

# Hi-Lumi RFD CM Project P455

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Hi-Lumi Collaboration meeting

September 2022

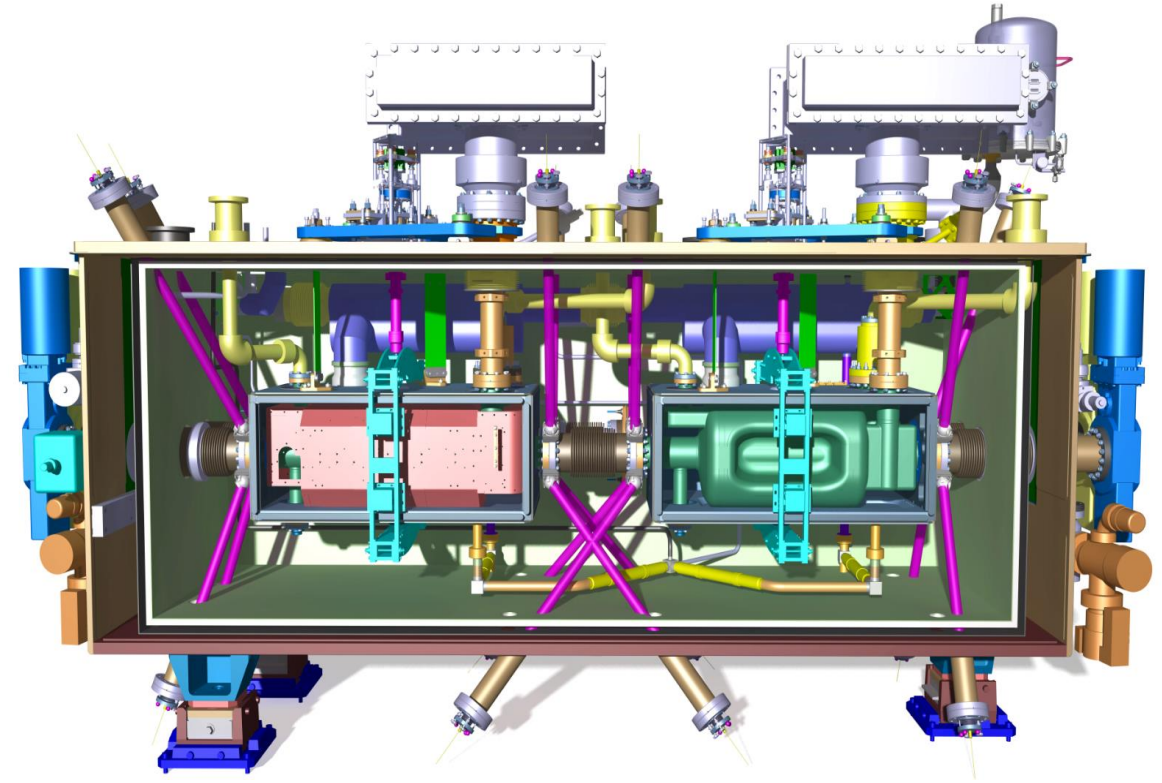
Uppsala



# RFD Cryomodule Project at TRIUMF – General Scope

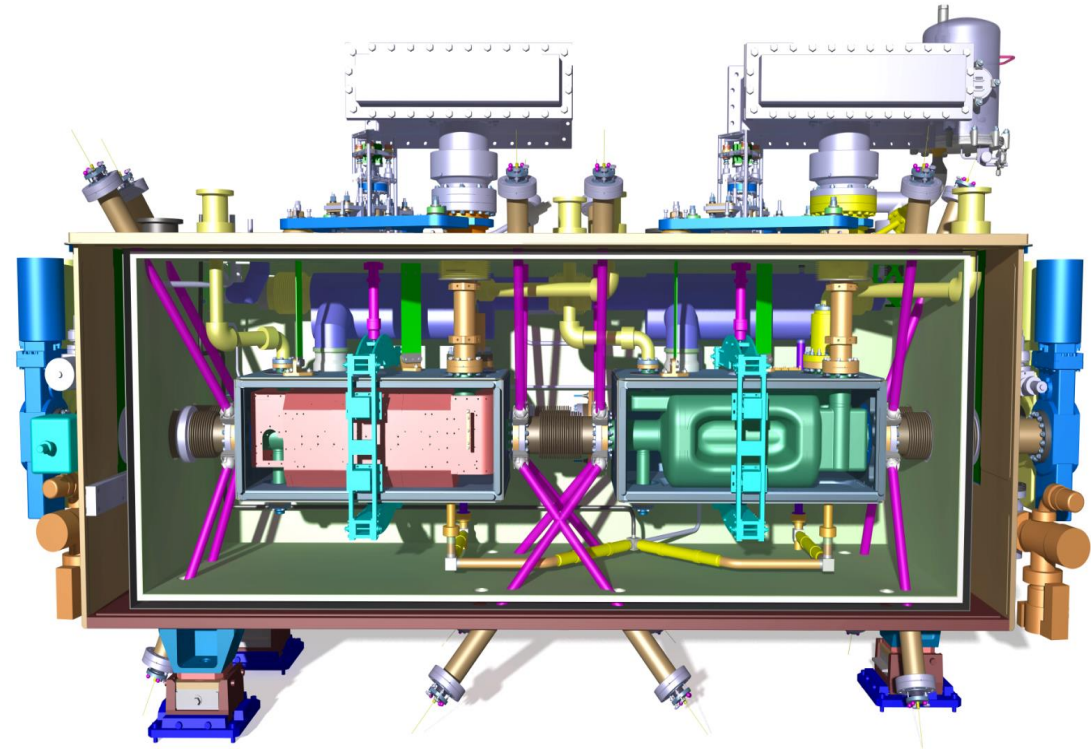
TRIUMF will:

- receive 10 dressed RFD resonators produced and qualified in AUP
- re-qualify the cavities in a cold test at 4K and 2K
- assemble the ten cavities into five cryomodules
- qualify the cryomodules through cold testing at TRIUMF
- Prepare and package the cryomodules for shipping to CERN



## Pre-series and series strategy

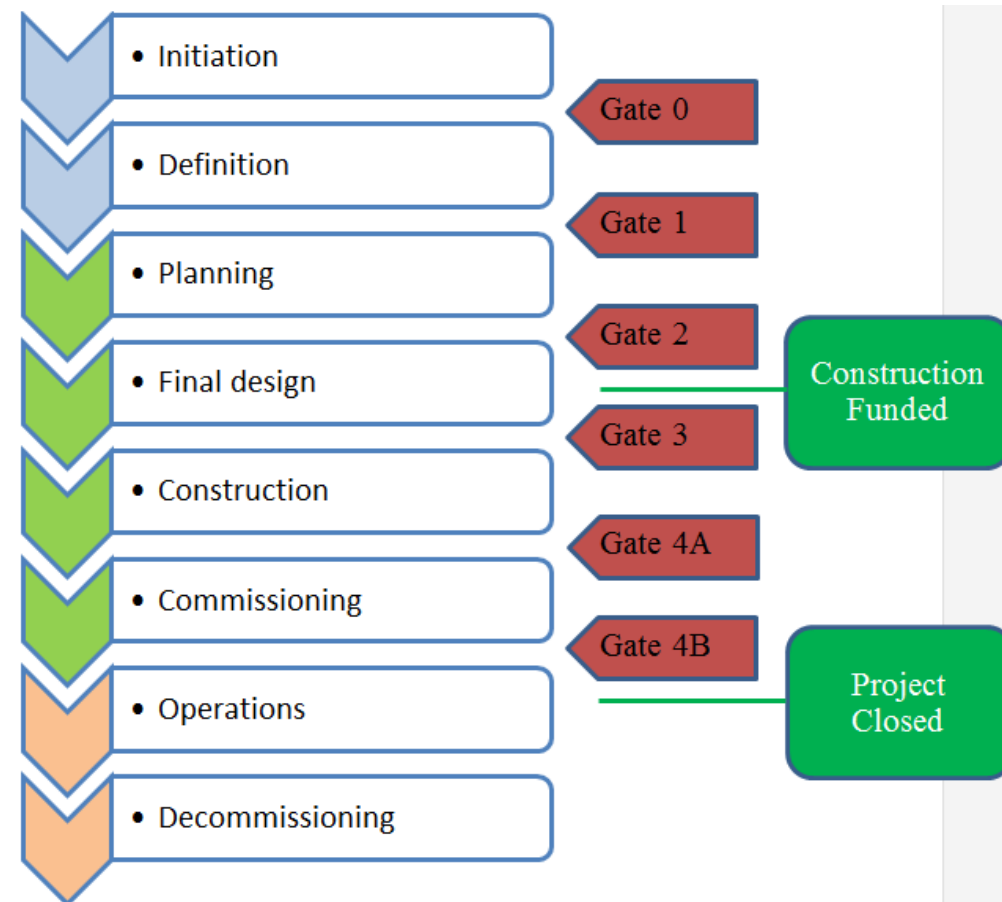
- As part of the quality assurance TRIUMF will build a pre-series module, TCM0
- AUP has agreed to ship one or two cavities to TRIUMF for assembly into TCM0 with delivery expected in spring 2023
- TRIUMF will fabricate parts and assemble TCM0 for cold test within 2023
- TRIUMF will follow up with the series production, TCM1-4, following receipt of the series cavities from AUP
- TCM5 will be a reworked TCM0
- Series production will span 2024-25



