

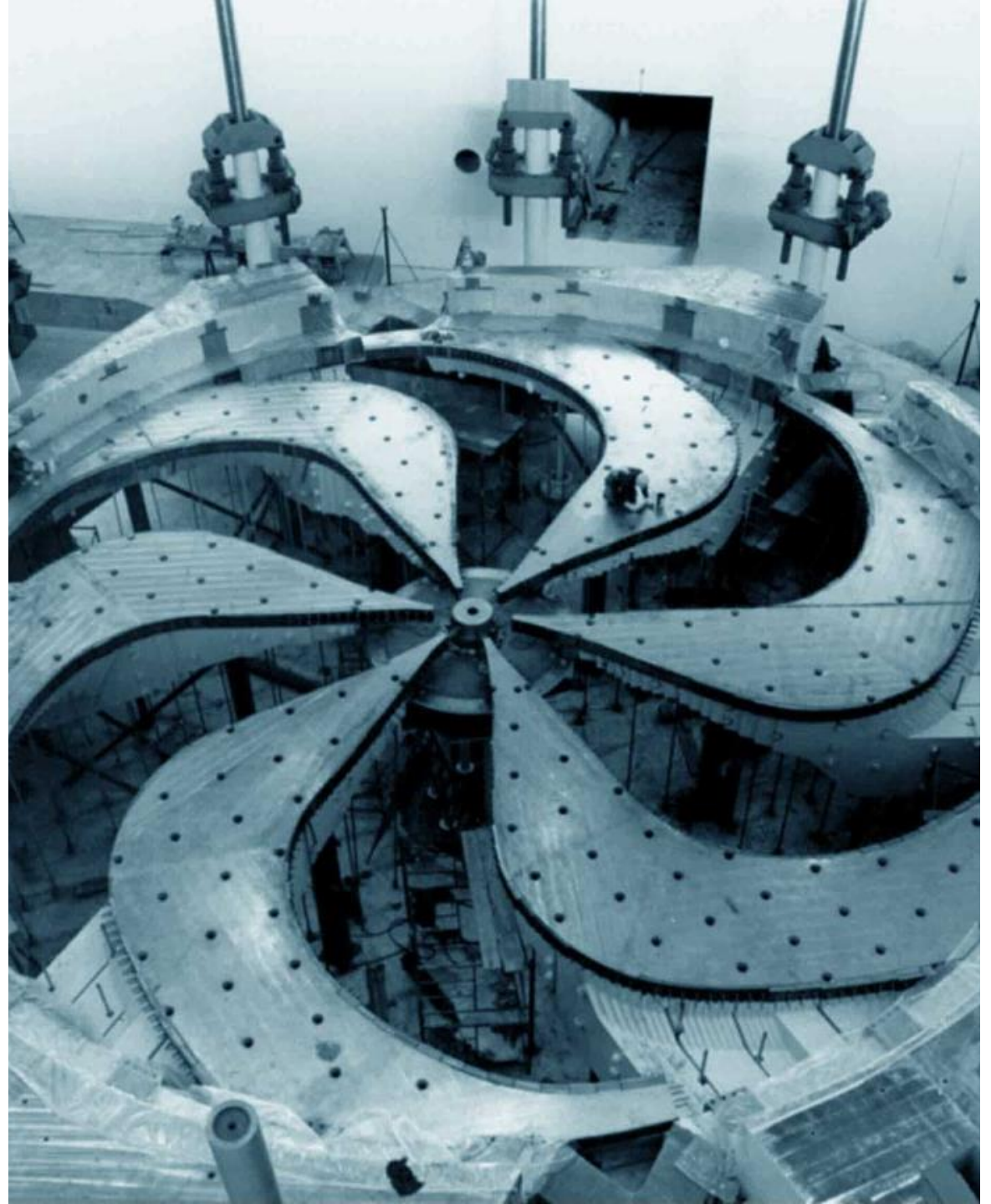
Series RFD Cryomodules for HL-LHC CC

Bob Laxdal

TRIUMF Hi-Lumi Technical Coordinator

International Review of Crab Cavity
System and Production Plan

June 19-21, 2019





Description

- Scope of the Canadian contribution to HL-LHC-WP4 including fabrication, assembly and testing
- Planning of the RFD cryomodules and integration into WP4 master planning
- Main interfaces and responsibility sharing between TRIUMF and CERN

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

Frédéric 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

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)

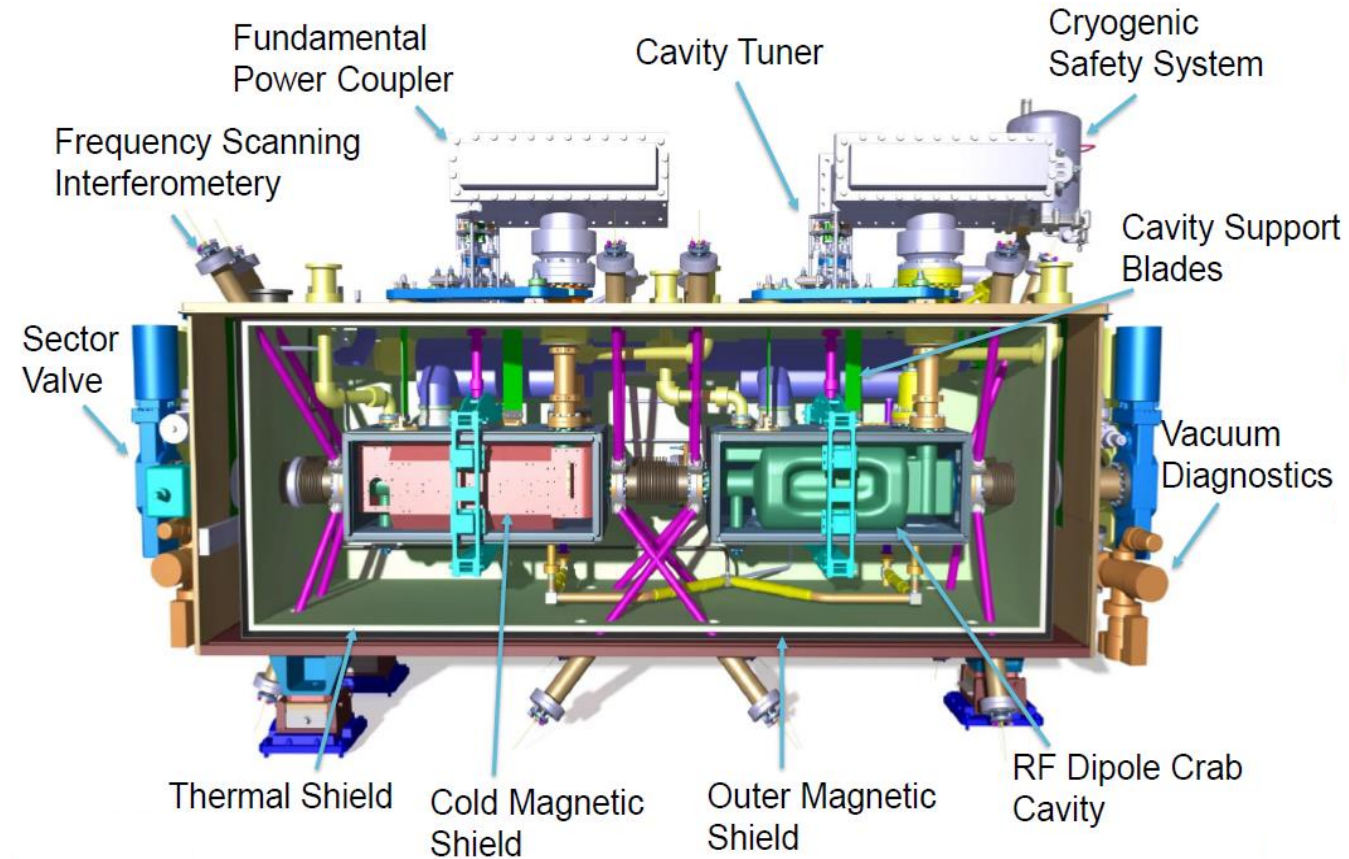
Concerning

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

HiLumi RFD Cryomodules

TRIUMF shall contribute to the construction of five (5) RFD Crab Cavity cryomodules

