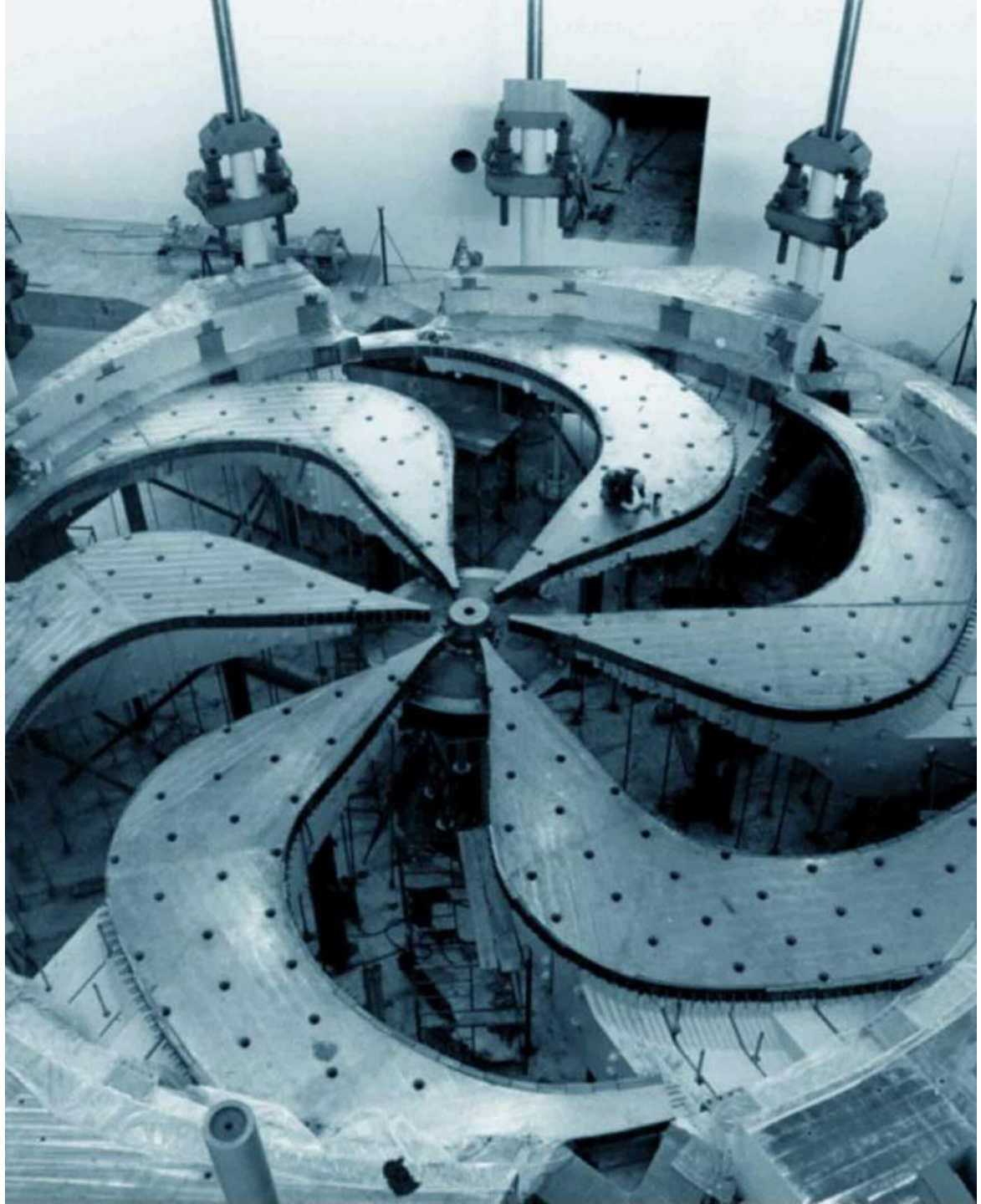
# RFD Canada – Status and Transport Aspects



Bob Laxdal

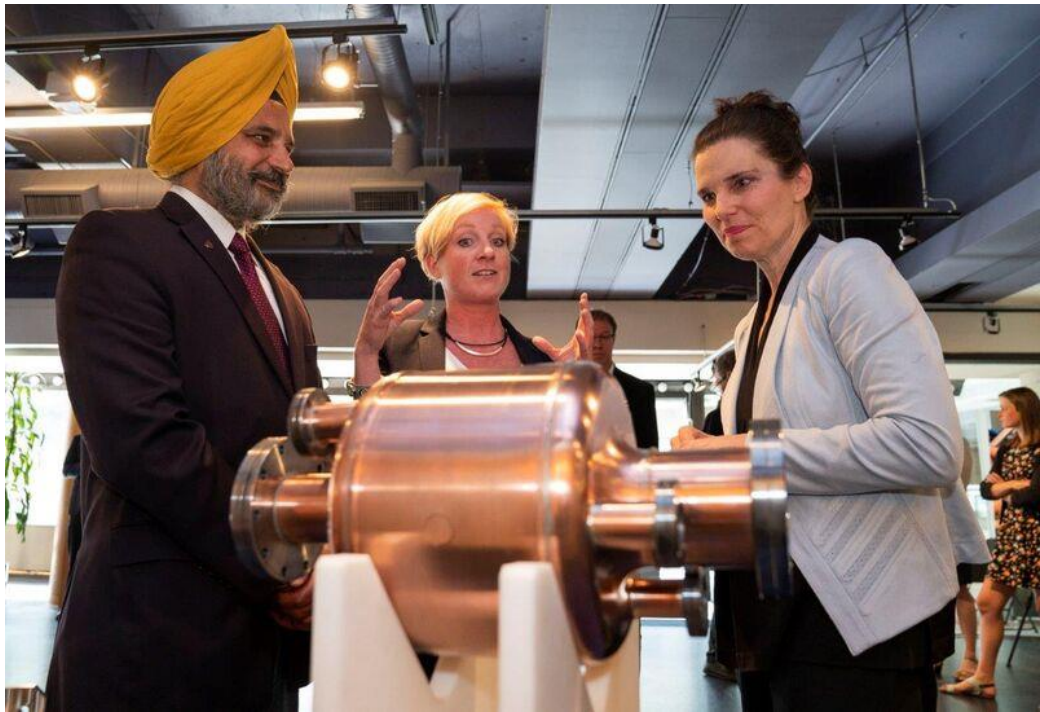
TRIUMF Hi-Lumi Technical Lead

2019-04-08

# 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.

# CERN-TRIUMF MOU – Addendum No. 3

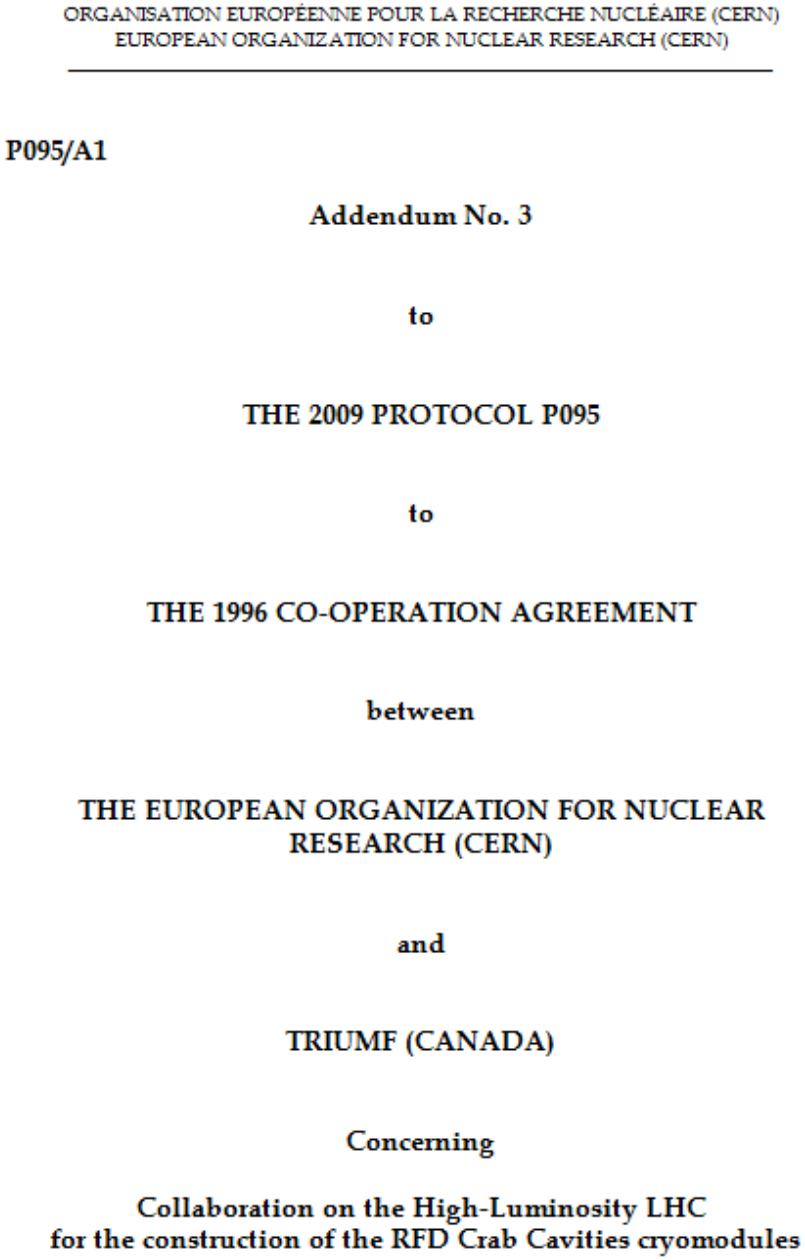
An agreement has been drafted – soon to be signed.

