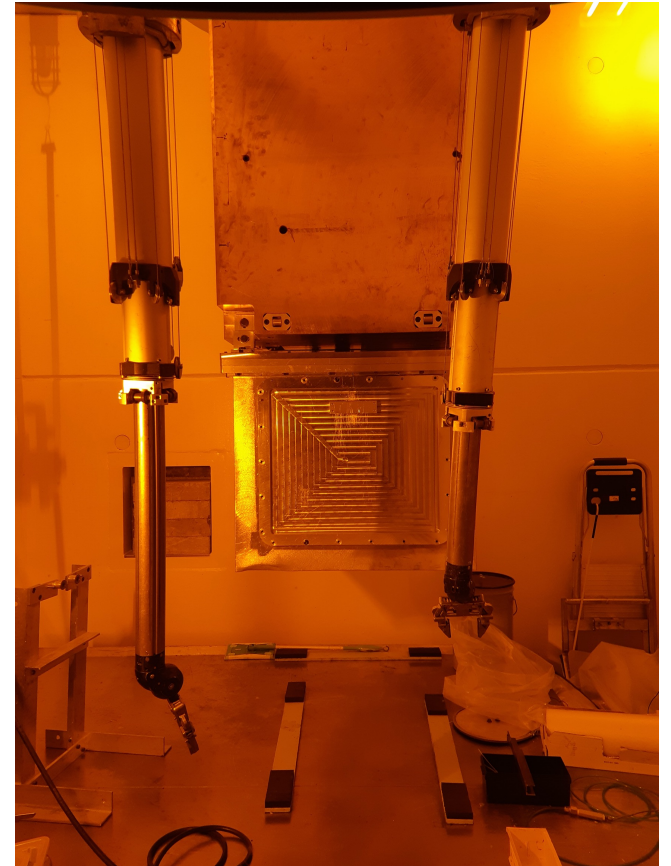
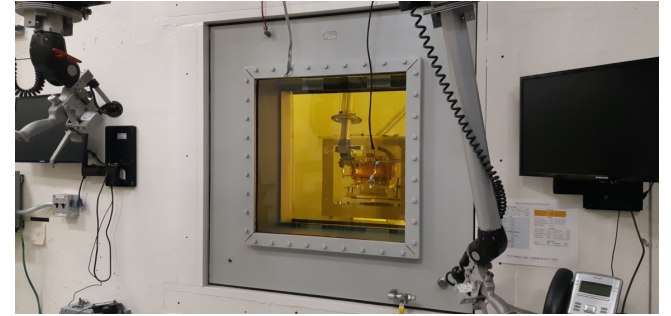


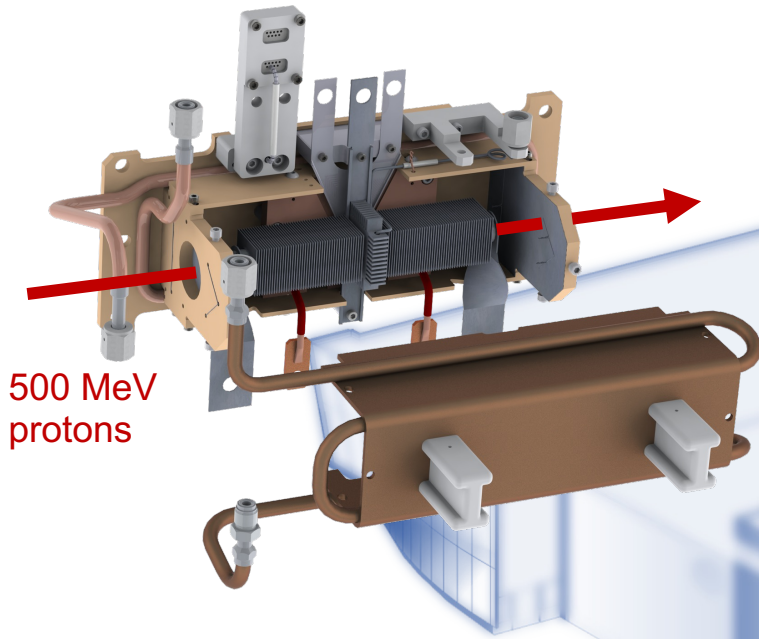
Recent infrastructure investments and refurbishments starting to pay off, examples:

