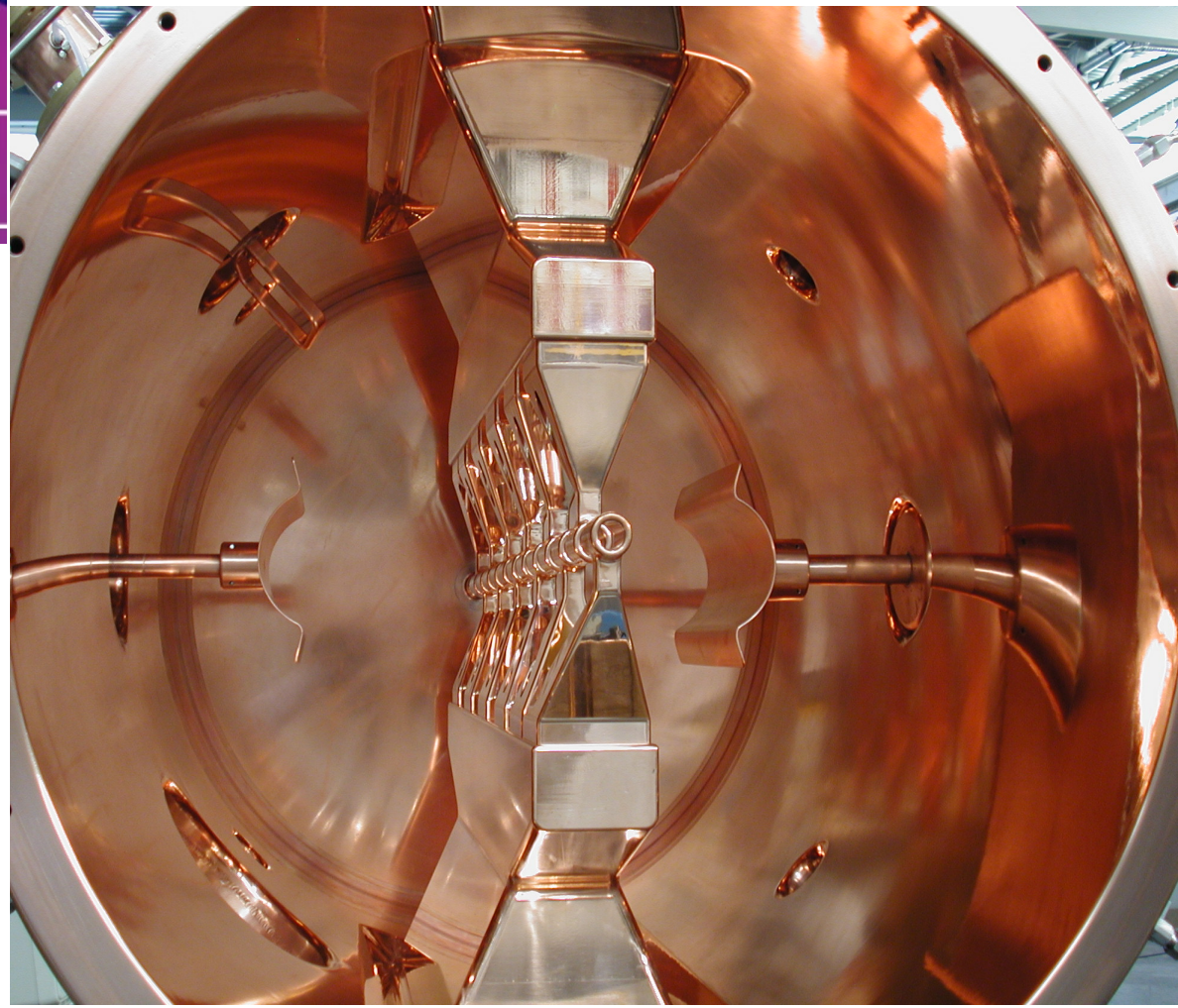
Five Year Plan 2025 – 2030 Accelerator Science

Oliver Kester

Director, Accelerator Division

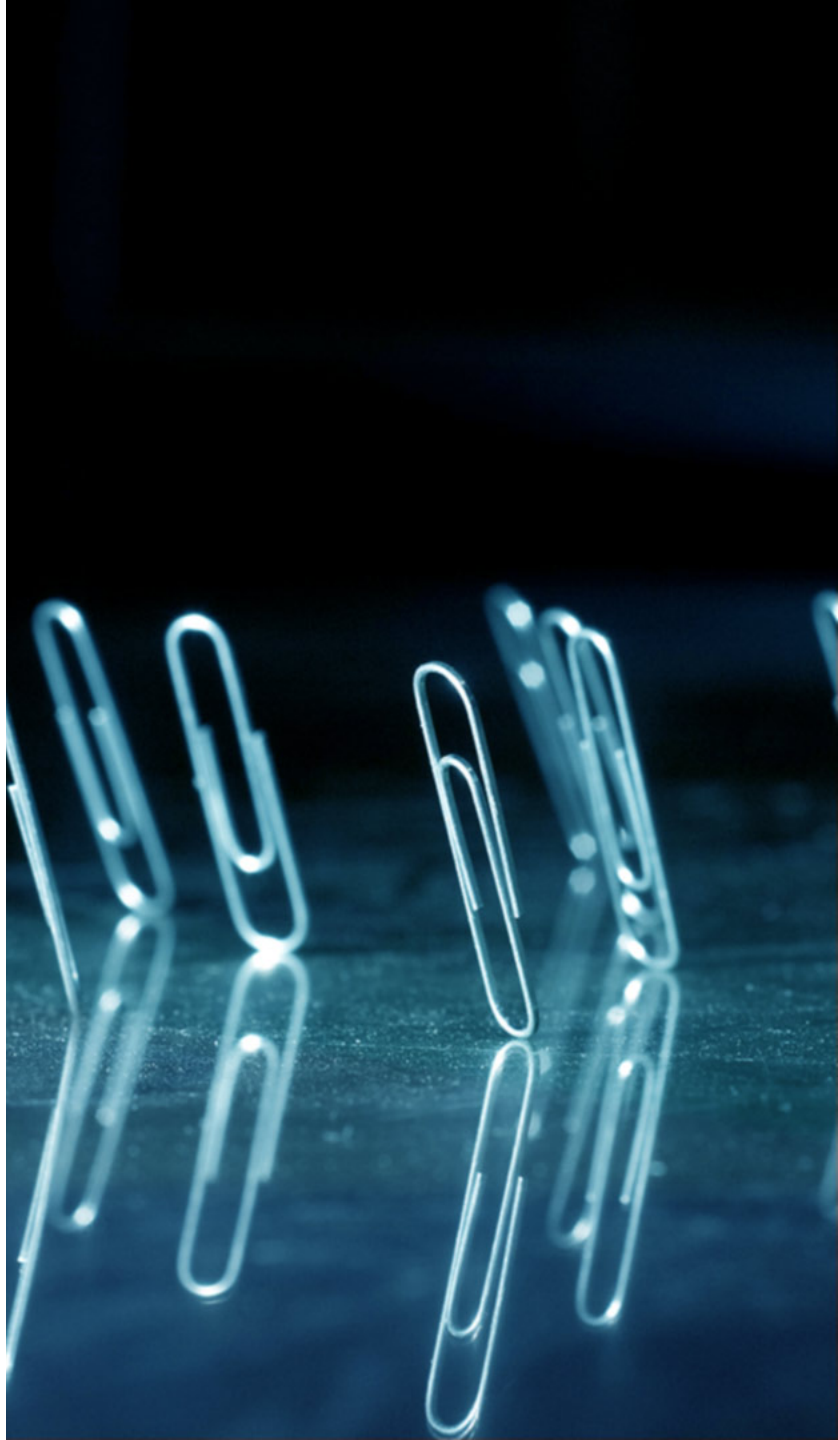
TRIUMF Science week
August 2, 2023



science week/23
Jul 31 - Aug 4

Outline

- TRIUMF Accelerator Division – 5YP
- The TRIUMF accelerator complex
  - Keeping the TRIUMF accelerator complex on high performance in the next 5YP
  - Gain in efficiency
- Increase of research capacity - ARIEL
  - ARIEL completion
  - The path towards ARIEL design performance
- Accelerator science at TRIUMF three pillars of excellence:
  - Beam physics, secondary particle production and SRF/RF
  - Present and future involvement in domestic and international accelerator projects



ACC 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.

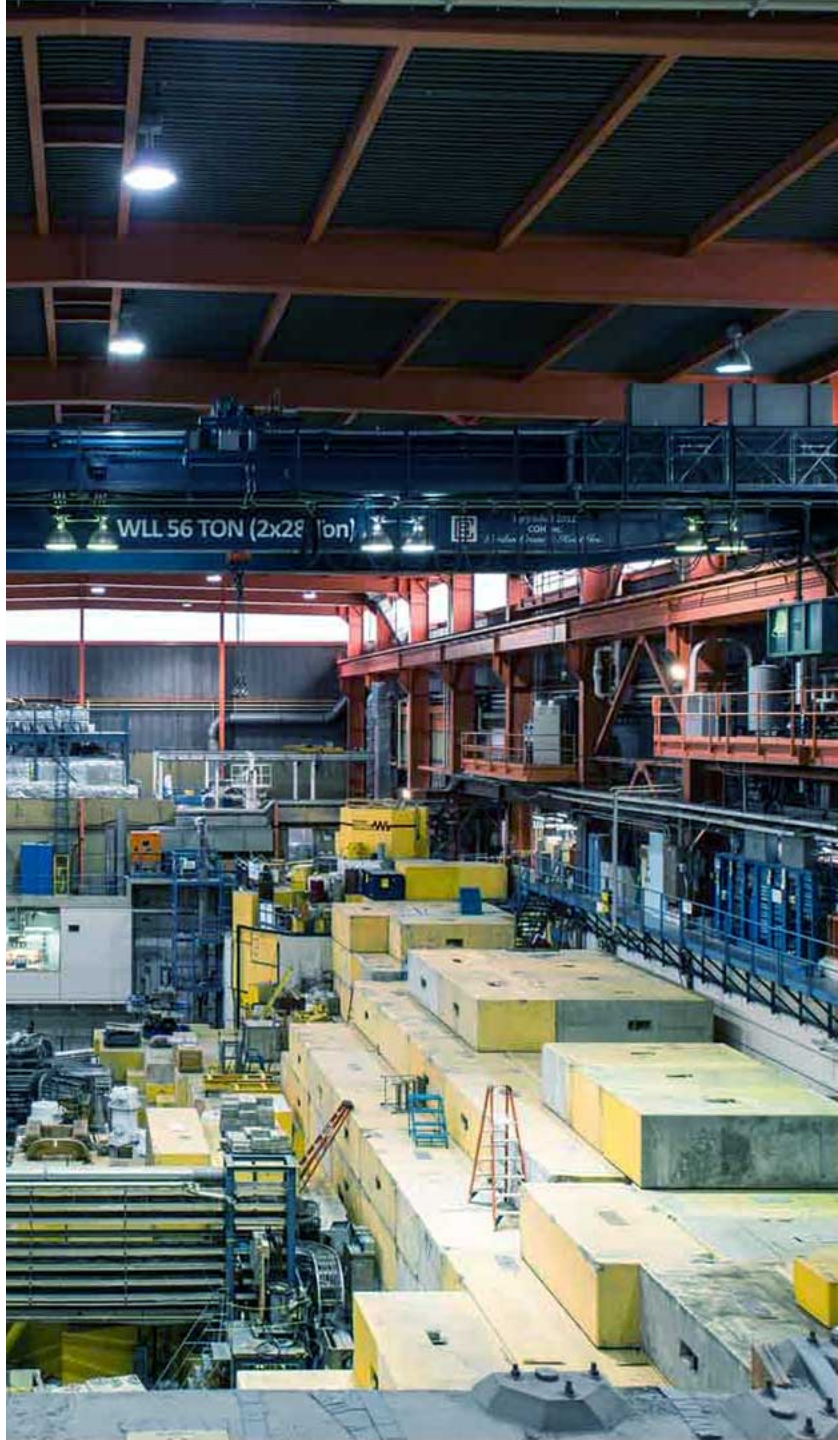
TRIUMF Accelerator Development and Research

Areas of activities:

- Operation, refurbishment and upgrade of the TRIUMF accelerator complex
- Capacity increase via design and construction of new accelerator systems (ARIEL, CANREB, THz radiation)
- Domestic and international accelerator projects
- Accelerator research and development (focused on TRIUMF)

based on three pillars of excellence in

- beam physics
- secondary particle production
- SRF/RF technologies and research



Who are we: Structure of the ACC Division

145 staff members (including post doctoral fellows)
34 staff members in ATG
15+2 graduate students (2 among staff)

Accelerator Operations
J. Aoki

Operation of the accelerator facilities including TR13 and TR24. Simultaneous delivery of multiple beams.

Accelerator Systems
Y. Bylinski

Beam line systems (electrostatic and magnetic), Vacuum systems, cryogenic systems, power converter technologies, high and low intensity beam diagnostics.

Applied Technology Group (ATG)
Y. Hosepyan

Operation and maintenance of TR30s, Solid Target Facility (STF) and Isotope Production Facility (IPF).

Beam Physics
R. Baartman

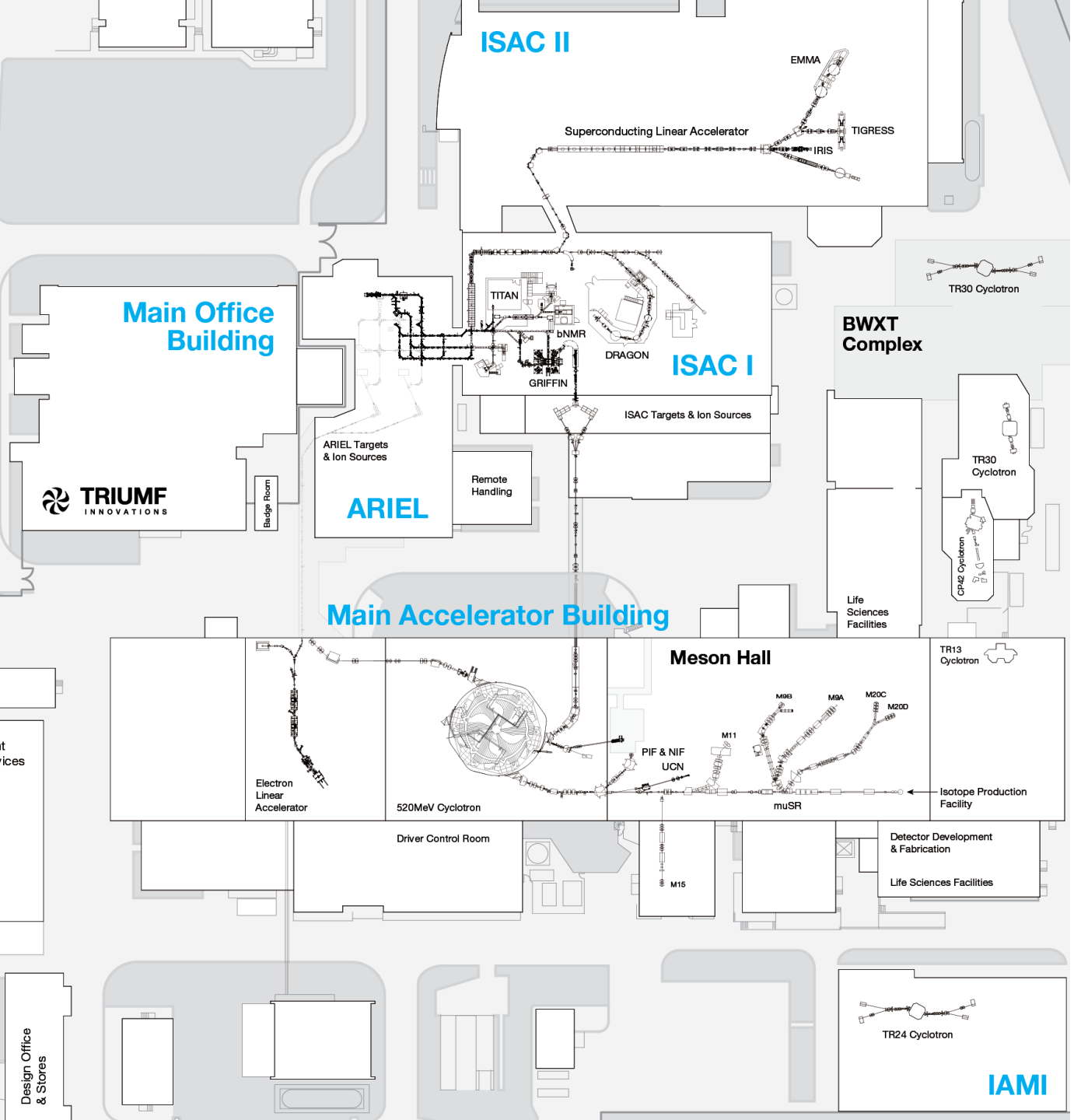
Accelerator commissioning & machine development. Simulation code development & beam tuning applications. High-power accelerators & colliders

RF / SRF
R. Laxdal

Low level and power RF, Superconducting RF, cavity development and cryomodules.