TRIUMF representatives on the Steering Committee
Jon Bagger – Director
Oliver Kester – Project Leader

TRIUMF's Technical Coordinator
Robert Laxdal – SRF Department Head

CERN representatives on the Steering Committee
Frédérick Bordry – Director for Accelerators and Technology
Lucio Rossi – HL-LHC Project Leader

CERN's Technical Coordinators and Safety Correspondents
Rama Calaga – HL-LHC Work Package 4 Leader
Ofelia Capatina – HL-LHC Work Package 4  Deputy Leader



ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE (CERN)
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

P095/A1

**Addendum No. 3**

**to**

**THE 2009 PROTOCOL P095**

**to**

**THE 1996 CO-OPERATION AGREEMENT**

**between**

**THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)**

**and**

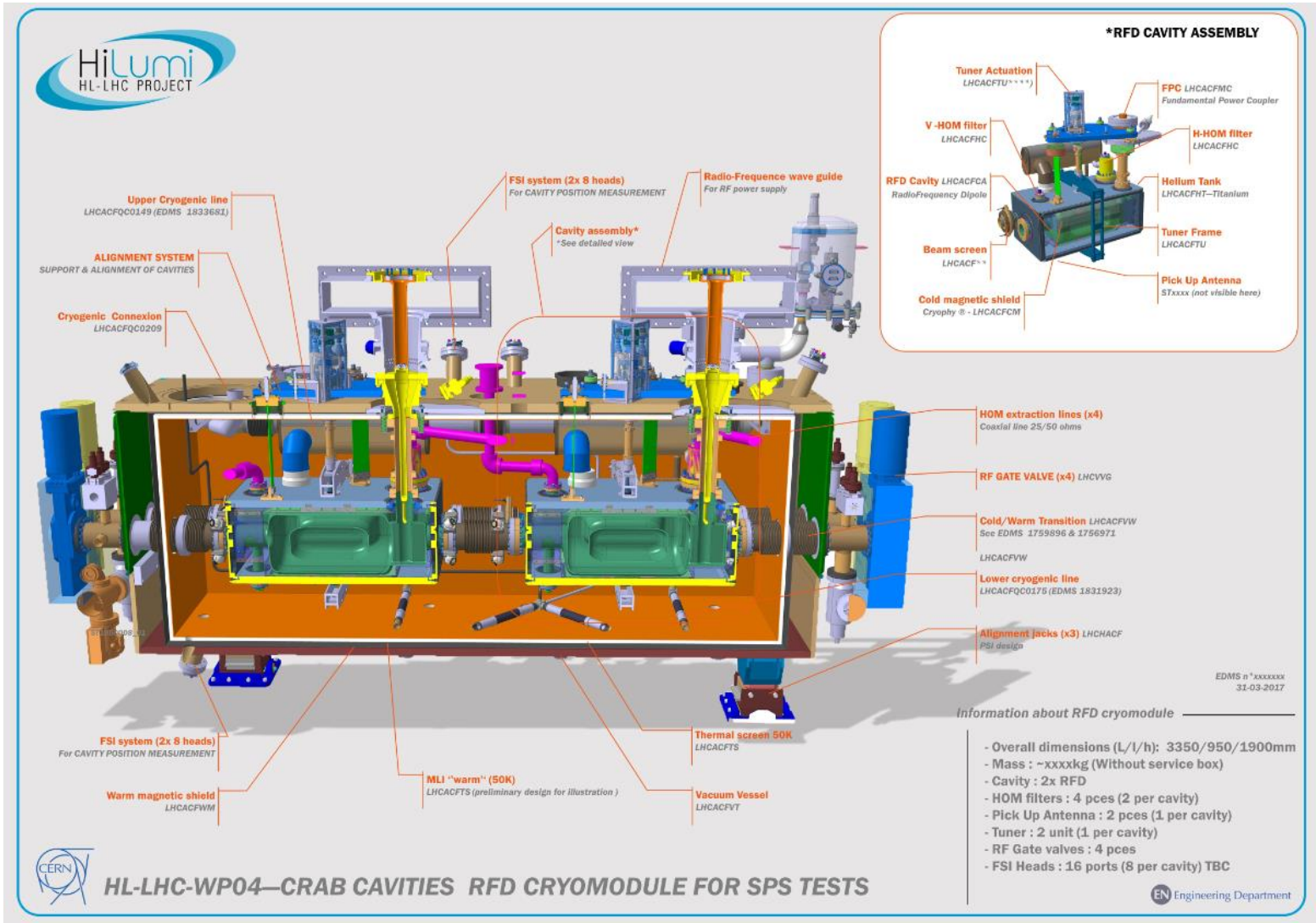
**TRIUMF (CANADA)**

**Concerning**

**Collaboration on the High-Luminosity LHC for the construction of the RFD Crab Cavities cryomodules**

# RFD Cryomodule Project

- TRIUMF to work with CERN and UK colleagues to develop RFD cryomodule design, assembly tooling and fixtures, assembly procedures
- TRIUMF to receive dressed RFD resonators produced and qualified in AUP, 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
- TRIUMF to work with CERN and UK to establish a suitable shipping method to retain the high performance of the module



# The TRIUMF Team

Technical coordinator – Bob Laxdal

Deputy Coordinator – Zhongyuan Yao

Engineer – Matt Brownell

Designer – Ben Matheson

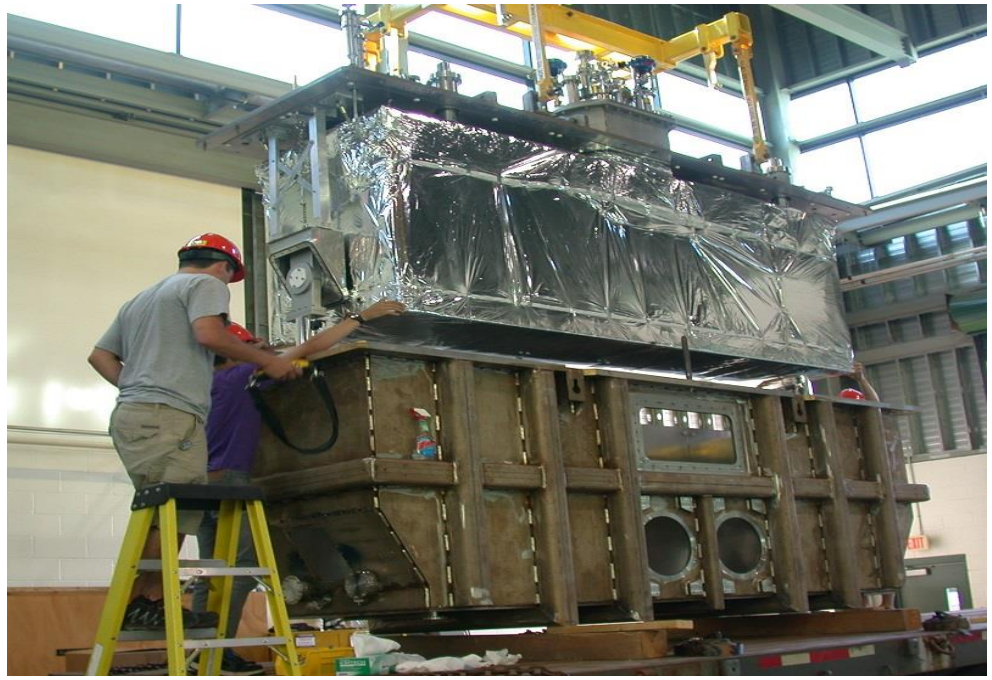
String assembly – Bhalwinder Waraich, Ruminder Sekhon

Cryomodule assembly – Devon Lang, James Keir, Student

Cabling – Sean Wang

Technical support – alignment, cryogenics, HLRF, machine shop

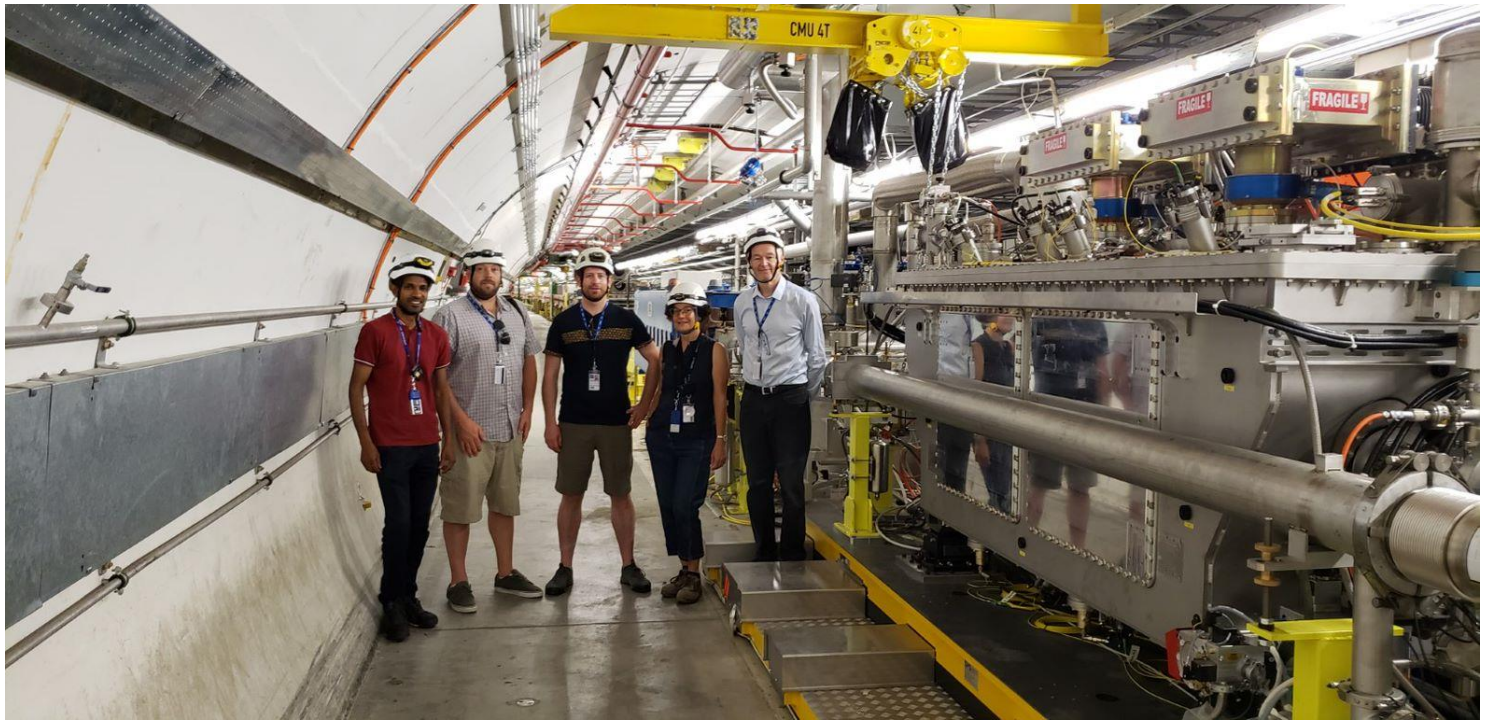
Administrative: Procurement, Finance

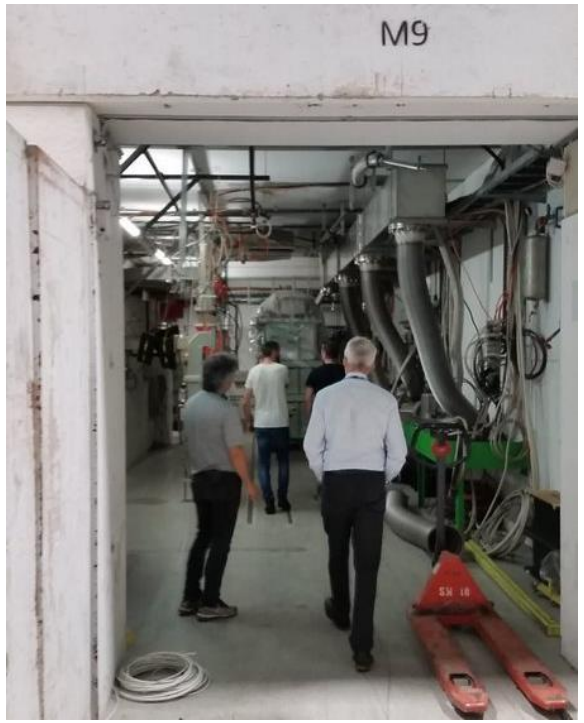


# CERN/TRIUMF – Hi Lumi technical meeting

June 26-28, 2019 Bob Laxdal (TRIUMF HiLumi Technical Coordinator), Ben Matheson (Designer) and Mat Brownell (Engineer) met with CERN technical personnel to discuss HiLumi cryomodule project