- Qualified RFD crab cavities will be delivered to TRIUMF
- TRIUMF will assemble the cavities into cryomodules and qualify the CMs
- Deliverables:
 - Documentation of fabrication and performance tests
 - The shipment of the five Cryomodules to CERN, according to the packaging and transport specifications
 - All tooling necessary for the maintenance and repair at CERN

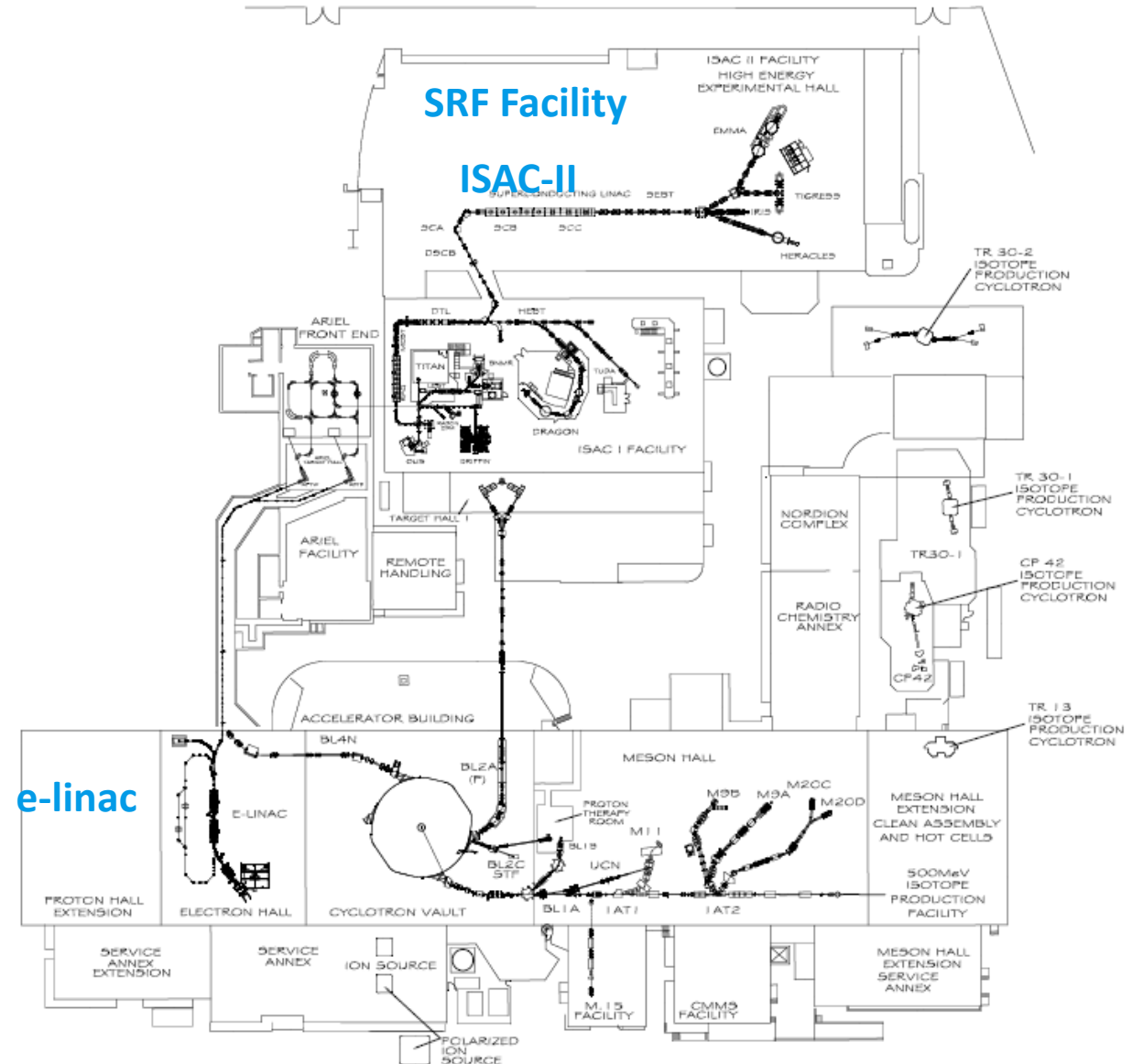


WP4 RFD Status and Collaborations

- RFD-SPS cavity fabrication started at CERN, cryostating to be performed at UK – SM18 test Q1 2021
- RFD-HL-LHC dressed cavities in-kind contribution from US-AUP
- RFD-HL-LHC cryostating is approved to be an in-kind from Canada-TRIUMF

TRIUMF SRF Program

- Program initiated in 2000 to support the development of the ISAC-II heavy ion linac
- TRIUMF now has two SC linacs installed – the 40MV ISAC-II heavy ion linac and the 30MeV ARIEL 1.3GHz electron linac
- We have an active program in student based SRF research and Work for Others to augment our operational capabilities