# TRIUMF Project milestones

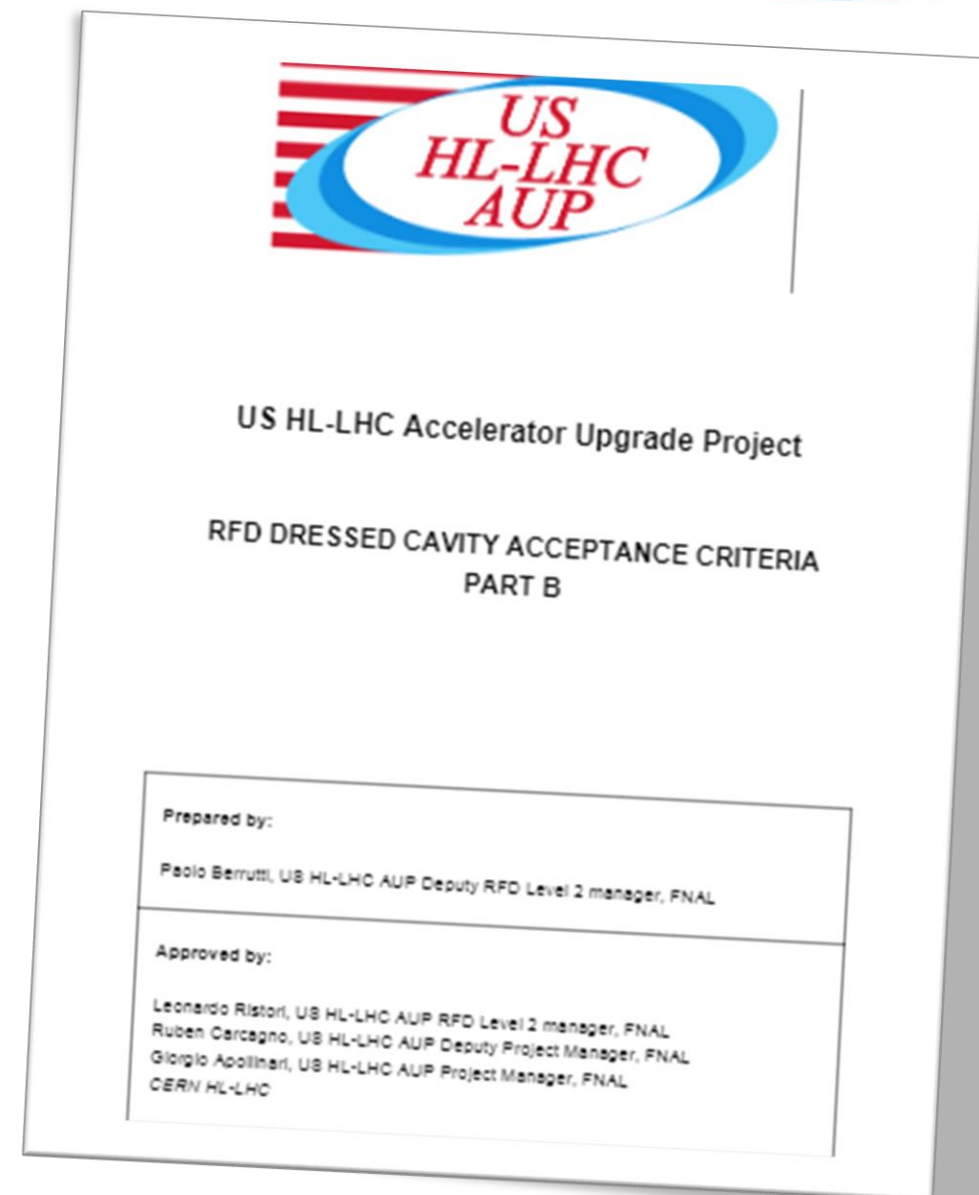
Progress within TRIUMF Project Gating system.

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



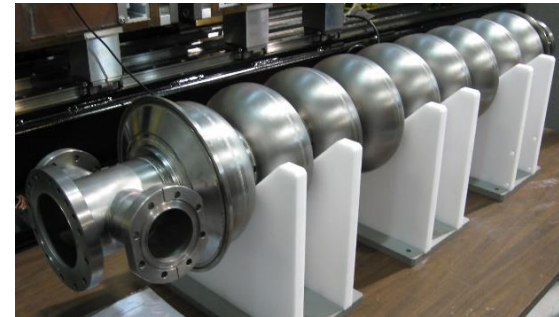
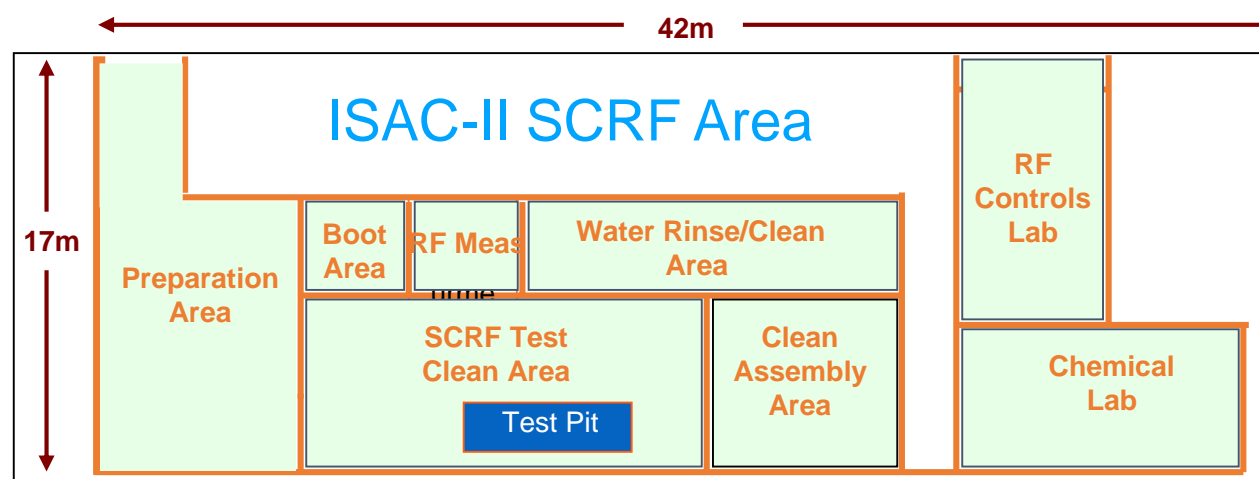
# Cavity Re-qualification at TRIUMF

- 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 with 2K capability
- Each test will take about a week with technical support from TRIUMF SRF and cryogenics group.