- Discussed deliverables and scope, CERN protocols, gained access to CERN drawing vault and EDMS (document server)
- Toured Crab cryo-module installation in SPS tunnel and SM18 CM assembly area

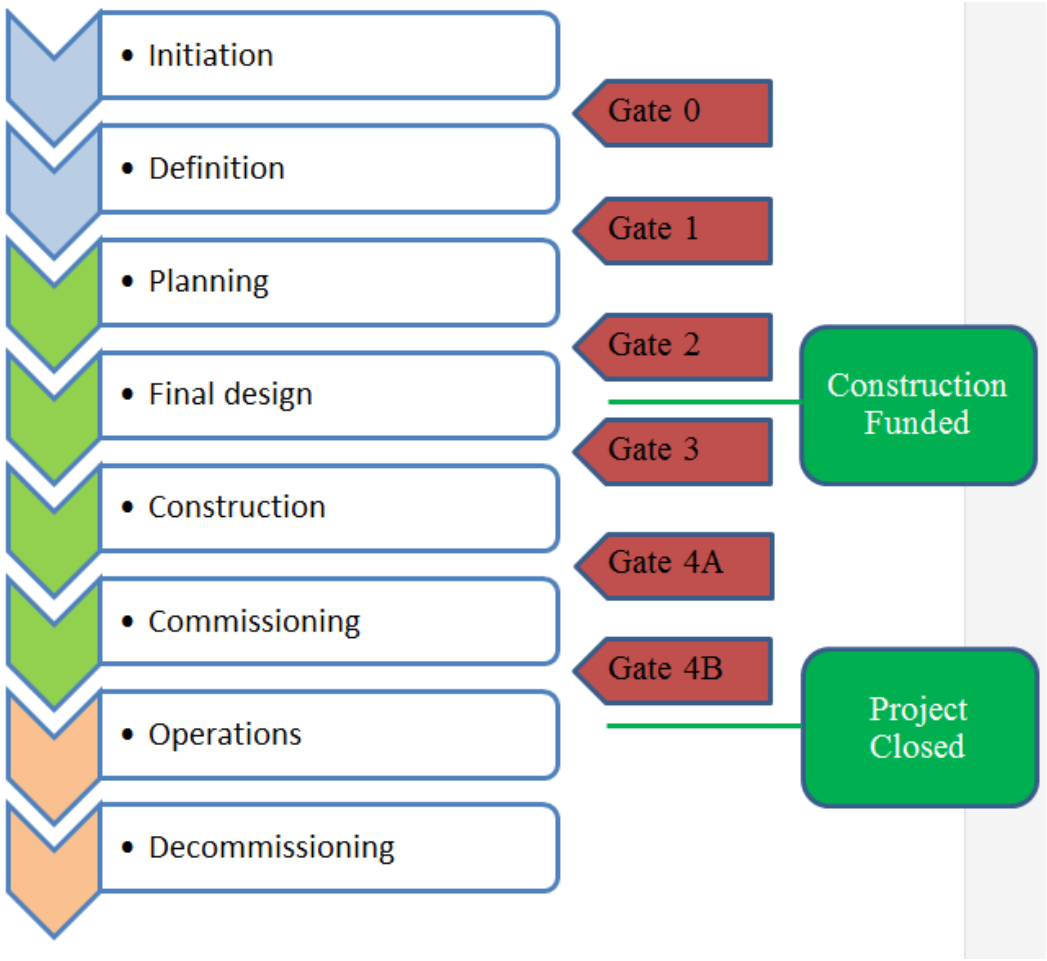


# TRIUMF Review process – next steps

TRIUMF employs a project review protocol similar to the DOE Critical Decision process with four Gates:

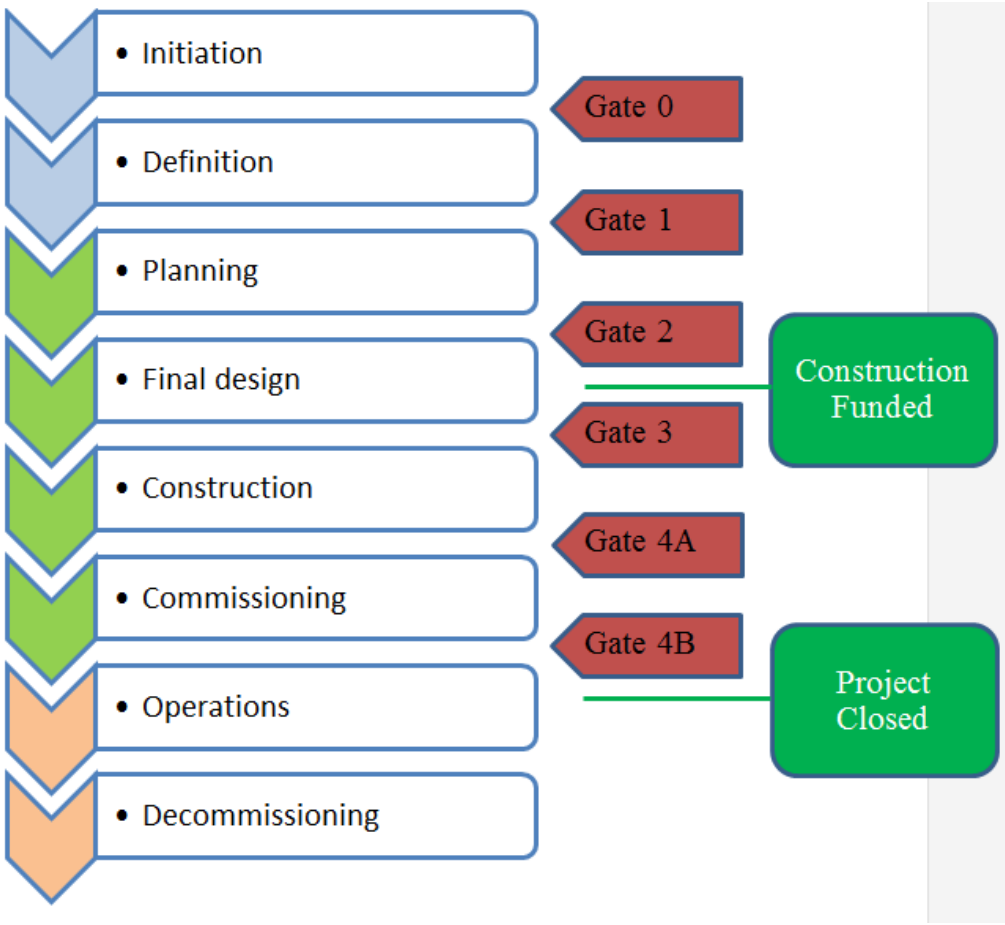
- The project has passed Gate 0 Aug. 2018
- Gate 1 inputs
  - Design Notes covering Conceptual Design
  - Initial Project Plan containing: Level 1 WBS, Initial Budget and Resource Estimates.
  - Initial Hazard analysis and Risk Registry
- Gate 2 inputs
  - Project Plan containing full WBS and budget
  - Resource Loaded Schedule and detailed budget to WBS Level 3
  - Initial Technical Design documentation
- Gate 3 – readiness review for construction
  - Final design documents and specifications released



# Project milestones - proposal

We want to link TRIUMF gate schedule with CERN technical milestones. In principle we would like to get to Gate 3 before standard procurements. The prototype TCM0 could be considered in a Gate 3A.

| Project Milestone | Proposed date | Hi-Lumi input |
|---|---|---|
| Gate 1 | Dec. 1, 2019 | Conceptual design review, preliminary scope def'n |
| Gate 2 | Feb. 1, 2020 | Final scope def'n, detailed budget |
| Gate 3A TCM0 | May 1, 2020 ? | TCM0 design review, released drawings and specifications |
| Gate 3B TCM1-4 | July 1, 2021 ? | Final design review, released drawings and specifications |



# Gate 1 Project definition

- Define a collaboration agreement
- Draft scope of the Canadian contribution to HL-LHC-WP4 including fabrication, assembly and testing
- Project plan released – level 1 WBS, initial budget and resource estimates
- Conceptual design released
- Initial hazard analysis and risk registry

# Gate 2 Project planning

- Define scope of the Canadian contribution to HL-LHC-WP4 including fabrication, assembly and testing
- Include RFD cryomodules and integration into WP4 master planning
- Define main interfaces and responsibility sharing between Canada and CERN
- Define acceptance criteria and compliance with engineering specifications.