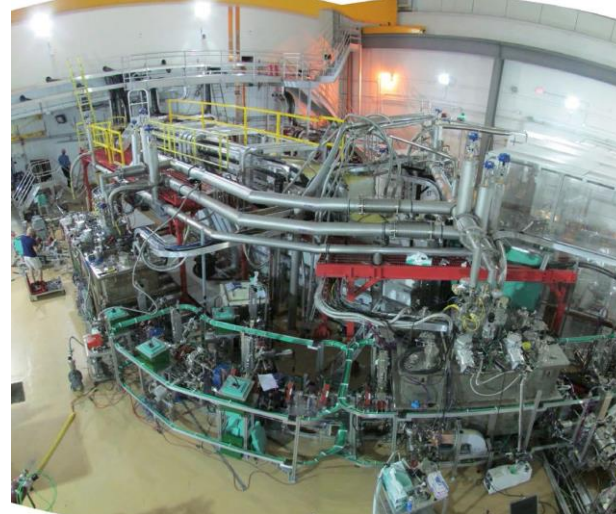


TRIUMF SRF Accelerators

40MV ISAC-II
SRF heavy ion
linac @ 106MHz
- operational
since 2006



30MV ARIEL SRF
10mA electron
linac @ 1.3GHz
- first beam
2014



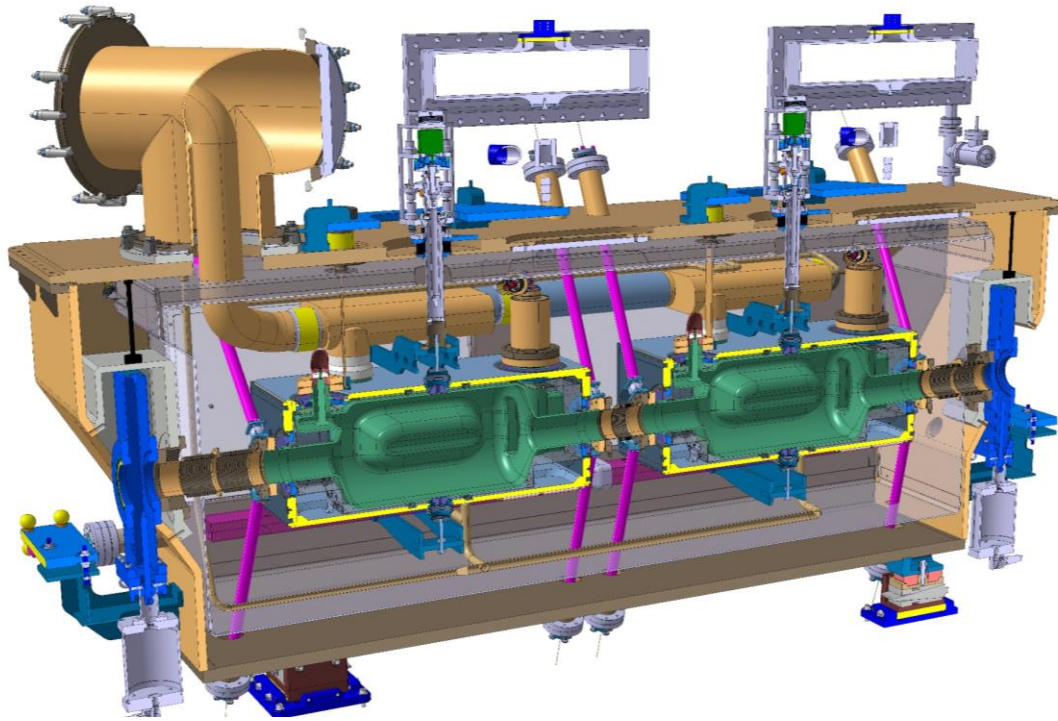
TRIUMF and SRF Cryomodules

TRIUMF has designed 5 CM variants and fabricated and tested 11 CMs in the last 14 years

The ARIEL ACM cryomodule (below) is similar in size and complexity to the Hi-Lumi RFD cryomodule

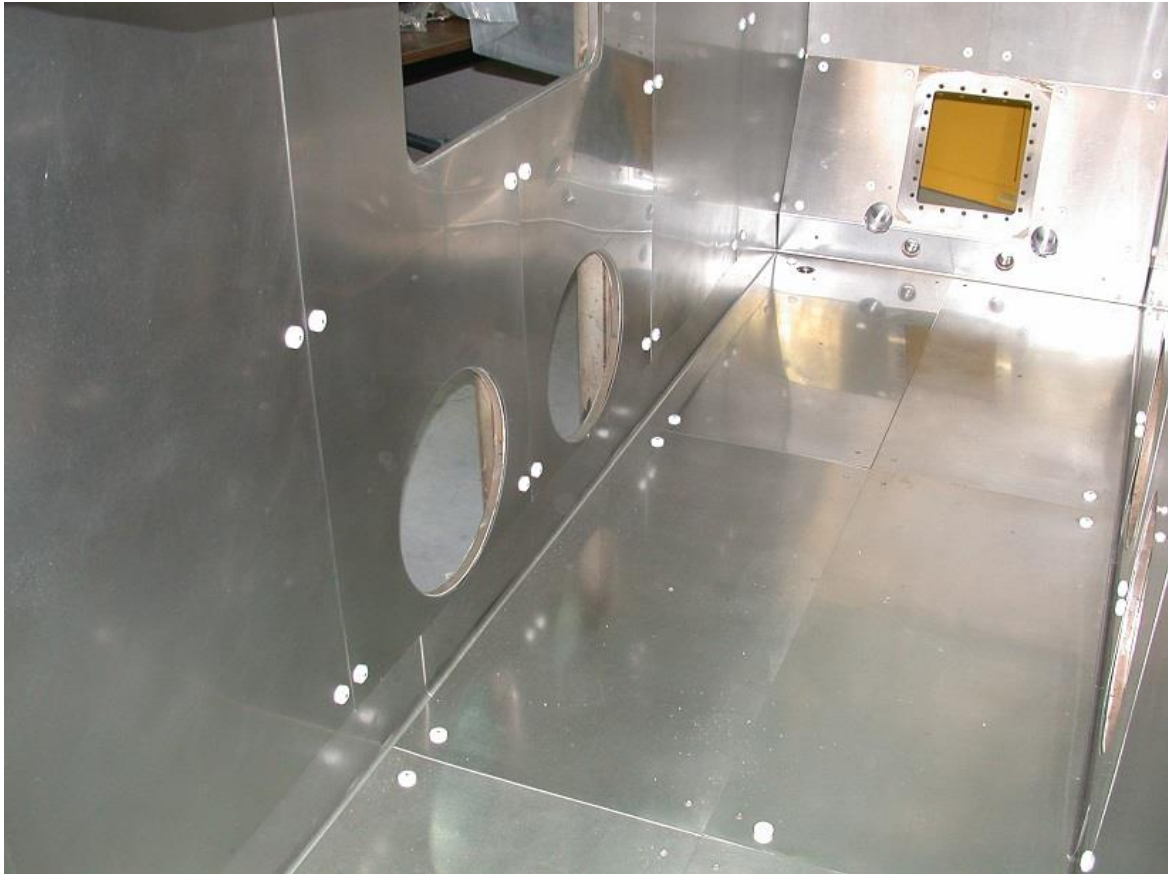


RFD Cryomodule vs ARIEL Cryomodule



RFD cryomodule overlaps in size and complexity with e-Linac accelerating cryomodules developed and fabricated at TRIUMF

