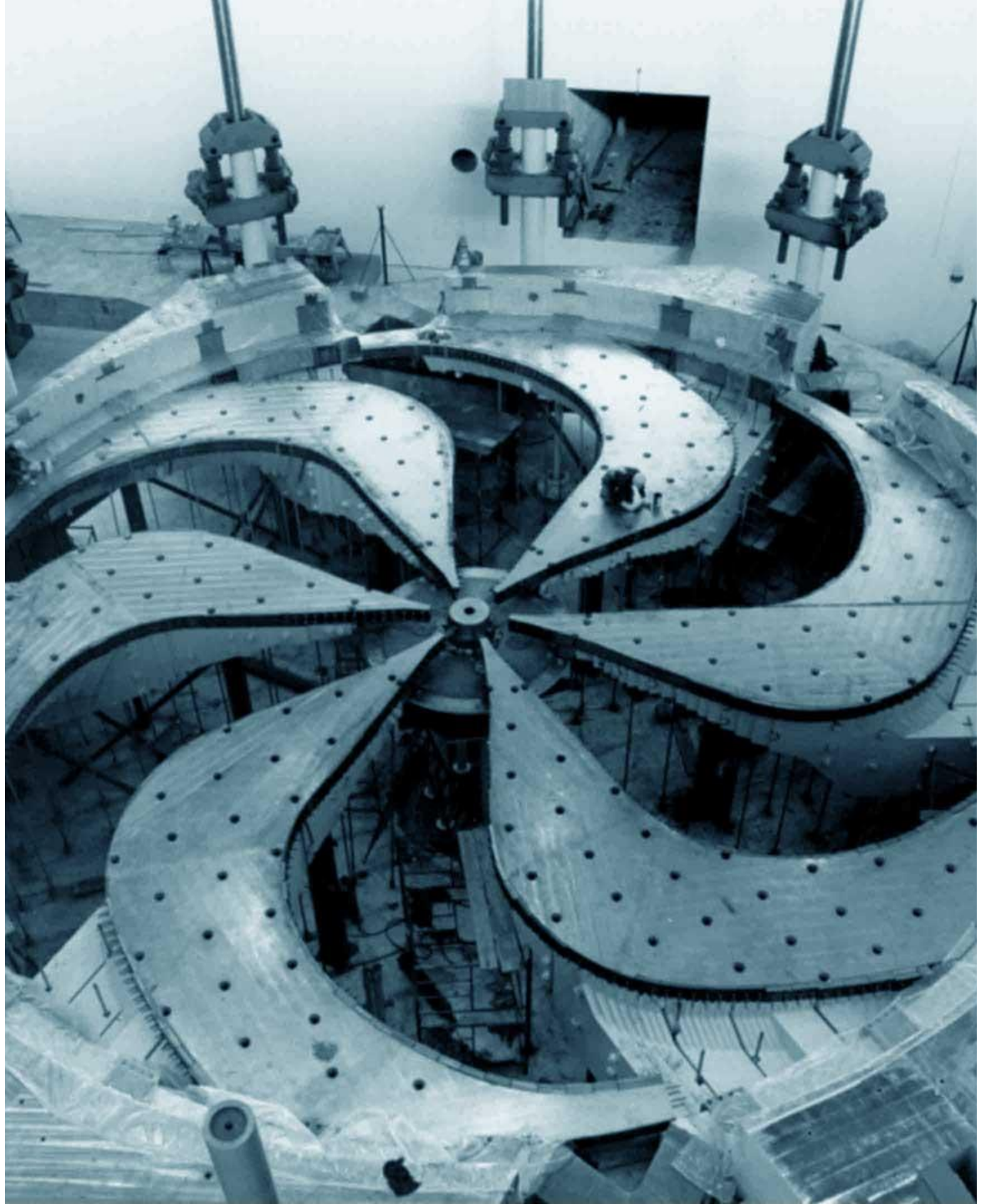
Status of Canadian Contribution to WP4

Bob Laxdal

TRIUMF Hi-Lumi Technical Coordinator

Sept. 25, 2023



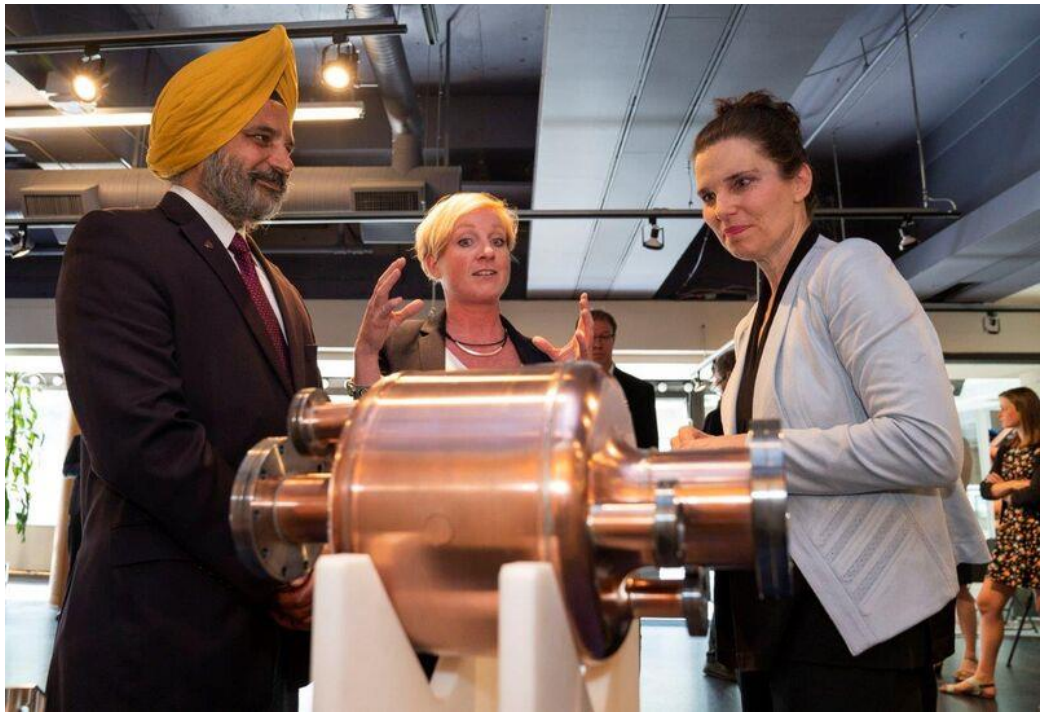
TRIUMF is Canada's particle accelerator centre