- 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





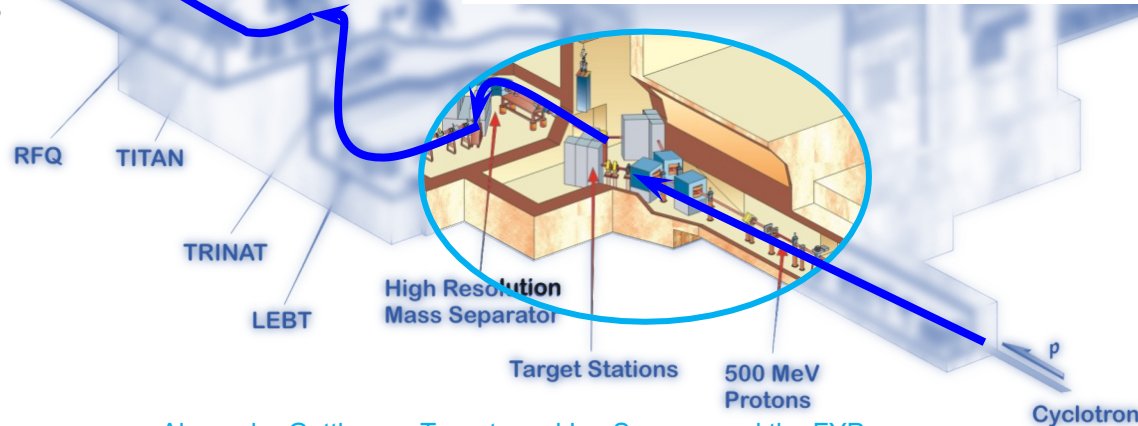
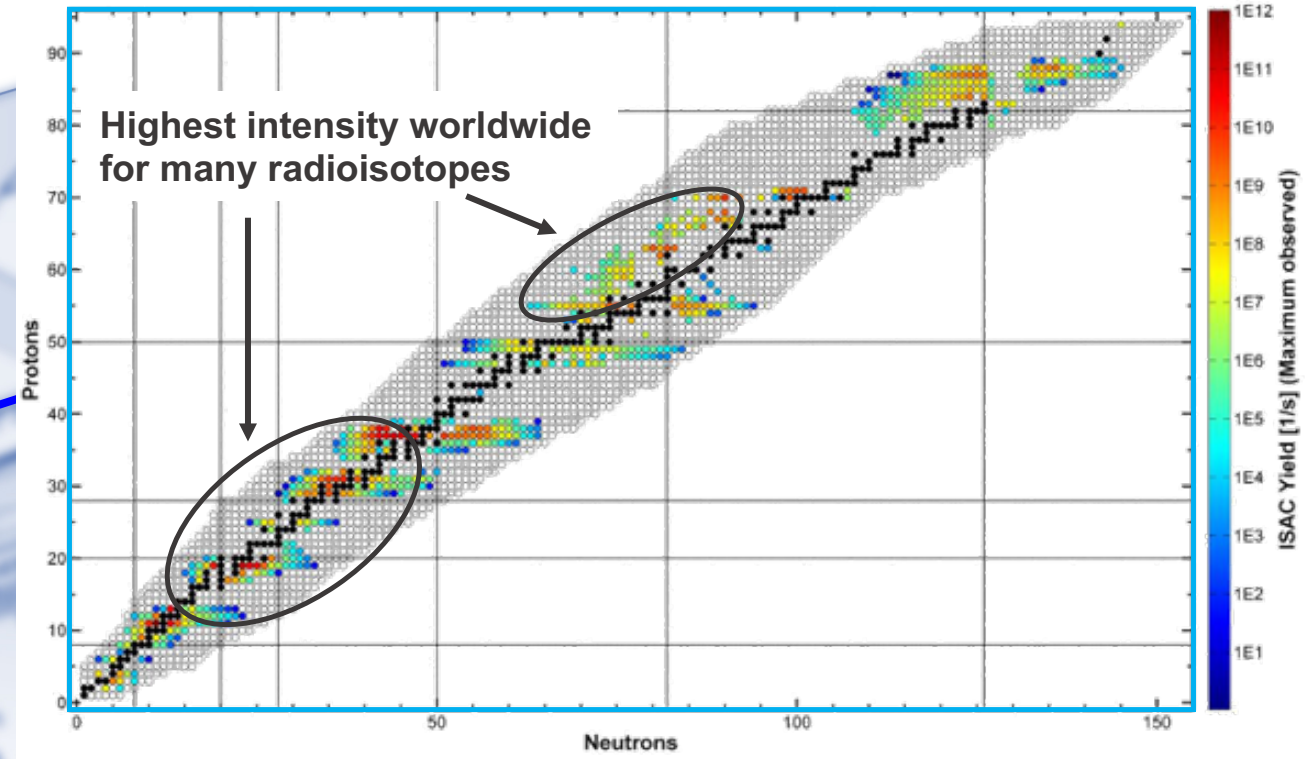
Target materials: Variable beam power

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

Variable transfer lines

Ion sources:

- surface
- resonant laser
- FEBIAD
- IG-LIS



- '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

Increasing UC₂ Target Availability at TRIUMF: Production Ramp-Up For ARIEL Era

Background Information

Due to the high and diverse production rates required for ARIEL, the current UC₂ target design is being replaced by a new design. The new design is being developed in collaboration with the ARIEL team and the UC₂ target production team. The new design is being developed in collaboration with the ARIEL team and the UC₂ target production team.

Previous UC₂ method limitations

- Restricted target availability
- Not suitable for the future greater ARIEL UC₂ demand
- Resource intensive

New UC₂ Production Method

Major advantages of the new UC₂ target design include:

- Increased target availability
- Reduced resource requirements
- Improved target quality
- Enhanced safety

Conclusions

The new UC₂ target design is being developed in collaboration with the ARIEL team and the UC₂ target production team. The new design is being developed in collaboration with the ARIEL team and the UC₂ target production team.

Next Steps

- Complete design of the new UC₂ target
- Manufacture and test the new UC₂ target
- Implement the new UC₂ target design

Acknowledgments

The authors would like to thank the TRIUMF staff and the ARIEL team for their support and assistance during the development of the new UC₂ target design.

Thermal Analysis of the ARIEL Electron Target East Hermetic Target Vessel

Background

The ARIEL Electron Target East Hermetic Target Vessel (ETV) is a critical component of the ARIEL facility. It is used to house the electron target and the electron gun. The ETV is subjected to high temperatures and pressures during operation. A thermal analysis of the ETV is required to ensure that it can withstand these conditions without failure.