# TRIUMF SRF Infrastructure

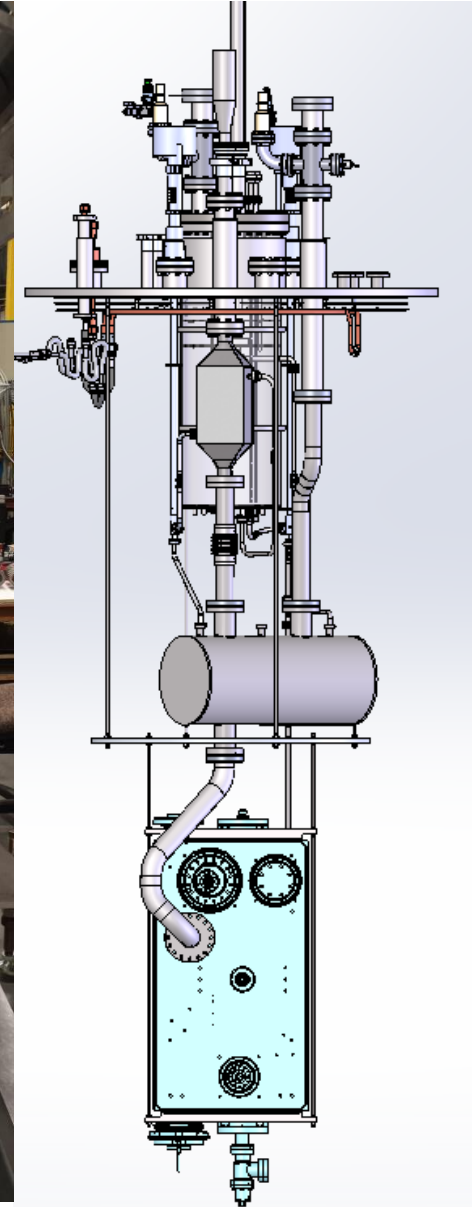
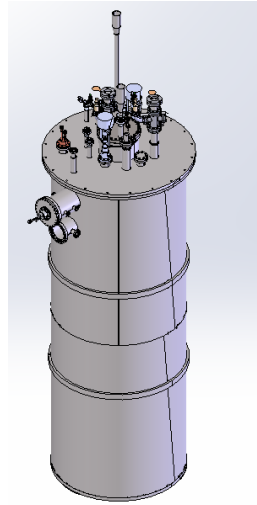
- TRIUMF hosts two SRF linacs (ISAC-II heavy ion linac and the ARIEL electron linac) and SRF supporting infrastructure.
- Activities range from student R&D on test resonators to work for others (prototyping cavities and components) and to full cryomodule assemblies
- US cleaning tanks, HPWR area, cryomodule assembly area (clean room for hermetic string assembly and larger CM assembly space in adjacent hall), chemical etching lab (BCP), rf testing
- Cryogenics: LHe and LN2 on tap with 40W@2K capability



# Preparations at TRIUMF

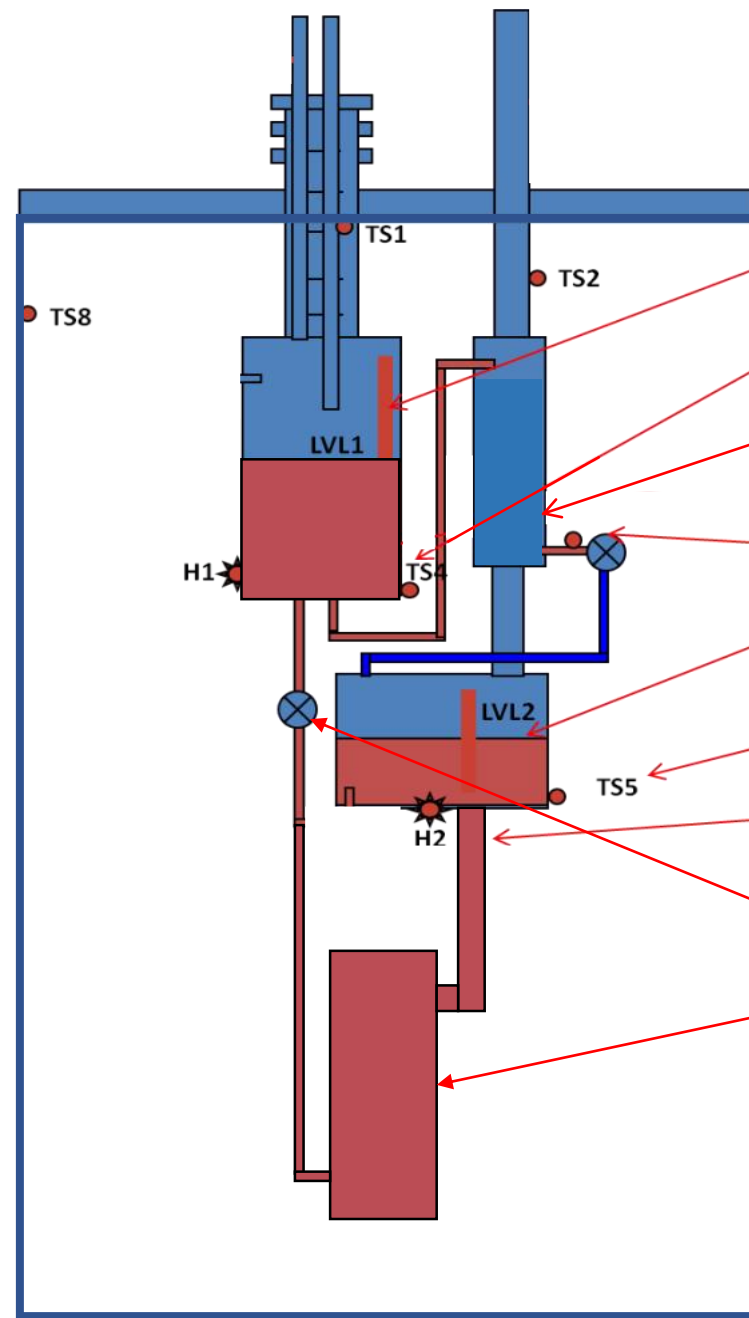
TRIUMF is preparing through

- Clean room upgrades
  - Additional particulate diagnostics
  - Upgraded garments
  - Dedicated pumping equipment
  - Reviewing pumping and venting criteria
- Enhancing capability for cavity testing at 2K
  - Doubling 2k pumping capacity to 40W at 2K
  - Completed a new 4k/2k cryo-insert for the multi-purpose test cryostat
- Initiating procurement for assembly fixtures and tooling

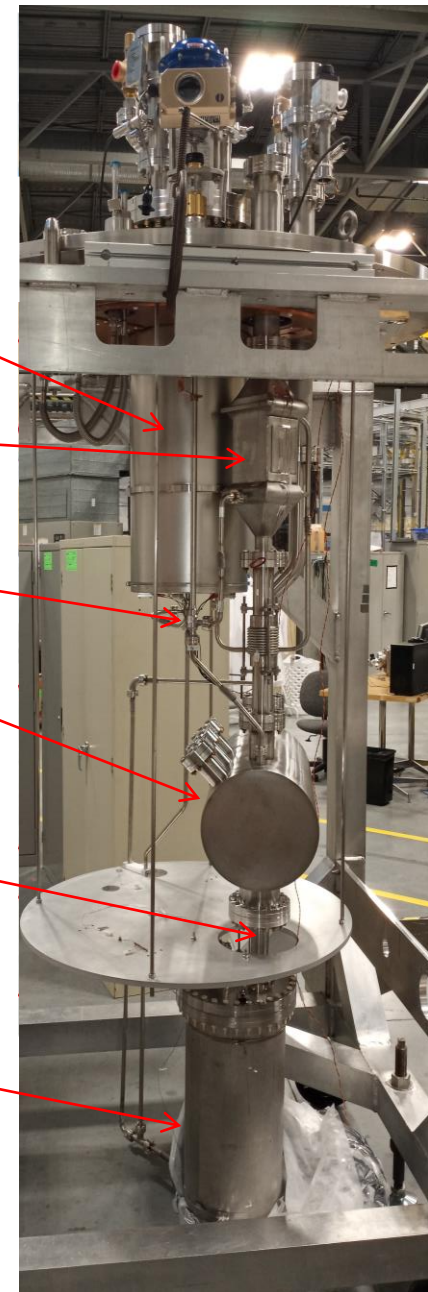


# Cavity testing status

- 4k-2k unit complete and ready for testing – test plan completed
- Gives us capability of jacketed tests of RFD cavity at 2K
- Will test the system on a dummy load this fall
- First cavity scheduled (presently) to arrive from AUP in spring 2023
- New 2k pumps installed in test area – 40W at 2K