TRIUMF

June 25, 2018
“Great science knows no borders.” Minister Kirsty Duncan

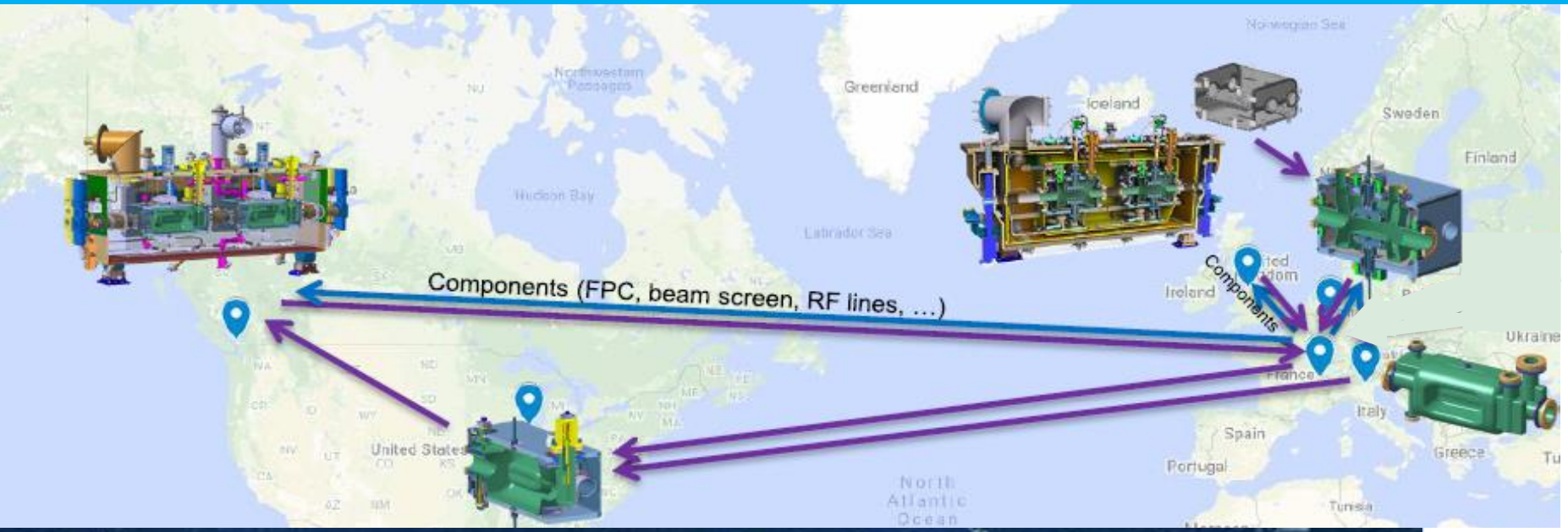
Canadian Minister of Science and Sport Kirsty Duncan announces 10M$ support for TRIUMF to build 5 Hi Lumi LHC RFD Crab Cavity Cryomodules

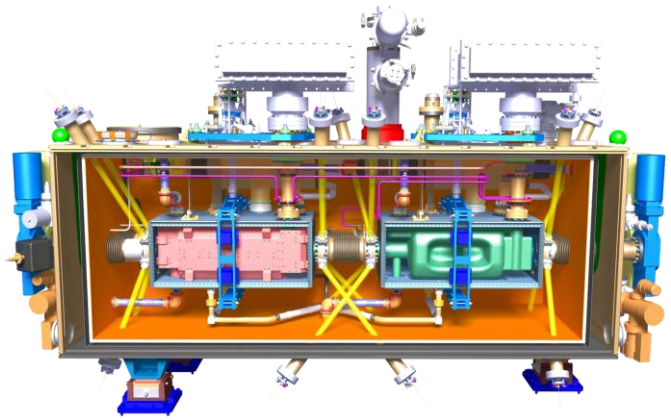
Working with the Canadian research community and industry, TRIUMF will lead the production of the cryomodules with a $2 million in-kind contribution for a total project value of $12 million.

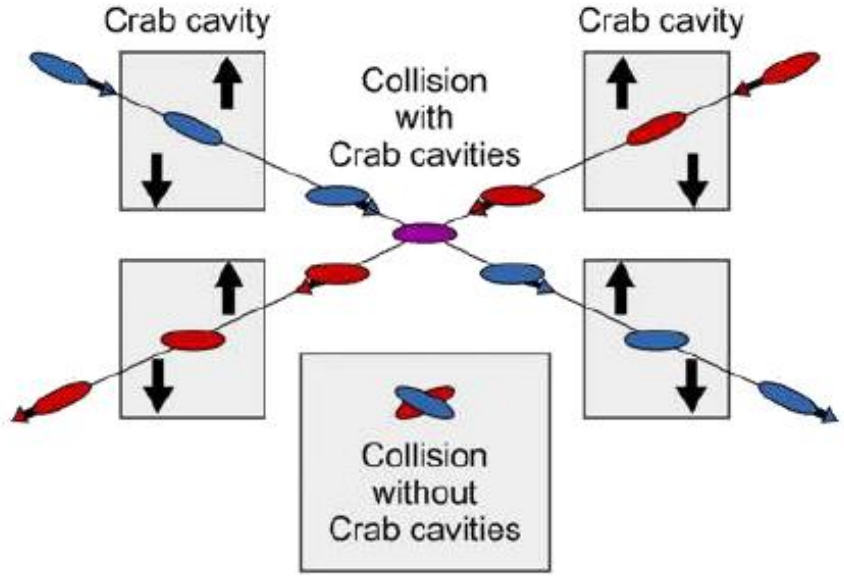


Scope and constraints

High Luminosity Canada – part of global collaboration (CERN, USA, UK) that will deliver Crab Cavity modules – essential for the luminosity increase at ATLAS and CMS