Objectives

- Determine the maximum temperature of the ETV during operation
- Identify the components of the ETV that are most at risk of failure
- Provide recommendations for the design and operation of the ETV

Methodology

The thermal analysis was performed using a finite element method (FEM) software package. The FEM model of the ETV was created using a mesh of elements. The boundary conditions for the FEM model were determined based on the design and operation of the ETV.

Results

The maximum temperature of the ETV during operation is approximately 1000°C. The components of the ETV that are most at risk of failure are the electron gun and the electron target.

Conclusions

The thermal analysis of the ARIEL Electron Target East Hermetic Target Vessel has shown that the ETV can withstand the high temperatures and pressures of operation. The components of the ETV that are most at risk of failure are the electron gun and the electron target.

Next Steps

- Perform a detailed thermal analysis of the electron gun and the electron target
- Implement the recommendations for the design and operation of the ETV

Acknowledgments

The authors would like to thank the TRIUMF staff and the ARIEL team for their support and assistance during the development of the ETV.

DEVELOPMENT OF A PROTON-TO-NEUTRON CONVERTER FOR RADIOISOTOPE PRODUCTION AT ISAC-TRIUMF

Introduction

The development of a proton-to-neutron converter for radioisotope production at ISAC-TRIUMF is a critical component of the ARIEL facility. It is used to convert protons into neutrons, which are then used to produce radioisotopes.

Motivation

The motivation for the development of a proton-to-neutron converter is the need for a high-intensity neutron source for radioisotope production. The current neutron source at ISAC-TRIUMF is a deuteron beam, which is less efficient than a proton beam.

Solution

The solution is a proton-to-neutron converter that uses a thick target of a material with a high cross-section for neutron production. The target is irradiated with a proton beam, which produces neutrons. The neutrons are then used to produce radioisotopes.

Standard Actinide target

The standard actinide target is a thick target of a material with a high cross-section for neutron production. The target is irradiated with a proton beam, which produces neutrons. The neutrons are then used to produce radioisotopes.

New proton-to-neutron converter target

The new proton-to-neutron converter target is a thick target of a material with a high cross-section for neutron production. The target is irradiated with a proton beam, which produces neutrons. The neutrons are then used to produce radioisotopes.

Converter and Target Design

The converter and target design is a thick target of a material with a high cross-section for neutron production. The target is irradiated with a proton beam, which produces neutrons. The neutrons are then used to produce radioisotopes.

Conclusions

The development of a proton-to-neutron converter for radioisotope production at ISAC-TRIUMF is a critical component of the ARIEL facility. It is used to convert protons into neutrons, which are then used to produce radioisotopes.

Next Steps

- Complete design of the proton-to-neutron converter
- Manufacture and test the proton-to-neutron converter
- Implement the proton-to-neutron converter

Acknowledgments

The authors would like to thank the TRIUMF staff and the ARIEL team for their support and assistance during the development of the proton-to-neutron converter.

Multi-physics simulations of a FEBIAD Ion Source for Radioactive Ion Beam Production at TRIUMF

Introduction

The multi-physics simulations of a FEBIAD ion source for radioactive ion beam production at TRIUMF are a critical component of the ARIEL facility. It is used to simulate the operation of the ion source and to optimize its performance.

Methodology

The multi-physics simulations were performed using a multi-physics software package. The software package simulates the electric, magnetic, and thermal fields of the ion source. The results of the simulations are used to optimize the design and operation of the ion source.

Results

The results of the multi-physics simulations show that the ion source can operate at a high current and a high voltage. The ion source is optimized for the production of a wide range of radioactive ion beams.

Conclusions

The multi-physics simulations of a FEBIAD ion source for radioactive ion beam production at TRIUMF are a critical component of the ARIEL facility. It is used to simulate the operation of the ion source and to optimize its performance.

Next Steps

- Perform a detailed multi-physics simulation of the ion source
- Implement the optimized design of the ion source

Acknowledgments

The authors would like to thank the TRIUMF staff and the ARIEL team for their support and assistance during the development of the multi-physics simulations.

Optimizing the FEBIAD ion source cavity for resonance laser ionization applications

Introduction

The optimization of the FEBIAD ion source cavity for resonance laser ionization applications is a critical component of the ARIEL facility. It is used to optimize the design and operation of the ion source for the production of a wide range of radioactive ion beams.

Methodology

The optimization of the FEBIAD ion source cavity was performed using a multi-physics software package. The software package simulates the electric, magnetic, and thermal fields of the ion source. The results of the optimization are used to optimize the design and operation of the ion source.

Results

The results of the optimization show that the ion source can operate at a high current and a high voltage. The ion source is optimized for the production of a wide range of radioactive ion beams.

Conclusions

The optimization of the FEBIAD ion source cavity for resonance laser ionization applications is a critical component of the ARIEL facility. It is used to optimize the design and operation of the ion source for the production of a wide range of radioactive ion beams.

Next Steps

- Perform a detailed optimization of the ion source cavity
- Implement the optimized design of the ion source cavity

Acknowledgments

The authors would like to thank the TRIUMF staff and the ARIEL team for their support and assistance during the development of the optimization of the FEBIAD ion source cavity.

Optimizing the FEBIAD ion source cavity for resonance laser ionization applications

Experimental setup

The experimental setup for the optimization of the FEBIAD ion source cavity for resonance laser ionization applications is shown in the figure. The setup includes the ion source, the laser, and the detection system.

