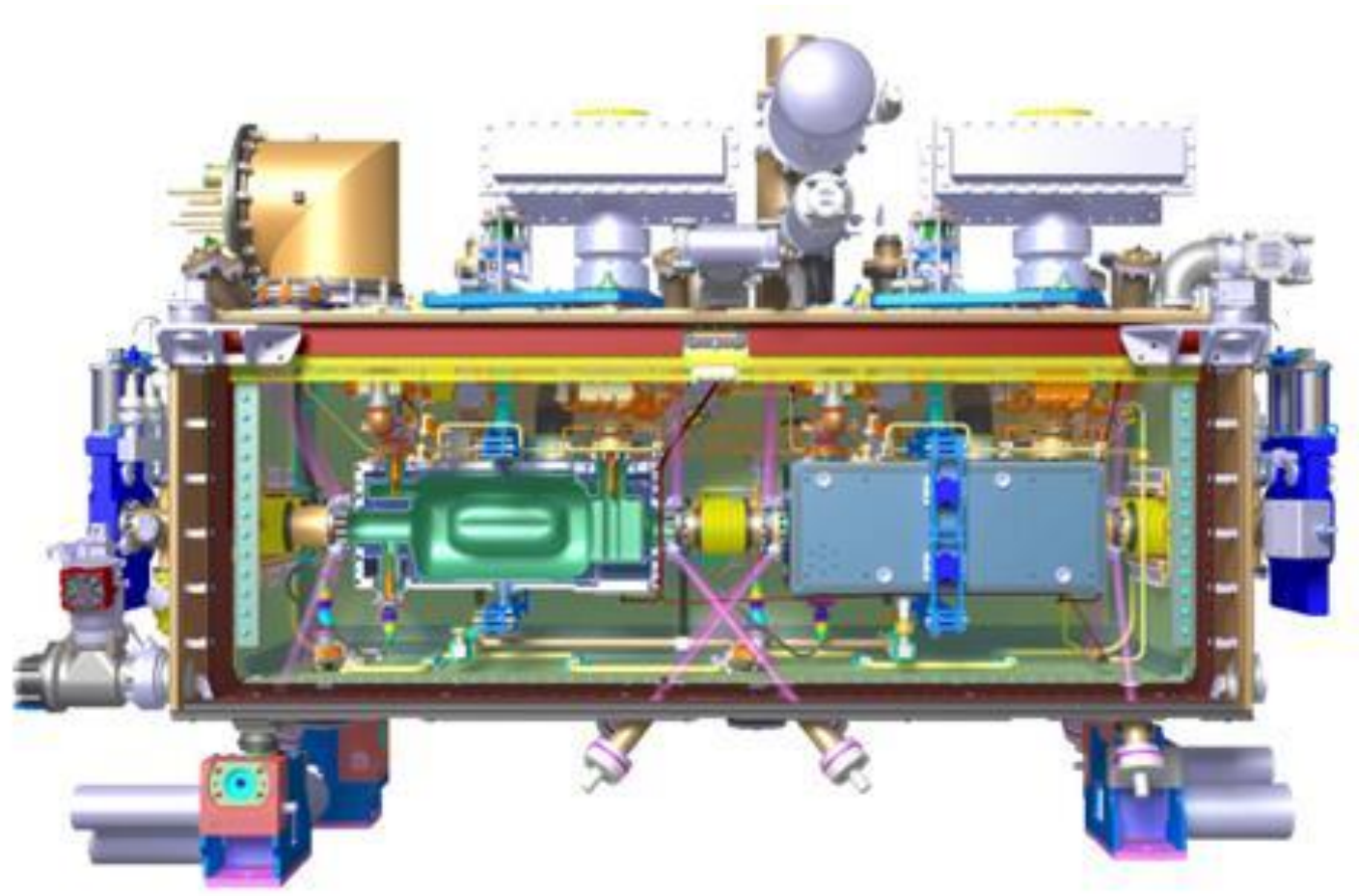


Canadian contribution (to the HL-LHC crab cavity cryomodules)