# Gate 3A Prototype design

- Prototype cryomodule technical design review complete, released drawings and specifications
- Gate 3A asks whether the project is ready for procurement
- Will define the launch of the TCM0 procurements

# What is TCM0?

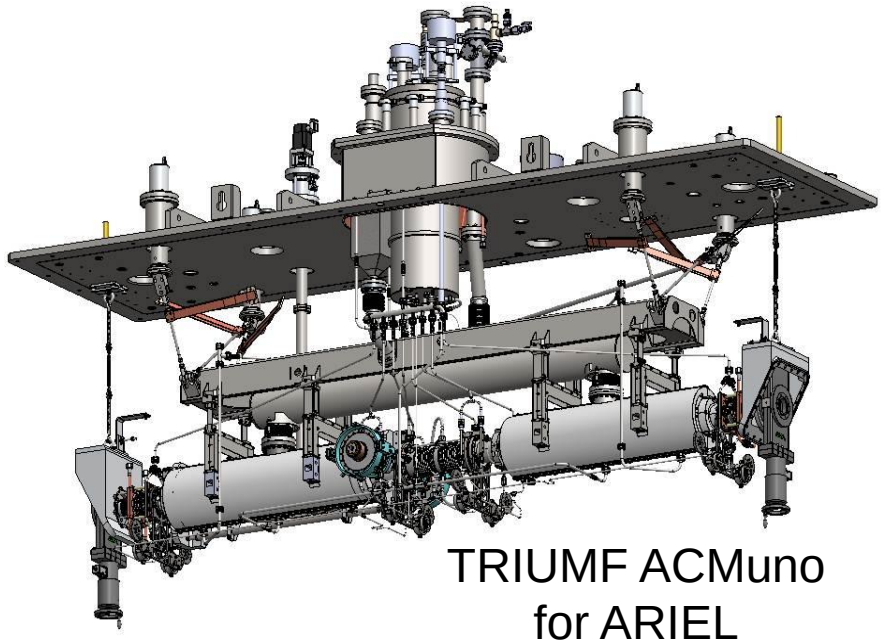
TCM0 is an early prototype of the RFD cryomodule to be built at TRIUMF

TCM0 would engage TRIUMF earlier and significantly reduce schedule risk once series cavities arrive

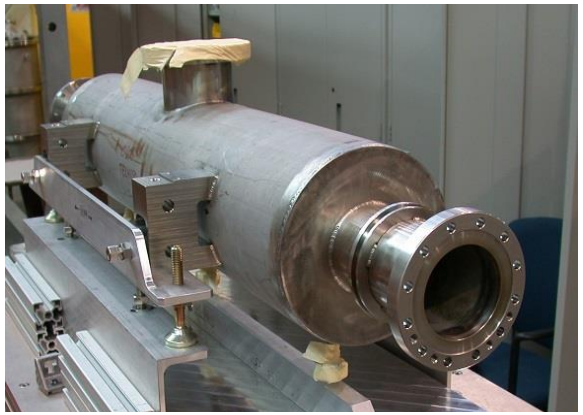
TCM0 would allow early preparation and qualification of tooling , processes, testing well before series production

Would require 2 (or even 1) dressed RFD cavities from AUP at the end of 2020 or early 2021

A dummy cavity could be used in one of the slots to replicate cavity geometry, interfaces and cryo-load (example ARIEL ACMuno)



TRIUMF ACMuno for ARIEL

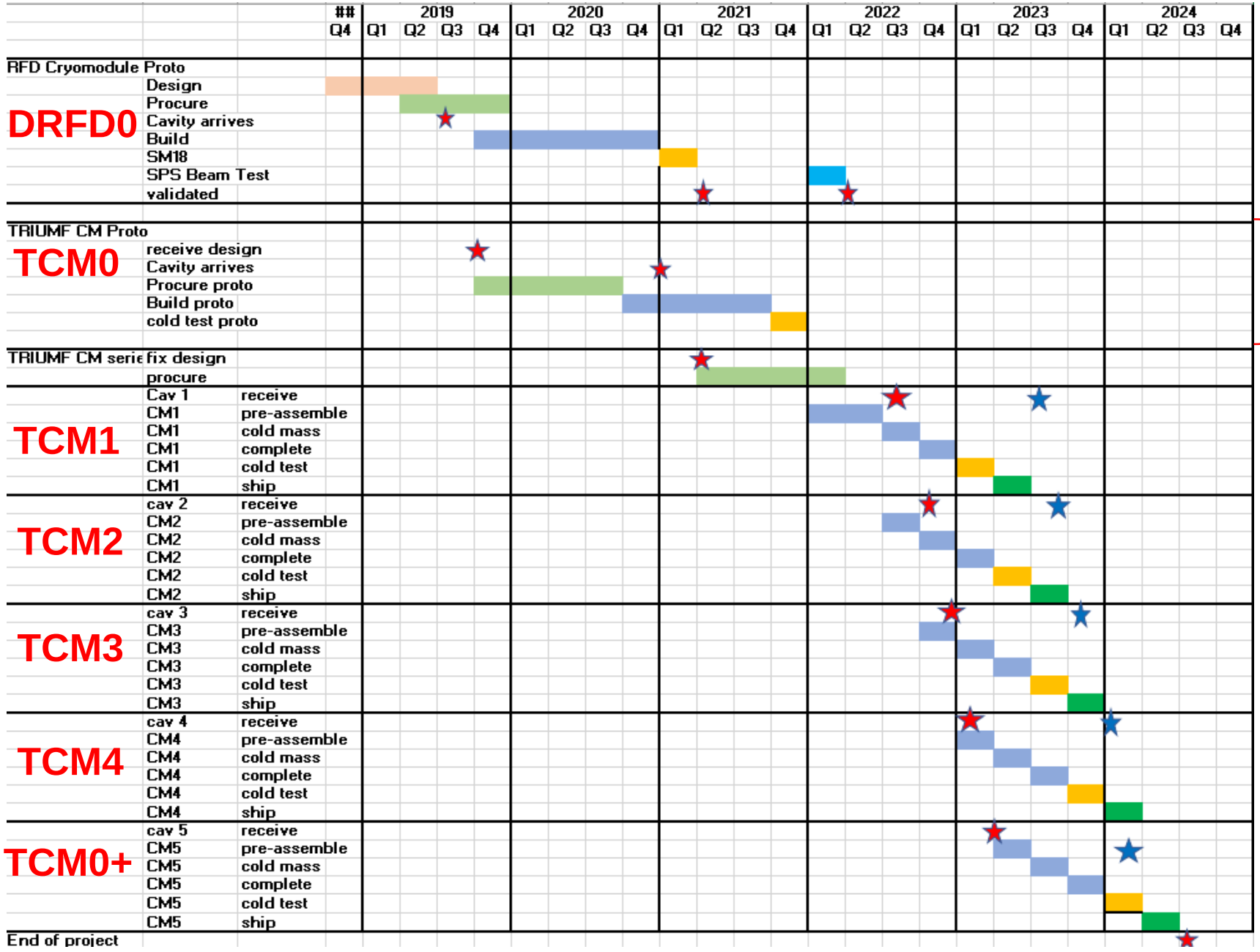


Dummy cavity

# Gate 3B – final series design

- Production cryomodule technical design review complete, released drawings and specifications
- Will define the launch of the TCM1-4 procurements
- How to resolve the schedule mismatch between the TRIUMF schedule and the testing at SM18 and in the SPS
  - We would like to launch final procurements starting July 1, 2021
  - RFD SM18 test is scheduled for completion Oct. 1, 2021
  - RFD SPS test will get results July 1, 2022
- Point for discussion