Targets/Ion Sources
A. Gottberg

Target technology for high power ISOL systems. Target ion sources. Nuclear spin polarization and muon production, material radiation damage and Remote handling.



TRIUMF accelerator complex

A diversity of accelerators from:

- High-power to rare-isotope beams
- Cyclotrons & Linacs
- Normal conducting to superconducting structures

Supporting:

- Flexible RIB delivery for science
- Medical isotope research & prod.
- Neutron & muon science
- Accelerator science R&D

ARIEL = new infrastructure on all fronts: driver, targets & RIB

Division planning process for 5YP 2025-2030

- Divisional planning started in spring 2022 with retreats of the Accelerator Division lead team.
- The retreats did focus on the mission, core competencies, SWOT analysis → major activities and initiatives in the next 5YP derived from an updated project and issue matrix and the divisional risk registry.
- In a next step priorities for projects and activities were derived as well as MRO volume and staffing for the ARIEL operation era.
- Development of the final activity list within the operational and sustainability model with focus on
  - Alignment with
    - TRIUMF 20-Year Vision
    - TRIUMF present Goals & Objectives
  - Delivering and operating ARIEL

1) Make groundbreaking discoveries across TRIUMF's multidisciplinary research portfolio.

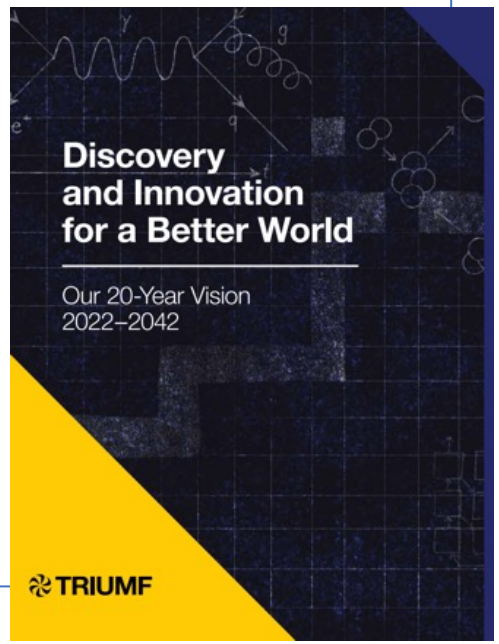
2) Reinforce TRIUMF as a globally leading particle accelerator centre.

3) Become a hub for interdisciplinary education and training

4) Inspire Canadians to discover and innovate

5) Translate knowledge and discovery into innovation

6) Increase national and international collaboration



Operational Model, sustainability concept

Operational model Accelerator Division:

- Core operation (Running and maintaining the accelerators, break fixes)
- Keep capability and do capacity development (can have an opportunity component)
  Divisional MRO activities (refurbishment projects, SAS activities)
  Divisional MRO projects and LDRD-type projects managed by PMOG/QRPP
- Science delivery

Sustainability model (categories of expenses):

- Core/baseline operation
  - MRO costs and work forces – Staff and machine operation costs (including labs)
- Keep capabilities and capacity development (Capacity for research)
  - Refurbishment (520 MeV cyclotron, RIB program and ACC infrastructure),
    ACC operation with new beams / beam parameter
  - ARIEL-II completion and towards ARIEL and e-linac design performance
- Science delivery (Research and innovation)
  - Grant driven projects like HL-LHC, EIC contributions, PC-CANS, e-linac and THz capabilities, DarkLight
  - Accelerator R&D, WFO, commercial projects

NRC Evaluation of TRIUMF in parallel with the 5YP planning process

Peer Review (November 29 – December 3, 2022)

- Science divisions participated in plenary talks, parallel sessions, poster session, tour

Some comments about ACC Division:

- The PRC found the TRIUMF accelerator division is internationally outstanding and has achieved major global scientific contributions.
- The major new ARIEL accelerator has demonstrated operation at its commissioning goal of 10 kW beam power, the limit of the beam dump in the e-hall, which is noted by the PRC as a significant accomplishment that demonstrates the outstanding capability of the accelerator group and TRIUMF.
- The ARIEL project achieved a recent milestone with the extraction of a beam from the 520 MeV H- cyclotron into the new beamline (4N).
- Researchers are contributing knowledge and technology to CERN's Large Hadron Collider (LHC) and are positioned to collaborate on future projects such as the Electron Ion Collider (EIC).

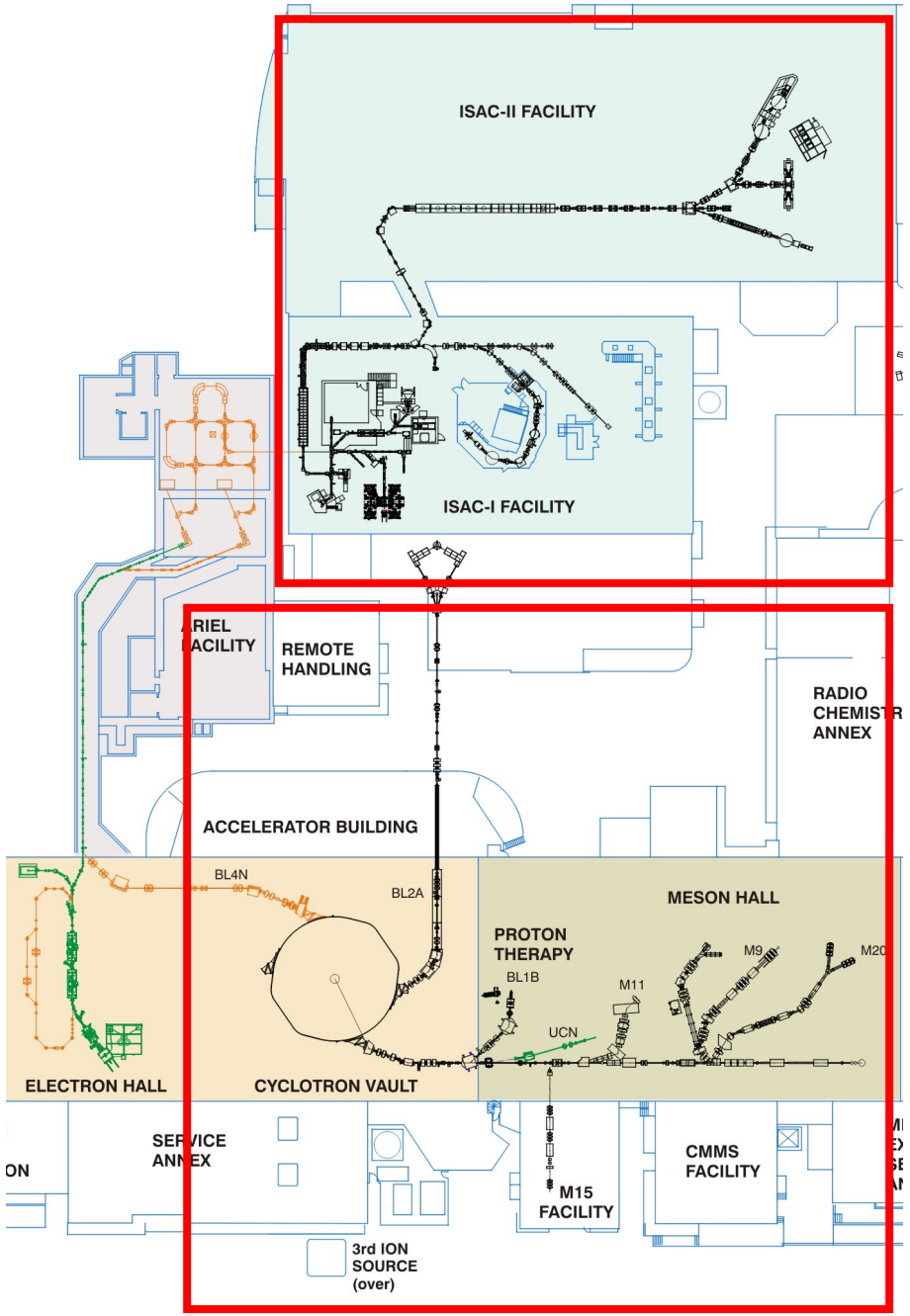
After the PRC →

TRIUMF

The TRIUMF accelerator complex – refurbishment and gain in efficiency

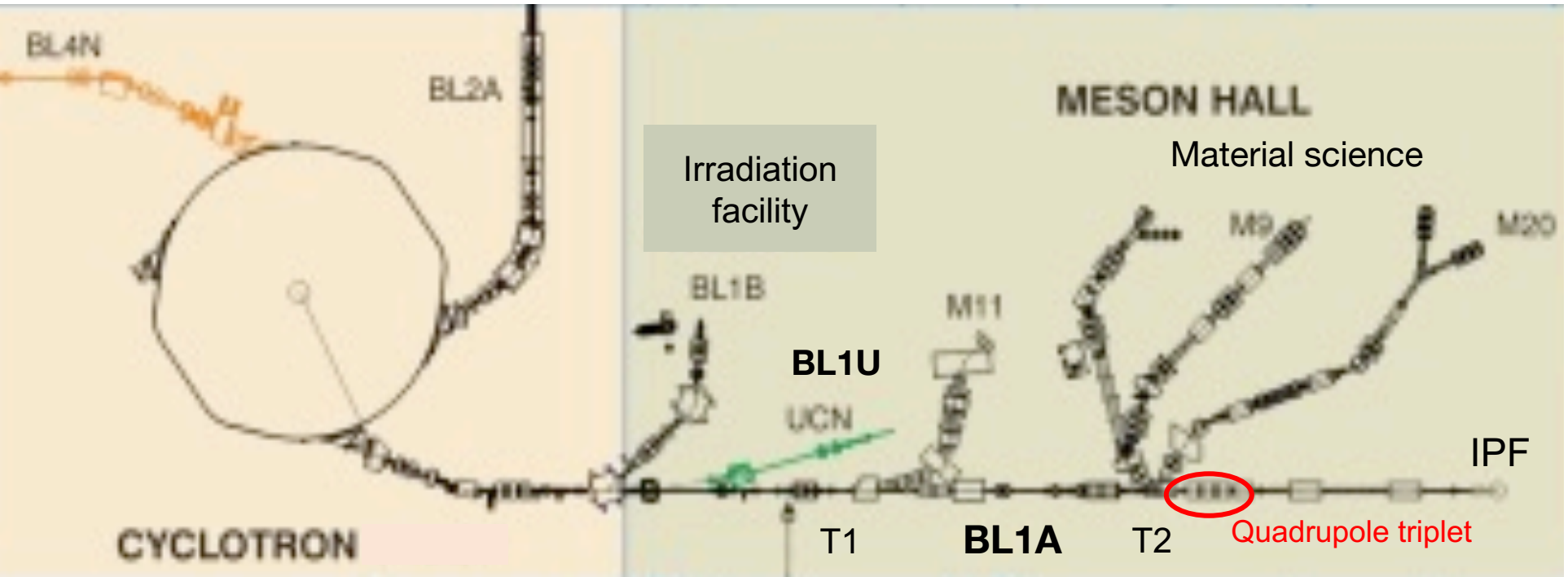
Refurbishment in the next FYP

- Chief goals of the continuing refurbishment program:
  - Risk mitigation against extended down-time as guided by the Division Risk Registry
  - Improving efficiency of operation → prerequisite for the ARIEL operation era – reduced maintenance requirements, model assisted tuning, power-smart, unification of site equipment, amalgamation of control rooms
- Cyclotron: RF system, remote handling, vacuum, BL1A upgrade, BL2A upgrade, Control system
- TRIUMF Control Center (TCC)
- ISAC: RF system, target hall infrastructure, laser ion source (LIS), Remote Handling, beam delivery



Refurbishment of BL1A

- The BL1A refurbishment project is a collection of activities to restore reliable beam operation and enhance functionality of BL1A.
- The refurbishment project did start with a revision of the beam optics give the boundary conditions of the targets T1 and T2 and their position, UCN and IPF.
- The project will address: Vacuum system, controls, diagnostics and collimators, additional steerer, T2 monument, replacement of the quadrupole triplet with a double doublet and phase 2 of the replacements of magnet power supplies (→ BC Hydro incentive).
- Replacement of old magnets does need remote handling capabilities → upgrade of the remote handling capabilities in the Meson Hall.



Remote handling (RH) activities

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 for cyclotron and primary beam transport lines
- Training programs on prototypes and hot cells, new tools
- International collaborations (T2K, CERN, SCK, VECC, RISP, etc.)

RH robotics development

- Refurbishment / exchange of aged and obsolete RH equipment and electronics:
- Cyclotron RH controls, Meson hall RH infrastructure shielding flasks, hot cells etc.).

- Exchange of obsolete remote handling controls and the consolidation of controls hardware into one central area in ISAC
- RH waste management program target handling for shipment, separation and sorting of waste material

CCS upgrade and the TCC

Cyclotron Control System (CCS) upgrade

- Scope: Replace legacy CCS CAMAC executive crates with in-house built hardware running EPICS.
- Motivation: Address a top-level risk – failure of the executive crate could cause months of downtime due to the scarcity of replacement parts – and allow for the removal of controls hardware from the site of the future TRIUMF Control Centre.
- Strategy: Develop and test the new system in parallel leaving legacy equipment largely undisturbed until the new control system has been commissioned.