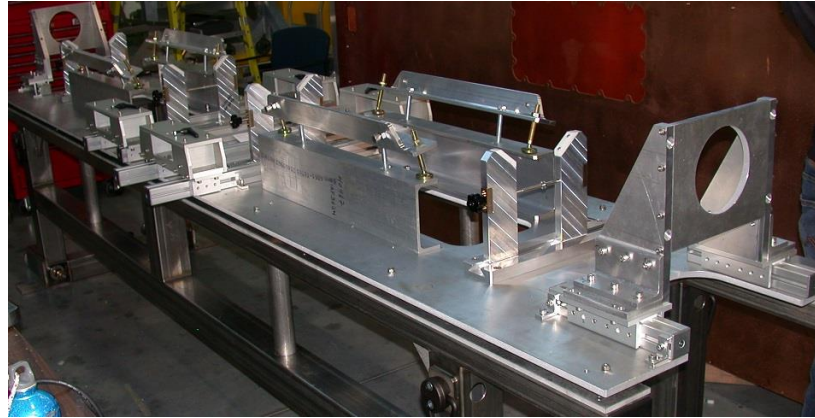
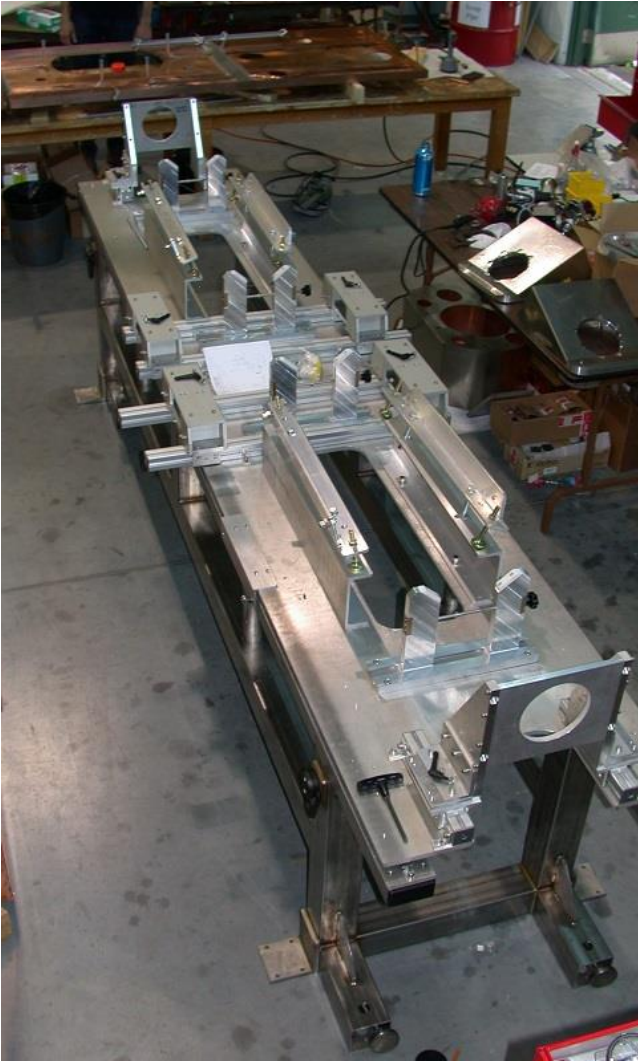
Tank and mu metal



Thermal Shield



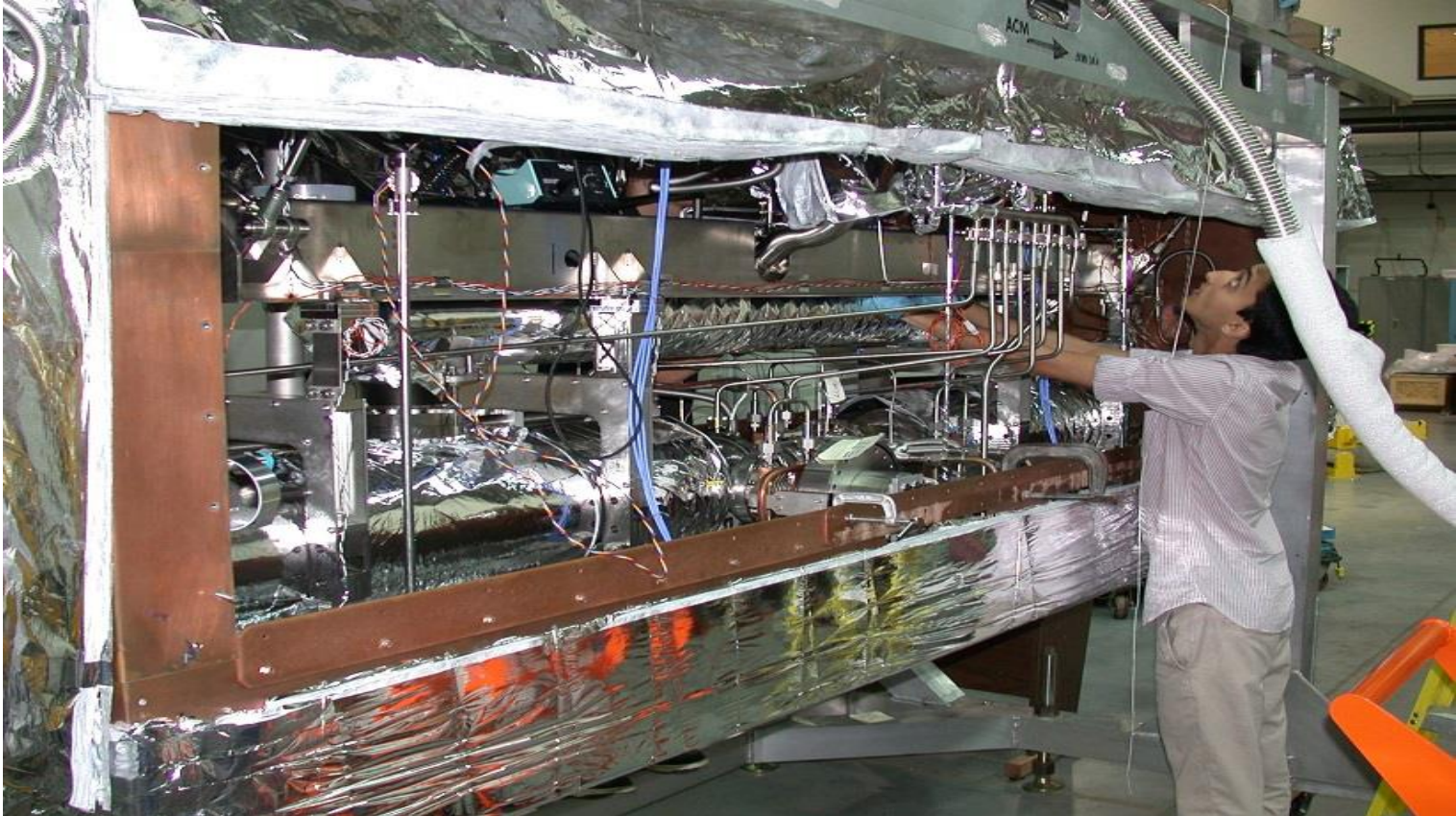
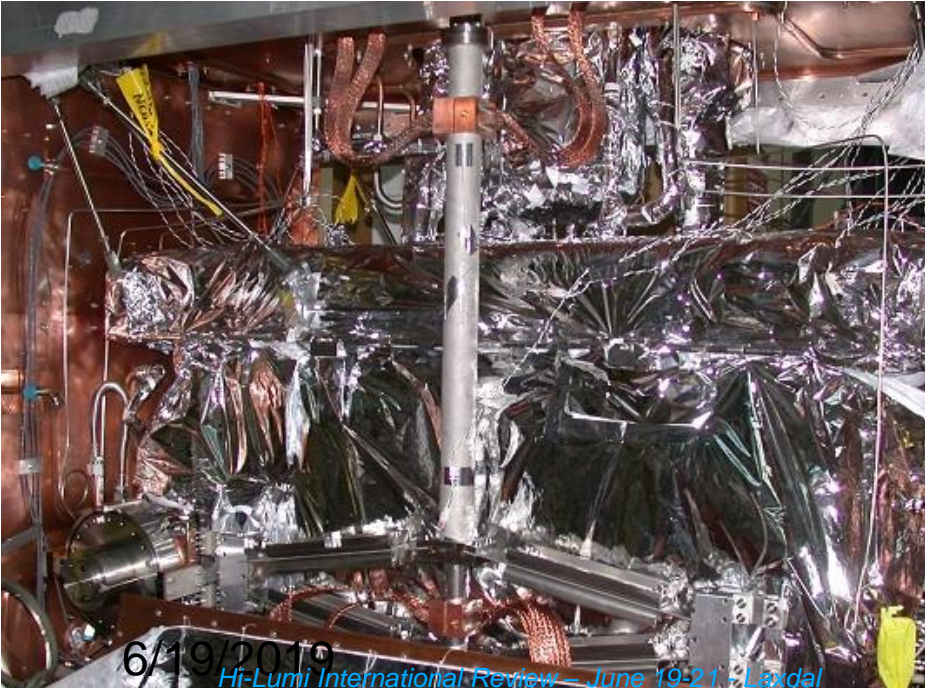
Clean Room Assembly