12th HL-LHC Collaboration Meeting

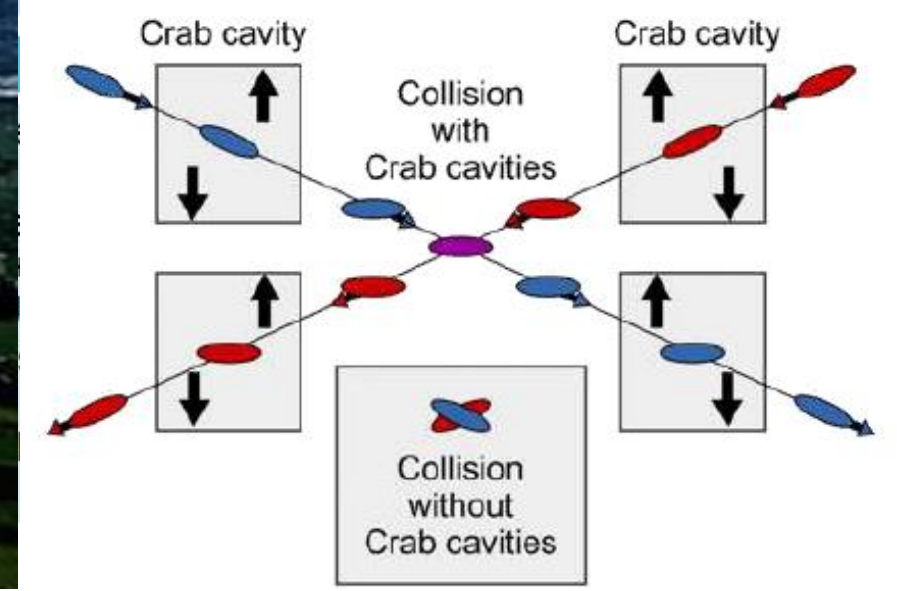
Oliver Kester
Director, Accelerator Division
TRIUMF



High Luminosity – Large Hadron Collider (LHC)

Crab Cavities – essential for the luminosity increase at ATLAS and CMS

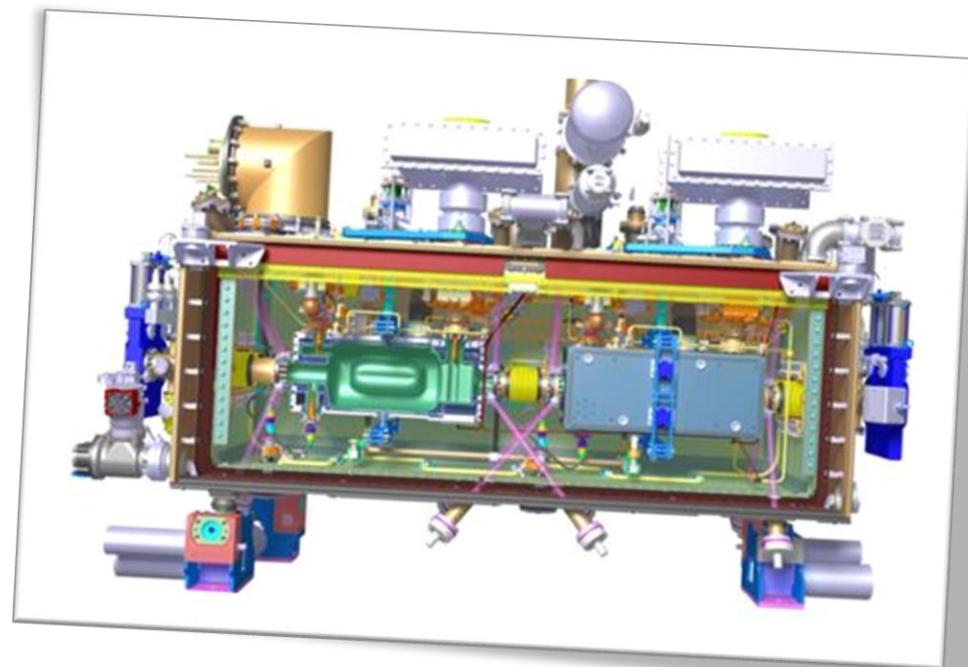
– collaboration with CERN, USA, UK, (Russia)



RF Dipole Cryomodule Project at TRIUMF

– General Scope

- TRIUMF to work with CERN and UK colleagues to develop RFD cryomodule design, assembly tooling and fixtures as well as assembly procedures.
- TRIUMF to receive dressed RFD resonators produced and qualified in AUP, to re-qualify, install the fundamental power coupler and to assemble each pair of RFDs into five hermetic strings
- TRIUMF to assemble hermetic strings into five cryomodules, which are built by industry in BC and assembled at TRIUMF
- TRIUMF to qualify the cryomodules through comprehensive testing (including RF tests) before packaging and shipping to CERN.
- TRIUMF to work with CERN and UK to establish a suitable shipping method to retain the high performance of the cryomodule.