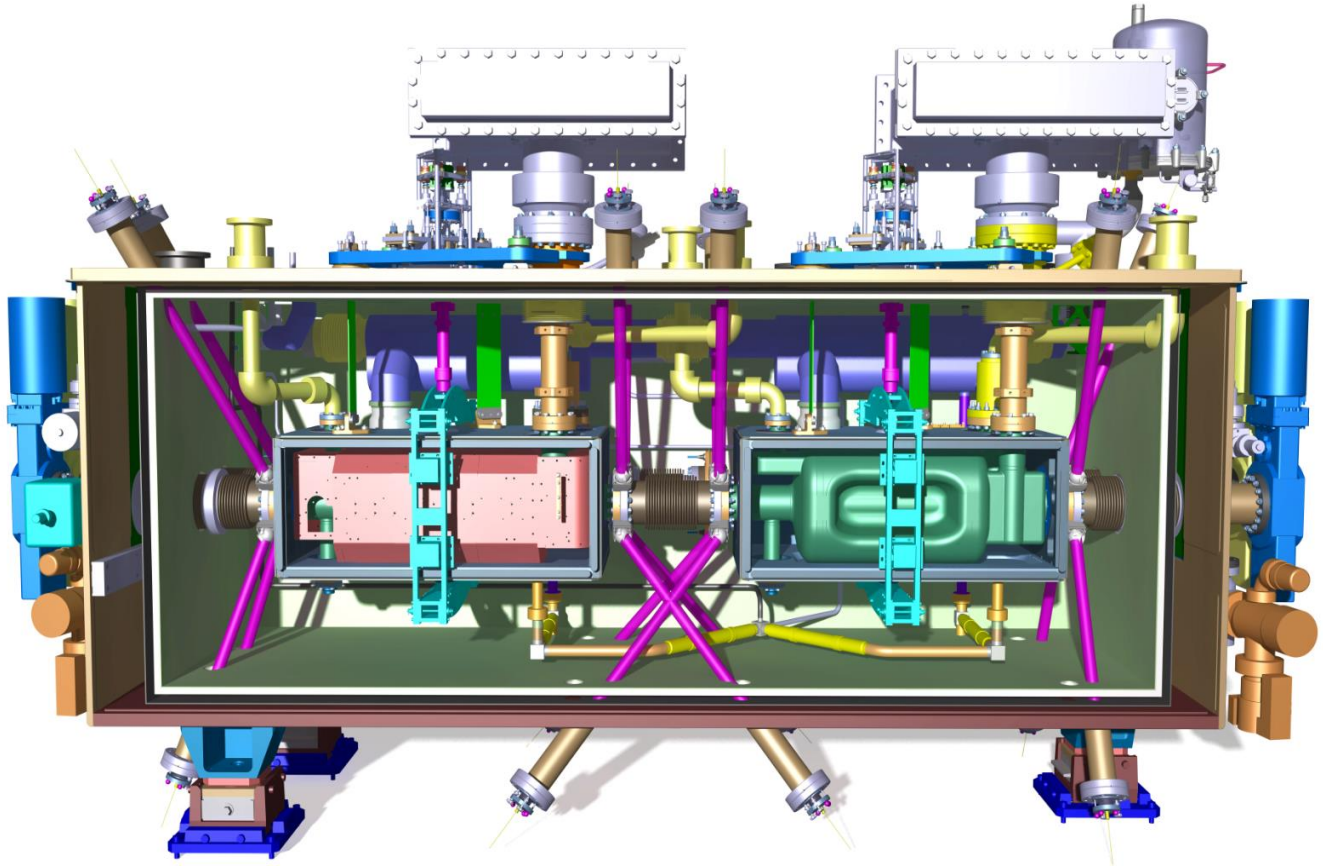




Scope of Canadian Contribution

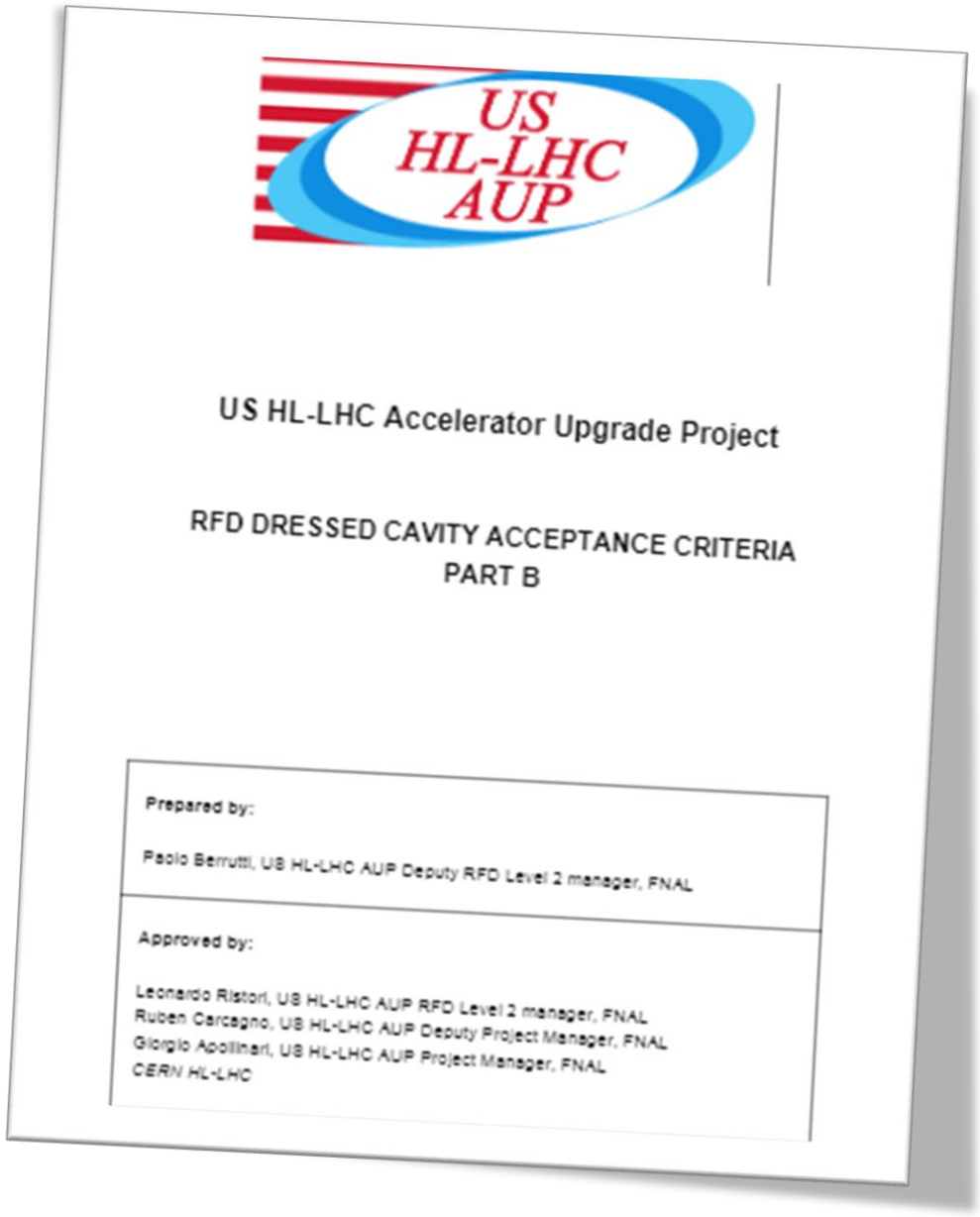
Scope:

- TRIUMF to work with CERN and UK colleagues to develop RFD cryomodule design, assembly tooling and fixtures, assembly procedures
- TRIUMF to receive 10 dressed RFD resonators from US-AUP, to re-qualify the cavities, to install the fundamental power coupler and to assemble each pair of RFDs into five hermetic strings
- TRIUMF to assemble hermetic strings into five crymodules
- TRIUMF to qualify the cryomodules through testing at TRIUMF before packaging and shipping to CERN



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
- 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.
- A cavity test is expected to take 10 days


US HL-LHC AUP

US HL-LHC Accelerator Upgrade Project

RFD DRESSED CAVITY ACCEPTANCE CRITERIA
PART B

Prepared by:

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Approved by:

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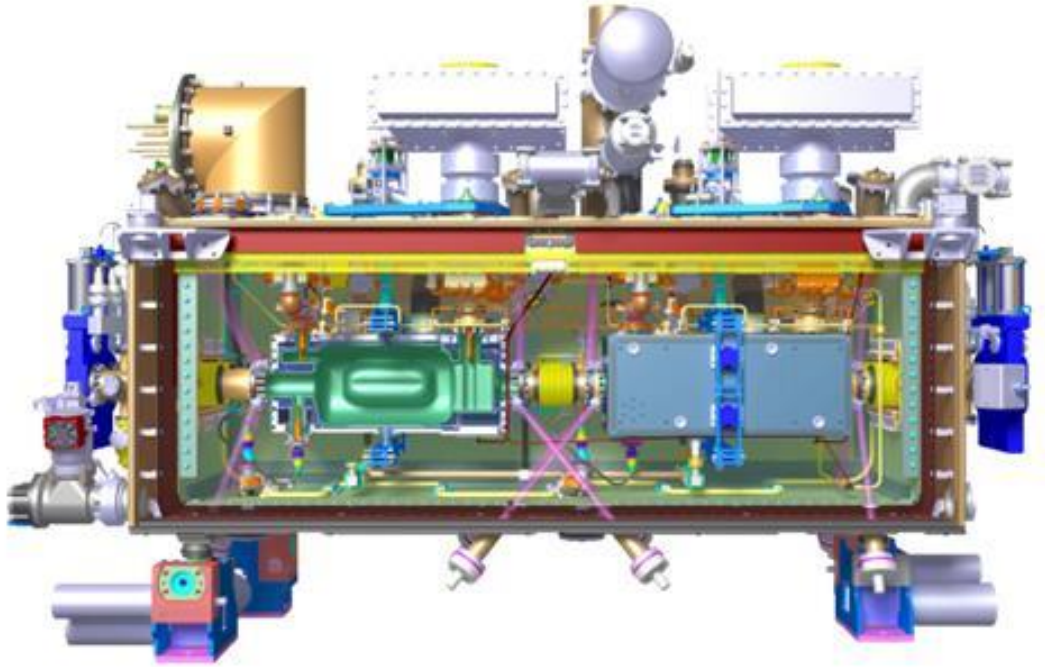
Ruben Carcagno, US HL-LHC AUP Deputy Project Manager, FNAL
Giorgio Apollinari, US HL-LHC AUP Project Manager, FNAL
CERN HL-LHC