Top Assembly Frame



ARIEL Top Assembly



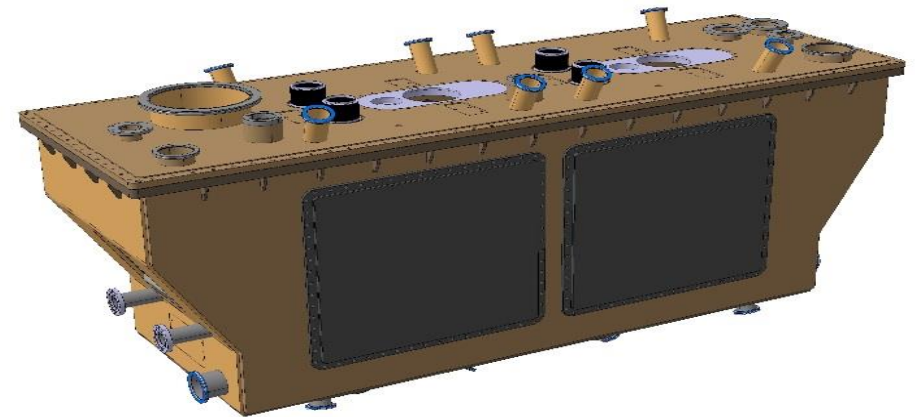
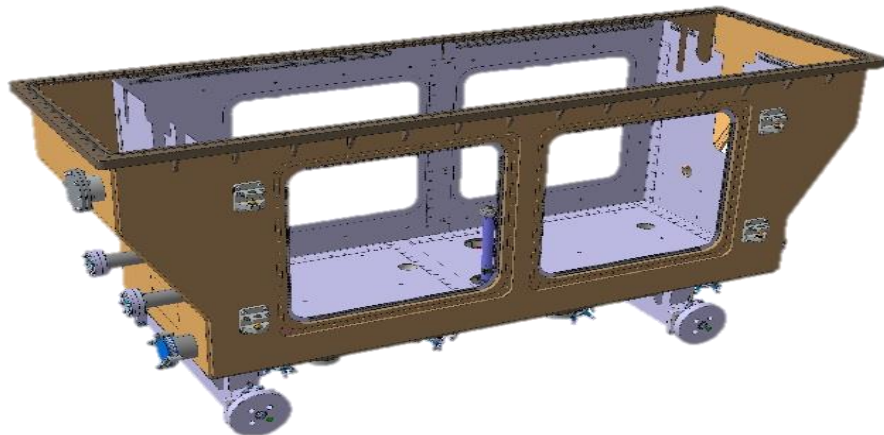
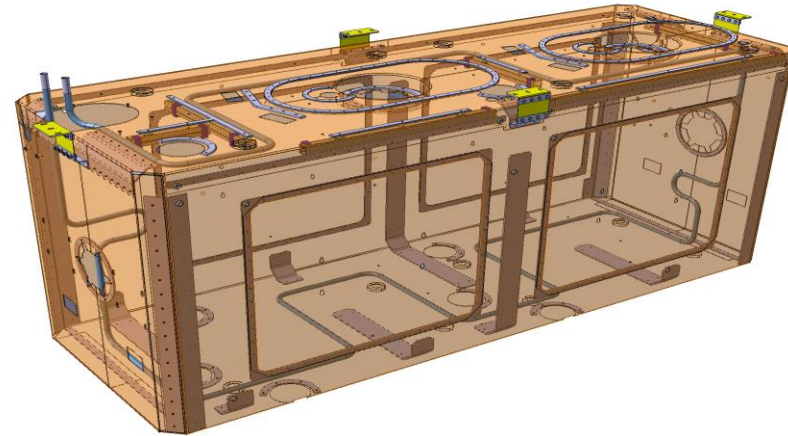
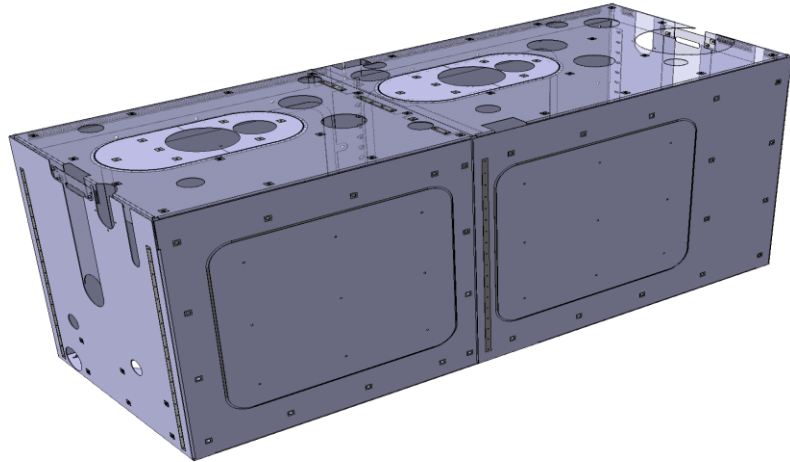
6/19/2019
Hi-Lumi International Review – June 19-21 - Loxdal

ARIEL Final Assembly

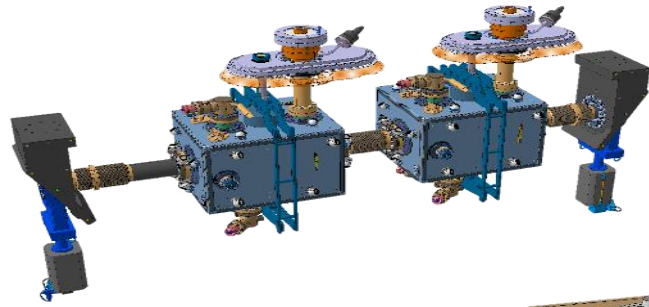


Hi-Lumi Cryomodule Components

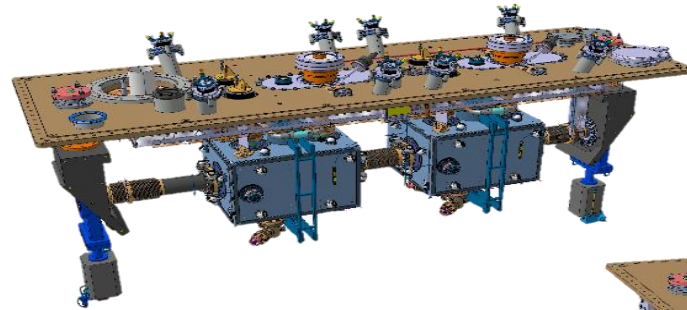
Basic building blocks looks like e-Linac cryomodule