June 25, 2018

“Great science knows no borders.” Minister Kirsty Duncan

Canadian Minister of Science and Sport - Kirsty Duncan - announces 10M CAD (7.5M CHF) support for TRIUMF to build 5 Hi-Lumi LHC RFD Crab Cavity Cryomodules.

Working with the Canadian research community and industry, TRIUMF will lead the production of the cryomodules with a 2M\$ (1.5MCHF) in-kind contribution of highly qualified staff for a total project value of 12M\$CAD (9MCHF).



RF Dipole Cryomodule Project at TRIUMF

– P455 project plan



Scope: Executes the TRIUMF scope of re-qualifying 10 RFD Cavities from AUP, package them into four cryomodules plus one spare, each containing two cavities and qualify the cryomodules and ship to CERN

Objectives (and interest of Canada):

- The project will advance Canadian core competencies in superconducting technologies.
- The project will draw Canadian industry into a world-class cutting-edge project, building expertise in superconducting technologies, and laying the foundation for future endeavours.
- The project will supply critical infrastructure to CERN, supporting both the HL-LHC and the Canadian IPP community.
- Beyond strengthening the TRIUMF capability in cryomodule manufacture the project also provides opportunities to students and young researchers enriching knowledge and experience in SRF cavity and cryomodule assembly, and cryogenic and RF systems commissioning.

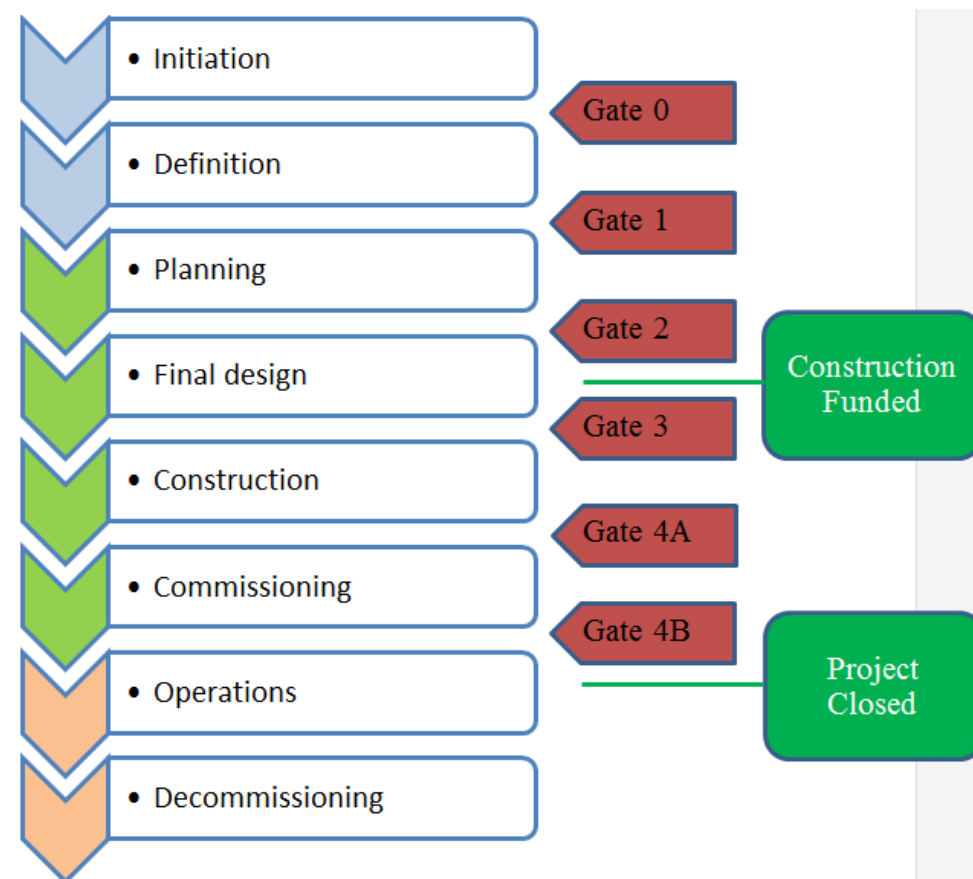
Roles: TRIUMF Project Sponsor – Oliver Kester
TRIUMF Project Leader – Bob Laxdal
Project Engineer – Matt Ishida
Designer – Ben Matheson
Technical support – SRF group and other service groups as required (Cryogenics, Vacuum, electrical/mechanical services, machine shop)