Establishing modes of operation

The modes of operation of the FEBIAD ion source cavity are established by adjusting the laser parameters and the ion source parameters. The modes of operation are characterized by the ion current and the ion energy.

Simulations validation

The simulations of the FEBIAD ion source cavity are validated by comparing the simulation results with the experimental results. The simulation results are used to optimize the design and operation of the ion source.

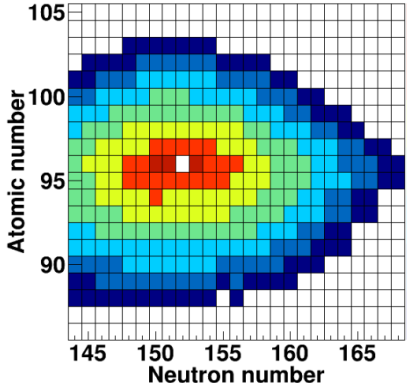
Implementation and experimental results

The implementation and experimental results of the optimization of the FEBIAD ion source cavity for resonance laser ionization applications are shown in the figure. The results show that the ion source can operate at a high current and a high voltage.

Factor 2 enhancement for Ca (off-line), Mg and Sr Factor 1.5 for Mo

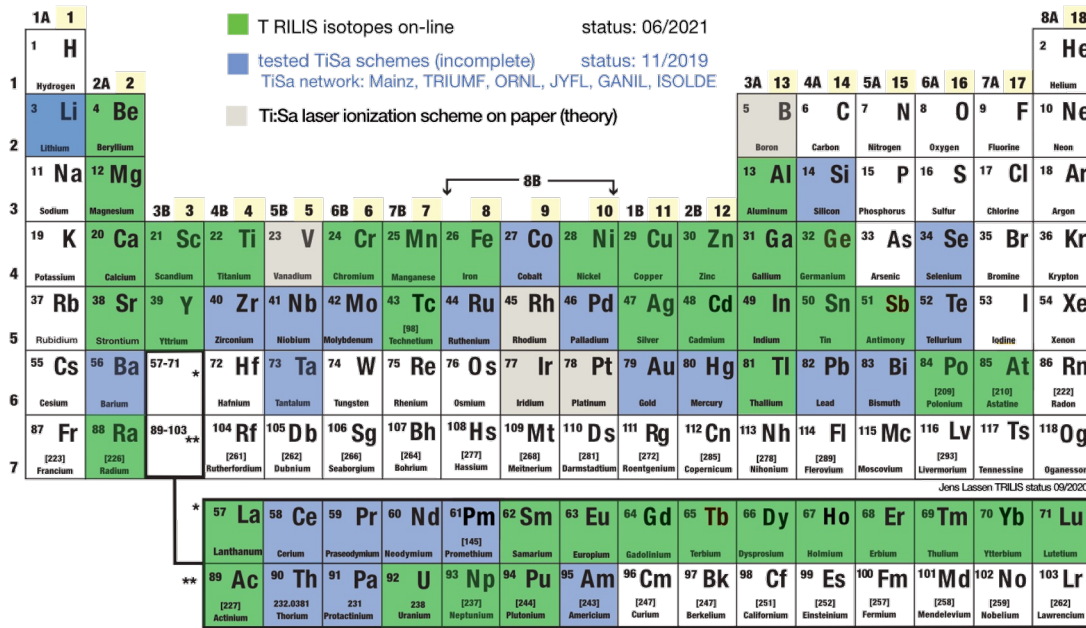
2025-2030:

- 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

Discovery, accelerated



Beam Delivery:

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

Beam Development:

- Target: 2 elements/y (increasingly difficult)

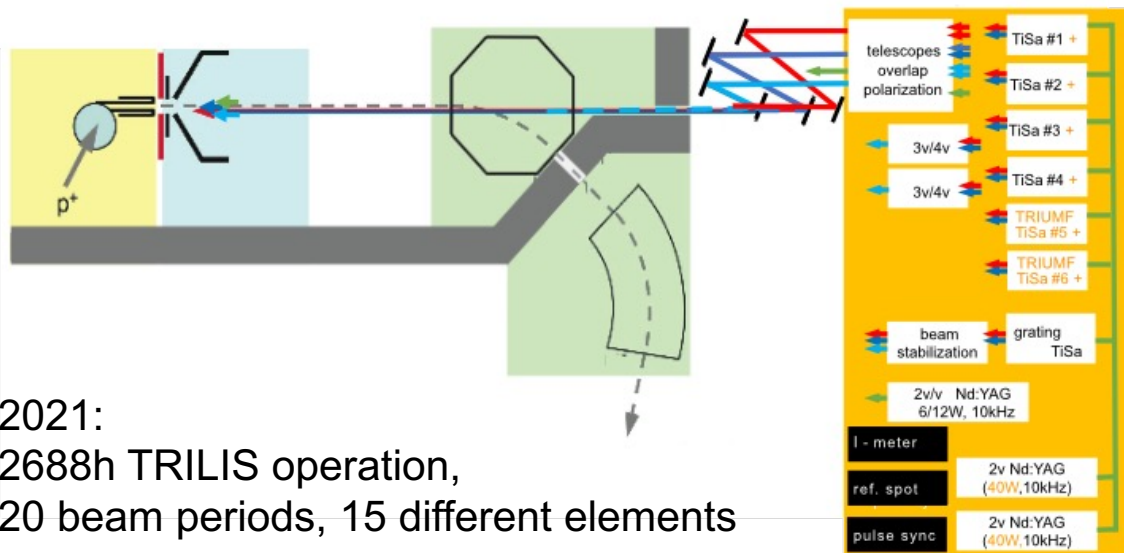
Upgrades:

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

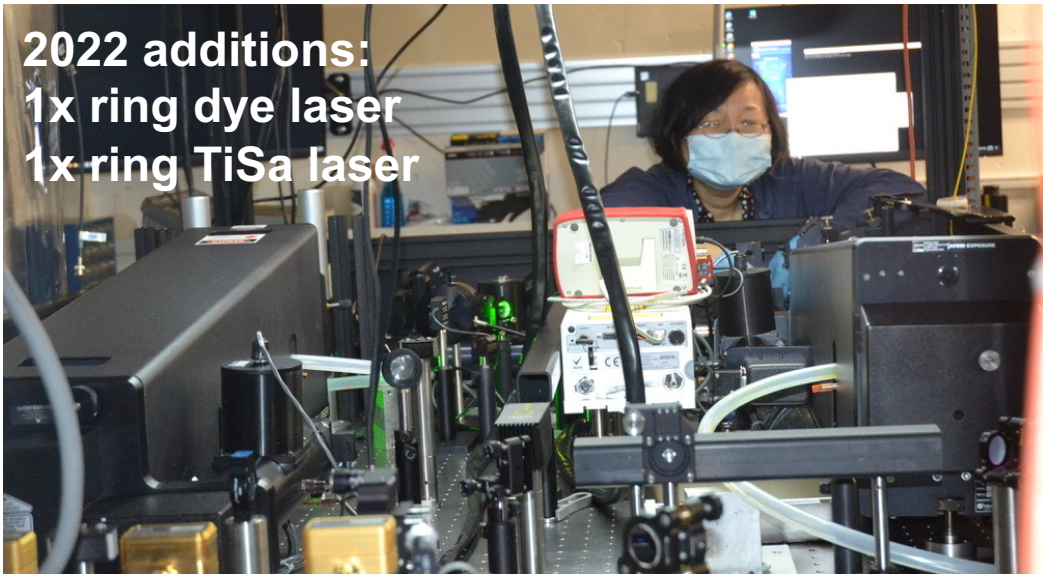
ARIEL startup

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

2022-07-21



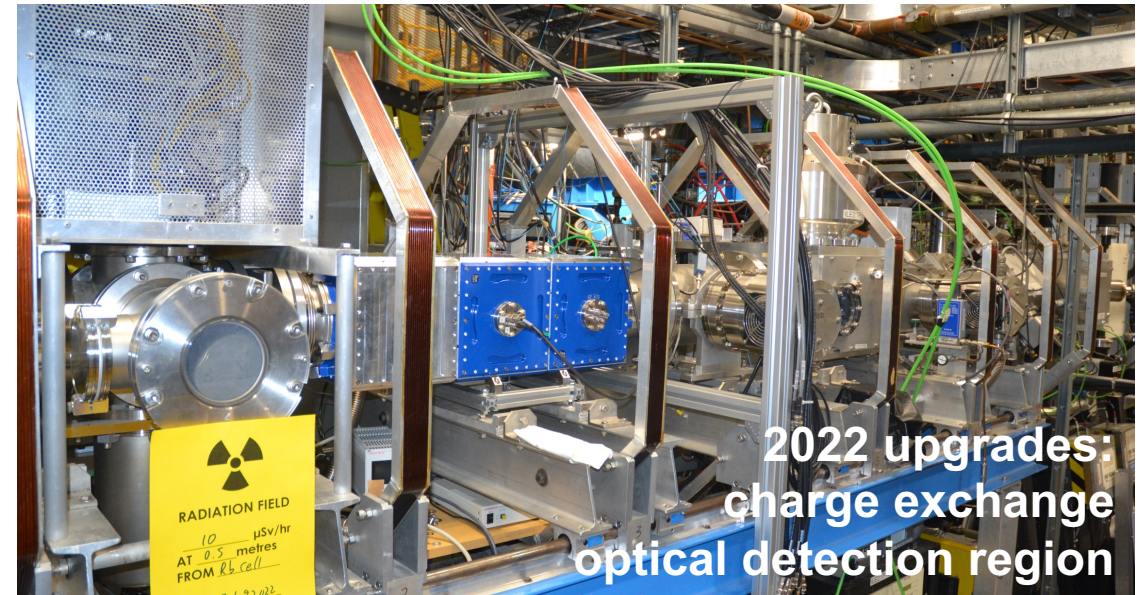
Alexander Gottberg – Targets and Ion Sources and the FYP