CCS executive crate

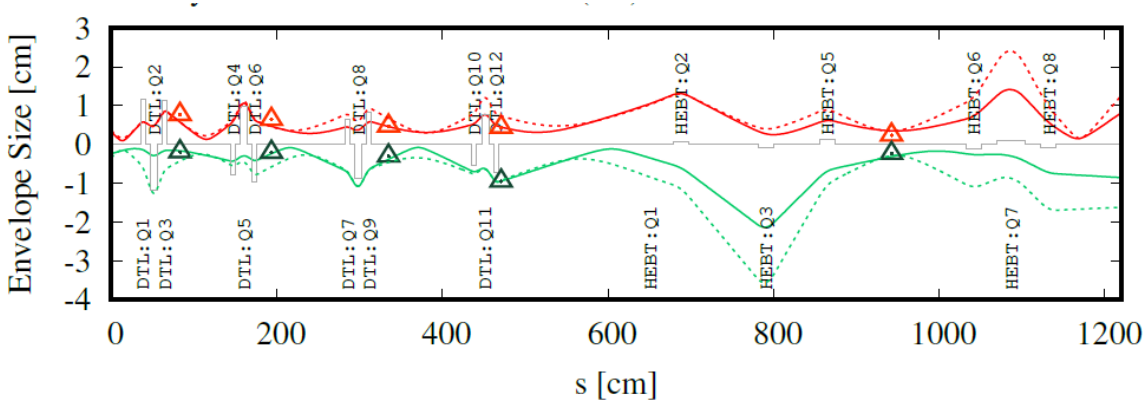

Driver Control Room

TRIUMF Control Centre (TCC)

- Scope: Consolidate Driver and RIB accelerator operation within a single space.
- Motivation: Gain operational efficiencies in terms of staffing and enable Accelerator Operations to better manage the paradigm shift as ARIEL transitions from commissioning to production.
  This transition will result in a significant increase of RIB output to experiments, supported by two driver accelerators and three target stations.

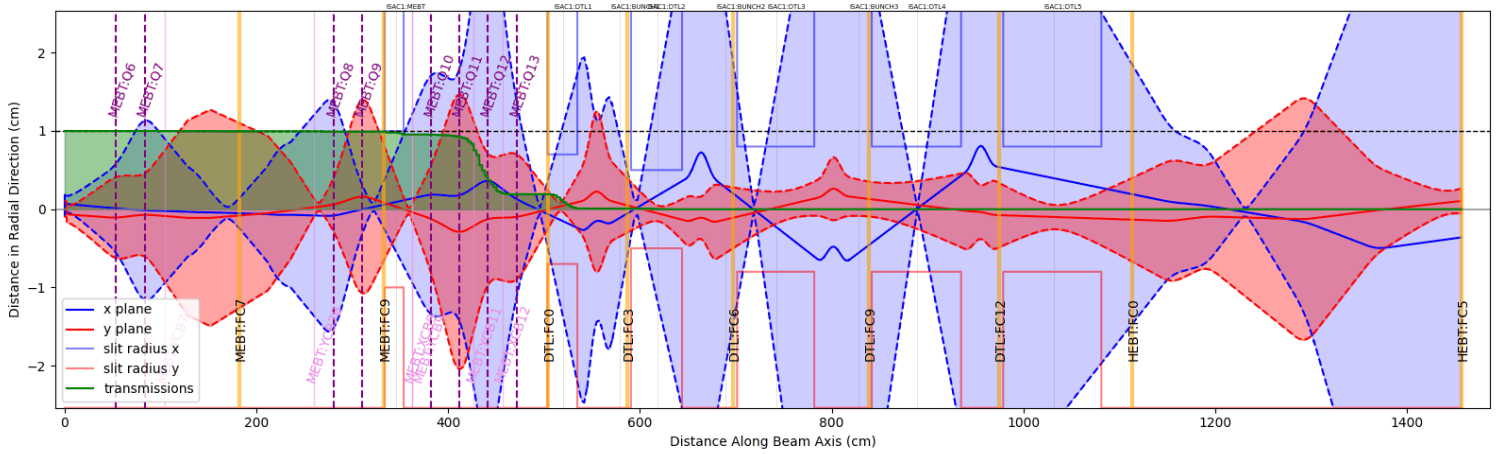
Advanced beam tuning – gain in operation efficiency and quality

- Web-based framework and python interface to communicate with the accelerator control system has been developed for
  High-level applications (HLA).
- Emerged from HLA → Model Coupled Accelerator Tuning (MCAT). (Presentation of Hui Wen Koay)



- All of TRIUMF's accelerators and beamlines will be integrated in model-based tuning. Significant reduction of beam delivery time and gain of beam quality.

- Using machine learning tools (Bayesian optimization) for reduction of beam tuning time. (presentation of Wojtek Fedorko)

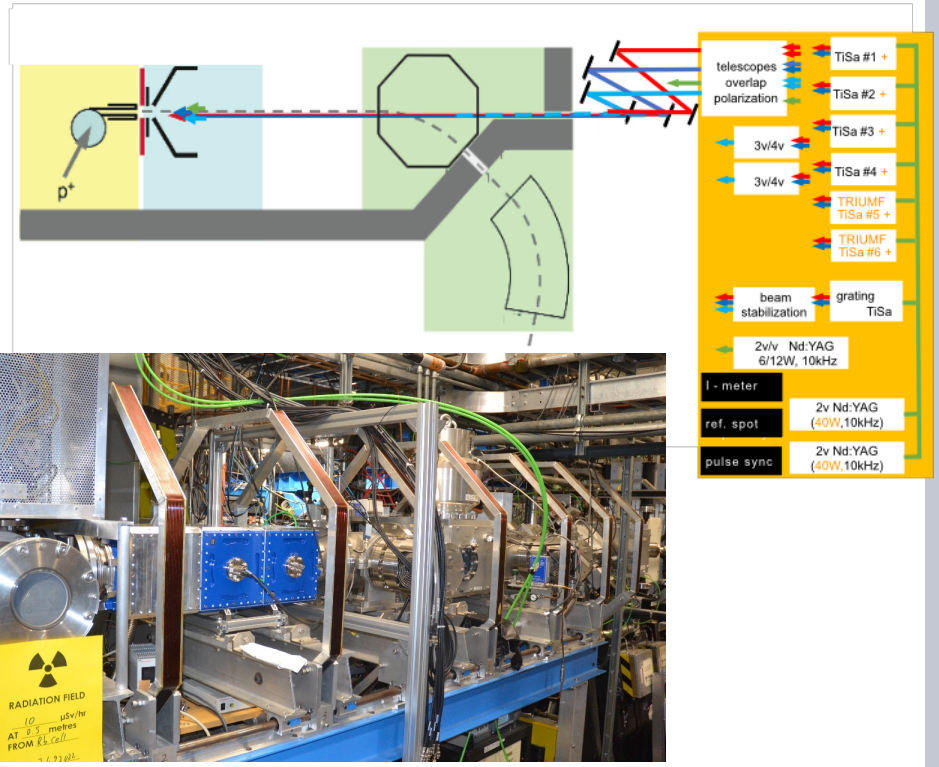


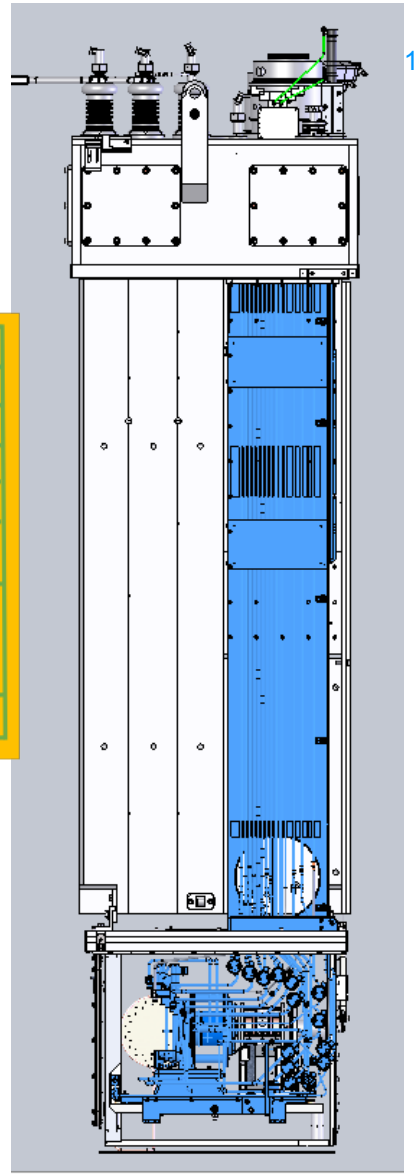
STEP: 0
'MEBT:Q6': 9.75
'MEBT:Q7': 14.44
'MEBT:Q8': 17.94
'MEBT:Q9': 23.43
'MEBT:Q10': 8.95
'MEBT:Q11': 21.43
'MEBT:Q12': 21.86
'MEBT:Q13': 12.01
TRANSMISSION: 0.0

- Computing infrastructure and beam instrumentation (low intensity diagnostic) are key.

ISAC in the next 5YP

- Full roll-out of regular target module refurbishment program (all major components except shielding). TM3 was the test case for a module refurbishment.
- Target production and conditioning systems renewal → lab infrastructure
- Electrical and mechanical systems refurbishment and procurement of critical spares.
- Laser Ion Source system of TRILIS needs refurbishment. It's the most demanded Target Ion Source at TRIUMF.
  Also, beam development becomes increasingly difficult (2 elements/y).
  Allow for more complex setups and ALIS (ARIEL) & TRILIS (ISAC) parallel operation!
- Continued infrastructure refurbishment for spin-polarized beams at ISAC.
- ISAC-I Linac RF system refurbishment
  Replacing 25 years old tube amplifiers with solid state amplifiers (SSA).





TRIUMF

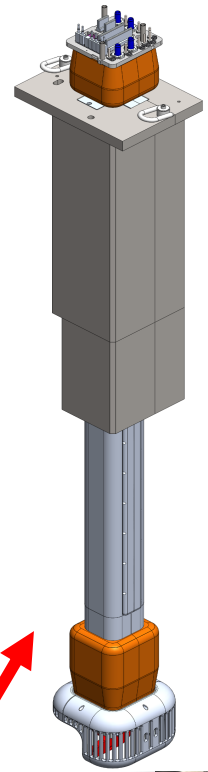
Capacity increase: The advanced rare isotope laboratory – ARIEL

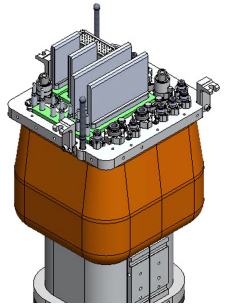
ARIEL: ISAC×3

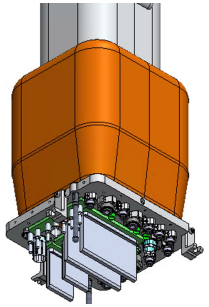
- ARIEL is the world's most powerful isotope separation online complex.
- It will triple ISAC's present rare isotope capabilities by adding
  - a 50kW proton target station
  - a 100kW electron target station
  - Unique beam preparation and transport system (CANadian Rare isotope facility with Electron Beam ion source - CANREB)
- ARIEL is the only rare isotope facility that will provide three RIB beams simultaneously to experiments.

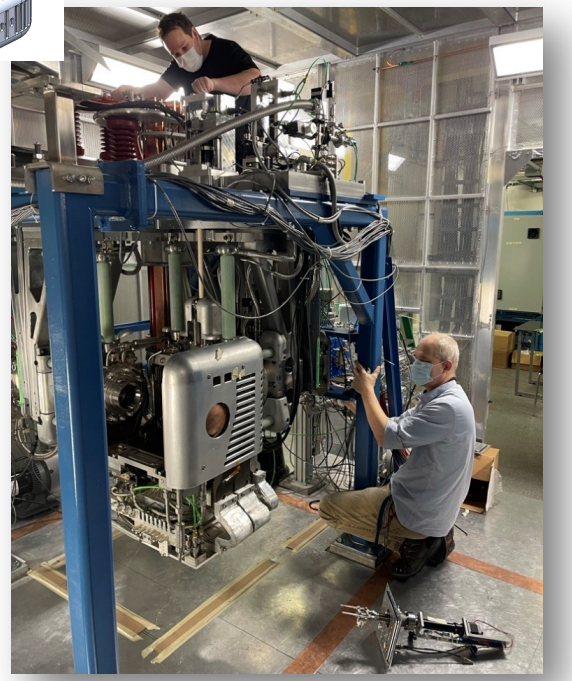
ARIEL status: Target Station

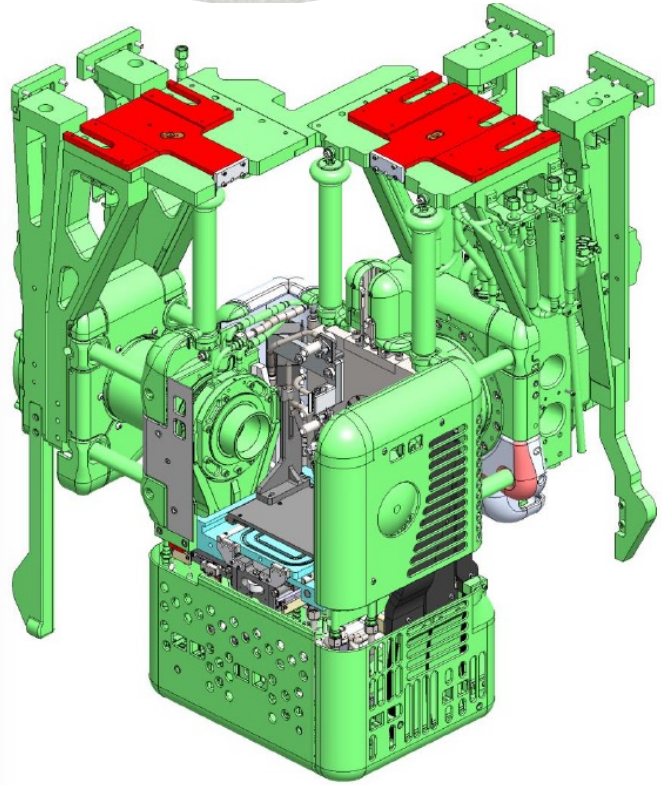
- AETE (ARIEL Target Station East) targetry protype testing complete, technical risks retired.
- VECC collaboration: AETE Target/Ion Source Front End Prototype shipped
- Target Module front end & High Voltage Feedthroug (HVFT): Design & drawings nearing completion and parts being completed by machine shop and HVFT ordered.