TRIUMF RFD crab cavity cryomodules

- The project has now completed Gate 3A within TRIUMF project planning
- Gate 3A enabled us to launch procurements to support cavity testing, infrastructure upgrades and for a prototype cryomodule (CM), TCM0
- Drawings for production are available, completion of TCM0 will depend on the cavity availability.

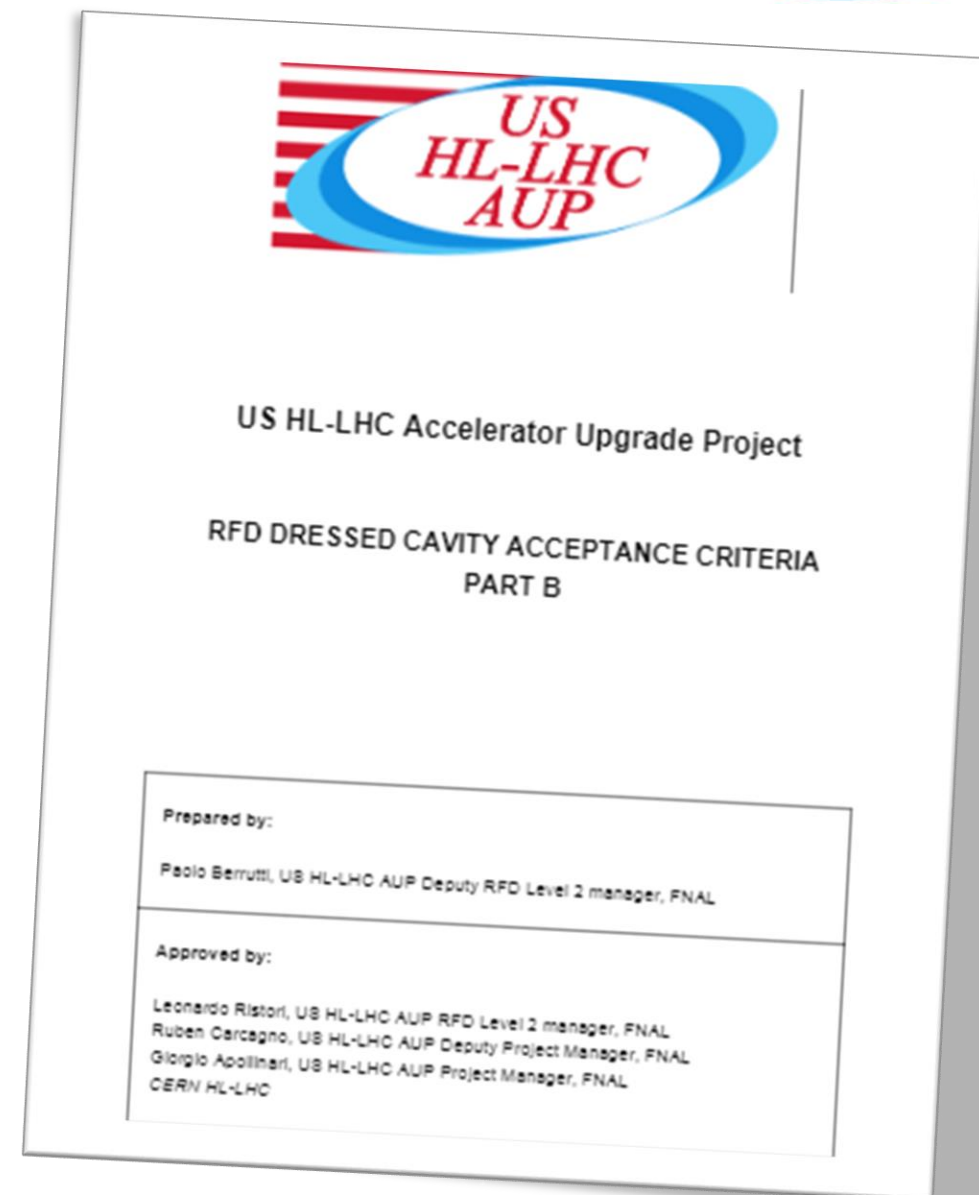
Project Milestone	Proposed date	Hi-Lumi input
✓ Gate 1	Dec 2019	Conceptual design review, preliminary scope def'n
✓ Gate 2	Aug. 2020	Final scope def'n, detailed budget
✓ Gate 3A TCM0	May 2021	TCM0 design review, released drawings and specifications
Tech review	Dec 2022	Launch long lead procurements
Gate 3B TCM1-4	Feb 2023	Final design review, released drawings and specifications