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 expect 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

Project Strategy

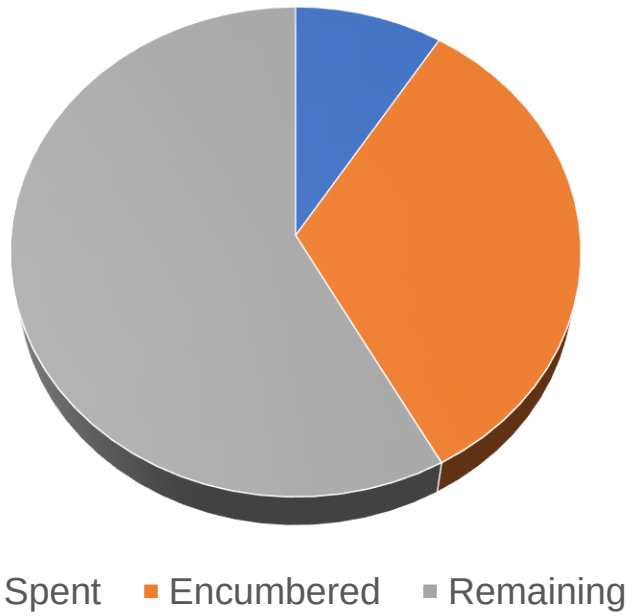
- The project strategy calls for procurement of parts for a single cryomodule, TCM0, followed by procurement of parts for the production series TCM1-4
- Gate 3A enabled us to launch procurements to support cavity testing, infrastructure upgrades and for parts to prepare prototype cryomodule (CM) as drawing readiness allows
- Project slippages due to Covid and other forces vs. boundary conditions on project funds are having an impact on this strategy
  - Shifting timelines for
    - TCM0 cavities from AUP
    - Released drawings and parts from CERN
  - Fixed timeline for spending the funds

Project Milestone	Date	Inputs
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

Funding and priorities

- Due to the nature of the funding agreement ALL funds for the project must be spent before April 2025
- Project slippage means that now spending is a major risk to the Canadian contribution and strategies are being modified
- TRIUMF has presently spent or committed 42% of the funds - TRIUMF will have to spend the remaining 58% in the next 18 months
- Risk mitigation requires
  - Ordering production quantities as soon as possible (In addition to TCM0 procurements)
  - Timely release of drawing packages for long lead items of series
  - Prioritization for higher cost items
  - Timely arrival of items where CERN is doing a group purchase for UK and Canada so cheques can be written

Year	Spent	Encumbrance	Total	Available
21-22	$338,027	$0	$338,027	$9,661,973
22-23	$202,100	$0	$202,100	$9,459,873
23-24	$356,297	$3,304,595	$3,660,892	$5,798,981
Total	**$896,424**	**$3,304,595**	**$4,201,019**	**$5,798,981**



Progress Milestones

Milestone	Application	Achieved
4k-2k Cryo insert qualified	Infrastructure	Nov 2022
OVC Drawings released	TCM0	Apr 2023
OVC tender released	TCM0	May 2023
OVC material order issued	TCM1-5	Jun 2023
Clean room tender released	Infrastructure	Jun 2023
Sector Valves received	TCM0	Jul 2023
OVC order issued (Axton)	TCM0	Jul 2023
Mu-metal tender released	TCM1-5	Jul 2023
Clean room contract issued	Infrastructure	Sep 2023
Mu-metal contract issued	TCM1-5	Sep 2023
MLI tender issued	TCM1-5	-