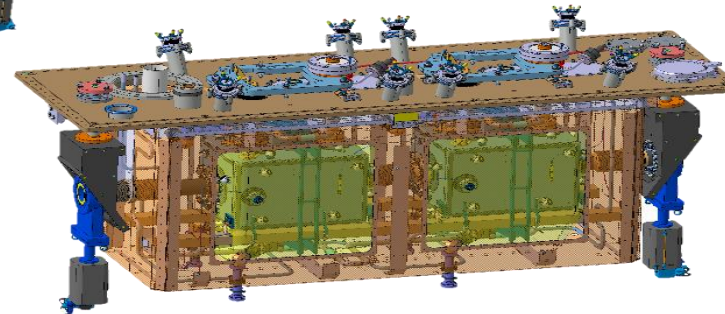
Assembly infrastructure exists from ARIEL assembly



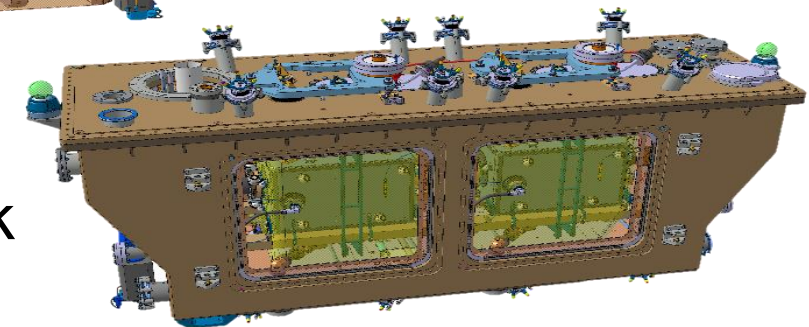
String assembly



Top assembly



With thermal shield

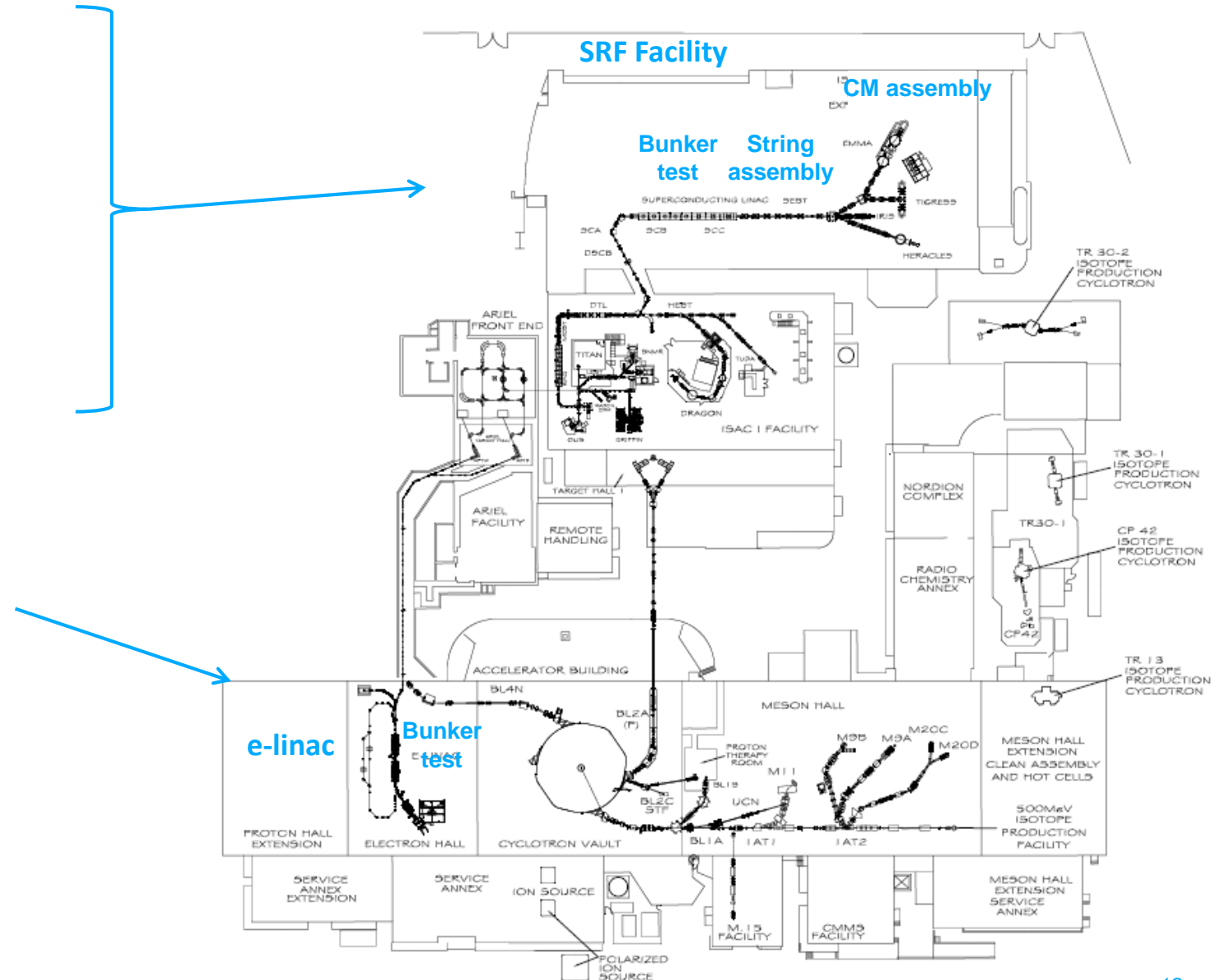


Install in tank

Will consult with UK and CERN on assembly fixtures/tools at UK and CERN – meeting next week at CERN together with TRIUMF engineer and designer

TRIUMF and Hi-Lumi RFD CMs

- RFD string to be assembled in the SRF clean room
- Top assembly in the CM assembly area
- Cryogenic test and rf test in the SRF test area – first choice – require rf from CERN
- Testing could also be done in the e-Linac hall depending on beam schedule