- 4k Reservoir
- 4K Temperature sensor
- Heat Exchanger
- JT valve
- 2K reservoir
- 2K Temperature sensor
- 2K Chimney
- Cooldown valve
- Cavity

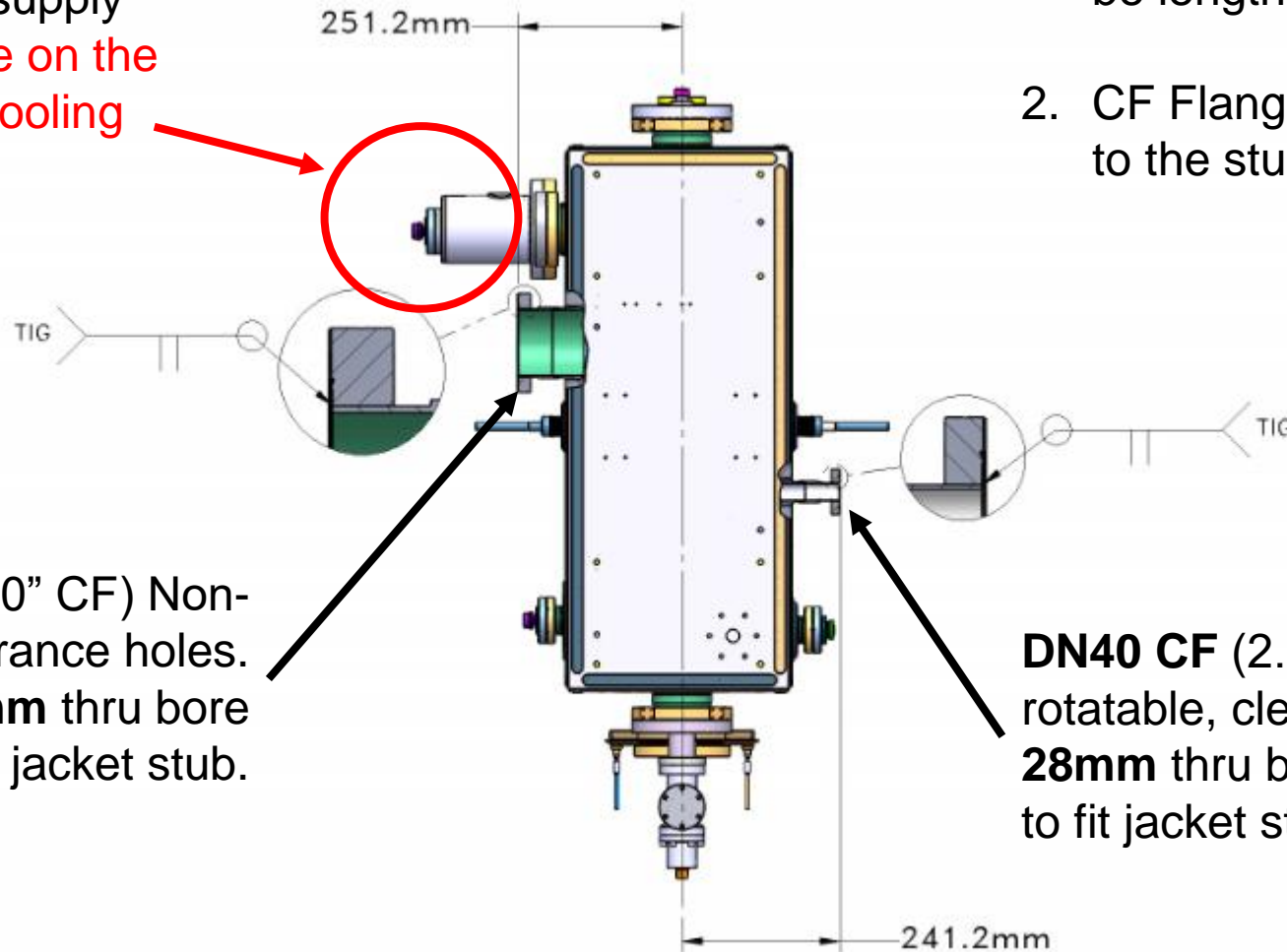




# Cavity Design Changes for TRIUMF Testing

TRIUMF will be testing in jacketed mode so we require flanges on the helium supply and return and a flange on the HHOM port for direct cooling

1. Helium tube stubs are to be lengthened by 5mm
2. CF Flanges will be welded to the stubs as shown.



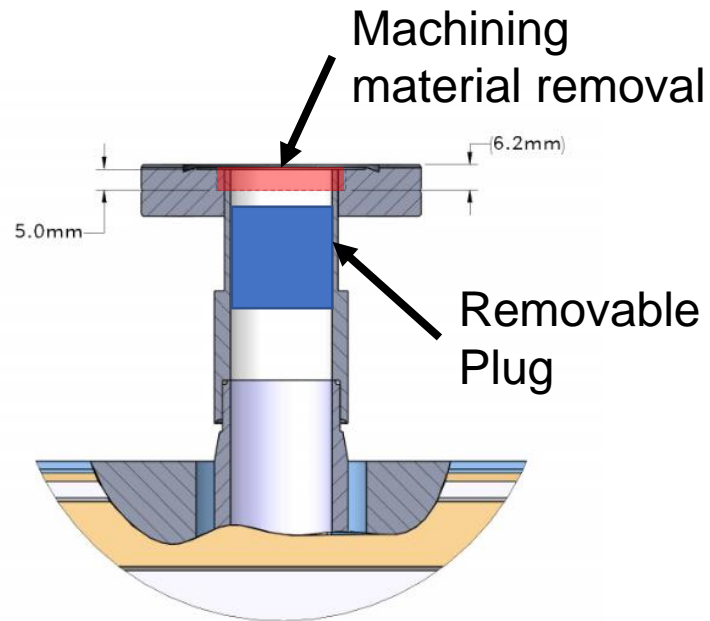
**DN100 CF (6.0" CF)** Non-rotatable, clearance holes. **104mm** thru bore machined to fit jacket stub.