Infrastructure preparations

Progress Milestones - Infrastructure

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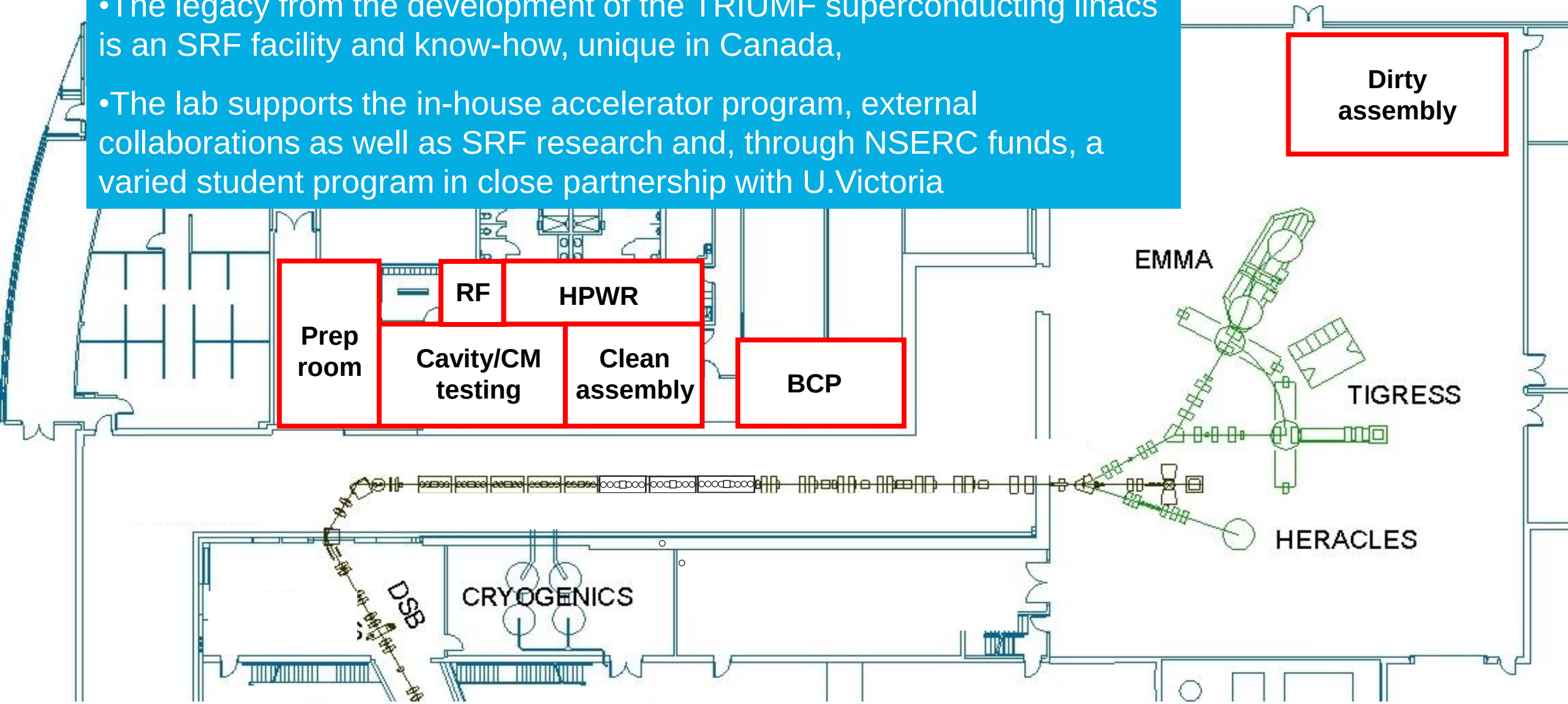
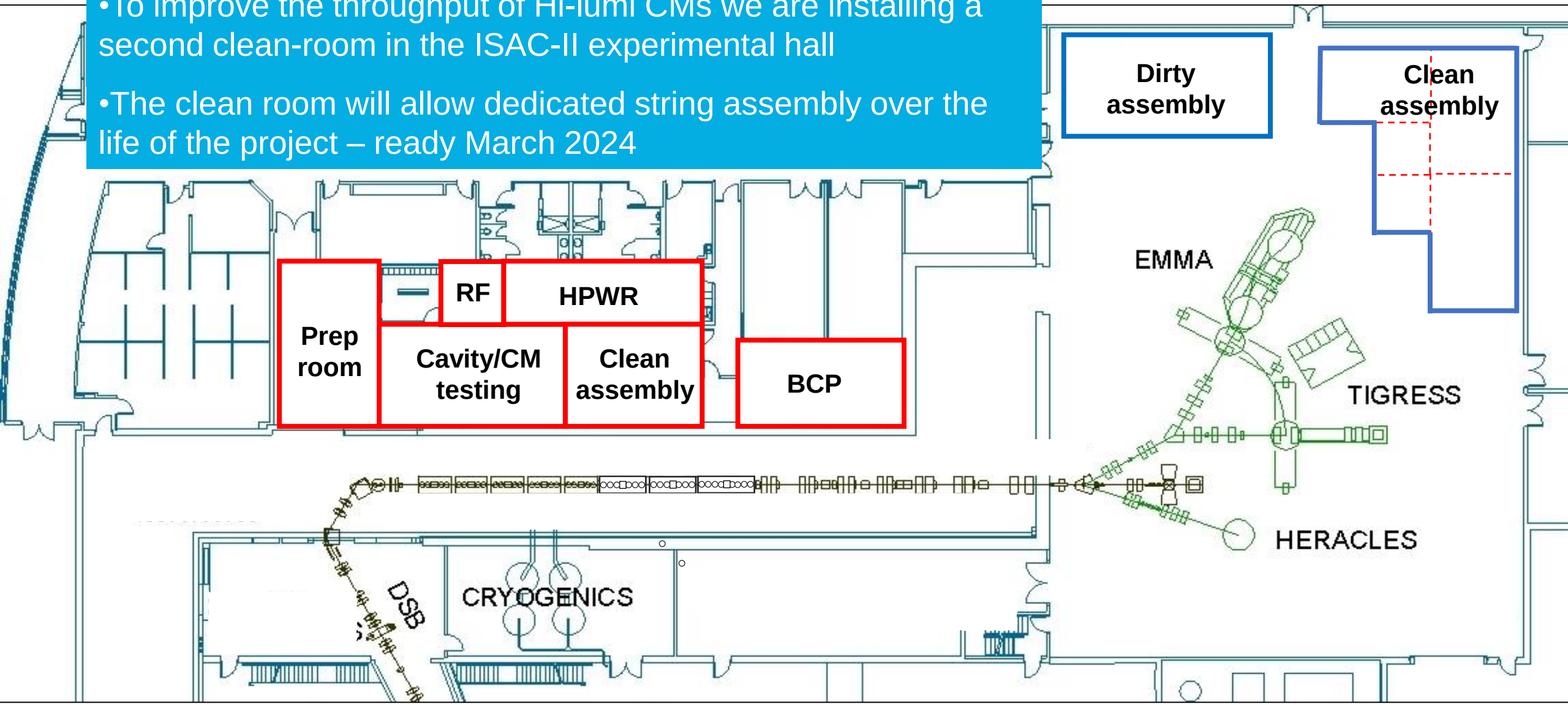
TRIUMF SRF Facilities

- The legacy from the development of the TRIUMF superconducting linacs is an SRF facility and know-how, unique in Canada,
- The lab supports the in-house accelerator program, external collaborations as well as SRF research and, through NSERC funds, a varied student program in close partnership with U.Victoria

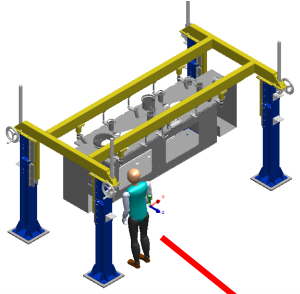


TRIUMF SRF Facilities – Hi-Lumi Upgrade

- To improve the throughput of Hi-lumi CMs we are installing a second clean-room in the ISAC-II experimental hall
- The clean room will allow dedicated string assembly over the life of the project – ready March 2024