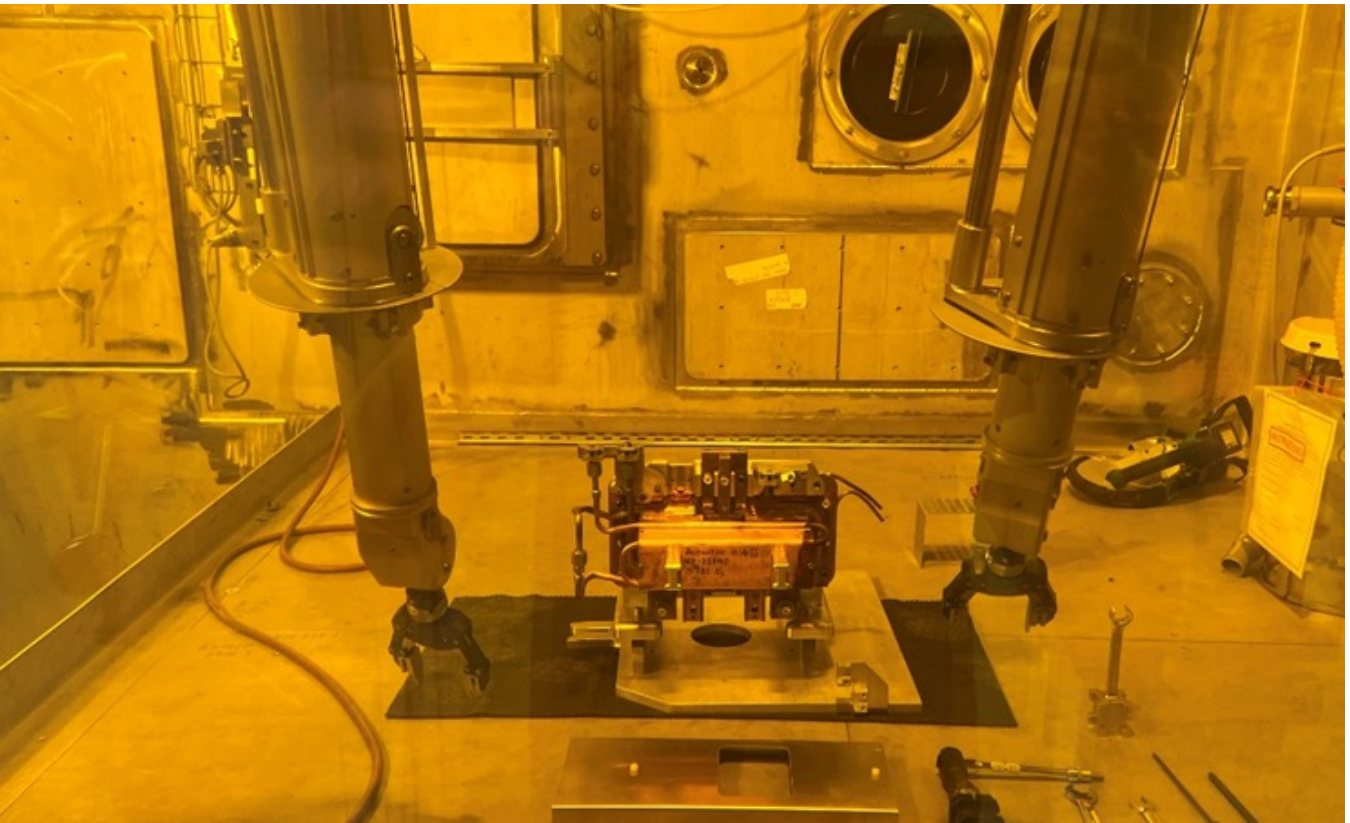


Target Hall Infrastructure

- Shielding construction of Level 2 successfully completed on time.
- Structural Supports for heavy ARIEL modules received and installation completed.

ARIEL status: Hot cell

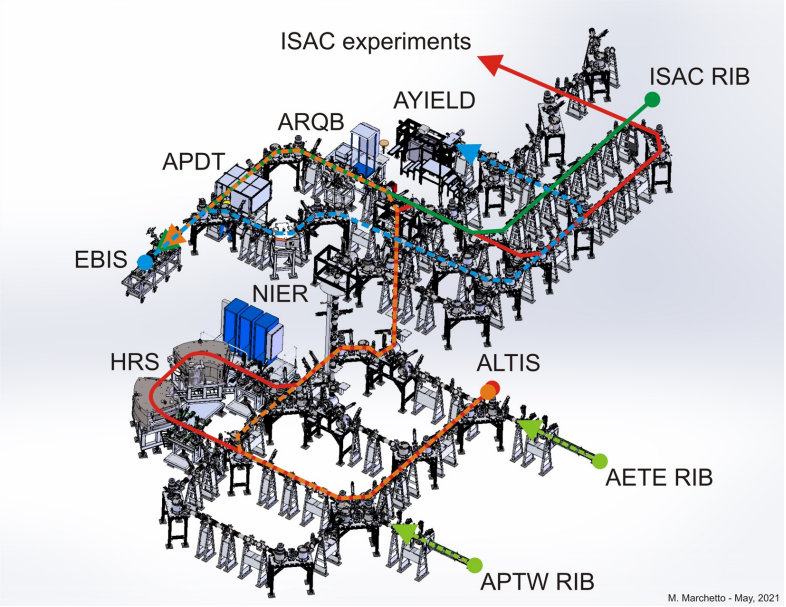
- Largest single capital investment for the project.
- Hot cell installation completed!



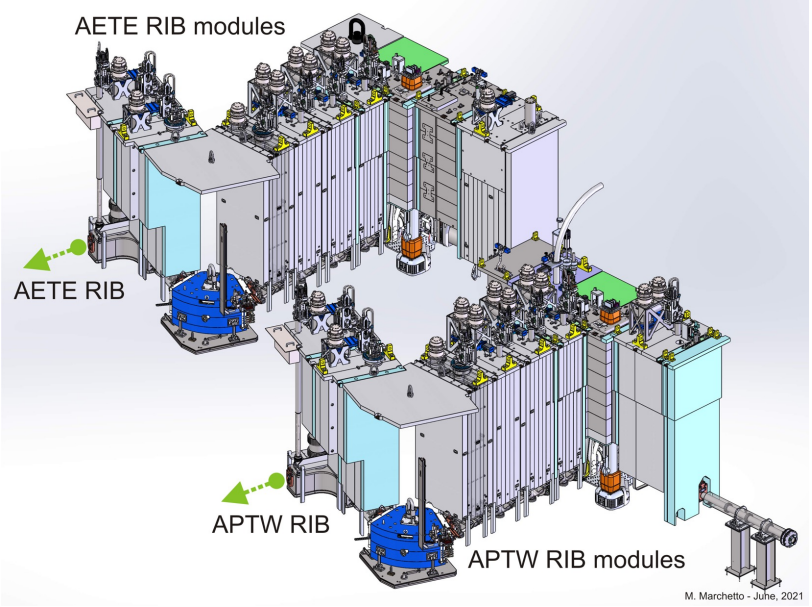
ARIEL status: RIB (transport) modules

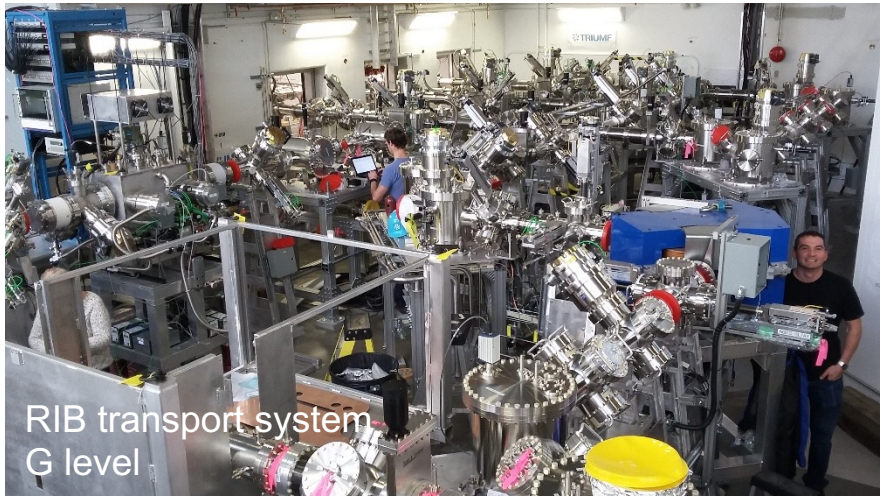
- RIB transport system outside the target hall (200 m of electrostatic beamline)
  >95% installed and commissioned
- RIB module vacuum chambers fabricated for VECC
- First RIB module vacuum dog-leg fabricated and assembled.
- RIB module steel shielding fabrication in progress!

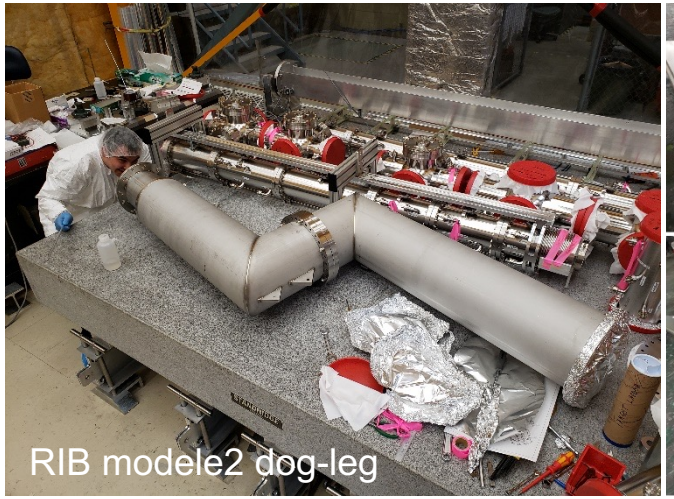
Front-end outside the target hall



Front-end inside the target hall

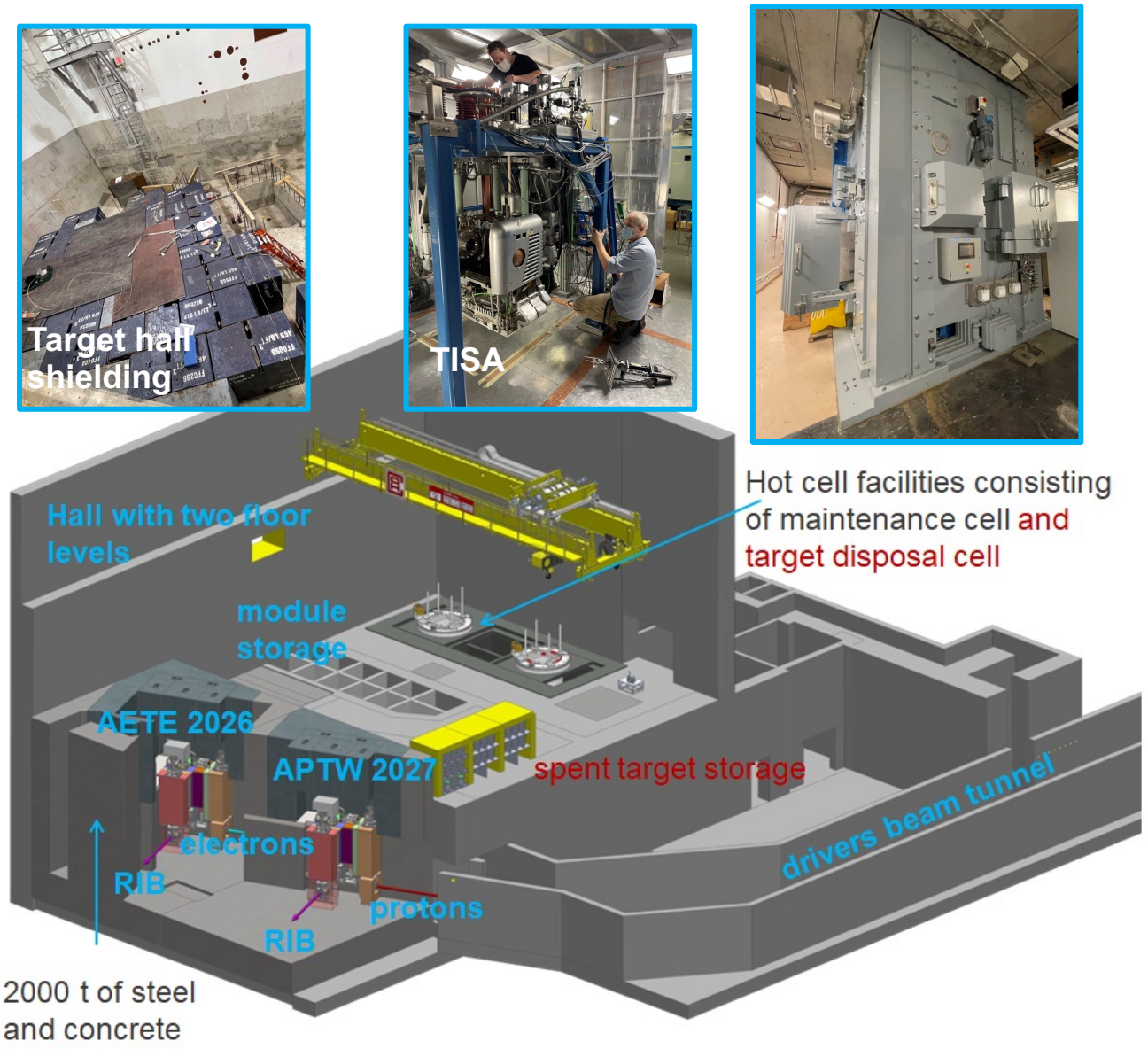






ARIEL completion and transition into Operation

- Electron target station completion and online in 2026
  Proton target station and BL4N completion in 2027
  (support from SCK CEN, Belgium)
- Required for the ramp up in operation to take full advantage of ARIEL over the next 5YP:
  - Target production laboratories
  - Target decay storage vault
  - Offline target acceptance stand – TISA completion
  - Resonant laser ion source for proton target station
  - APTW proton beam raster system
- Design goal 9000 hours beam time and 3 simultaneous RIBs. Only possible within the funding request of $450 M.

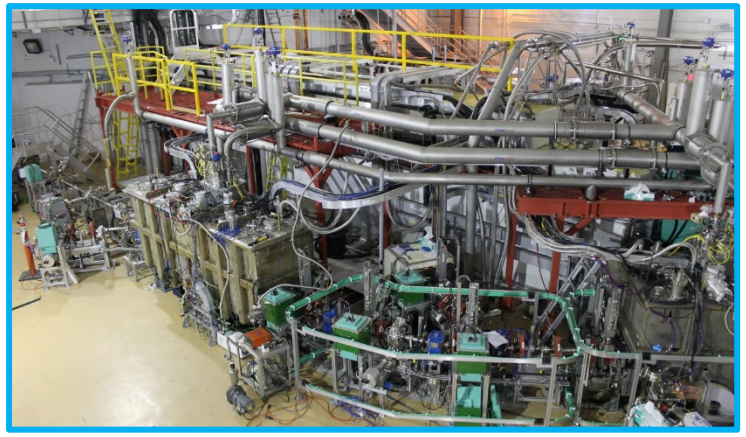


ARIEL operation – ramp up of beam delivery

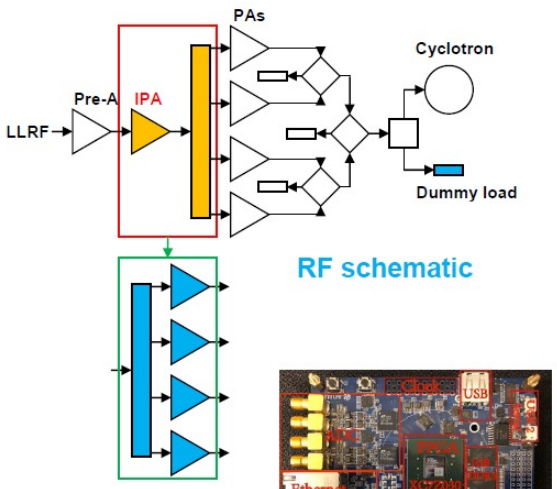
- Commissioning of the electron line in the ARIEL tunnel followed by a gradual power ramp up to the electron target.
- Commissioning of BL4N followed by a gradual Cyclotron extracted current ramp up to 400 μA, with stable beam current in 3 high-energy beamlines.
- Roll out of the ARIEL-era operational model:
  TRIUMF will become a facility much more complex to operate.
  Success will require: TCC, Model-Based Tuning and integrated multi-facility maintenance.
- After the commissioning phase, the reliable delivery of high-power electron and proton beams to ARIEL requires regular machine development and targeted technology development programs.