**DN40 CF (2.75" CF)** Non-rotatable, clearance holes. **28mm** thru bore machined to fit jacket stub.

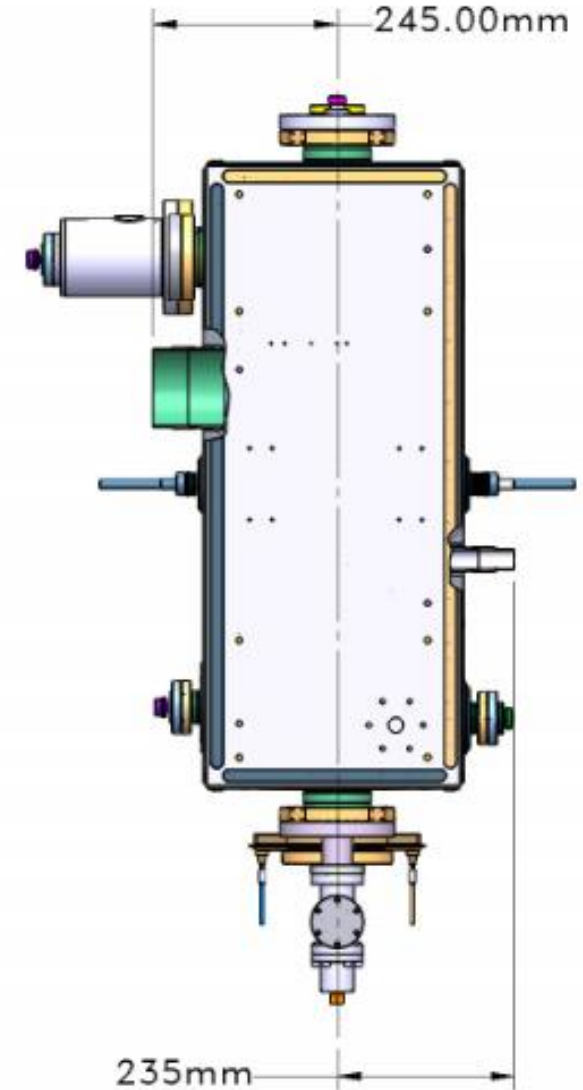
# Manufacturing to be Completed at TRIUMF

After cold test, 5mm will be machined from tube stubs effectively returning the cavity to its original design state.

A removable plug will be used to ensure machining debris and coolant will not contaminate the helium space.

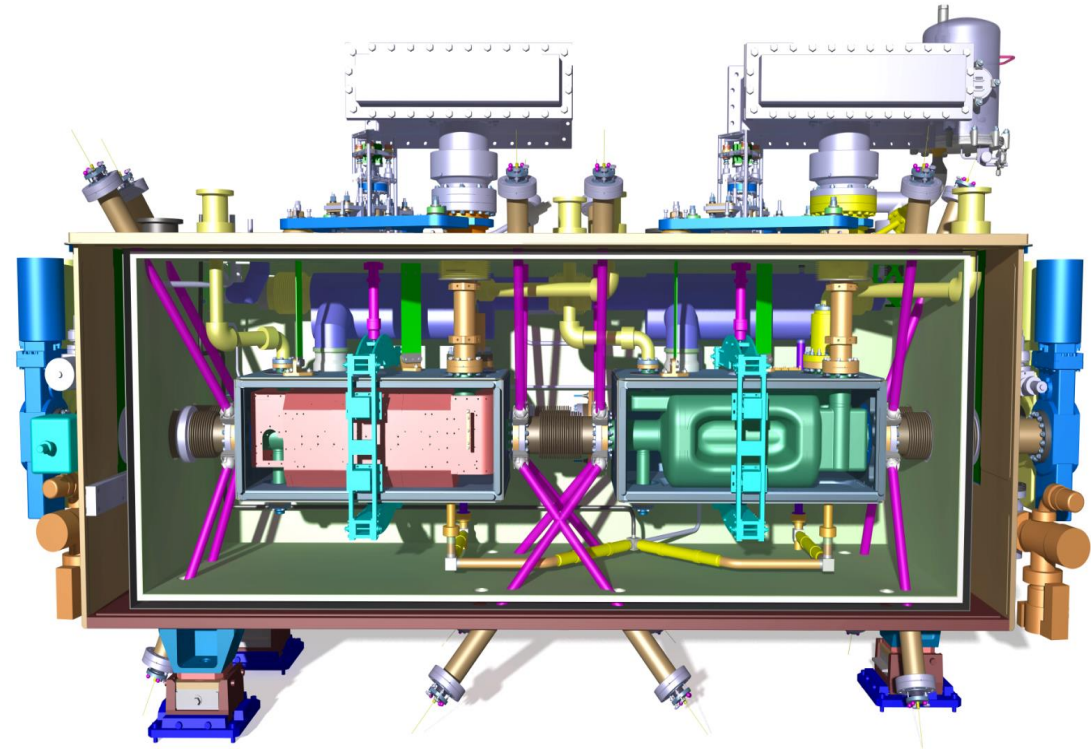


*Typical both flanges*



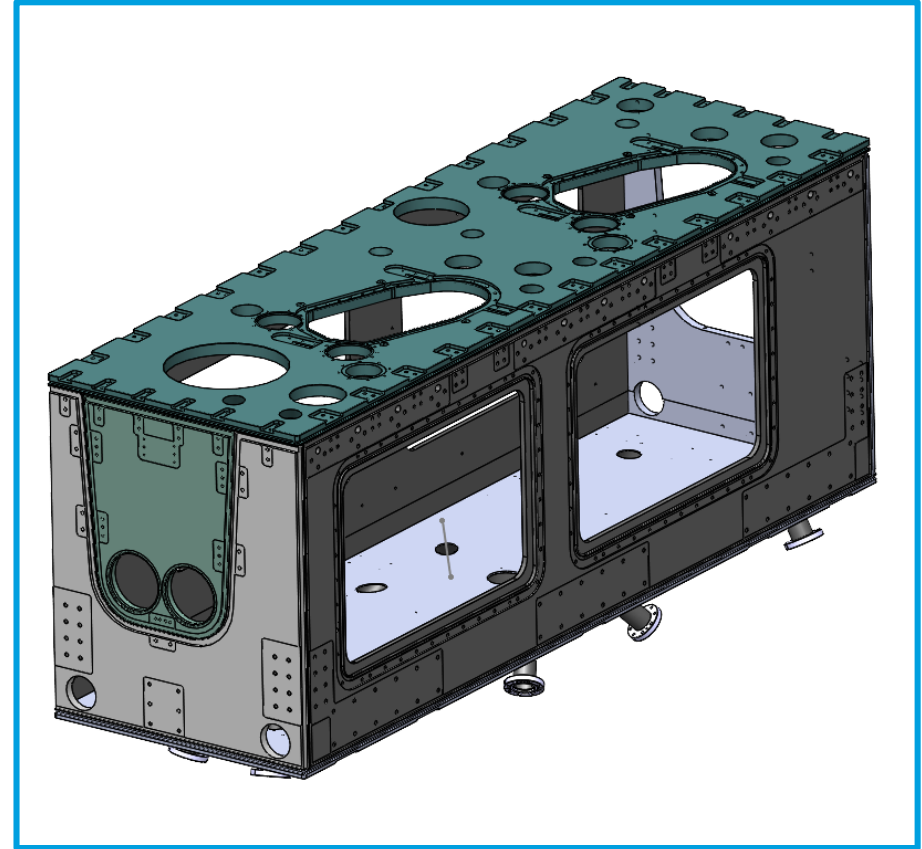
# TCM0 fabrication

- Launching procurements for
  - Hermetic string assembly cart
  - OVC (Outer vacuum chamber)
  - Mu metal
  - Thermal shield
  - Top assembly frame
  - MLI
- Requesting CERN scope delivery dates
- CERN has agreed to bulk purchase the sector valves and the vacuum equipment for the collaboration
- Initiating design/fabrication of dummy cavity