2022 additions:
1x ring dye laser
1x ring TiSa laser

- 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

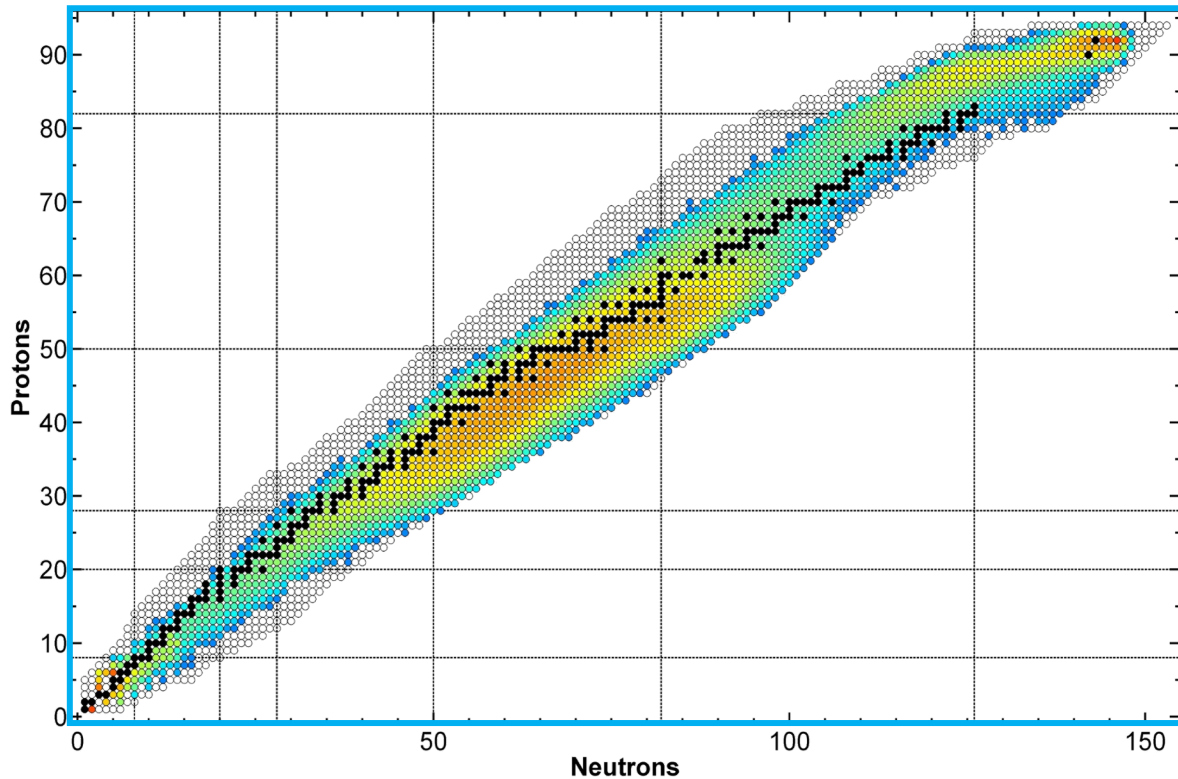


2022 upgrades:
charge exchange
optical detection region

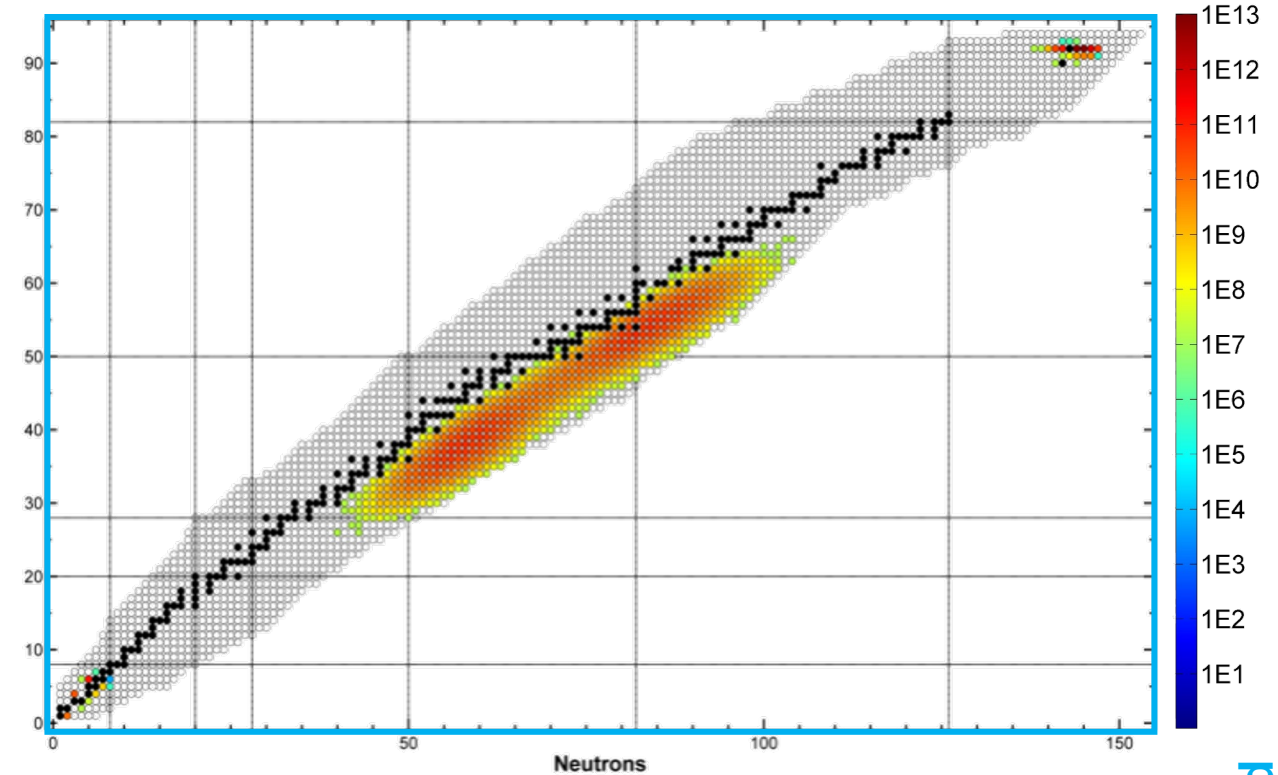
Advanced Radioisotope Laboratory (ARIEL)