TRIUMF SRF Facilities



New Hi-Lumi Area

Dirty assembly

Clean assembly

Prep room

RF

HPWR

Cavity/CM testing

Clean assembly

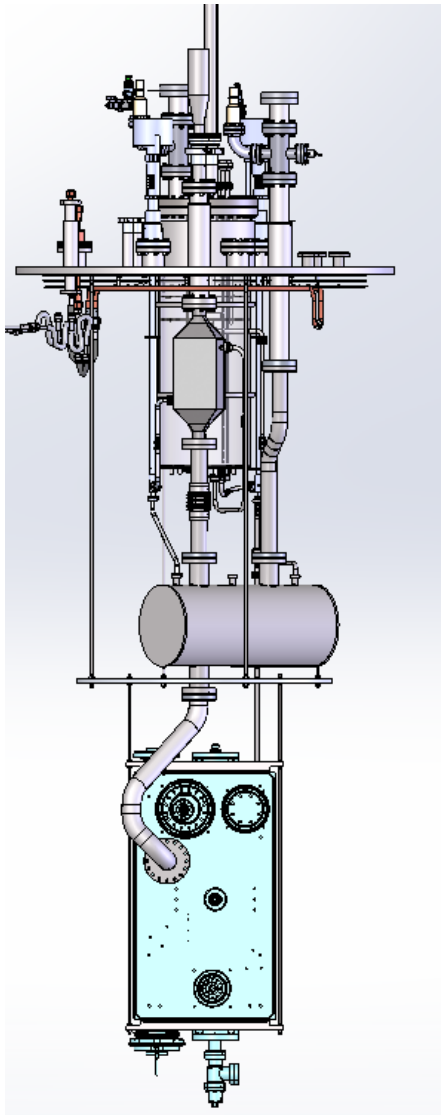
BCP

DSB

CRYOGENICS

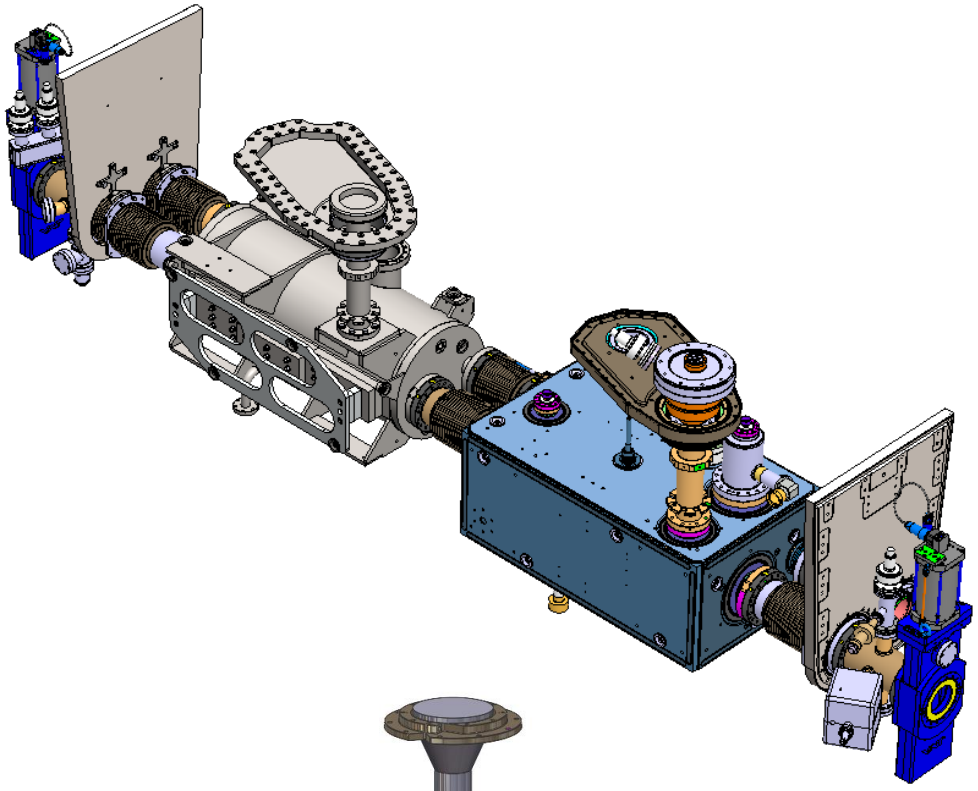
Preparation for cavity testing

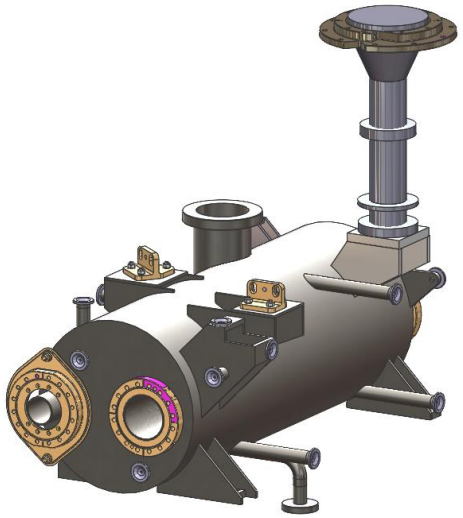
- TRIUMF will requalify the AUP cavities upon delivery from JLab
- TRIUMF has upgraded the cavity test facility in preparation for cavity delivery
  - Prepared and qualified cryo-insert for multi-purpose cryostat to test dressed cavities at 2K in jacketed mode
  - Upgraded cavity test diagnostics
  - Upgraded 2K pumping capacity
- **Ready for jacketed 2K testing of AUP cavities**



Dummy cavity for TCM0

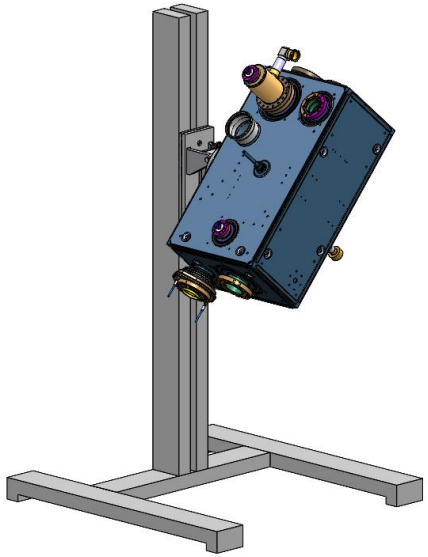
- AUP anticipates only one TCM0 cavity in Spring 2024
- TRIUMF is fabricating a Dummy cavity
  - Identical LHe volume and mass as the actual cavity
  - Identical beam and helium interfaces as the RFD cavity
  - Identical support interfaces
- Will be used for testing prior to cavity delivery and during assembly of TCM0 cavity string