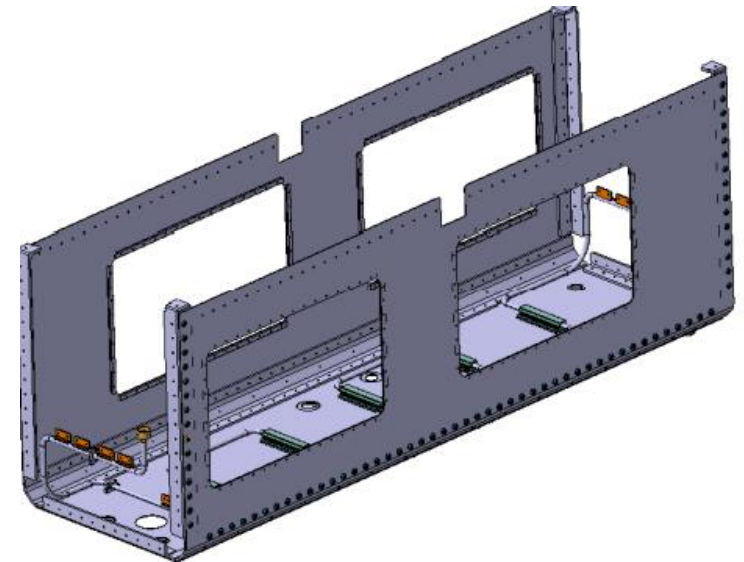
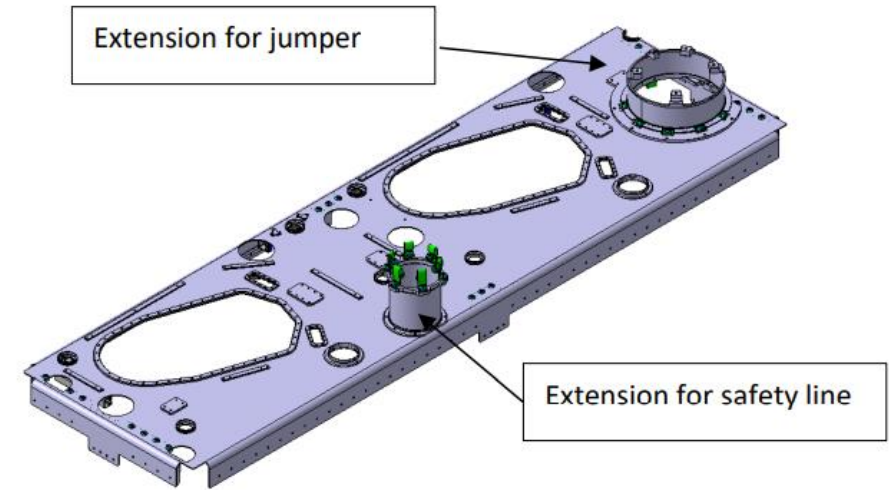
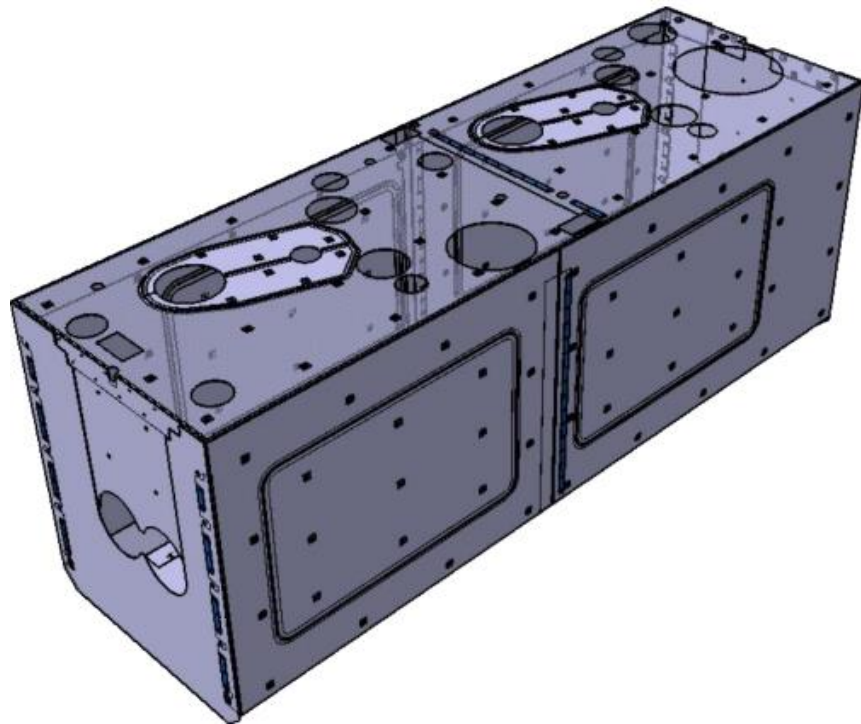
# TCM0 Tank Manufacture

- Tender specification written for the outer vacuum chamber (OVC) – in review
- Drawing package completed - in review
- Issue 1
  - Interpreting European PED for North American vendors who are used to ASME
  - TRIUMF acts as contractor (to CERN) and vendor acts as sub-contractor to TRIUMF
- Issue 2
  - Low Co 316L stainless is hard to find In North America (and globally)
  - We have one quote from Industeel ArcelorMittal for 150 tons minimum order – they recommend 316LMo
  - Consider derating to 304 low Co (readily available for nuclear industry) or CERN considers a bulk order



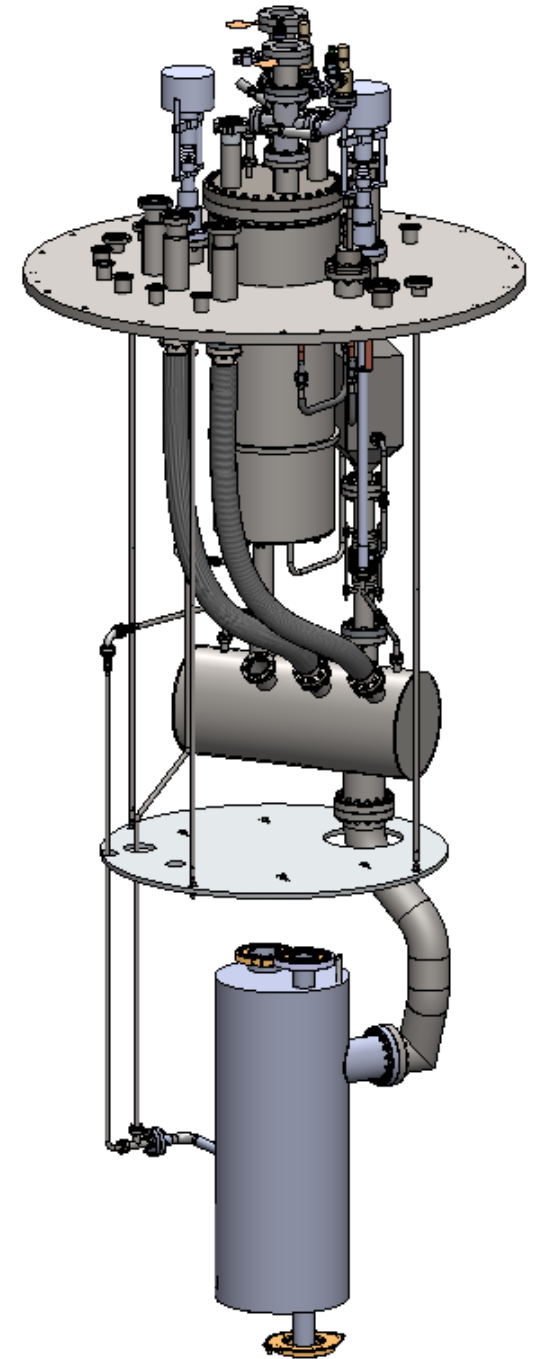
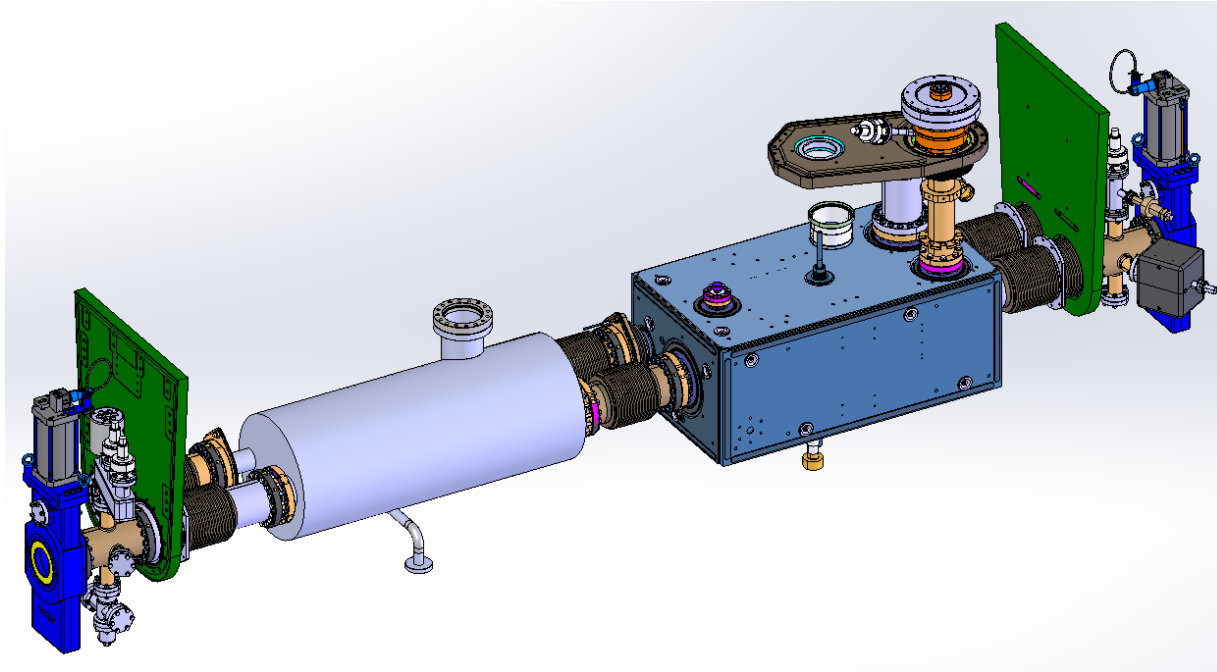
# TCM0 Manufacture