Driver accelerators for ARIEL

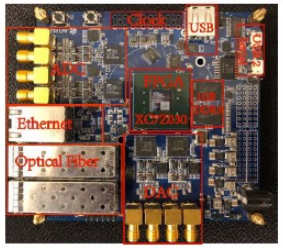
- E-linac towards high reliability and 100 kW beam power
  - R&D on particulate contamination, Plasma cleaning
  - Develop software tools to support beam ramp-up and high-power operation
  - Intense THz and IR radiation – realize photo-gun and optics
  - Support science (DarkLight, FLASH, etc.)



- Towards reduced cyclotron maintenance time (lid-up only every second year)
- Continue cyclotron refurbishment RF system (SSA and digital LLRF) for high current operation!



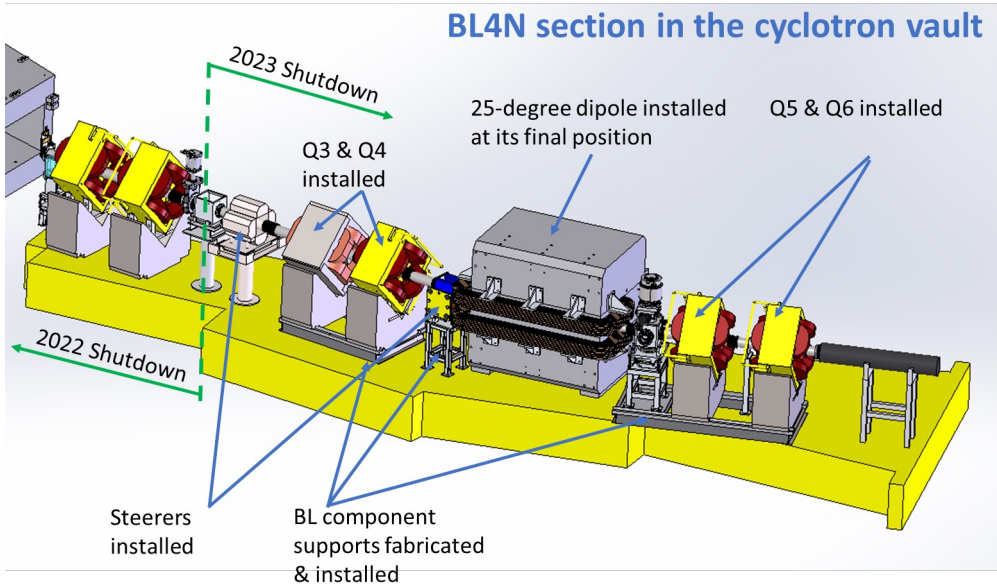
RF schematic



Digital LLRF board

- Primary proton beam line - BL4N

  All beamline components for the vault section installed.



Staffing towards the ARIEL operation era

- Basis for the staffing decision towards the ARIEL operation era is the Operational model for ARIEL (Document-129655).
  → Factory model, where the three RIB target areas are each scheduled in three-week cycles with each cycle starting on a subsequent week.
- The operational model analysis includes an estimation of the extra effort required to commission, operate, develop and maintain a significantly expanded facility, over and above the present effort.
- From this analysis we identified additional hires, taking the gain of efficiency into account!
  (TCC, advances beam tuning, IT tools, refurbished equipment)

TRIUMF

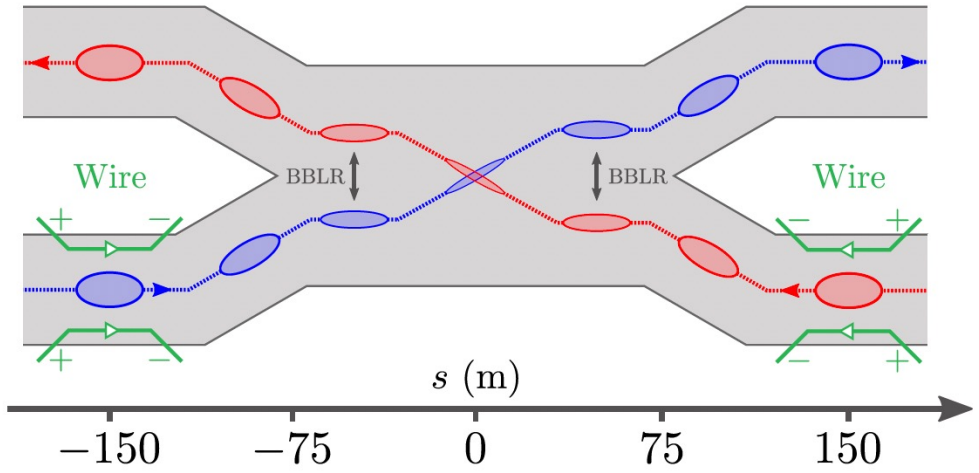
Accelerator science at TRIUMF:

Three pillars of excellence.

Beam Physics

Beam Physics will focus internally on cyclotrons and linacs and externally on ring accelerators / colliders:

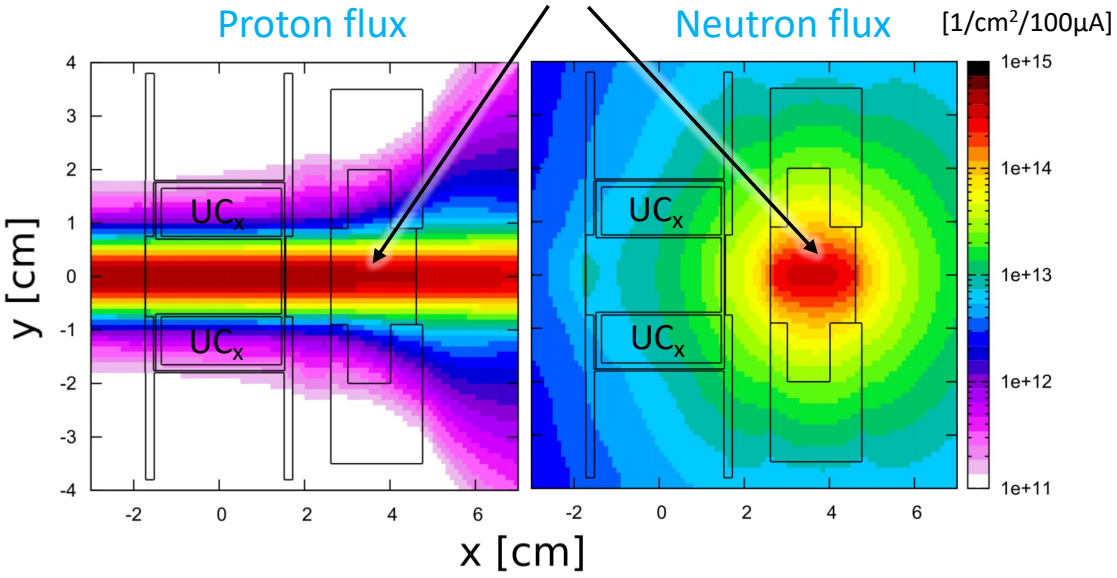
- Beam physics studies of the ARIEL e-linac for THz radiation and DarkLight. Recirculation ring and Energy Recovery Linac operation mode.
  Rastering of 100 kW e-beam on the ARIEL electron convertor target.
- Commissioning protons (BL4N), simultaneous electron&proton operation.
  Increasing the beam current in the cyclotron (500 μA capability, 400 μA daily operation) and overcome issues of high current beam extraction into three beam lines.
- RIBs from ARIEL → towards regular ARIEL HRS operation at a resolution oft 20,000.
- Internal accelerator facility tuning development, model based beam tuning and Machine Learning applications.
- Dust in accelerators – new hot topic in the accelerator community.
  → UFO analysis in LHC and dust migration in SC linacs.
  UFOs lead to sudden loss spikes or even beam dumps!
  Investigating the charging mechanism of dust and migration in the system.
- Important collaborations with CERN LHC:
  Beam-Beam Long Range and compensation methods
  (presentation of Hui Wen Koay)



Test of Wire Compensators for LHC Run 3 around IP1 and IP5

Targets and Ion Sources Research Examples

Converter targets
(example Proton-to-neutron)

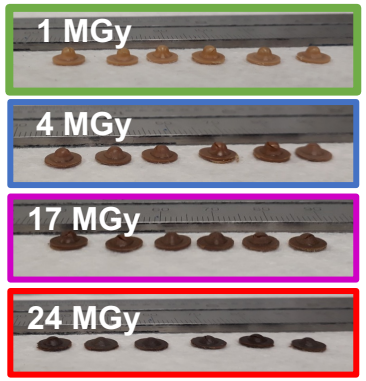


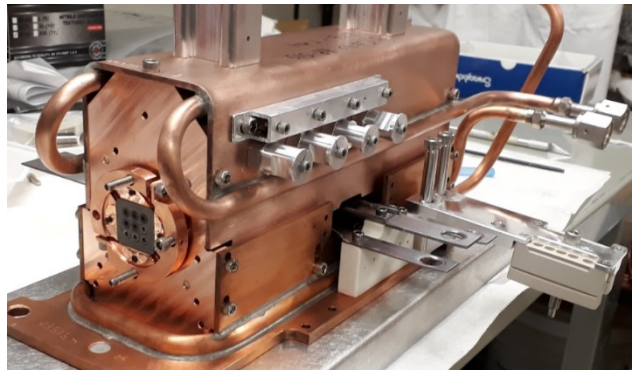
R&D on high power electron convertor target for ARIEL

Research focus:

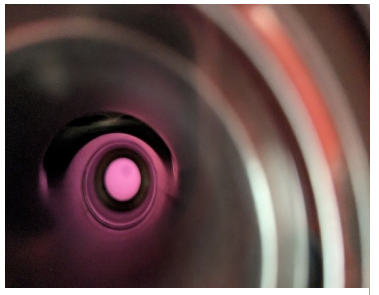
- Target materials for intense radioisotope release
- Ionization schemes and laser ionization efficiency
- Material irradiation damage for accelerator and nuclear applications
- Applications of accelerators and high-power targets for neutron and medical isotopes production

Irradiation damage studies – example: PEEK
Tensile and fracture properties





RF/SRF research activities



Plasma cleaning

Furnace degassing

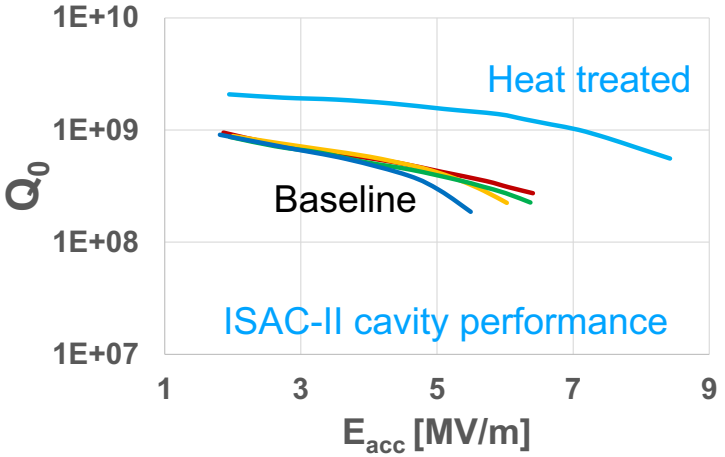
To support on-site accelerators, student focused R&D and external collaborations (like HL-LHC crab cavity cryomodules, presentation of Philipp Kolb)

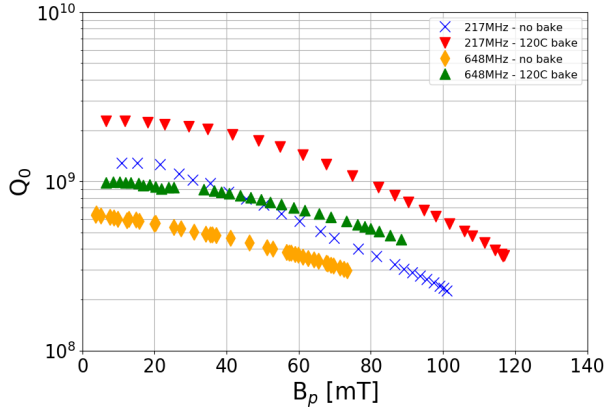
Linac developments

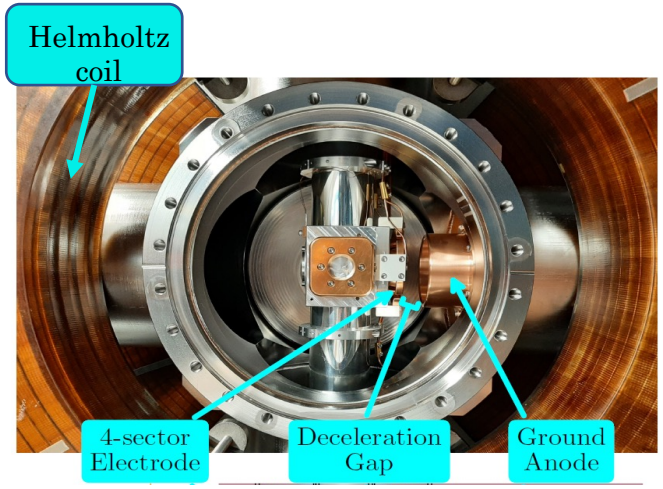
- E-Linac – plasma cleaning for in-situ processing, model and mitigate particulate migration
- ISAC-II – implement heat treatments to improve gradient and Q

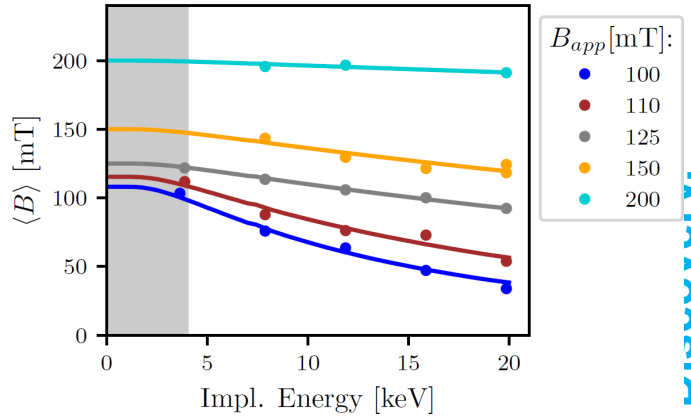
SRF R&D

- Exploit coaxial cavities to develop new insight into optimized design, fabrication and processing (furnace baking, electro-polish, Temperature-maps)
- Exploit beta-SRF to develop new SRF processes and materials and understand fundamental limits