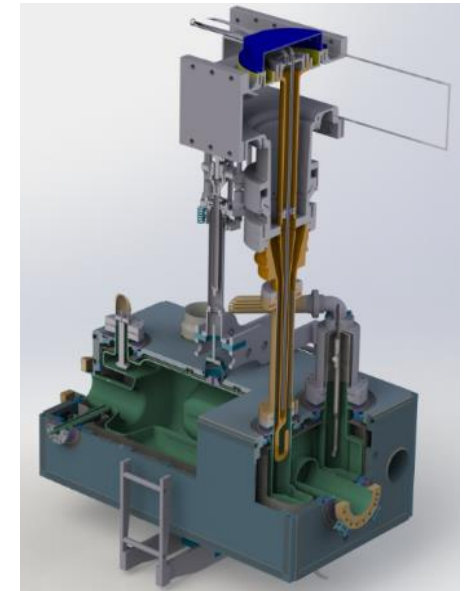
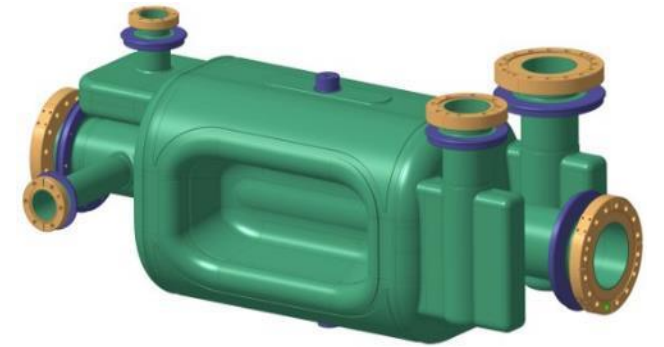
Shipping experience

Shipping frame designed by and fabricated at TRIUMF for shipping VECC 1.3GHz cryomodule to Kolkata – shipping in 2 months



RFD Cryomodule Series Scope

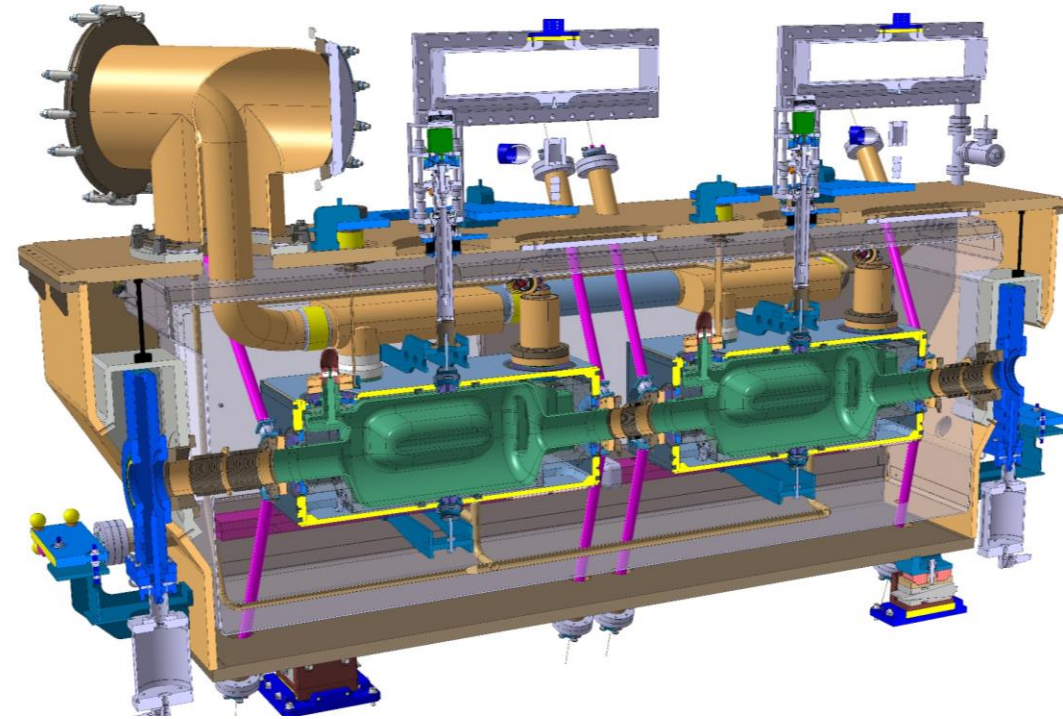
- U.S. Accelerator Upgrade Project (AUP) will complete 10 RFD (8+2) cavities
 - AUP would provide the dressed cavities (minus FPC) – fully processed and characterized
- TRIUMF to assemble, qualify and ship CMs (4+1)
- TRIUMF installation includes with parts from (x)
 - FPCs (CERN), HOM couplers (AUP), pick-up (AUP)
 - Internal rf lines (CERN?- TBD)
 - Tuners – (TRIUMF - mechanics, CERN – warm system (TBD))
 - Hermetic unit assembly – Valves, WCT, CCT, couplers
 - Support structure
 - Establish Alignment
 - Thermal shield, Mu metal, Vacuum vessel,
 - Diagnostics (TS, level probes, heaters, alignment)



Need to sit with CERN colleagues to finalize agreement

Qualification at TRIUMF

- Qualify at room temperature
 - the operation of diagnostics
 - Leak check and pressure test – all volumes
 - Warm rf frequency, alignment
- Qualify at 77K
 - Cooldown to 77K
 - leak check, alignment check
- Qualify at 4K
 - Cooldown cold mass to 4K
 - Check alignment
 - Check rf frequency
 - Check operation of tuner
 - Rf and LLRF -
 - 15kW at 400MHz
- Pump to 2K – measure Q, freq, microphonics