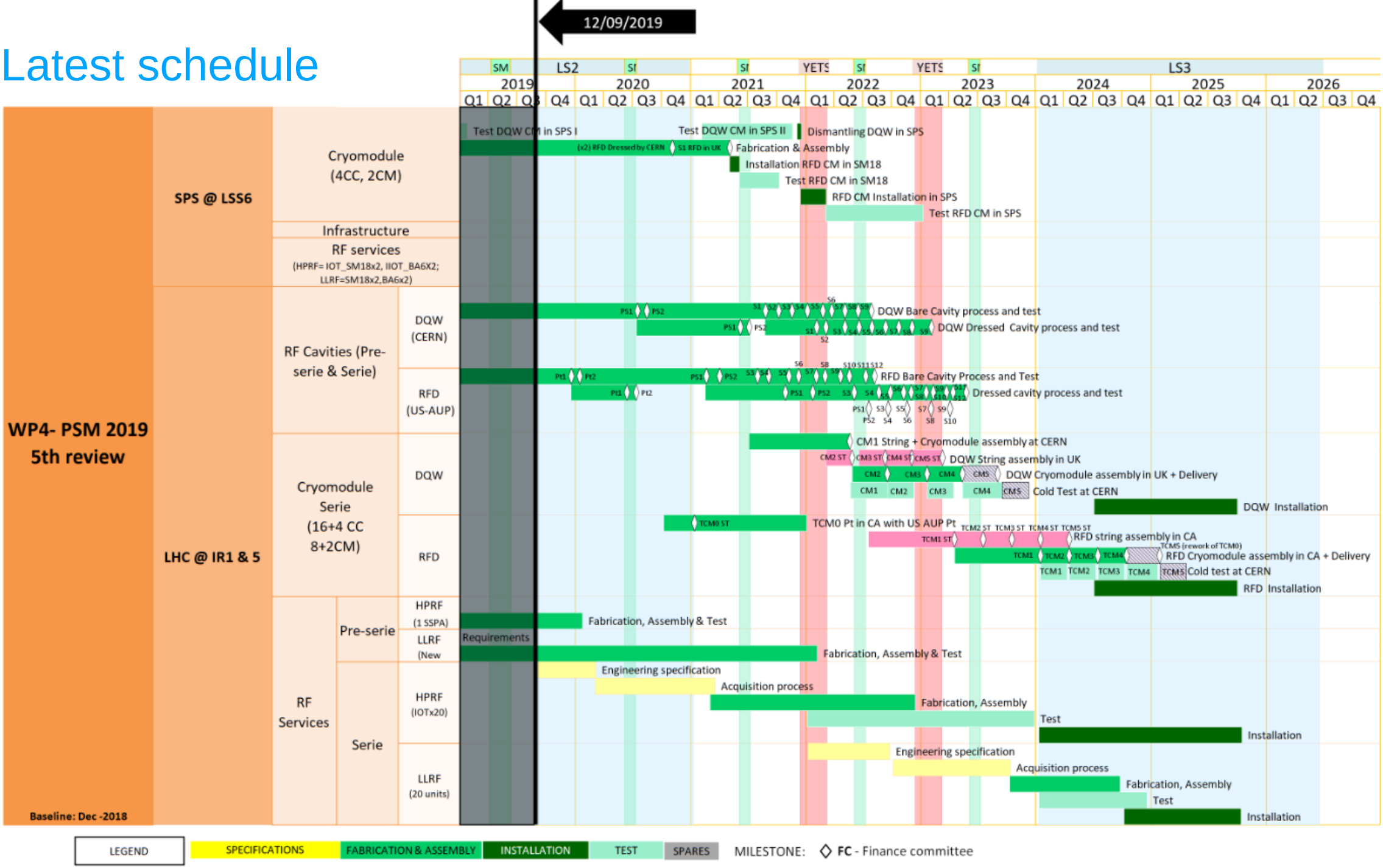
# Proposed schedule in Oct. 2018



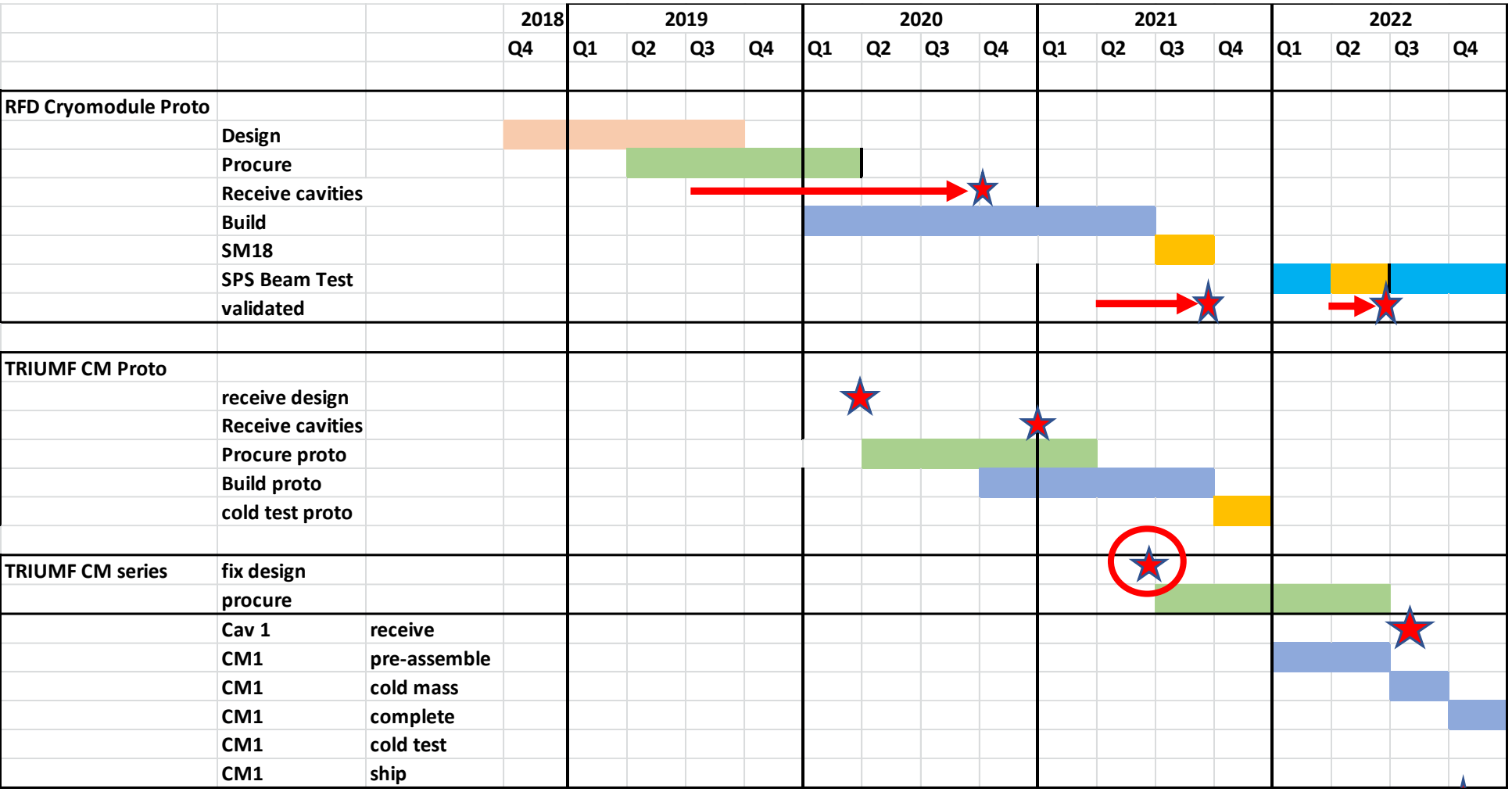

TCM0: Would engage TRIUMF earlier and significantly reduce schedule risk once series cavities arrive

TCM0+ - retro-fit for LHC as required

# Latest schedule



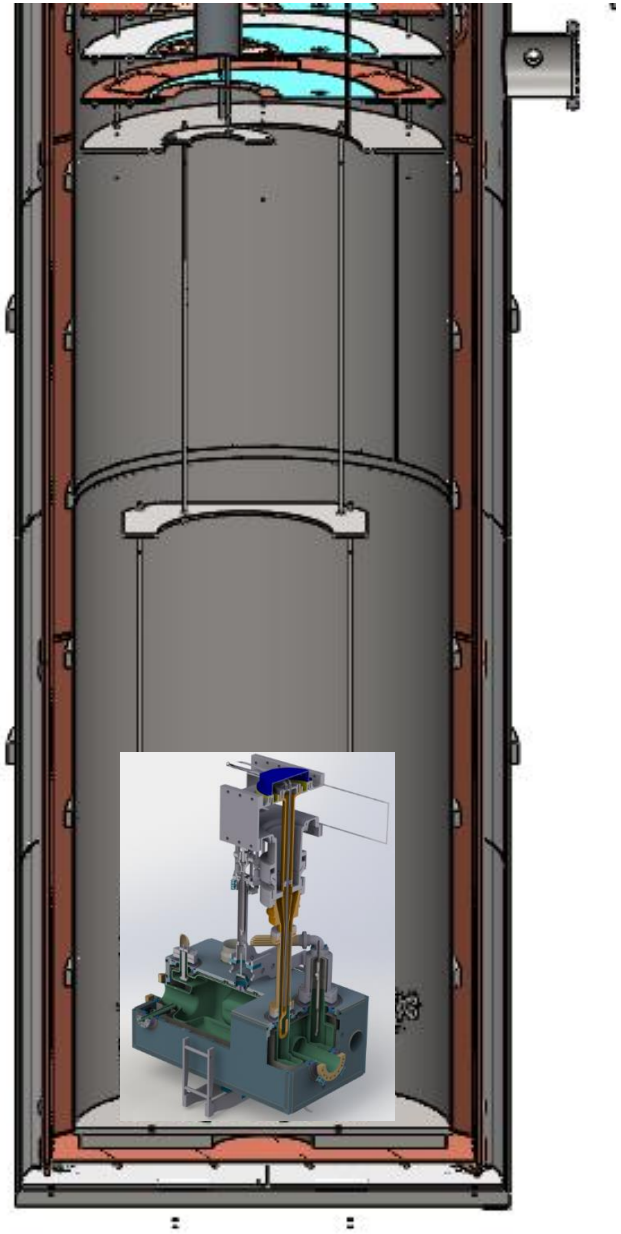
# Updated schedule in Oct. 2019




SM18 and SPS RFD tests are after the date TRIUMF would like to fix the CM design

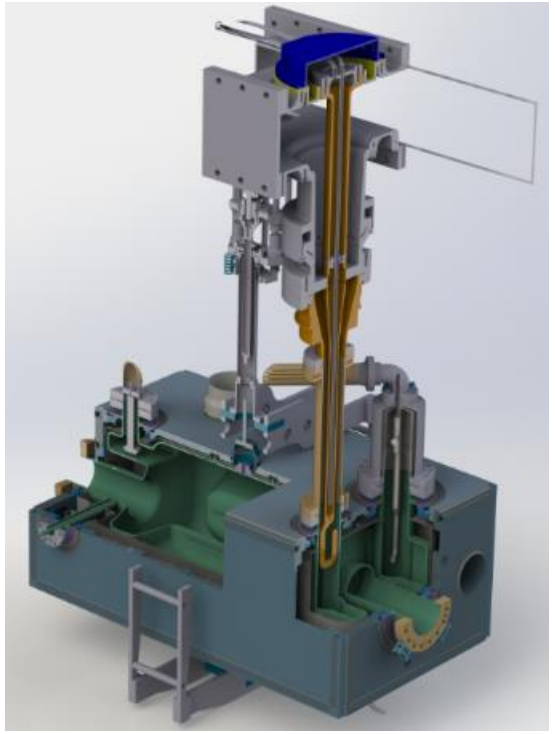
# Cavity Tests at TRIUMF

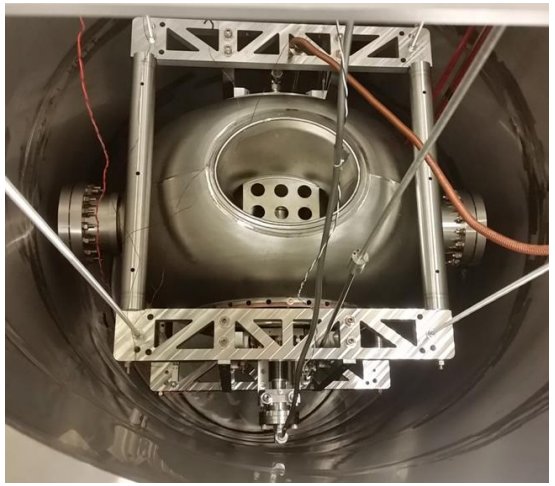
- Propose to receive and test (a subset of?) the cavities at TRIUMF in our large cryostat
  - Best would be to cold test as delivered without venting
  - can the first units be delivered with a test coupler?
- Subsequent test would be to assemble a single cavity with FPC and test the fully assembled unit
  - Would be the only opportunity for a full qualification before cryomodule assembly



# Required inputs

- Solid works model of dressed cavity – will be used for planning cavity testing program after receipt of cavity from AUP at TRIUMF
- Discussion of timing of deliverables and configuration of dressed equipment from AUP
- Would need an rf source from CERN before cavity delivery





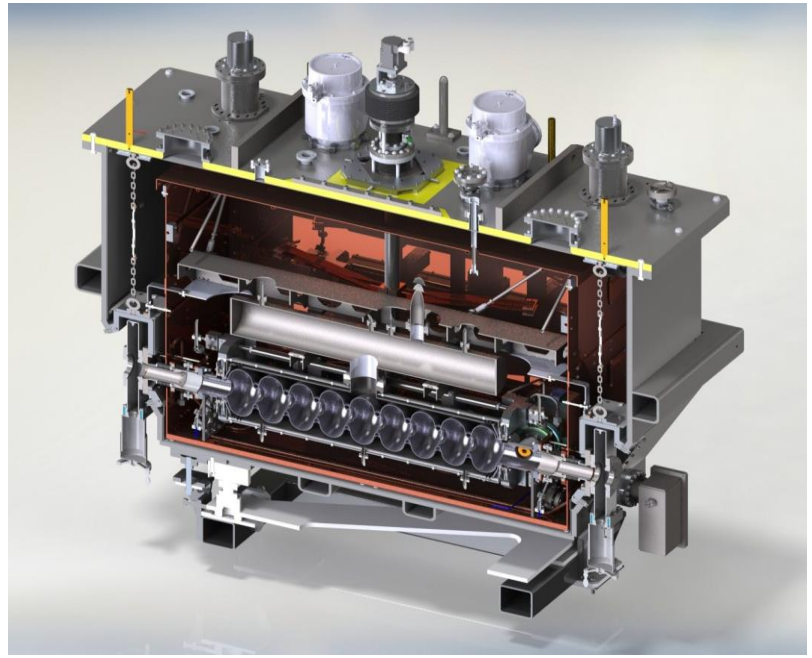
# Goals for 2020

- Execute Gate 1, Gate 2 and Gate 3A at TRIUMF in consultation with CERN
  - Establish scope
  - Agree on detailed design for TCM0
  - Establish acceptance criteria for cavities at TRIUMF
  - Establish acceptance criteria for cryomodules at TRIUMF
- Launch procurement of TCM0, fixtures and tooling