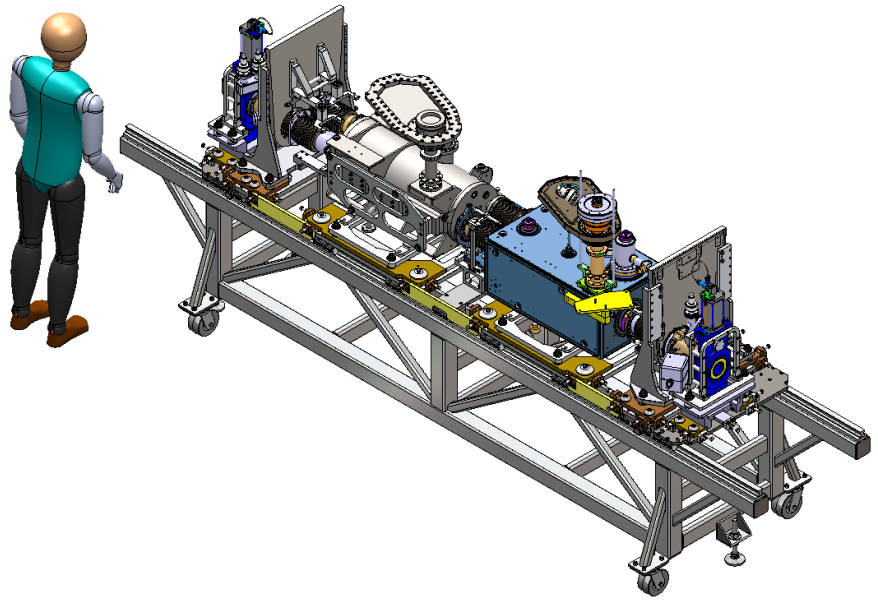


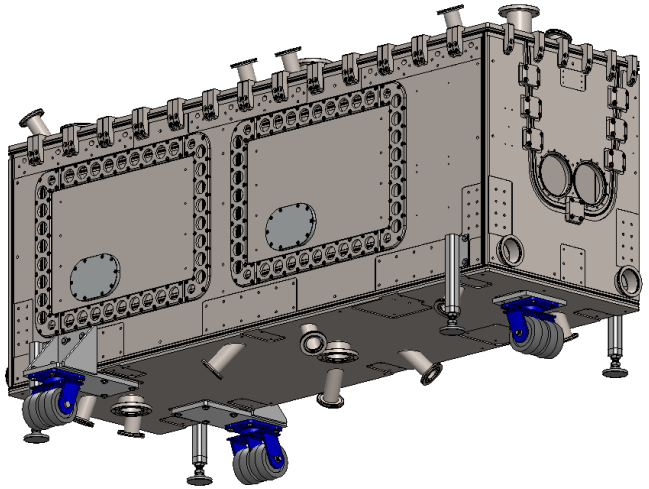


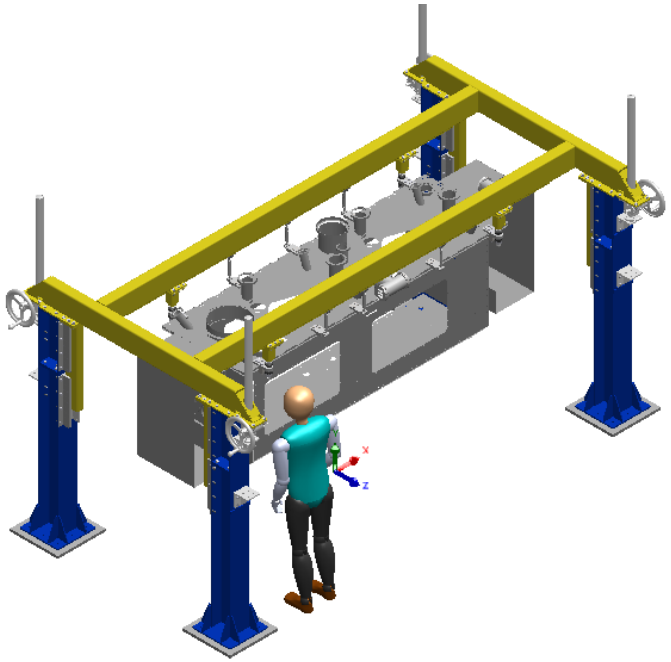
Infrastructure in the queue

- String assembly frame
  - Based on UK design
  - Ready to send for manufacture
  - Rails and castors received
- Cavity manipulation/rinsing tooling
  - In design
- Top assembly frame
  - Detailed design
- Cryomodule trolley
  - Detailed design









Infrastructure upgrade status

		specified	designed	ordered	received
Clean room upgrade	Garments	✓		✓	✓
	Particulate monitoring	✓		✓	✓
	Vacuum equipment	✓		✓	✓
	New clean room	✓		✓	
Cavity testing	4k/2k insert	✓	✓	✓	✓
	Test diagnostics	✓	✓	✓	✓
	2k pumping capacity	✓	✓	✓	✓
Assembly fixtures	Hermetic string cart	✓	✓	parts ✓	parts ✓
	Dummy cavity	✓	✓		
	Cavity handling tooling	✓	50%		
	Top down assembly stand	✓	90%		
	Cryomodule trolley	✓	50%		

HiLumi HL-LHC PROJECT

Cryomodule Fabrication

Progress Milestones - Cryomodules

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4k-2k Cryo insert qualified	Infrastructure	Nov 2022
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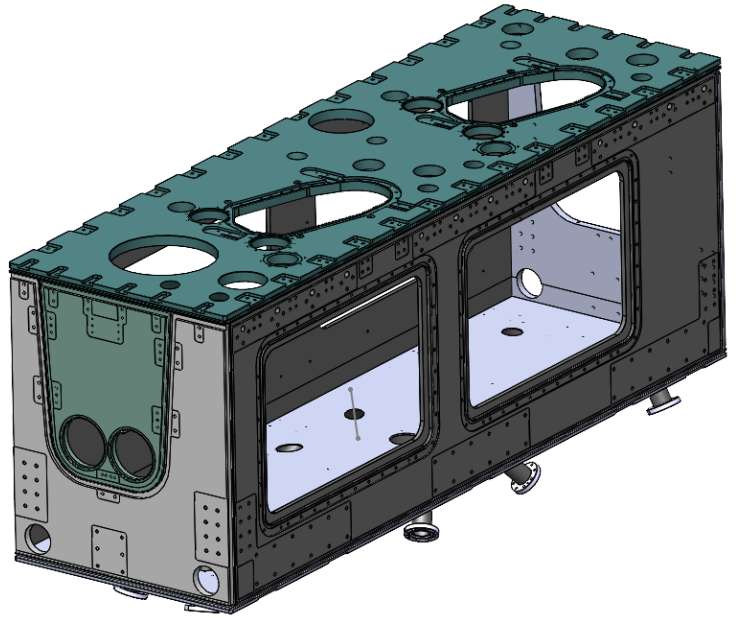
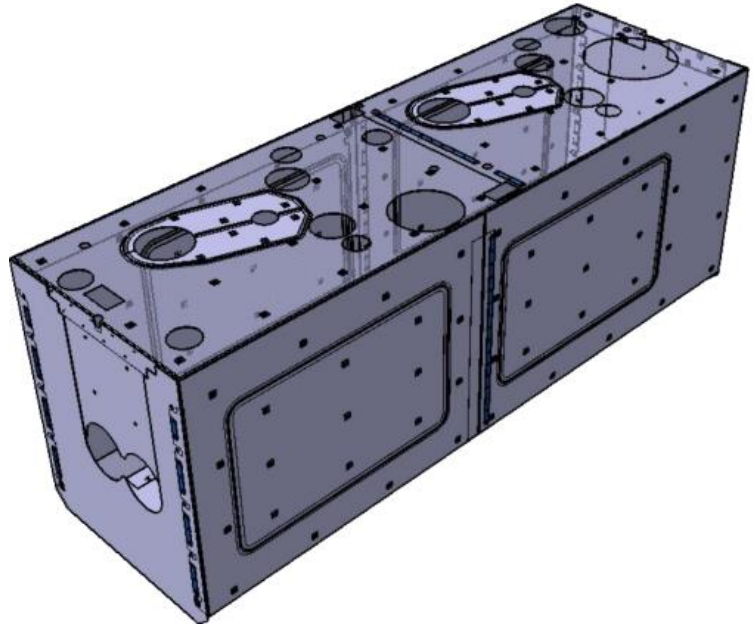
MLI tender issued	TCM1-5	-

Cryomodule fabrication milestones

- Drawings for OVC completed and RFQ issued
  - Considerable effort to translate EU/CERN specifications for NA vendors
  - Good learning exercise
- Contract for one outer vacuum chamber (OVC) issued to Axton (Vancouver)
- Material for five OVCs ordered from Outokumpu – delivery in Oct. 2023