Delayed by 1 year



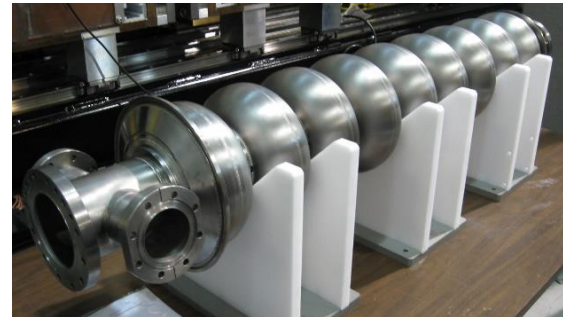
Cavity Re-qualification at TRIUMF

- CERN acceptance of AUP cavities will happen at TRIUMF
- Acceptance criteria are established in a document from AUP in consultation with TRIUMF
- We will receive qualified cavities under vacuum and with test coupler and vacuum diagnostic on board – a traveler form will be delivered with each cavity
- The acceptance document itemizes a series of warm and cold measurements to confirm that the cavity has not been degraded during transport and is acceptable to be installed in the CM.
- The tests will be done with TRIUMF and AUP staff.
- TRIUMF has diagnostic equipment and a multi-purpose test cryostat is compatible with the listed tests.
- Each test will take about a week with technical support from TRIUMF SRF and cryogenics group.



TRIUMF SRF Infrastructure (I)

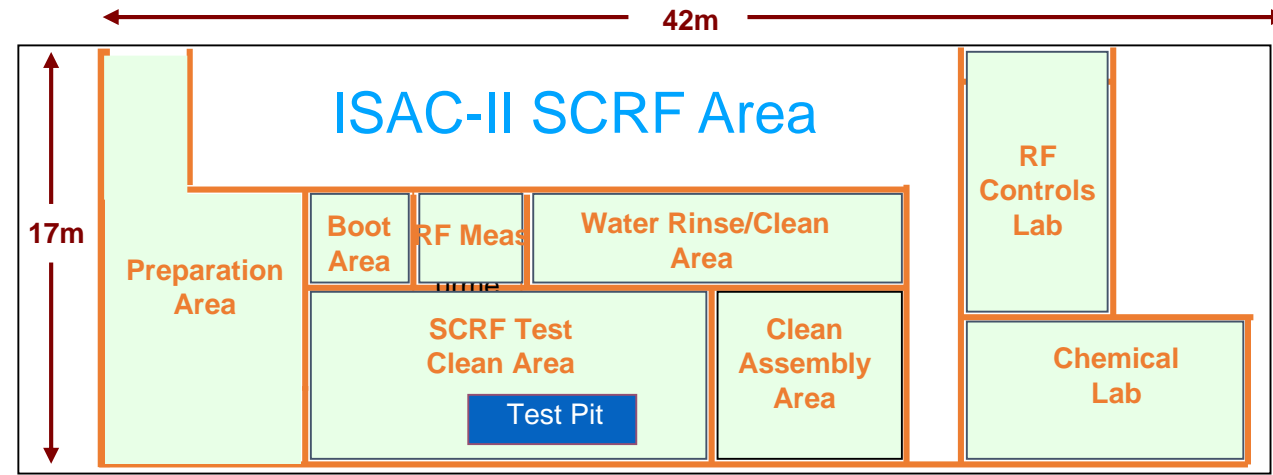
- TRIUMF hosts two SRF linacs (ISAC-II heavy ion linac and the ARIEL electron linac) and SRF supporting infrastructure.
- Activities range from student R&D on test resonators to work for others (prototyping cavities and components) and to full cryomodule assemblies
- For student training and R&D we have added
 - UHV RF induction oven
 - Coaxial test resonators for fundamental studies
 - New high parallel field spectrometer for beta-NMR