# VECC Injector Cryomodule Transport

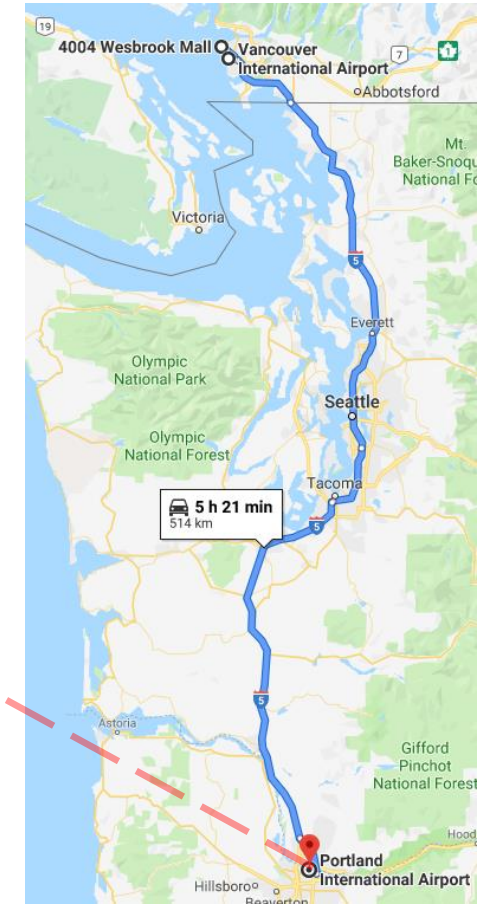
# Transport of VECC ICM2

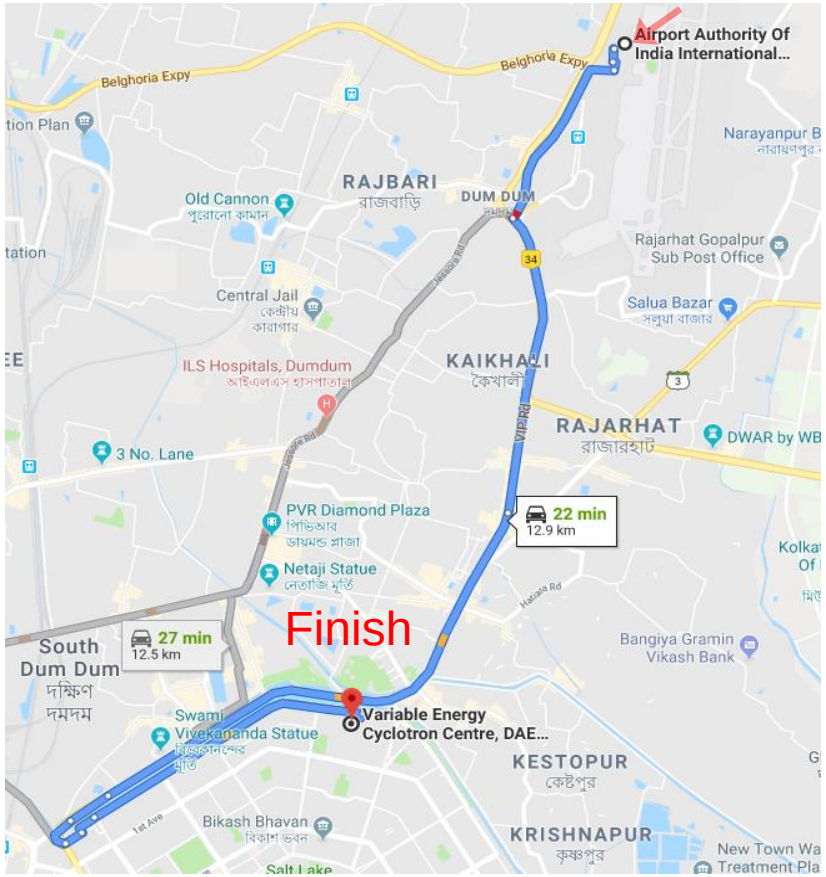
- In 2008 TRIUMF signed an MOU for the construction of a second Injector Cryo Module (ICM2) to be sent to VECC.
- This module is a twin to ICM1 that is currently operational at TRIUMF
- ICM2 hosts one nine cell 1.3GHz cavity, two 50kW FPC, coaxial HOM dampers



# Journey to Kolkata

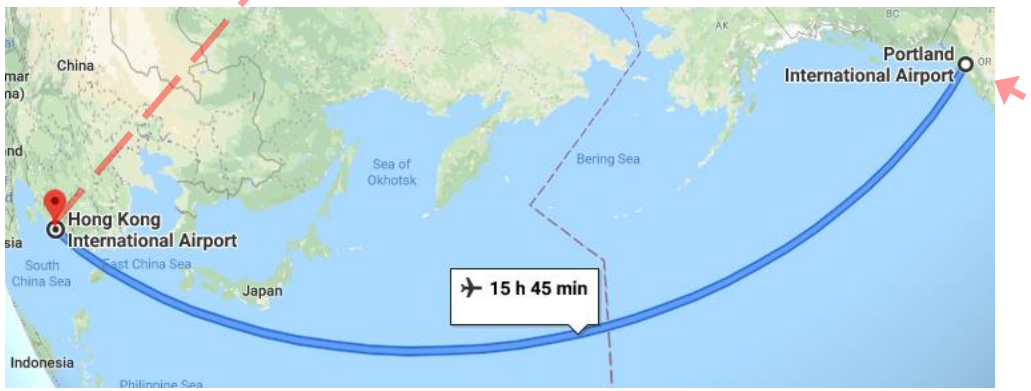

Start



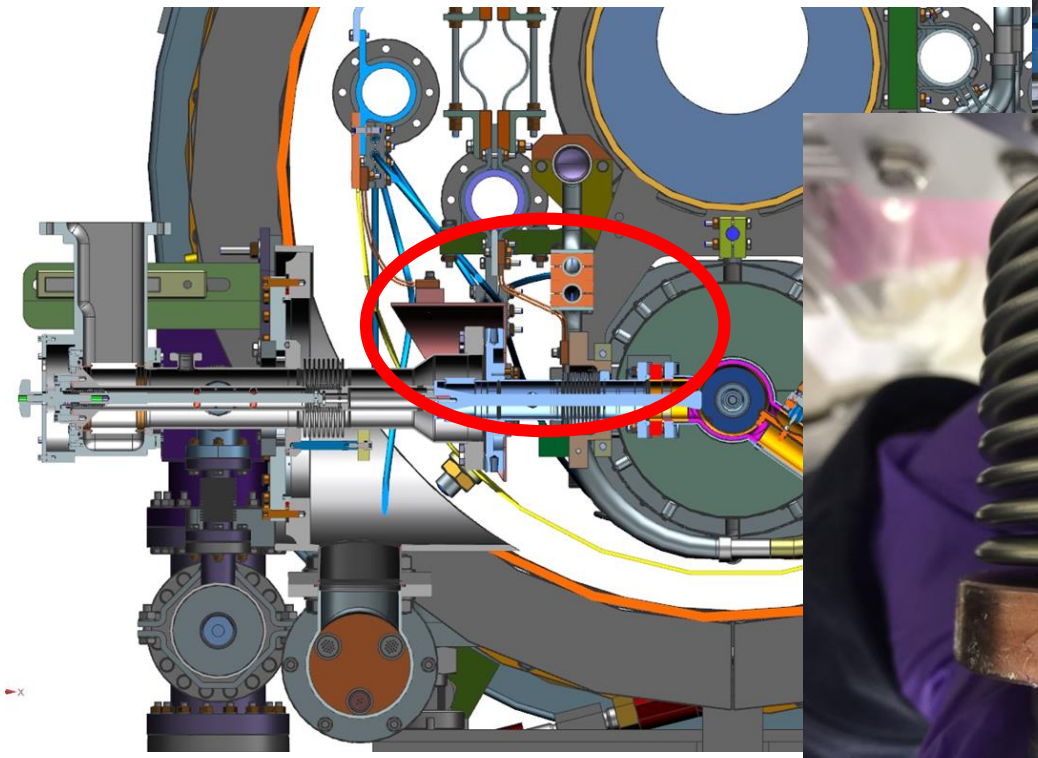

Total travel to VECC includes;

- 530 km of road travel
- 20 hours of flight time
- 5 freight transfers
- Via YVR, PDX, HKD and CCU



# Lessons Learned from LCLS-II



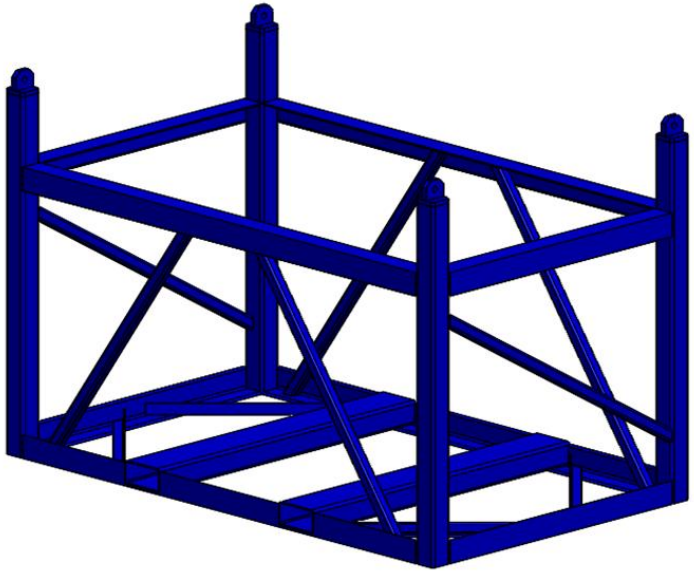


- During shipment from FNAL to SLAC it was found that a number of bellows had cracked and vented the cavity string to atmosphere.
- It was found that vibration from road noise had driven a resonance and it had fatigued in the 3400 km (2130 mile) trip.