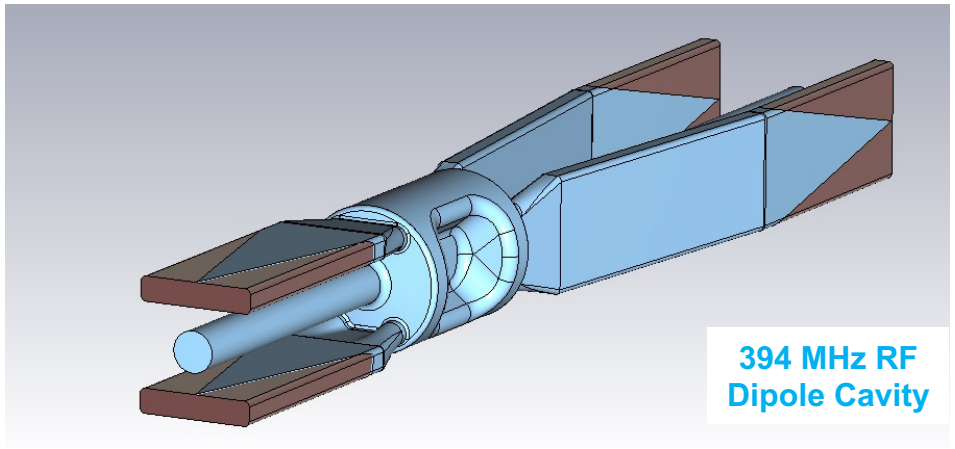


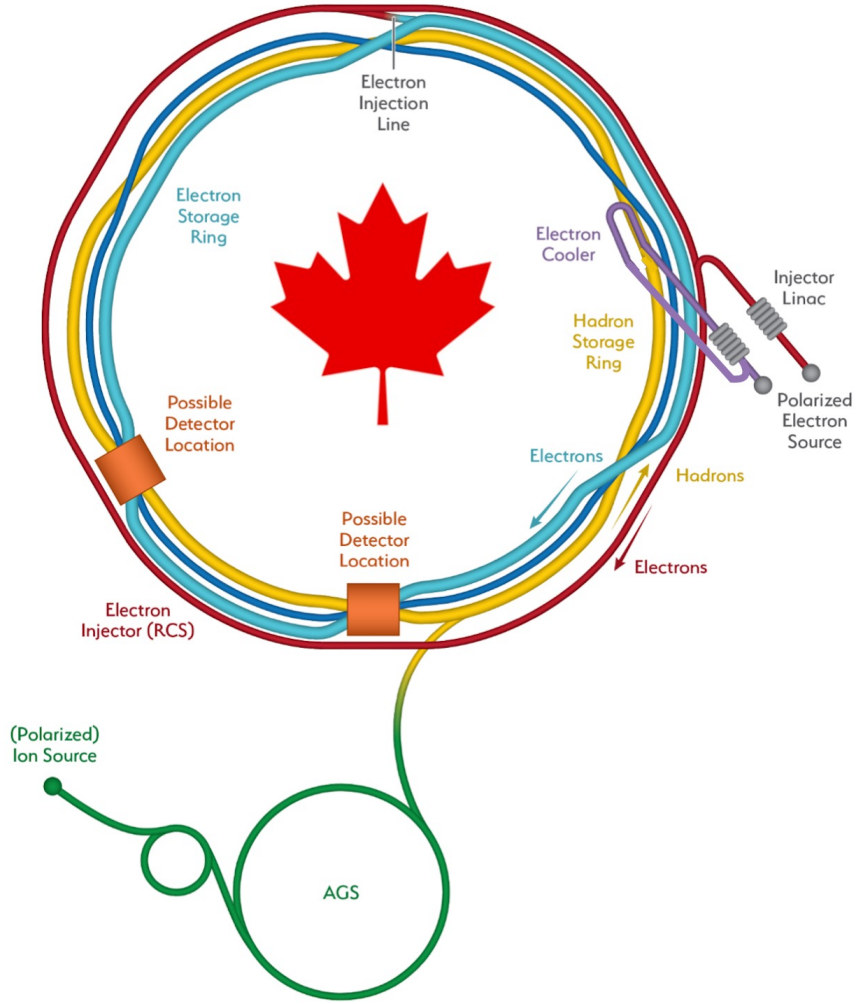


Discovery, accelerated

Electron Ion Collider (EIC) at BNL

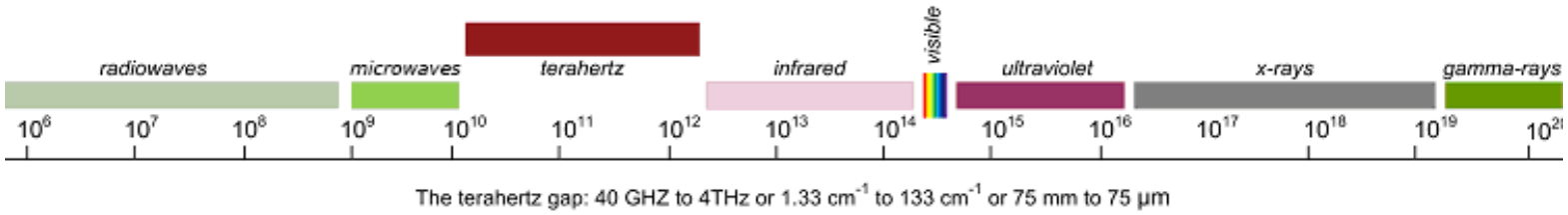
- The EIC is the next discovery machine to be built in North America at Brookhaven National Laboratory.
- TRIUMF is working with EIC-Canada to seek Canadian funding to support in-kind contributions.
- TRIUMF's SRF group has started work on the design of the 394 MHz crab cavity – similar size to HL-LHC 400 MHz crab cavity with significant challenges in managing the higher order modes (HOM) excited by the high circulating beam current.
- TRIUMF to contribute to the design of kicker systems in collaboration with CLS and BNL.

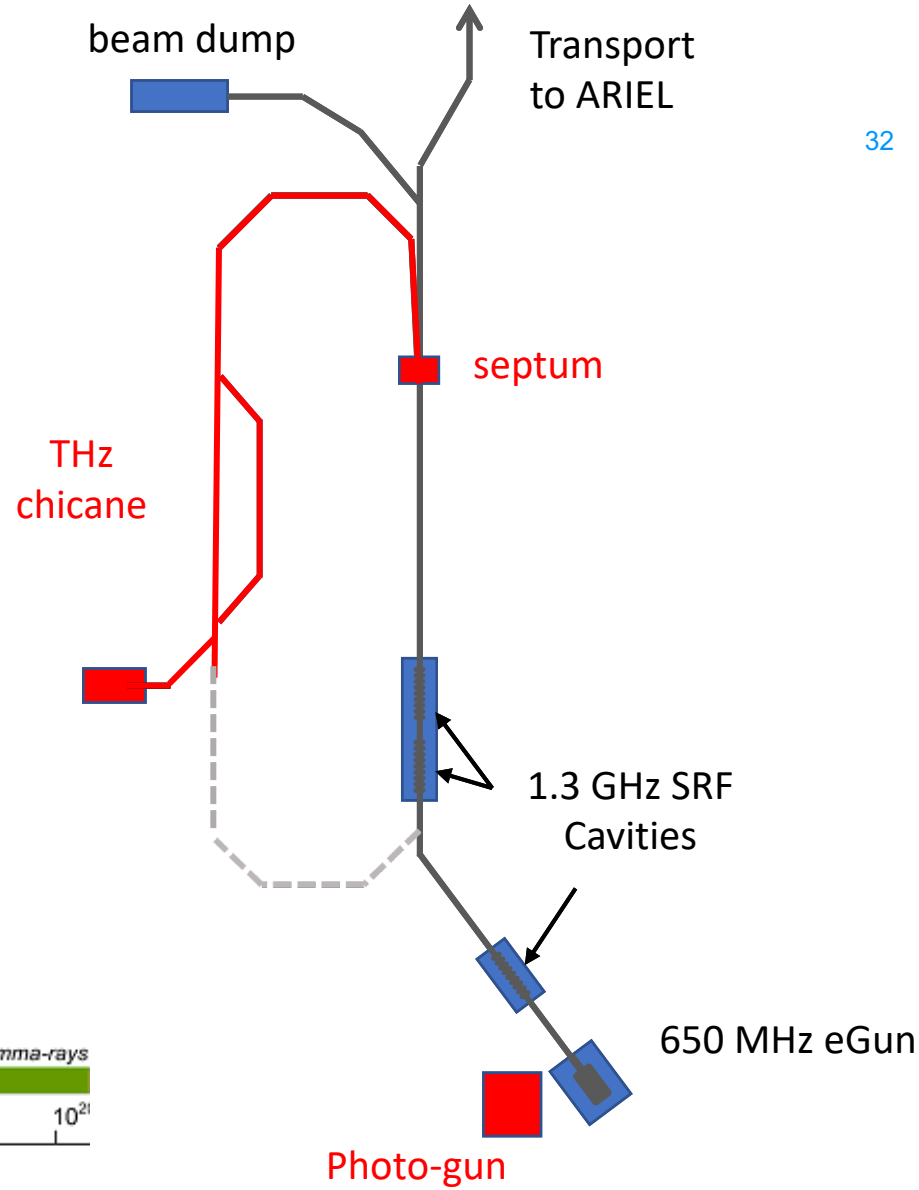




THz radiation project

- TRIUMF, as part of a pan-Canadian collaboration (including TRIUMF and CLS), will receive CFI funding to develop a THz light source within the ARIEL e-linac hall.
- Addition of a new photo-gun to produce short, high brightness, low emittance, beam bunches, and a bunch compression chicane.
- A partial recirculation arc and septum will be used to install the chicane off the main linac beamline.
- Additional funds are being sought to complete the recirculation ring for either Energy Recovery or Energy doubling for Darklight for instance.





Summary of Accelerator topics in the next 5YP

Driver accelerators:

- Cyclotron refurbishment and upgrades
- e-linac towards full performance and for new experiments
- beam lines (BL1A), BL4N completion for ARIEL

TCC – TRIUMF Control Center (combines Driver and RIB control rooms) and Cyclotron Control System upgrade

RIB facilities:

- ISAC target hall consolidation, target module refurbishment, labs, ISAC-I Linac
- Target ion sources – Laser ion sources and polarizer and Remote Handling
- ARIEL completion and ramp up of operation

Research and education:

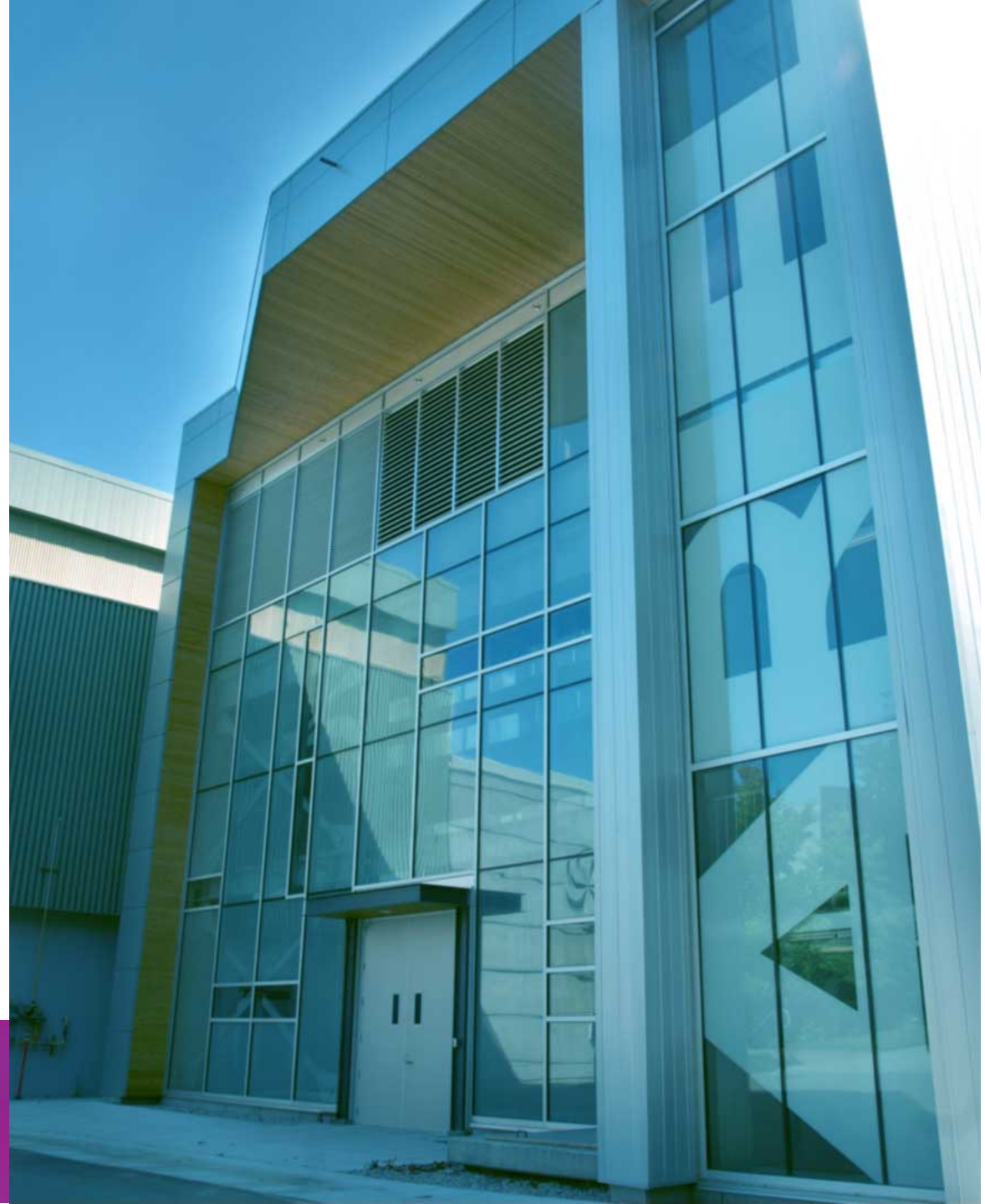
- HLA, model coupled beam tuning, machine learning and high power beams – e-linac, HL-LHC, EIC
- Cyclotron technology (injection, high beam intensity operation → beam loss reduction)
- SRF research - plasma conditioning, heat treatments, particulate migration, cavity development, SRF materials and fundamental limits
- High power targetry and material R&D, Laser Ion Sources R&D

Domestic and international projects:

- THz radiation, DarkLight, FLASH and PC-CANS
- CERN HL-LHC, EIC

TRIUMF

Thank you



science week/23
Jul 31 - Aug 4

Discovery, accelerated

Additional slides

Core Competencies of the accelerator Division

- Operation of a sophisticated accelerator facilities with simultaneous delivery of multiple beams
- Particle sources: H^--sources, Heavy ion sources, charge state breeder (ECR and EBIS), electron guns
- Beam physics: Simulation codes, beam tuning applications, physics of space charge dominated ion and electron beams, collider beam physics
- Beam transport systems: Electrostatic and magnetic beam line systems, high resolution mass separators
- Target technology and ISOL systems: High power RIB targets, target ion sources (SIS, FEBIAD, LIS), in-target beam purification technologies (IG-LIS, cold transfer line, proton-to-neutron converter), nuclear spin polarization, muon production targets, high-power targetry, material radiation damage
- Remote handling: Hot cell technology, robotics, irradiated target and radioisotope handling, manipulation of activated and contaminated parts, cyclotron services, radioactive waste management
- Accelerators: Linacs (heavy ions and electrons) normal and superconducting, cyclotrons (H-), synchrotrons, FFA, accelerator design
- Accelerator systems: RF (low level and power RF, SRF, cavity development), cryomodules, vacuum (including UHV), cryogenic systems, power converter technologies, high and low intensity beam diagnostics (ions and electrons), machine protection
- Accelerator Application: Medical isotope production, irradiation (material, therapy, electronics,…)
- Education: Seminars, lectures, lab research projects and thesis research