TRIUMF SRF Infrastructure (II)

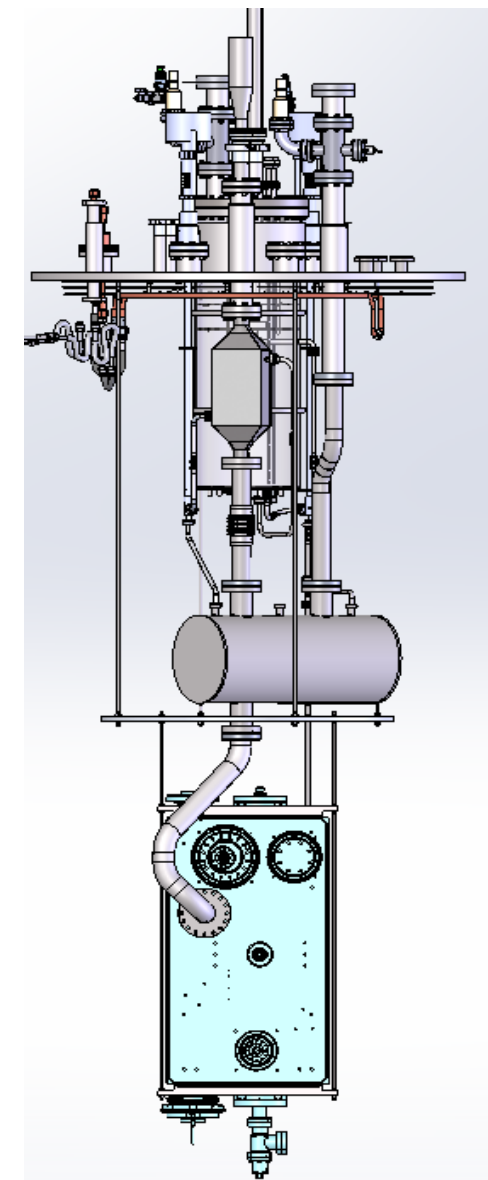
TRIUMF SRF test and assembly areas

- 500m² of floor space, overhead crane
- US cleaning tanks, HPWR area, cryogenics on tap, cryomodule assembly area (clean room for hermetic string assembly and larger CM assembly space in adjacent hall), chemical etching lab (BCP), rf testing
- Minor upgrades of clean room required plus rf amplifier from CERN
- Cryomodule test capability in ISAC-II
 - LHe – 100ltr/h in falling level, 200W at 4K, 40W at 2K
 - LN2 at 1.5 Bar
 - Shielded pit, LLRF, controls