AUP Series Delivery – Early and Late

RFD Dressed Cavities

11 months float

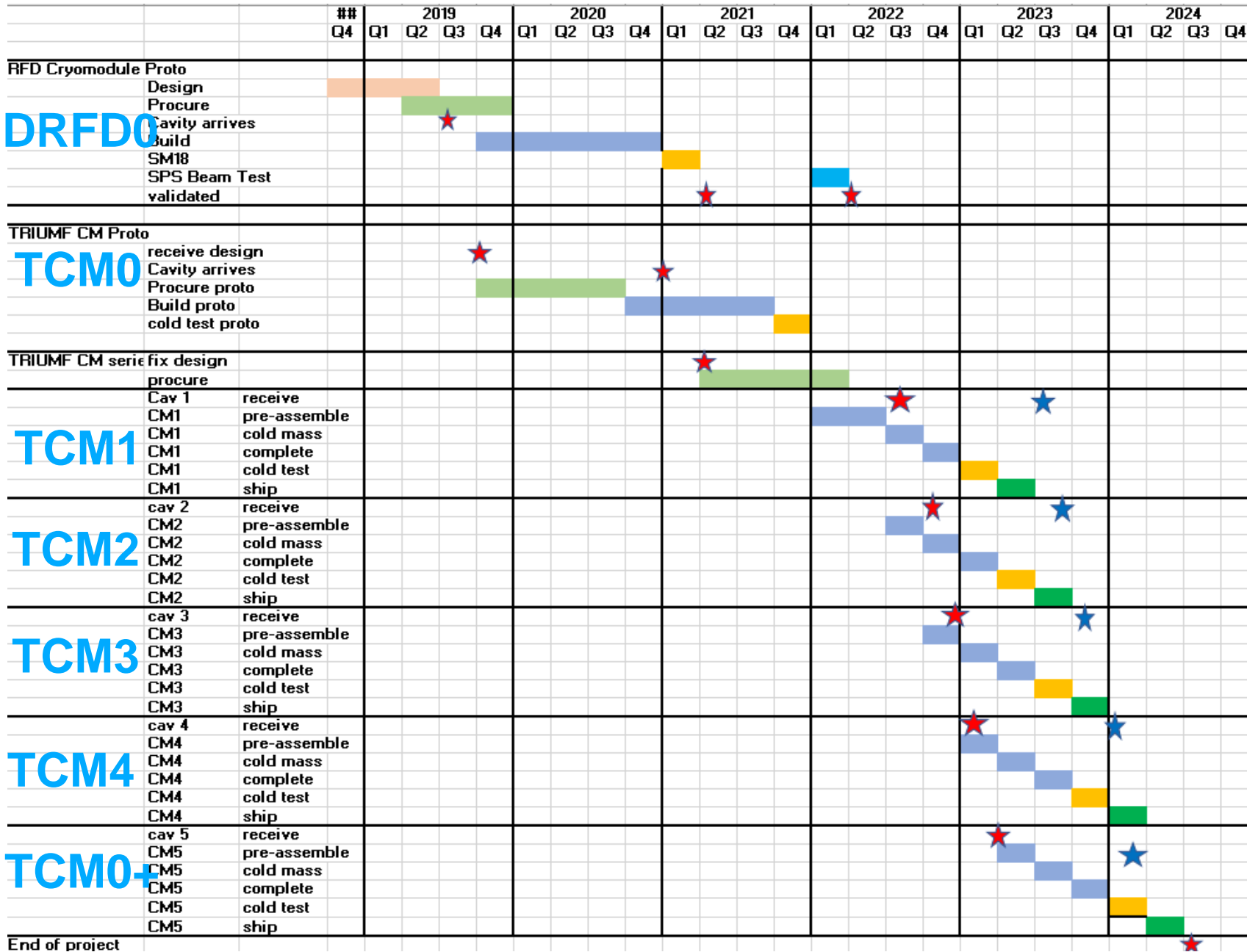

	HL project schedule	US project schedule
HCACFDC002-UP000001	July 2022	June 2023
HCACFDC002-UP000002	July 2022	June 2023
HCACFDC002-UP000003	September 2022	September 2023
HCACFDC002-UP000004	September 2022	September 2023
HCACFDC002-UP000005	November 2022	December 2023
HCACFDC002-UP000006	November 2022	December 2023
HCACFDC002-UP000007	January 2023	February 2024
HCACFDC002-UP000008	January 2023	February 2024
HCACFDC002-UP000009	March 2023	May 2024
HCACFDC002-UP000010	March 2023	May 2024

RFD CM series strategy

To reduce schedule risk TRIUMF proposes to assemble RFD pre-series cryomodule (TCM-0) in 2021 with cold test in late 2021

- Would require prototype dressed cavities from AUP in late 2020 – **or mock-up**
- Would enable early completion/validation of clean room and top assembly tooling and fixturing
- Would allow completion of pre-series TCM-0 for cold test end of 2021 to compare with UK SPS-RFD tests in SM-18 in early 2021 – **if mock-up then cryo tests only**
- Advantages
 - Early start on clean room and top assembly fixturing and procedures
 - Confirmation of TRIUMF readiness for series production
 - Essentially would have two CM prototypes tested in 2021 – DRFD0, TCM0
- Risks
 - Some parts in TCM-0 may have to be remade after cold test feedback to retro-fit it to series model

Proposed schedule



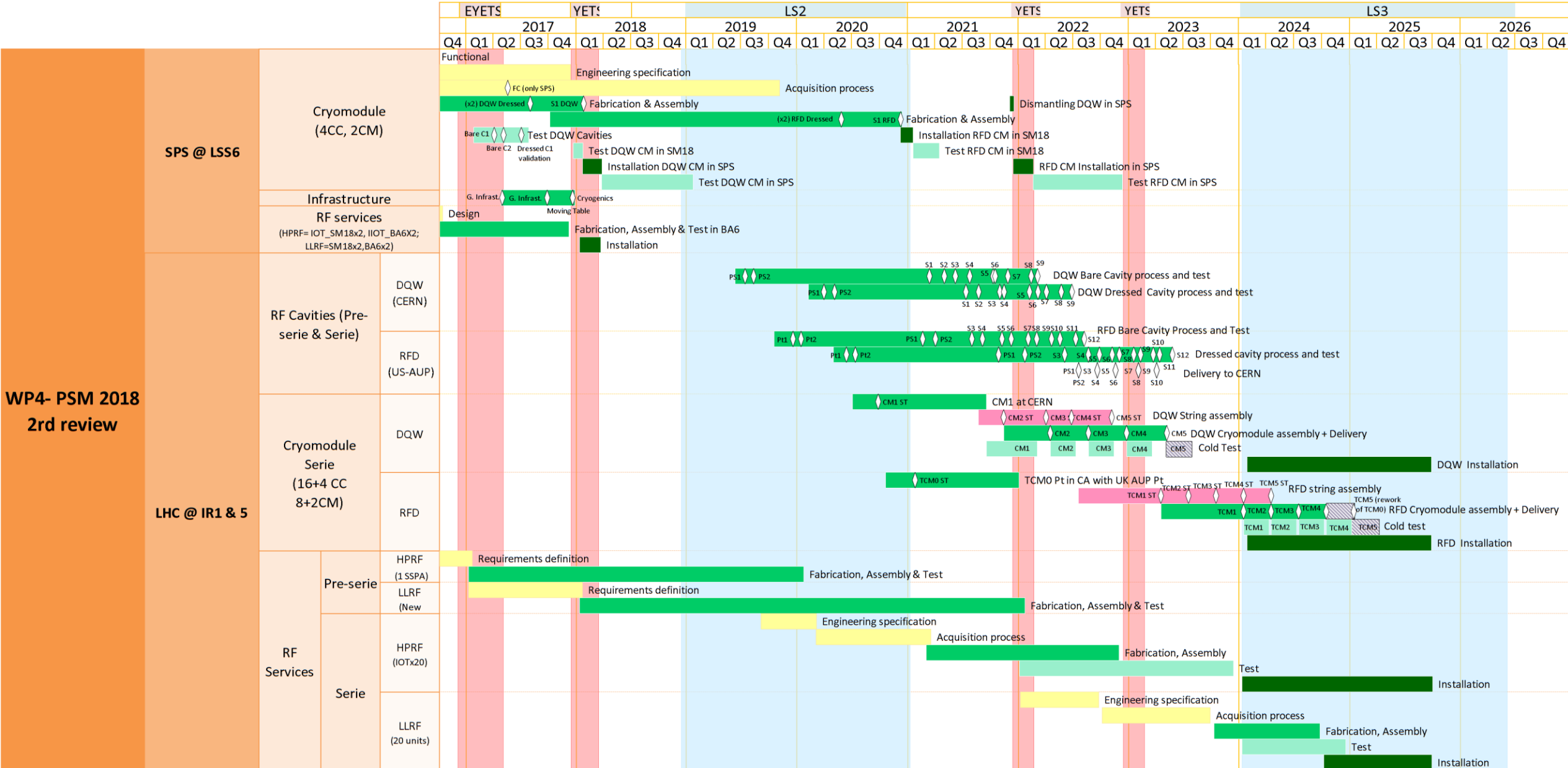
TCM0: Would engage TRIUMF earlier and significantly reduce schedule risk once series cavities arrive

Can we get AUP dressed first RFDs at end of 2020?

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

TCM0+ - retro-fit for LHC as required

Schedule reflected in present baseline



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.

Addendum 4 to CERN-TRIUMF MOU in preparation. Technical meetings next week.

Conceptual plan is in place to assemble an earlier pre-series module (TCM0) in 2021