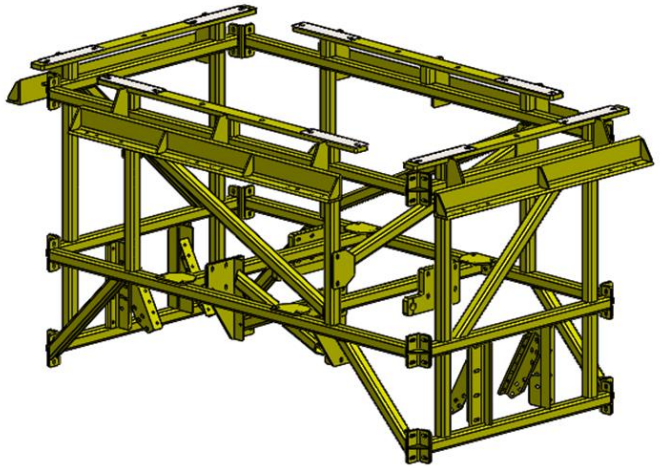
Tom Peterson – TTC 2019

# Transport Frame

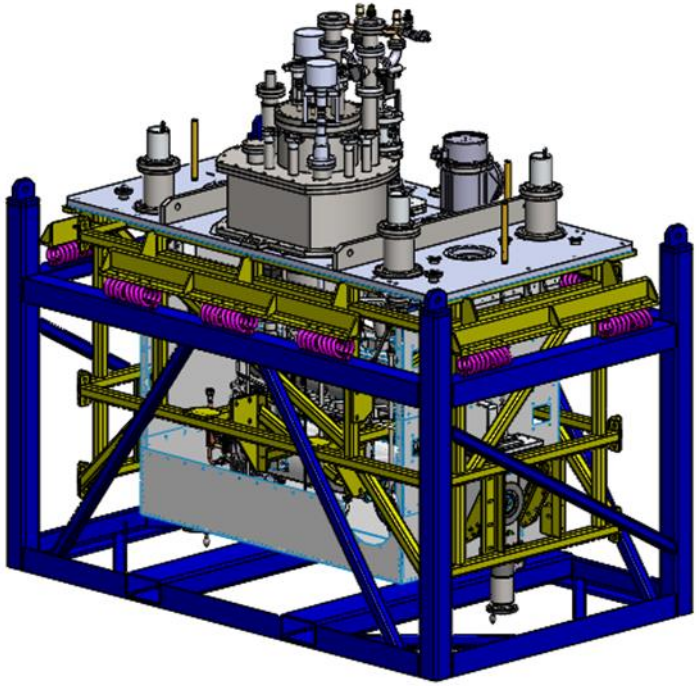




Shipping Frame



Skeleton Support Frame



Complete Transport Frame

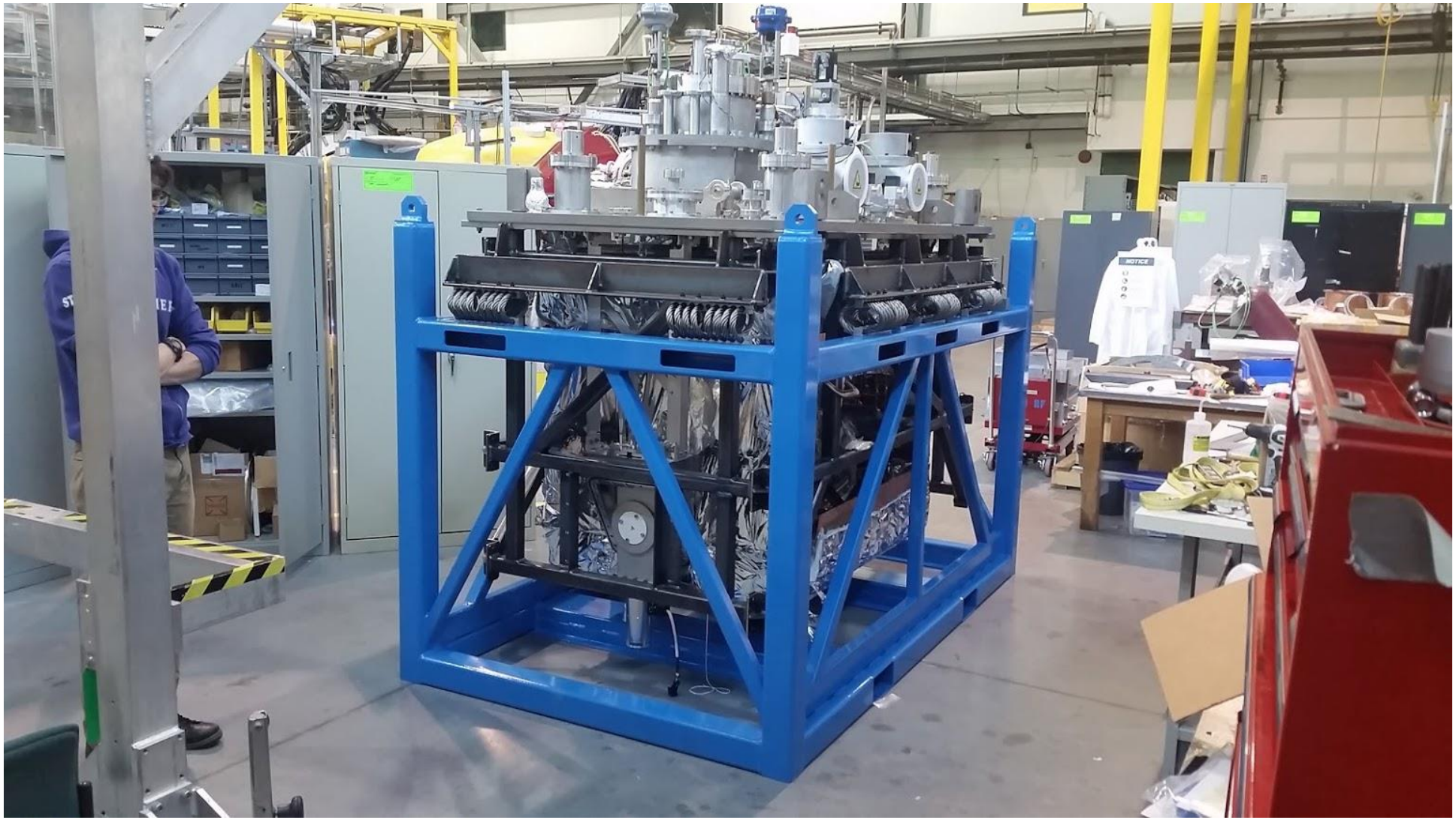
- After numerous simulations it was determined that ICM2 would be too fragile and sensitive to vibrations to transport as one complete device.
- The Yellow Frame is designed to provide support to prevent yielding of the internal components.
- The Yellow Frame is supported in the Blue Frame using ten wire rope springs to provide vibration and shock isolation.

# Transport frames

The two frames – internal frame not yet painted

# Lid and cold mass lowered into frame





# Wire Rope Isolators

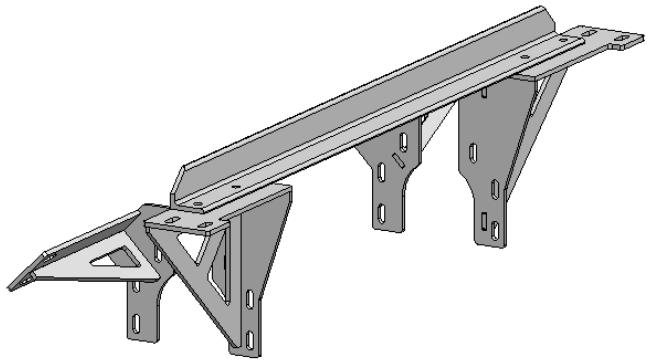


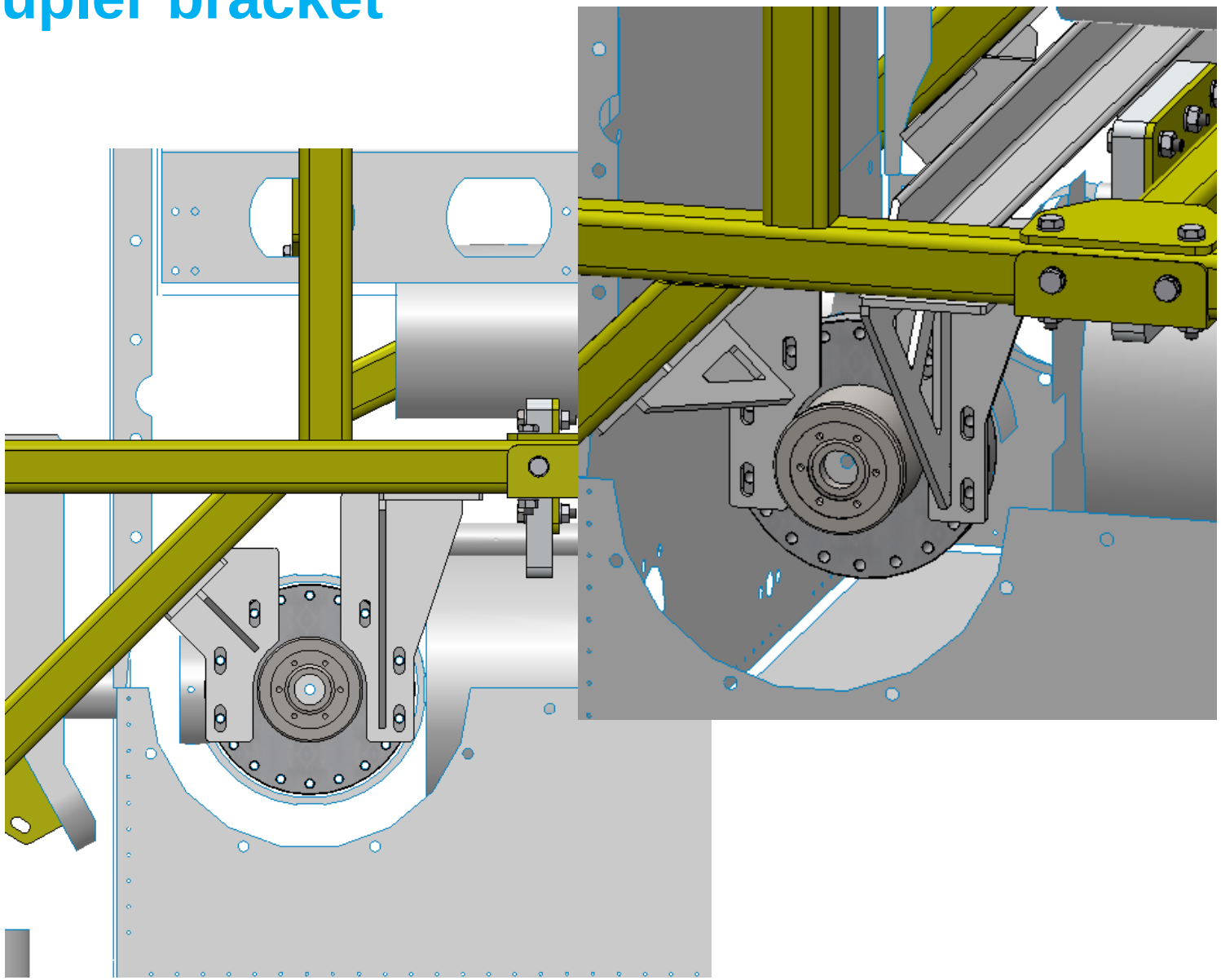
Springs are VibroDynamic FH60-3608-C2 wire rope isolators