Risk registry


TRIUMF

Risk Registry - Accelerator Division

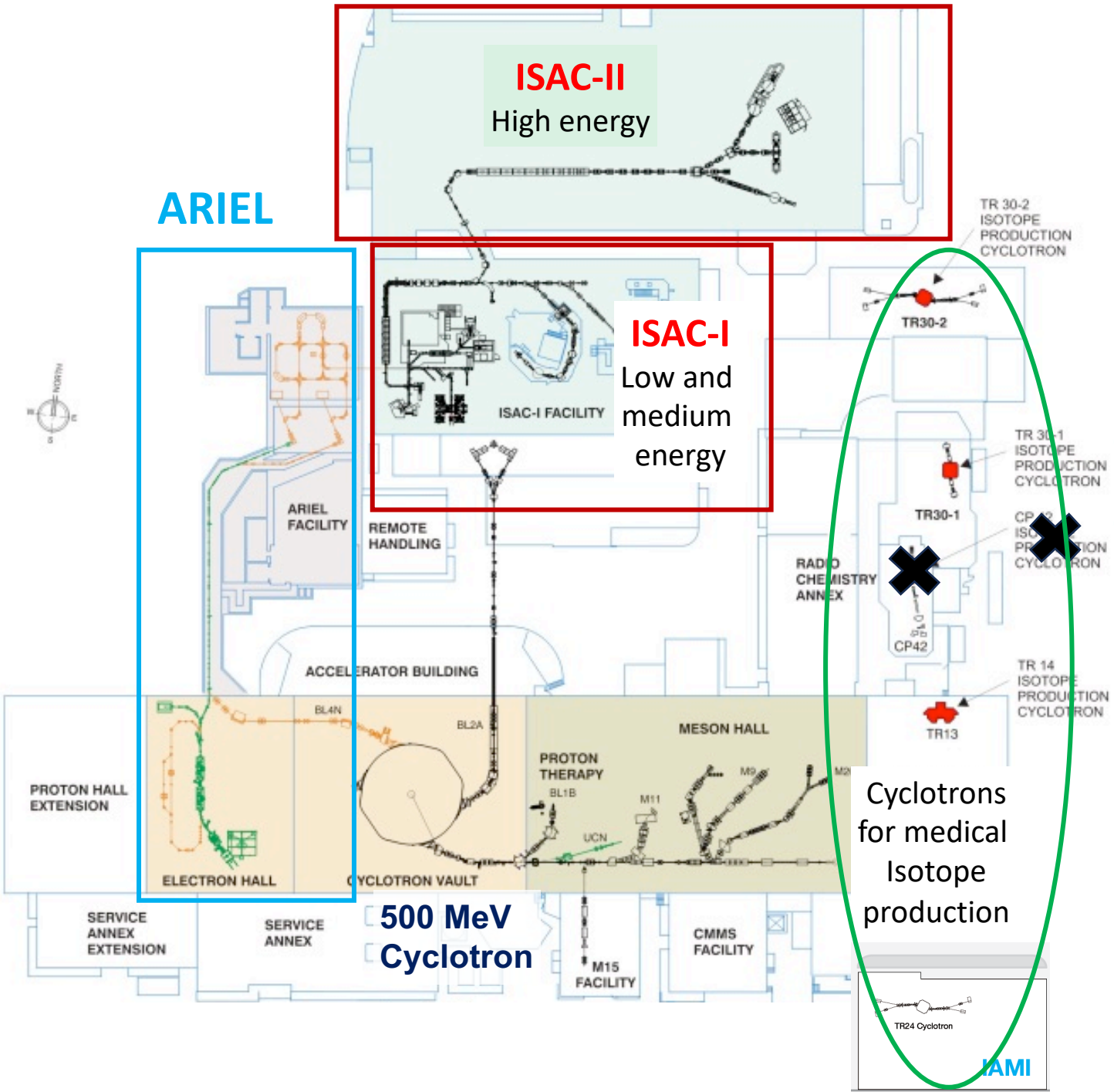
Owner: Director ACC Division
Date: March, 2023

Reference: ISO31000:2009
TRIUMF ERMP

Risk ID	Risk Sources: Human Perf. Difficulty	Risk Sources: Equipment difficulty	Risk Sources: Natural disaster or sabotage	Risk Sources: Financial	Risk Identification: Products and services	Risk Identification: Relationship	Risk Identification: Resource	Affected Objective (where appropriate include links to relevant documents)	Risk Event	Owner	Existing Mitigations (where appropriate include links to documents describing these mitigations)	Initial Risk: Consequence	Initial Risk: Likelihood	Initial Risk: Risk Level	Evaluation: Adequacy of exisiting mitigation	Evaluation: Risk Tolerance	Treatment: Risk Treatment Action	Treatment: Mitigating Actions (where appropriate include links to documents describing these mitigations)	Treatment: Owner	Treatment: Due By	Monitor and Review: Severity	Monitor and Review: Likelihood	Monitor and Review: Risk Level	Monitor and Review: Status / Trend	Monitor and Review: updates
ACC-R1	x							Primary beam delivery, cyclotron availability	Given that the main Cyclotron rf system is required for operation a failure would impact the protron driver beam. Vulnerabilities include resonators (water leaks, arcing, difficult access with high radiation), rf coupler (arcing, failure) , high power amplifier (high-power tubes that are expensive with poor vendor pool, aging and obsolete components), high power transmission lines (water leaks, arcing).	RF/SRF Department Head	Purchase new tubes. Add dummy load for high power tuning (in progress), add water leak diagnostics, Maintain spare parts including capacitors, transmission line components, spare resonators, spare coupler, refurbishment program for the IPA system, and a site plan to upgrade the HV transformers to regular line voltage (UBC).	4	3	HIGH	Adequate	Acceptable w/ Treatment	Treat	Refurbishment of the rf-system is ongoing, replacement of pre-amps with modular solid state amplifiers is a long term goal but needs $$, new dummy load for HP amp tests up to 800kW in progress and a tube test stand for pre-conditioning are part of this 25M$ complement. Replacement of LLRF system with digital system along with plans for event recognition software will allow improved protection with fast response capability to reduce the possibility to exchange a resonator with RH (see R17)	RF/SRF Department Head		4	3	HIGH	constant	The 25M$ project P492 is addressing some of the vulnerabilities but $$ will need to be extended into the next FYP to continue the work. Receiving LANL tubes would certainly help so we can put $$ elsewhere. Development of long term road-map for main cyclotron rf is in progress.
ACC-R2	x							Primary beam delivery, cyclotron availability	Given that the Cyclotron Control System (CCS) is using old hardware and that knowledge on the controls code is partially lost, a failure could impact the TRIUMF primary beam delivery. Most impacting would be a failure of the Executive crate.	Cyclotron facility coordinator	Investigation of the CCS2EPICS transfer (P0313), update of controls soft- and hardware in a staged approach - initiated P557 - passed Gate 1	4	3	HIGH	Inadequate	Unacceptable	Treat	Staged transfer of the CCS to EPICS. Upgrade must address the replacement of the most risky elements (executive crates) with a more redundant, modern hardware and software. Need to mature the plan - in progress. Know how on the CCS need to be preserved (Controls personnel).	Group leader Controls		4	3	HIGH	constant	The staged transfer of the controls system from CCS to EPICS is now covered by P557 - CCS upgrade. March 30, 2023: Risk escalated to enterprise level
ACC-R3	x							Primary beam delivery, cyclotron availability	Given the age of the horizontal section in ISIS, the beam line's oil contamination, lack of modern diagnostics, downtime and labour intense operation is a result.	Cyclotron facility coordinator	Exchange of the horizontal section of ISIS and a new injector and terminal in I2	4	3	HIGH	Adequate	Acceptable w/ Treatment	Treat	P481, replacement of the horizontal section, has reached Gate 2. P372 0 new I2 injector as well. Both projects are proceeding well.	Head of the Accelerator Physics Engineering group		4	3	HIGH	constant	P481 has reached Gate 3 and production of components will start. Completion fo the project will retire this risk.
ACC-R4	x							Operation of TRIUMF cyclotron and primary beam production	Given the ageing remote handling infrastructure of the cyclotron, in particular the electronics, failures will not allow for maintenance and break fixes.	Head remote handling	Repacement of electronics, controls and electromechanical systems.	3	3	MEDIUM	Adequate	Acceptable w/ Treatment	Treat	Refurbishment and modernization of the remote handling systems and components. Submitted a PRIS in progress as part of 25M$ package (O503/O504) - succession planning - training of new recruit in progress Update Jan 2023: Training completed, project plan	Head remote handling		2	3	MEDIUM	reduced	
ACC-R5	x		x					Operation of TRIUMF cyclotron and primary beam production	The Linde 1630 Compressor ages and in case of a failure it will suspend cyclotron operation	Cyclotron facility coordinator	A spare compressor need to be refurbished or have a back-up system in case of a failure	4	2	MEDIUM	Adequate	Acceptable w/ Treatment	Monitor	Now have a second compressor as back-up and original compressor has been refurbished.	Head Cryogenics Group		1	1	LOW	reduced	Retired in summer 2021
ACC-R6	x							Beam production and delivery	Inflector cannot be installed after service or does not provide the required performance	Department head ACC systems	Inflector test stand and redesign of the inflector area.	4	2	MEDIUM	Adequate	Acceptable w/ Treatment	Treat	Inflector test stand in construction, re-design of the inflector region by the new Beam Lines Engineering Physics Group. - in progress - will go out for machining on a inflector development magnet - then we will fabricate a vacuum chamber	Head of the Accelerator Physics Engineering group		4	2	MEDIUM	constant	

- The Accelerator Division Risk Registry summarizes potential risk for the operation of systems of the TRIUMF accelerator complex.
- The risk registry addresses the primary beam accelerators the 520 MeV cyclotron and the ARIEL e-linac and the according beam lines. It also refers to the RIB delivery systems, Target-Ion sources and the RIB preparation and acceleration facilities.
- It also comprises a list of issues (risks that have been materialized) and need to be addressed. One example is the mitigation of the shortage of LHe.

TRIUMF accelerator complex



Primary beam driver:

Cyclotron, 500 MeV, H^-

Produces rare isotopes, neutrons and muons!

Isotope Separator and Accelerator facility - ISAC

Isotope Separator Online (ISOL) facility

ISAC-I: Normal conducting-linac, 0.15-1.5 MeV/u

ISAC-II: Superconducting-linac, 5-15 MeV/u

Advanced Rare Isotope Laboratory - ARIEL

Superconducting electron linac

30 MeV, 10 mA, cw

4 Cyclotrons for medical isotope production

(with a TR24 to be commissioned in the Institute for advanced Medical Isotope – IAMI)

Medical Isotope Production Facilities

Applied Technology Group (ATG) incorporated in the Accelerator Division since 2018

- Applied Technology Group (ATG) works closely with BWXT. Prior relation to NORIDION for ~30 years.
- ATG provides irradiation services to BWXT
- 34 people: engineers, technicians, applied science staff
- 2 dedicated cyclotrons: TR30-1, TR30-2
- Plus STF (100MeV) and IPF (400+MeV), → beam from the 520MeV cyclotron

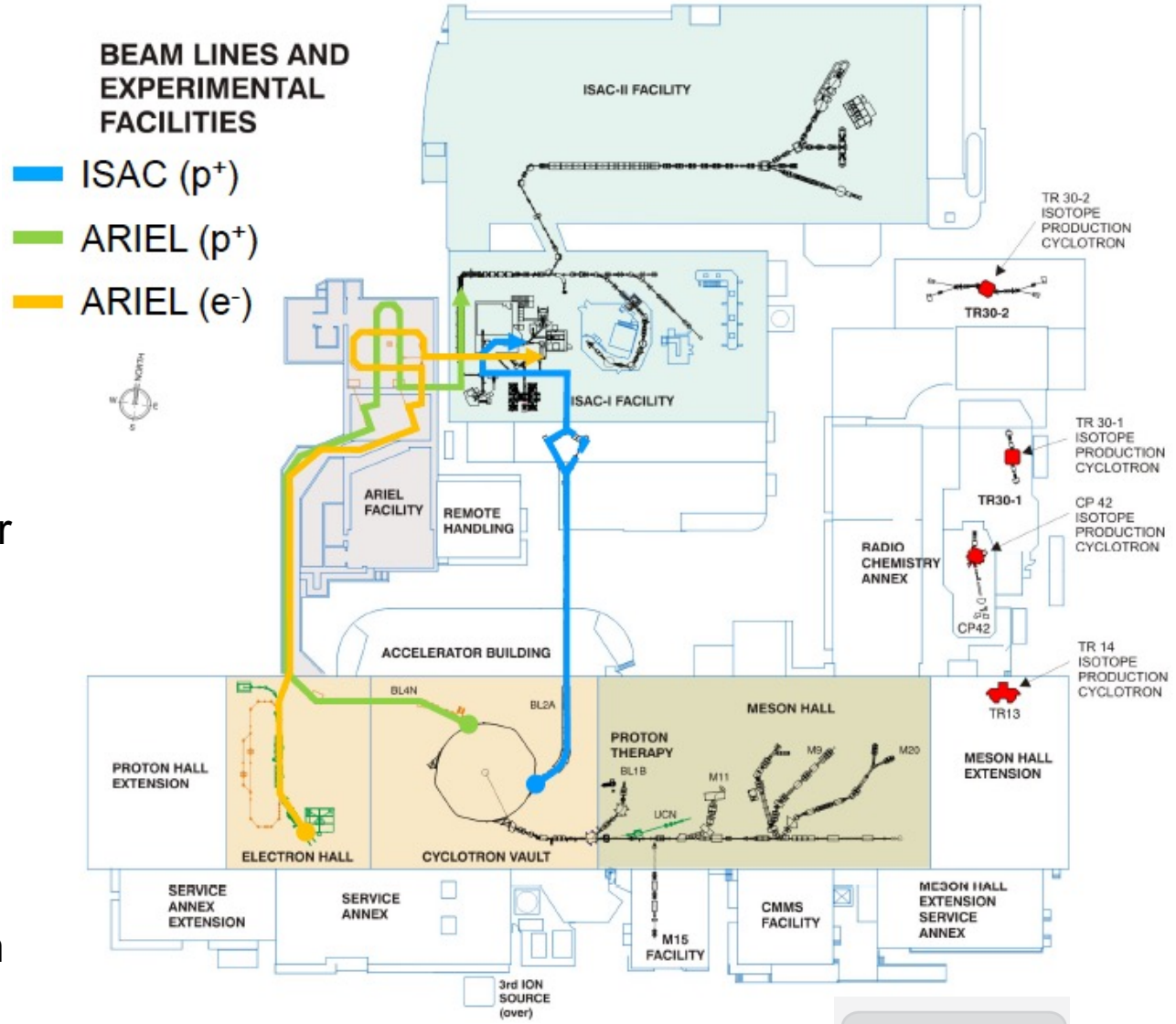
Accelerator Division together with Life Sciences:

Operates TR-13 and upcoming IAMI TR-24 cyclotron

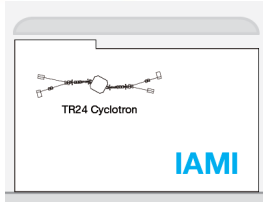
ARIEL - TRIUMF's flagship project

(see ARIEL sessions on Thursday)

- Simultaneous RIB production from 3 targets
  - 50 kW existing ISAC proton target
  - 50kW new ARIEL proton target
  - 100kW new ARIEL electron target
- **ARIEL will triple ISAC's present rare isotope capabilities.**
- Multi-user capability with more and new isotopes for
  - Nuclear Structure and Dynamics
  - Nuclear Astrophysics
  - Fundamental Symmetries
  - Materials Science
  - Life Sciences
- Unique beam preparation and transport system (CANadian Rare isotope facility with Electron Beam ion source - CANREB)
  - High resolution separator
  - Beam preparation with RFQ and EBIS