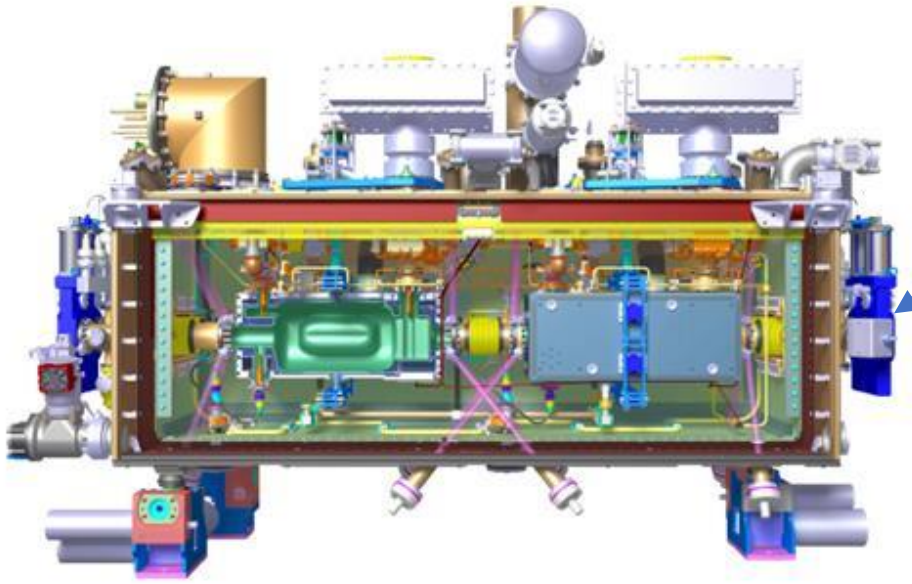
- Tender complete for 5 mu-metal shields
- Successful bidder selected
- First article by Feb. 2024 – final article by Dec. 2024



First articles received

First articles shipped from CERN to TRIUMF

- 5 Sector valves were received by TRIUMF SRF Group on July 21, 2023



Cryomodule fabrication strategy

CM string assembly requires cavities from AUP, FPCs and beamline assemblies from CERN – first articles are required to assemble TCM0.

Next items for series production where TRIUMF requires released drawings

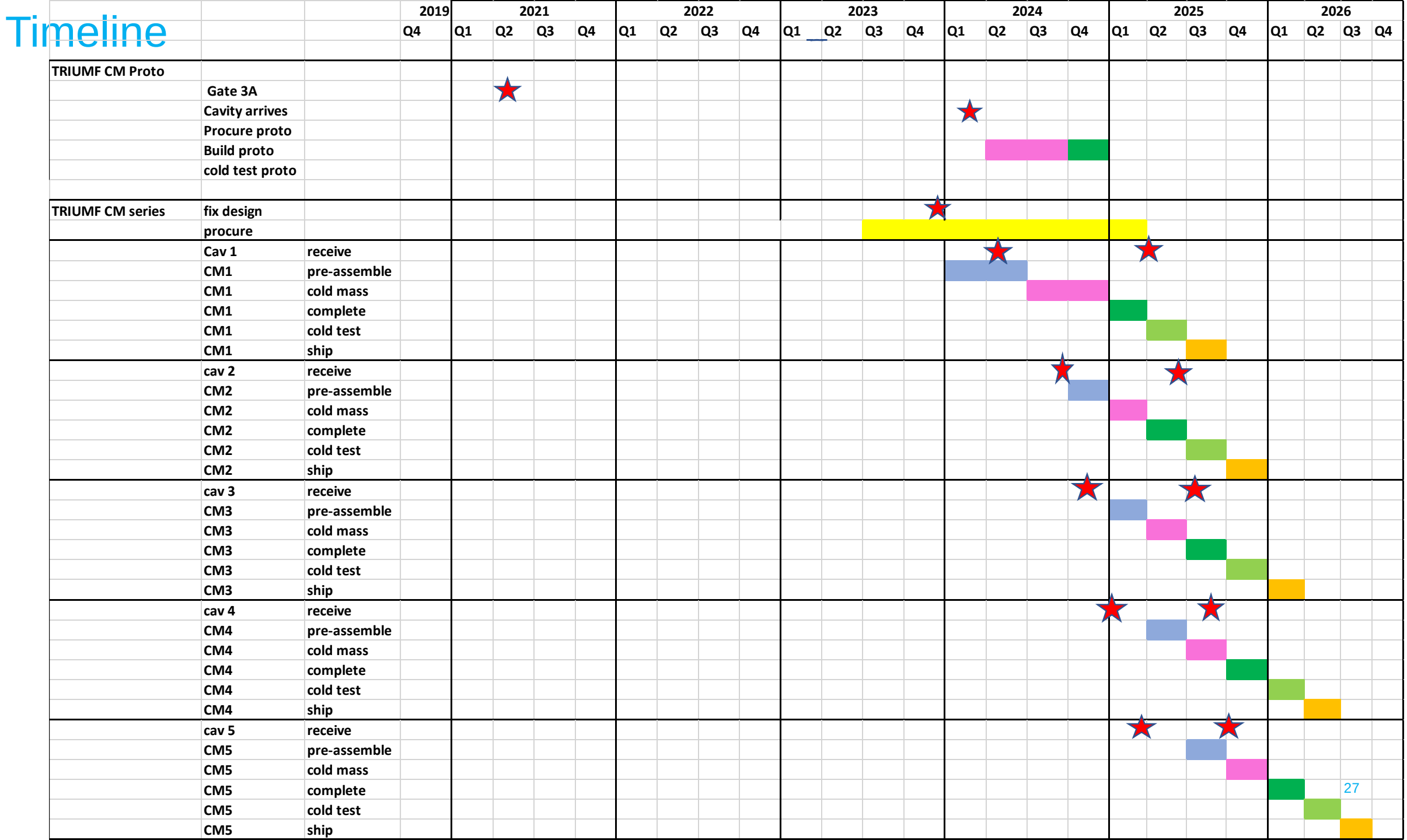
- MLI blankets
- Thermal shield
- Cold tuner frame and warm tuner actuator assembly
- Cryogenic internal lines and supports

TRIUMF also requires delivery of CM parts in CERN scope and group purchased parts (at least for first articles):

- Cavity testing - rf components – Jan 2024
- String assembly – Mar 2024
- Cryomodule assembly – Apr 2024
- Cryomodule testing – May 2024

AUP Delivery Projection			
Cavity Pair	**Module**	**Early dates**	**Late dates**
Pre-series Cavity	TCM0	Mar 2024	-
Series 1 and 2	TCM1	May 2024	Apr 2025
Series 3 and 4	TCM2	Sep 2024	Jun 2025
Series 5 and 6	TCM3	Nov 2024	Jul 2025
Series 7 and 8	TCM4	Jan 2025	Sep 2025
Series 9 and 10	TCM5	Mar 2025	Oct 2025

Timeline



			2019	2021				2022				2023				2024				2025				2026			
			Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
TRIUMF CM Proto																											
	Gate 3A																										
	Cavity arrives																										
	Procure proto																										
	Build proto																										
	cold test proto																										
TRIUMF CM series	fix design																										
	procure																										
	Cav 1	receive																									
	CM1	pre-assemble																									
	CM1	cold mass																									
	CM1	complete																									
	CM1	cold test																									
	CM1	ship																									
	cav 2	receive																									
	CM2	pre-assemble																									
	CM2	cold mass																									
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	CM5	ship																									

Summary

- Revamping strategy to address finite time window for available funds
  - Prioritizing with CERN the release of drawings for CM series to launch other long lead items
  - Milestone dates for CERN deliverables communicated to CERN
- Preparing TCM0 and series production CMs
  - OVC production launched – TCM0
  - OVC material ordered - series
  - Mu-metal vendor selected – series
  - Sector valves received from CERN
- Cavity testing infrastructure
  - 4k/2k assembly tested and meets all specs
  - Pumping station installed
  - Ready for 2k testing
- New clean room ordered for March 2024 – tooling in preparation