# Custom supports – ie Coupler bracket



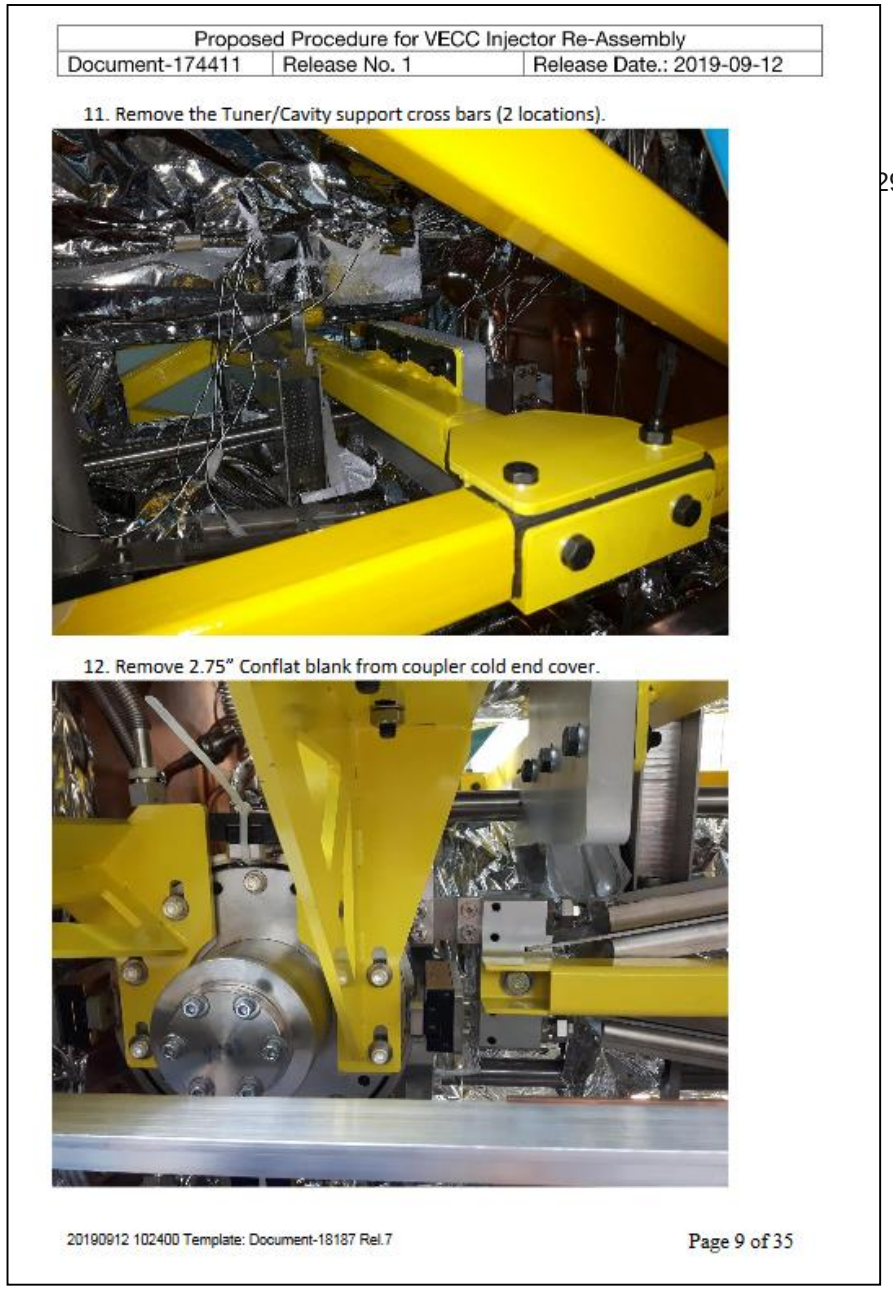
- Brackets are fabricated from water jet cut and welded ¼” steel plate.
- Support bar is 2x2 ¼” steel L-angle
- Bracket connects to the coupler over the cover flange allowing attachment of existing aluminum supports.
- All bolted connections are slotted to allow adjustment.





# Disassembling and Packing ICM2

- The ICM was dissembled, small components were documented then packed into 10 individual boxes, with a combined weight of 275 kg (600 lb)
- The vacuum tank was placed on a pallet and crated separately.
- The cold mass and top assembly were then installed in the yellow frame and critical components were attached to the frame.
- Photos were taking during the entire process to create a set of assembly instructions for the technicians at VECC to follow, to put ICM2 back together.


Proposed Procedure for VECC Injector Re-Assembly

| Document-174411 | Release No. 1 | Release Date.: 2019-09-12 |
|---|---|---|

11. Remove the Tuner/Cavity support cross bars (2 locations).

12. Remove 2.75" Conflat blank from coupler cold end cover.

20190912 102400 Template: Document-18187 Rel.7 Page 9 of 35

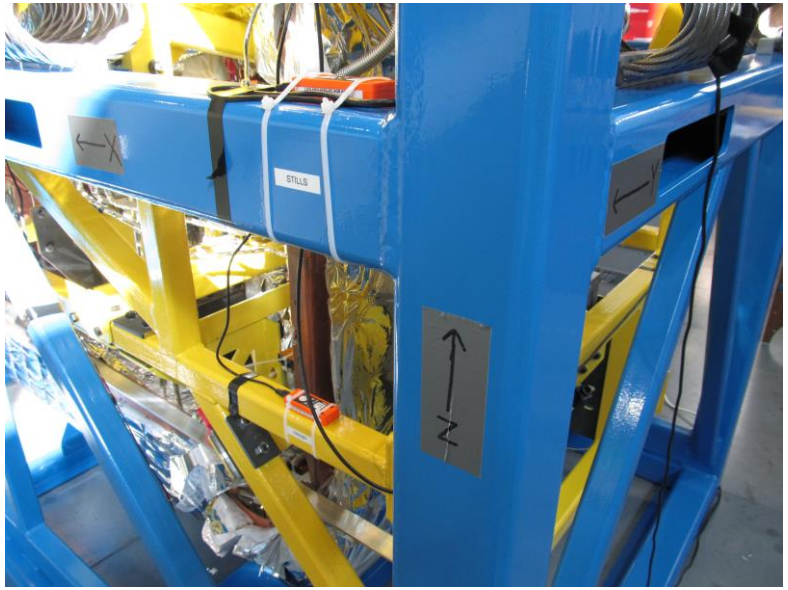
# Vibration and Shock Monitoring




MIDE – SLAM STICK

3 axis accelerometer
8 GB storage
12.5 to 3200 Hz sample rate
22 hour internal battery

Three SLAM STICK® sensors are installed and two 7.2 Ah AGM batteries are installed keep the sensors charged for 15 days.

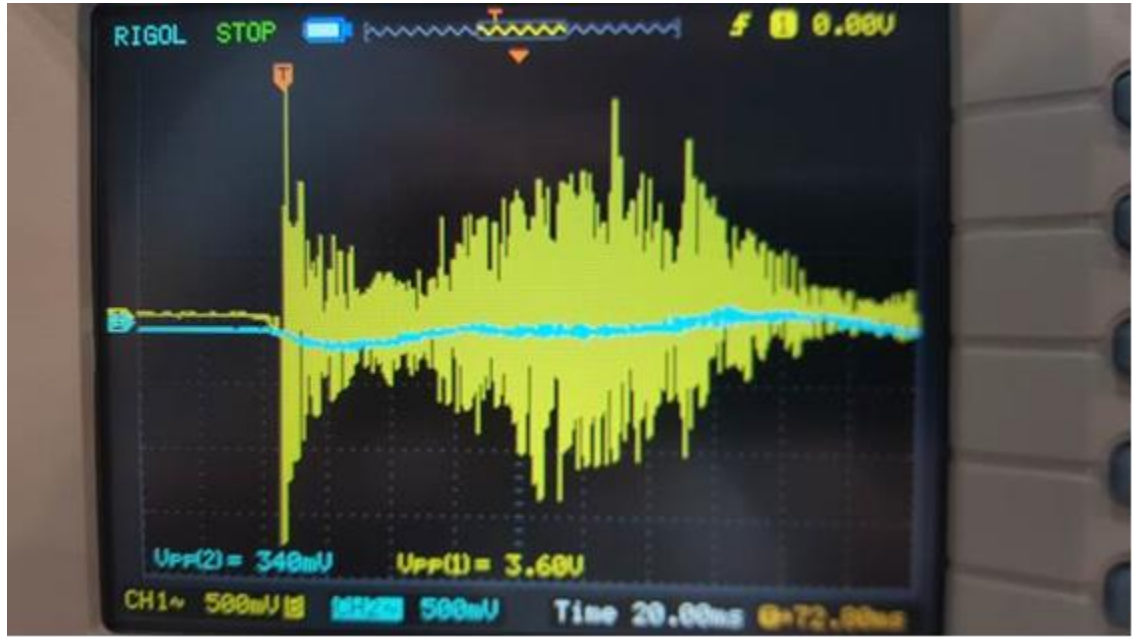



Two are installed on both yellow and blue frame, configured for high resolution vibration study sensors


One configured for low resolution shock/environmental watchdog w/ 40 days of memory

# Vibration Testing and Final Crating






Results from a drop test that shows the attenuation of shock loads between outer (CH1) and inner frame (CH2)

This test showed a 90% reduction in a 3g external shock


ICM2 was then packed in three wooden crates

Shown loaded on an air-ride flat deck as it begins long journey to VECC

# Summary

TRIUMF has secured funding to construct and deliver five RFD Crab Cavity cryomodules to the HiLumi LHC Project in Collaboration with CERN and Hi-Lumi partners.

We would like to set the dates of near term TRIUMF project milestones, to finalize the scope, to discuss acceptance tests after receipt of cavities and after assembly of the modules.

TRIUMF has gained recent experience in transporting a cryomodule to India – now in transit.