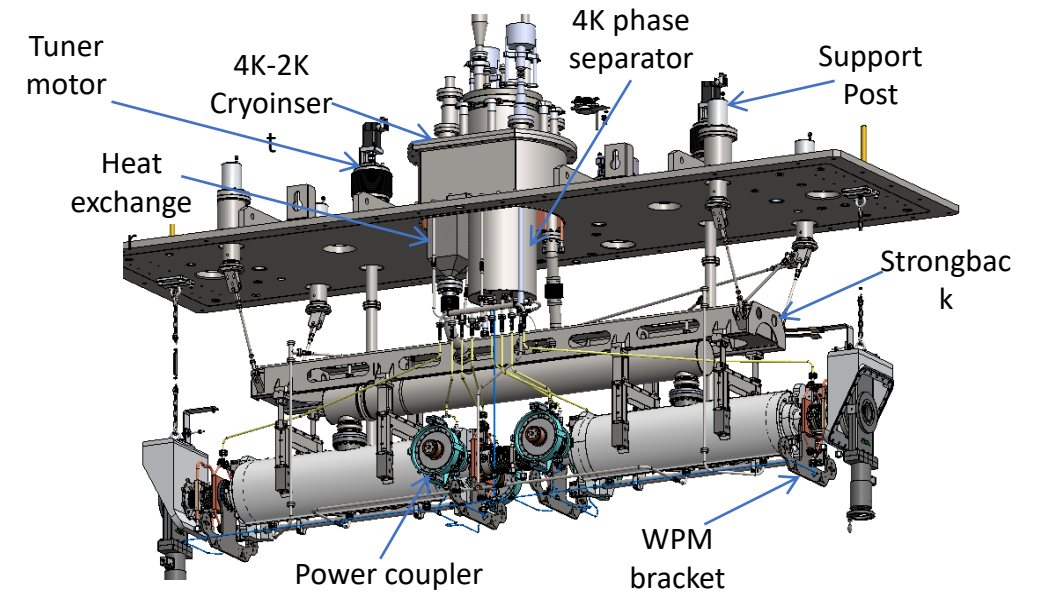
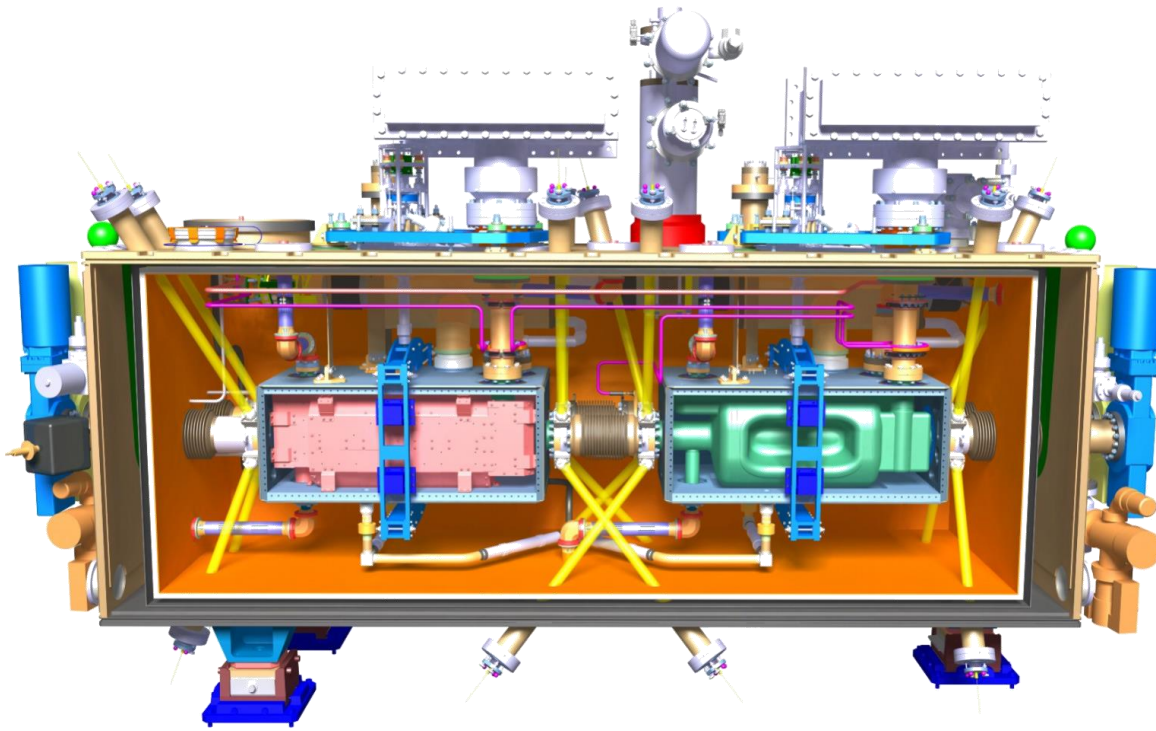


TRIUMF status - SRF infrastructure upgrade to be compatible with Hi-Lumi scope

- Clean room upgrades to reduce chance of particulate pollution completed.
 - Dedicated vacuum equipment and upgraded particulate monitoring and gowning.
- Testing infrastructure prepared to qualify AUP dressed cavities at 2K in jacketed mode:
 - Completed 4K/2K insert for multi-purpose cryostat to allow testing dressed cavities at 2K in jacketed mode.
 - Upgraded cavity test diagnostics and 2K pumping capacity.
- Cryomodule assembly tooling and fixtures in progress.