Production rates from $^{238}\text{UC}_x$

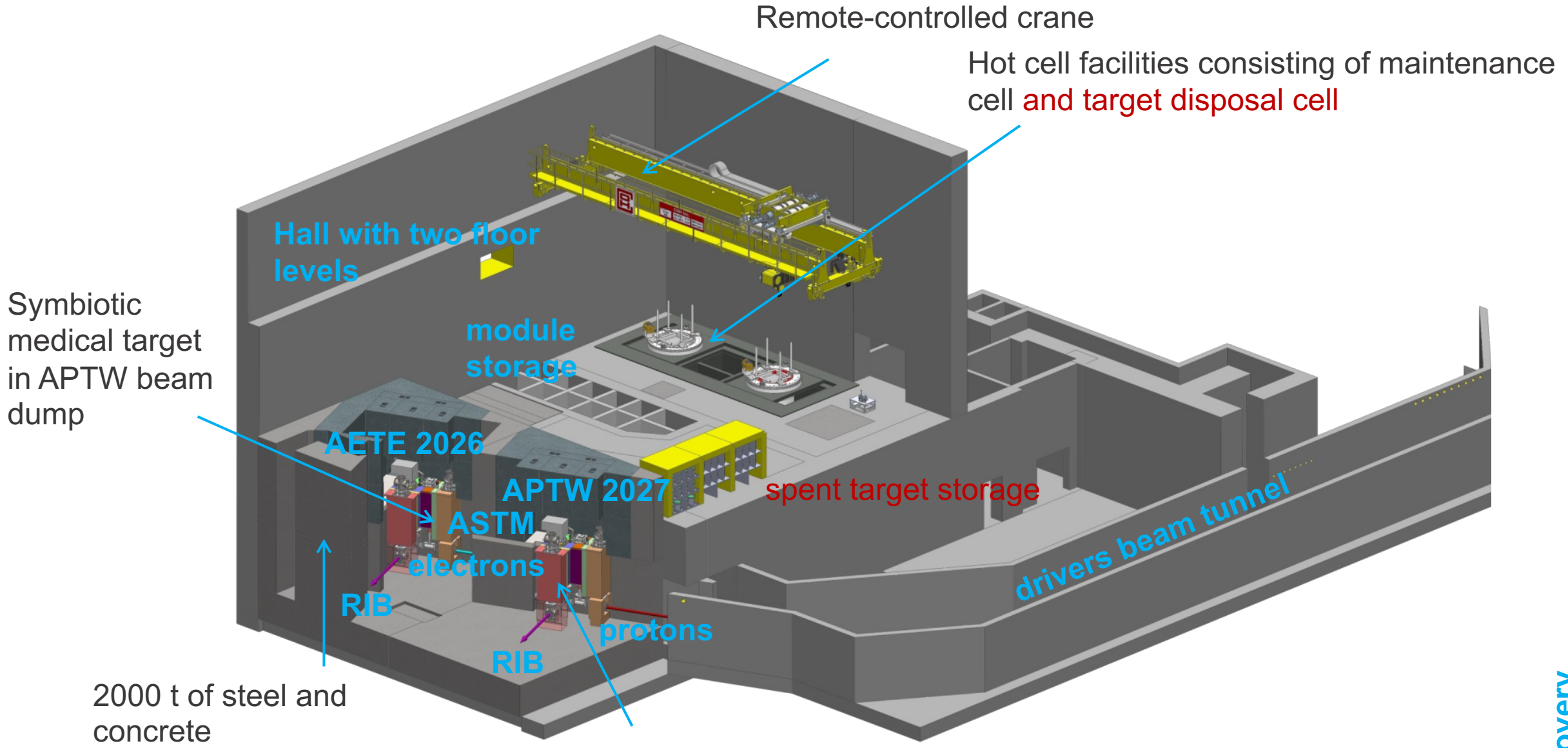
500 MeV x 10 μA protons [1/s]



35 MeV x 10 mA electrons [1/s]



Advanced Radioisotope Laboratory (ARIEL)



Modular RH high-power infrastructure

Alexander Gottberg – Targets and Ion Sources and the FYP

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

- 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

www.triumf.ca

Follow us @TRIUMFLab



Discovery,
accelerated



- 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)