- Next up
  - Drawing package and specification for thermal shield and mu metal
  - Will launch procurement in Fall 2022



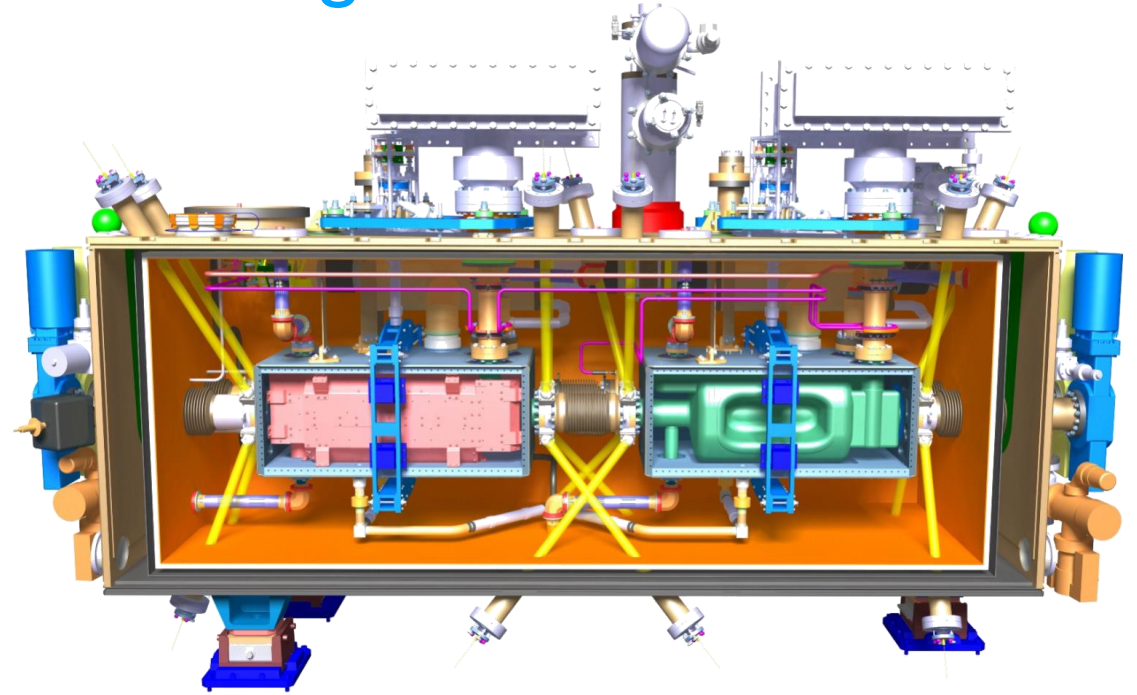
# TCM0 manufacture - Dummy cavity

- AUP anticipates only one TCM0 cavity in Spring 2023
- TRIUMF is planning to build 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



# 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, frequency check
- 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**

# TCM0 manufacture – CERN deliverables

- **Spring 2023** - Cavity string
  - FPC – x1 (based on Leonardo's projection)
  - Beam screen
  - Extremity chamber type 1 with Rf insert
  - Extremity chamber type 2 with Rf insert
  - Cavity cold warm transition long with RF insert
  - Cavity cold warm transition short with RF insert
  - Beam screen cold warm transition long with RF insert
  - Beam screen cold warm transition short with RF insert
  - Inter cavities chamber with RF insert
  - Inter beam screen chamber with RF insert
  - **Sector valves – x 4 and vacuum equipment**
- **Summer 2023** – Cryomodule assembly
  - RF Internal Lines (HOMs, pick-up, FPC outer tube)
  - FSI Cavity Alignment System
  - Cryogenic Instrumentation CERNOX
- **Fall 2023** – Cryomodule testing
  - **RF system for cold test in Canada at TRIUMF**