Hi-Lumi CM vs ARIEL CM



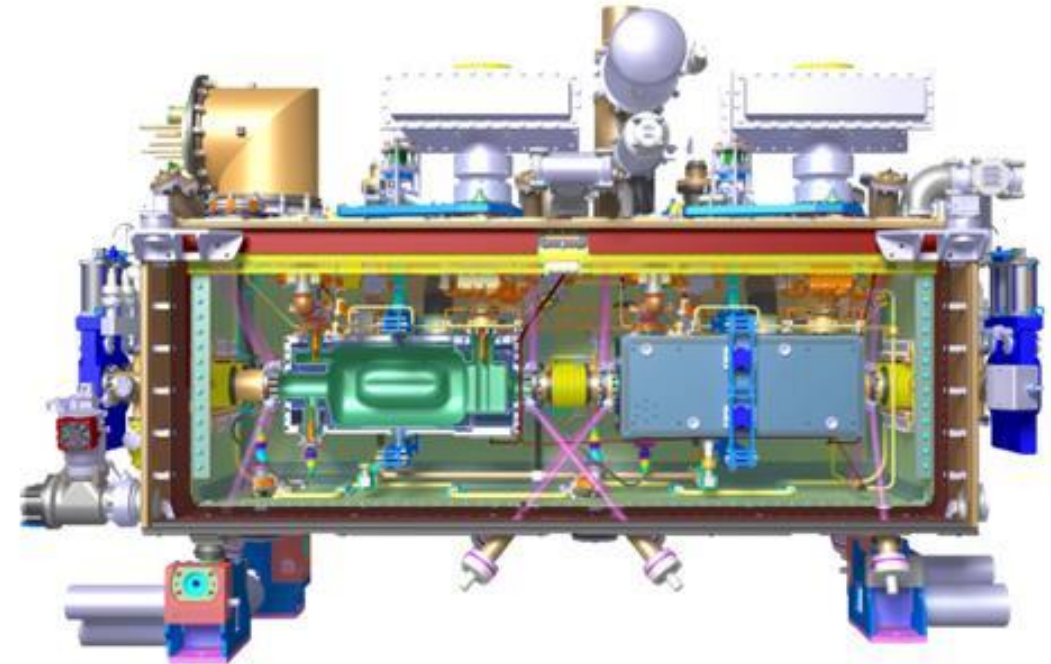
The Hi-Lumi cryomodule design borrows from the ARIEL e-Linac module developed and fabricated at TRIUMF. The TRIUMF team is familiar with this type of CM. Details are discussed with our UK partners and CERN.



ARIEL Cryomodule

Cryomodule Qualification/Commissioning at TRIUMF

- Hardware checks
 - Check the operation of diagnostics at room temperature
 - Leak check and pressure test – all volumes
 - Measure warm rf frequency, alignment
- Qualify at 77K
 - Cooldown to 77K
 - leak check, alignment check
 - Check rf frequency
- Qualify at 4K
 - Cooldown cold mass to 4K
 - Check alignment
 - Check rf frequency
 - Check operation of tuner
 - Power each cavity independently to check gradient and Q
 - Check static load to 4K based on falling level



The testing will be done in the SRF test area. A CM test is expected to take 4 weeks with 1 week of preparation, 2 weeks of testing and 1 week of warm-up and removal.

The amplifier will be supplied by CERN

Cavity Delivery from AUP

- RFD cryomodule production is obviously a relay race – any delays in delivery of dressed cavities from AUP will impact final delivery.
- The Preparation work in the form of the prototype module (TCM0) to be built first will mitigate further schedule risk.



TCM0 timeline

Latest schedule has one TCM0 cavity delivered in Spring 2023 with second possibly in fall 2023 – we are making plans to assemble TCM0 with only one real cavity and one dummy cavity.

Cavity Pair	Module	Initial early delivery	Latest projection
Pre-series Cavity	TCM0	Dec 2021	Spring 2023?
Series 1 and 2	TCM1	June 2022	Feb 2024
Series 3 and 4	TCM2	Sep 2022	Aug 2024
Series 5 and 6	TCM3	Nov 2022	Sep 2024
Series 7 and 8	TCM4	Jan 2023	Nov 2024
Series 9 and 10	TCM5	Mar 2023	Jan 2025

Summary

- Crab cavity cryomodule project passed Gate 3A that allows the TCM0 construction.
- We have the full capability to qualify the AUP dressed cavities at 2K in jacketed mode – test with dummy load in October.
- Schedule for TCM0 and the cryomodule series has been updated with latest dates from AUP
 - TCM0 cavities – Spring 2023
 - delivery of 5th batch of series cavities in early 2025
- For more details, please join the talk of Bob Laxdal, Wednesday morning in the WP4 session.



Thank you
Mercy

www.triumf.ca

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