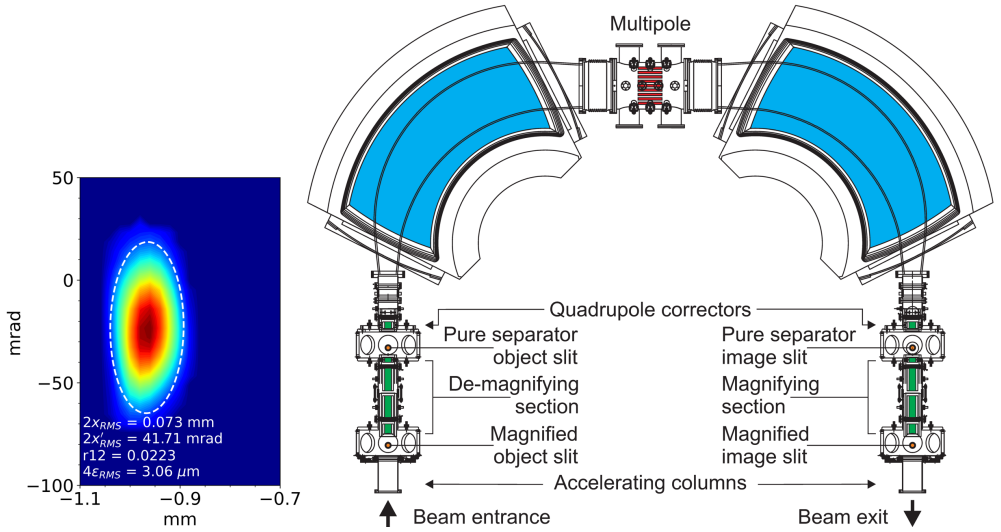


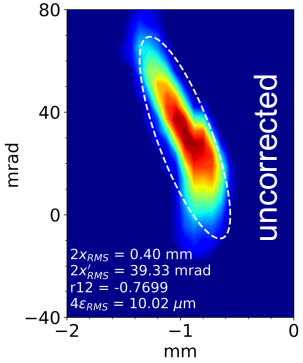
TRIUMF campus

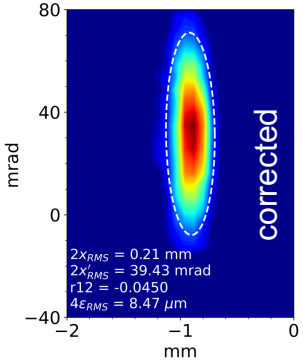


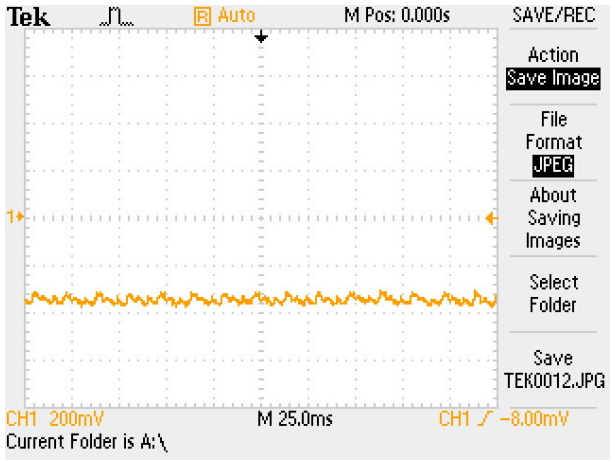
HRS development status

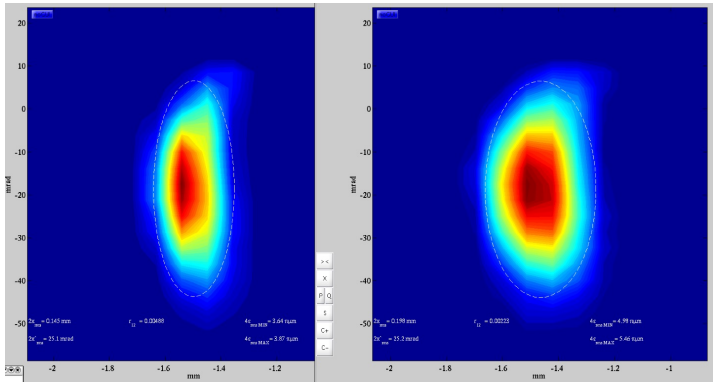
- Example of internal collaboration between Engineering Physics and Beam Physics groups
- Design parameters: 20,000 resolving power for 3 μm transmitted emittance
- Development runs with 10,000 and 16,000 resolving power tunes:
  - Multipole corrector can successfully correct for any aberration
  - Emittance growth due only to widening of transverse position (not angle) due to a 60 Hz beam energy jitter
- Recently, 60 Hz beam jitter successfully compensated for 10,000 resolving power tune

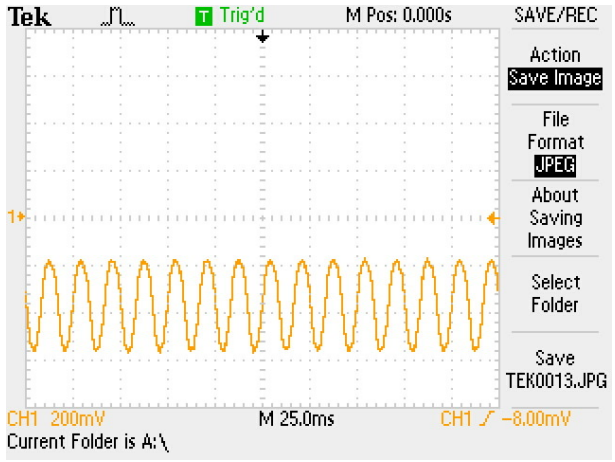






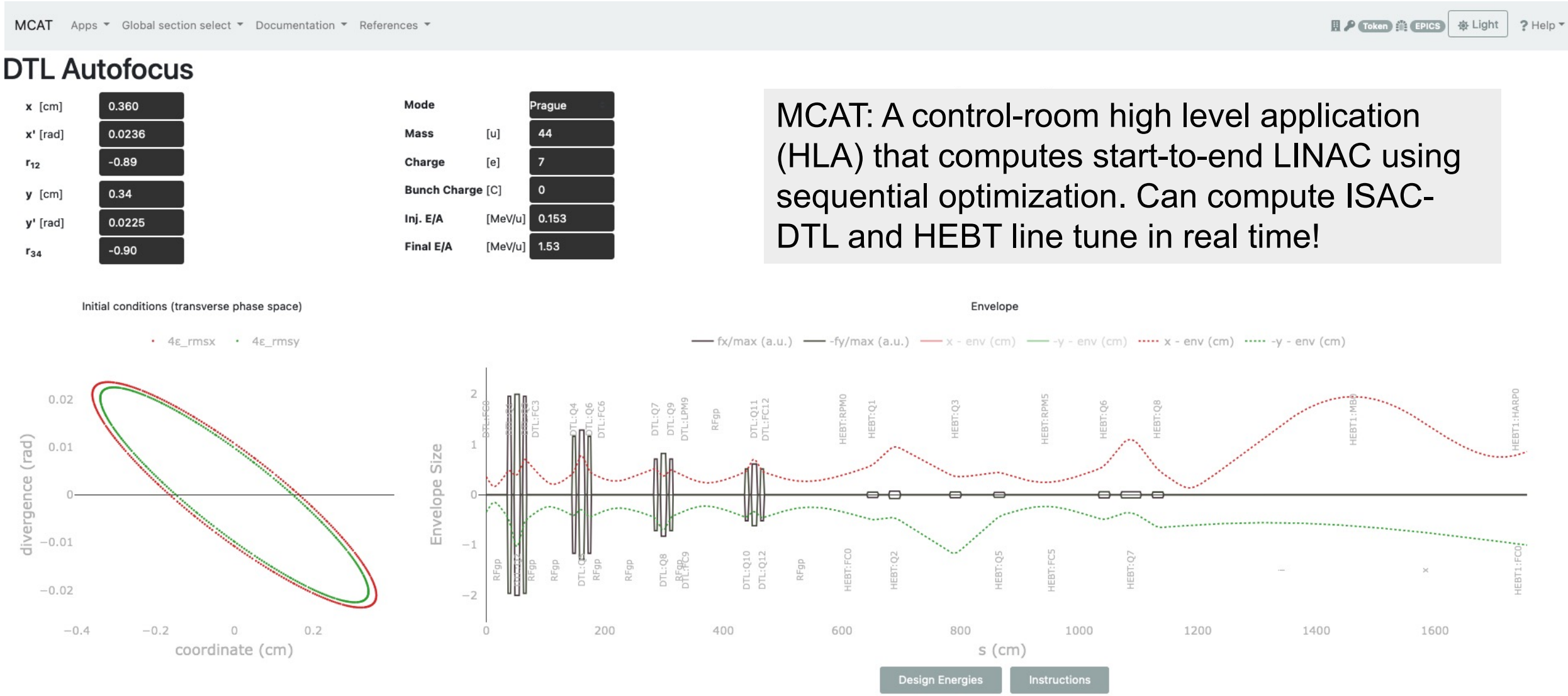






ISAC: Model Coupled Accelerator Tuning (MCAT) to Autofocus Beam

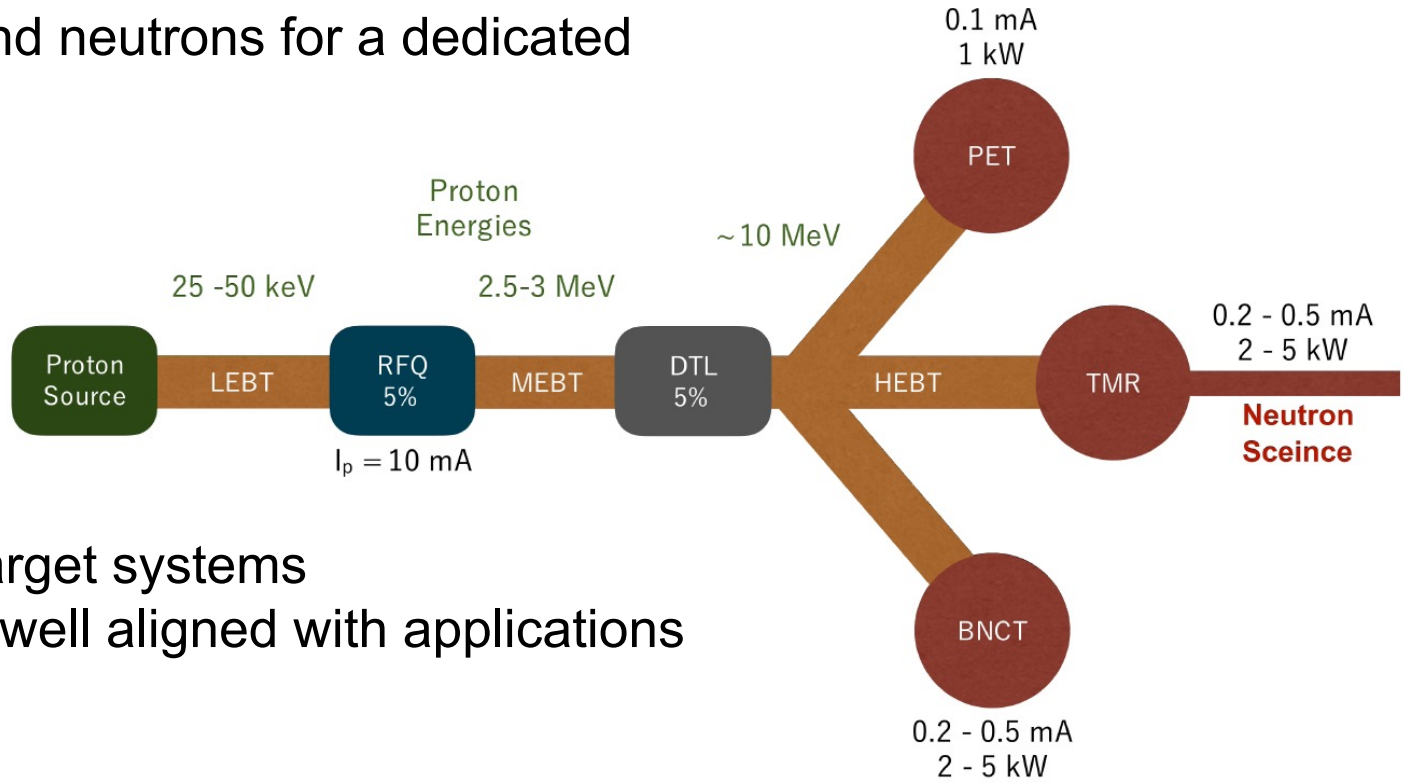
(PhD thesis of Olivier Shelbaya)



MCAT: A control-room high level application (HLA) that computes start-to-end LINAC using sequential optimization. Can compute ISAC-DTL and HEBT line tune in real time!

Example domestic: PC-CANS

- TRIUMF is collaborating with the University of Windsor and the Canadian neutron scattering community towards an accelerator-based neutron facility
- Collaboration has conceptualized a stageable prototype CANS facility, PC-CANS, based on linac technology.
- PC-CANS will allow competitive rates for neutron science, while simultaneously producing F18 for PET and neutrons for a dedicated BNCT research and development facility.
- The PC-CANS prototype will be the first CANS in Canada and the first for BNCT in North America.



- The project will augment and solidify TRIUMF core competence in linac and target systems and the proton accelerator technology is well aligned with applications

20-Year Vision

Five themes make up the foundation of the 20-Year Vision document. The Accelerator Division vision links to all themes:

1. **A global leader in discovery science, delivering breakthroughs that unlock the deepest mysteries of the universe:**
   Strengthening Canada's leadership in groundbreaking particle and nuclear physics

2. **A world-class accelerator centre driving use-inspired research – from the life sciences to quantum and green technologies:**
   Leveraging our unique infrastructure to pursue research in Canada that will change the world

3. **An inclusive multidisciplinary talent incubator, attracting and developing the best people from around the world:**
   Producing Canada's future science leaders and innovators

4. **A leader in a flourishing national Big Science ecosystem:**
   Catalyzing the success and growth of Canada's network of major research facilities

5. **A national innovation hub translating discovery science into health and sustainability solutions:**
   Responding nimbly to complex societal challenges for the benefit of Canadians

Our 20-year Vision for TRIUMF Accelerator Science and Facilities

Isotope Valley

With ISAC+ARIEL+IAMI we will greatly expend our capabilities, and establish TRIUMF as a leading global center for isotope research.

- Isotopes for physical science
- Isotopes for life science
- Isotopes to cure Canadians

Canadian Hub

We are Canada's centre of excellence in accelerator-related science and technology.

We centralize knowledge, and diffuse it through training, counsel, and collaborations.

With our always evolving expertise we remain a leader in Canada's transformation to a knowledge based economy.

Big Science — Big Tech

International collaborations are key to contribute to the most significant discoveries, attract talents, and maintain cutting-edge expertise.

We support international projects by leveraging our core knowledge and engaging Canadian industry.

We build on our strengths to serve science and invent life-changing technologies.

https://beamphys.triumf.ca/~tplanche/20-year-vision-acc.pdf