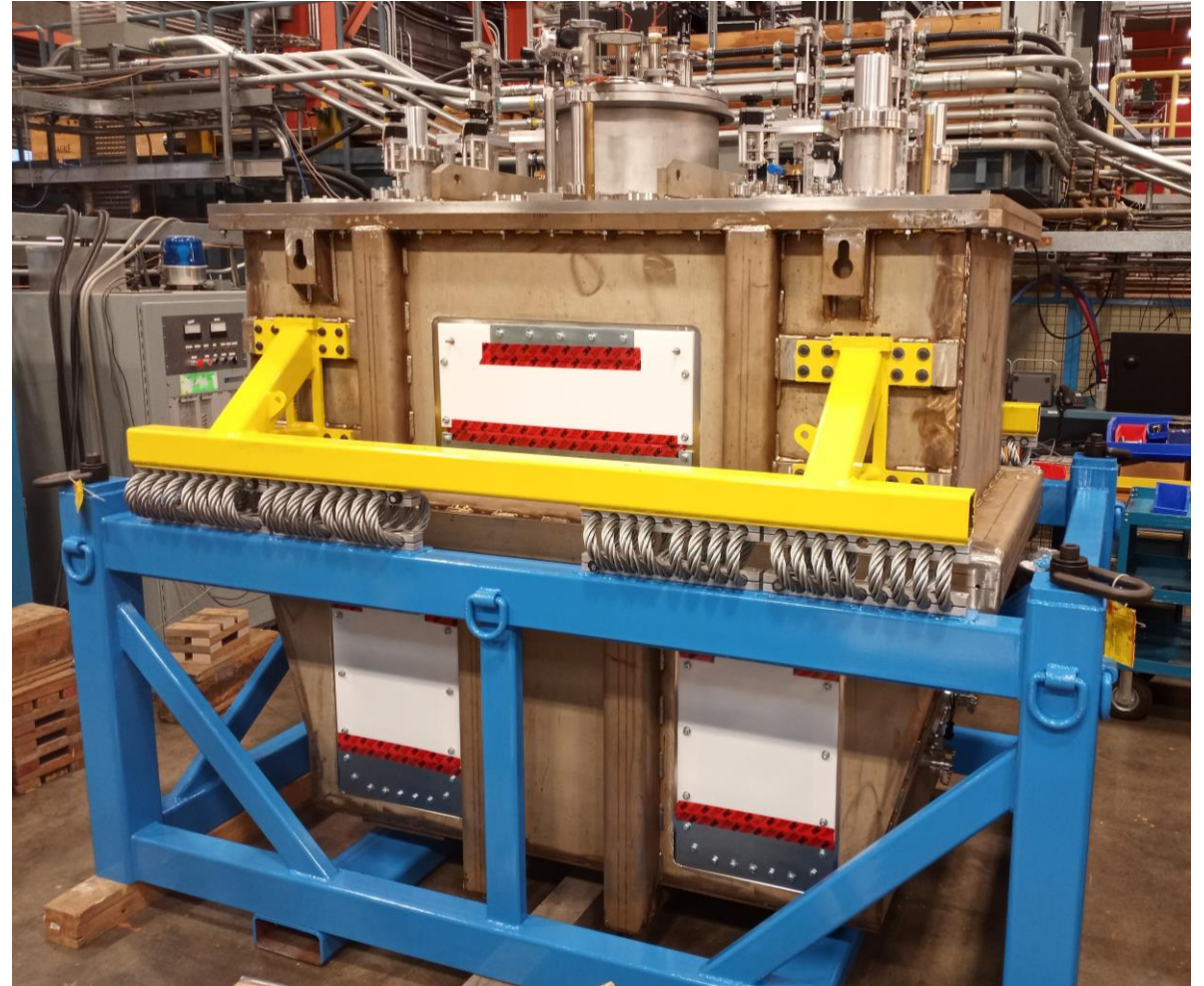
# Collaboration

- TRIUMF Hi-Lumi team visited Daresbury from Sept 5-7
- Reviewed string assembly
- Presented a 'Lessons Learned' session for the clean room assembly and worked through the complete assembly steps
- Many thanks to UK colleagues for a very productive visit



# Collaboration – VECC (Kolkata)

- TRIUMF recently completed a heavy ion SRF cryomodule for VECC
- Now being prepared for shipping
- This will be the second CM shipped to India



# Parts Delivery (AUP/CERN)

## TCM0 dates

Latest schedule has one TCM0 cavity delivered spring 2023

Dates for delivery of equipment from CERN need to be nailed down

Hermetic string parts need to be at TRIUMF spring 2023 – FPC, beam screens and chambers

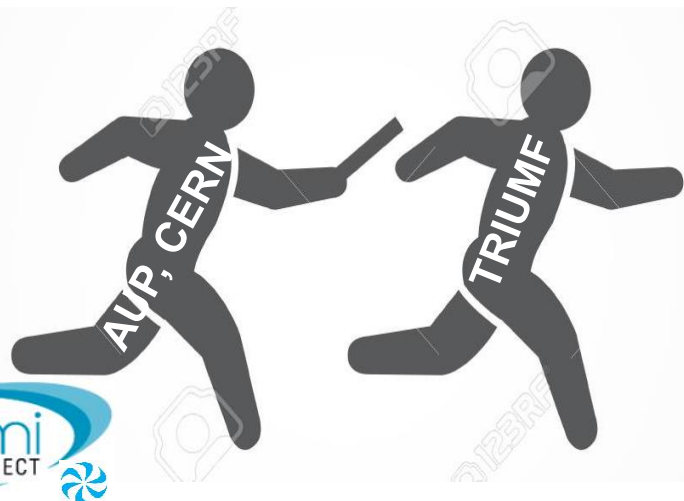
Top assembly parts Summer 2023

Fall 2023 – require 20kW amplifier for CM test



TCM0 - we are making plans to assemble TCM0 with only one real cavity and one dummy cavity

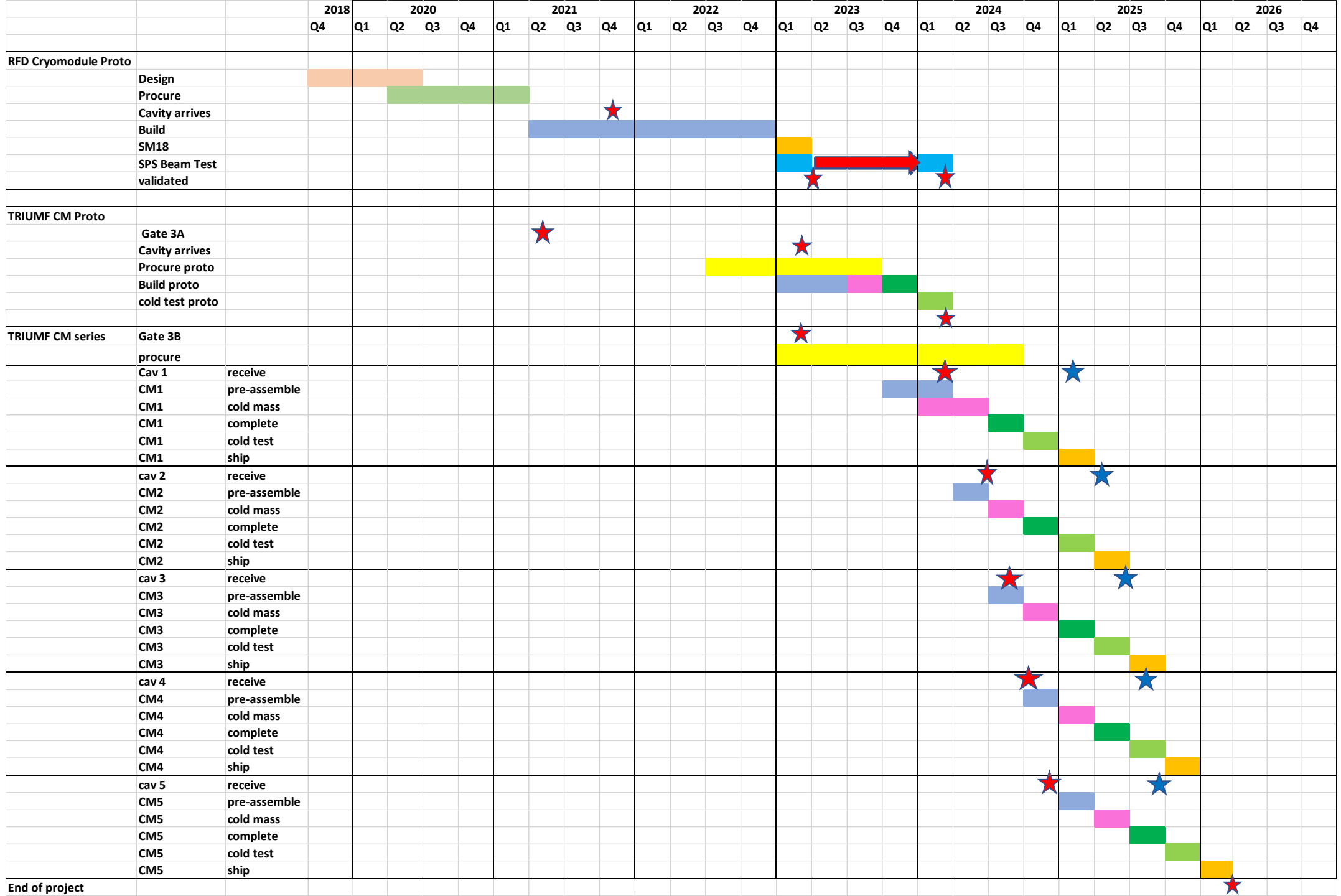
<b>AUP Delivery Projection – Sep.2022</b>			
<b>Cavity Pair</b>	<b>Module</b>	<b>Early dates</b>	<b>Late dates</b>
Pre-series Cavity	TCM0	Spring 2023	
Series 1 and 2	TCM1	Mar.2024	Feb.2025
Series 3 and 4	TCM2	Jun.2024	May.2025
Series 5 and 6	TCM3	Jul.2024	Jun.2025
Series 7 and 8	TCM4	Sep.2024	Aug.2025
Series 9 and 10	TCM5	Oct.2024	Sep.2025



UK



Canada



# Summary

- 4k/2k unit completed for testing in Oct. 2022
- Upgrades to 2K pumping completed
- Launching procurements for TCM0 – reviewing TRIUMF OVC drawing package and sourcing material → mu-metal, thermal shield
  - TCM0 cavity – spring 2023
  - Dummy cavity in design
- Assuming the following delivery dates for CERN deliverables
  - Hermetic String - spring 2023
  - CM equipment – summer 2023
  - CM testing equipment – Fall 2023
- AUP production delivery dates incorporated into planning – last CM delivered in early 2025