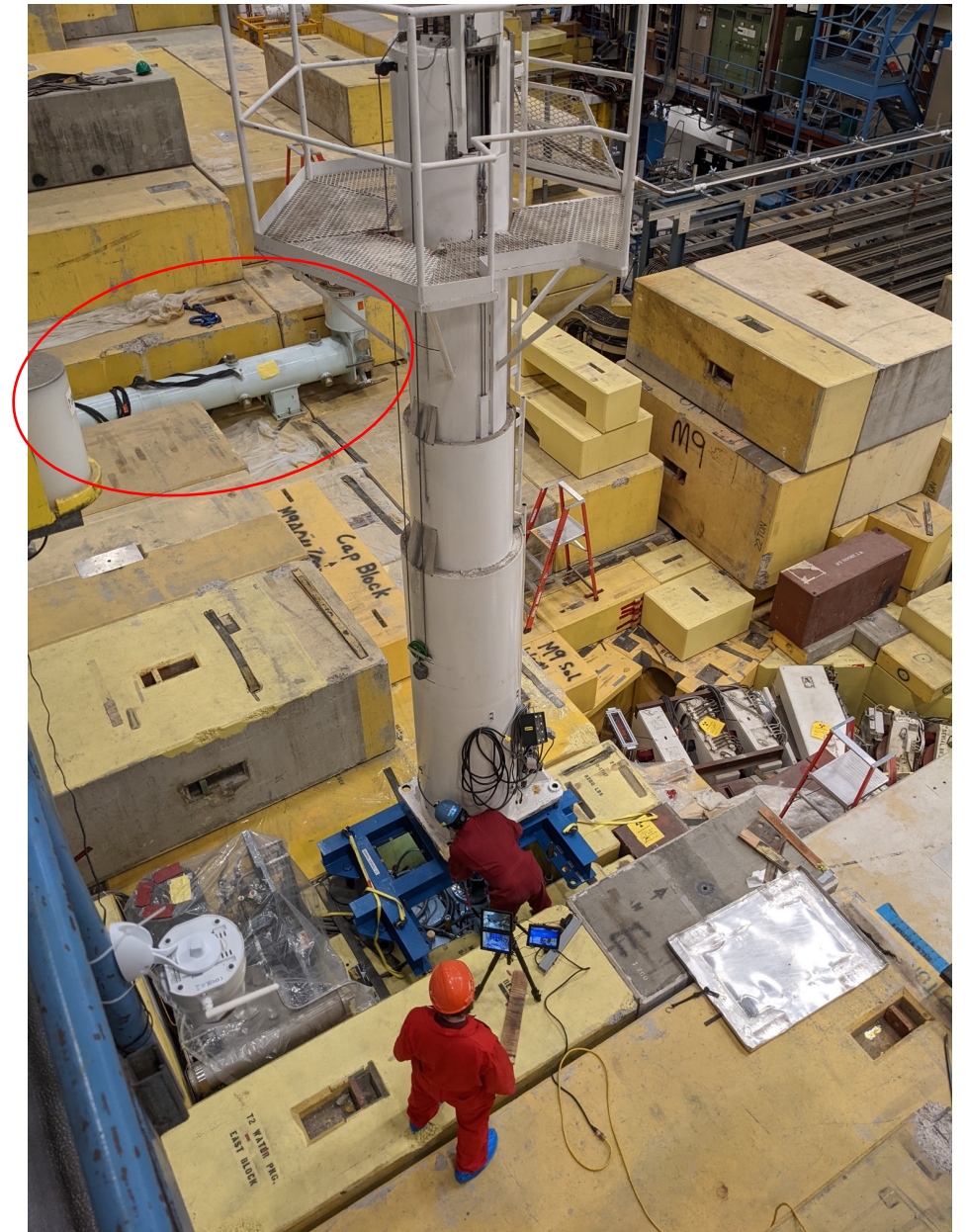
Task	Approx. Cost	Human Resources
Beamline is no longer straight – investigate	TBD	TBD
Cabling, waterline, and airline overhaul	TBD	TBD
Water leak detector installation at key points	TBD	TBD
Shielding block modifications to improve serviceability	TBD	TBD
Misc. support equipment upgrades	\$5-15k per year,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



Beamline example highlighting magnets, cabling, etc.

2022-07-21

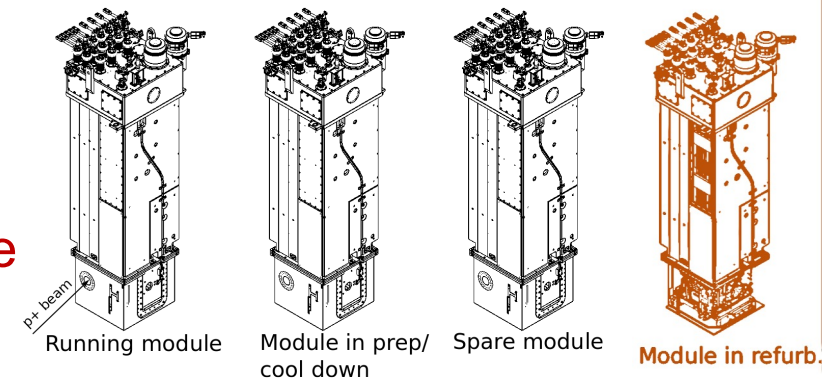
Alexander Gottberg – Targets and Ion Sources and the FYP



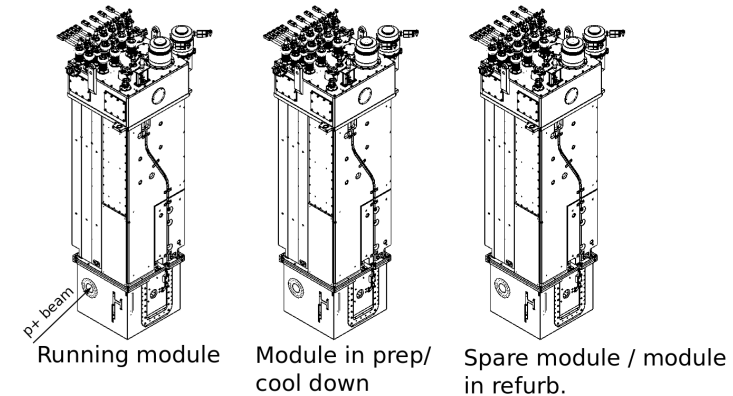
M9 currently resting on blocks, awaiting disposal

26

- 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

