WP4-RFD/DQW cryomodule design for LHC

12th HL-LHC Collaboration Meeting, CERN - 19-23 September 2022

Teddy Capelli on behalf of the WP4 collaboration in particular :
STFC Daresbury (UK), Triumf (Canada), CERN EN/MME, ATS/DO, SY/RF, EN/ACE, EN/SMM, HSE, TE/CRG, TE/VSC.

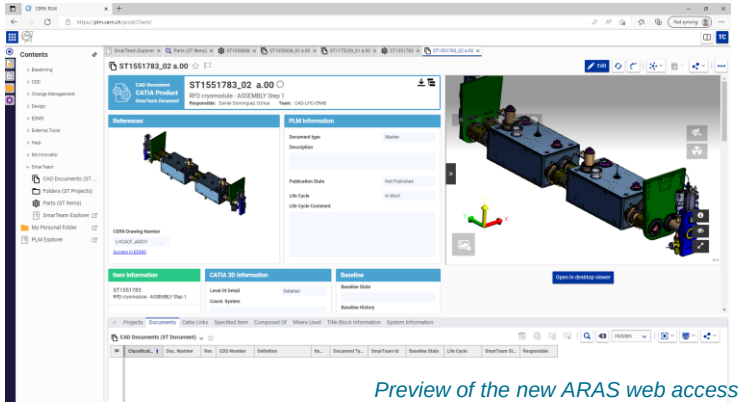
Outline

- Cryomodule design challenges
- DQW & RFD cryomodules overview
- DQW & RFD dressed cavity comparison
- Additionnal design work :
  - Assembly sequence study and planning
  - Tooling design
- Status and on-going activities

Cryomodule design challenges for LHC

- Organization and collaboration
  - International collaboration for the design and manufacturing

  (see presentations from R.Calaga, M.Garlaschè, N.Templeton & R.Laxdal)
  - Exchange of knowledge and information (specification, calculation, drawing folder, procedures)
  - PDM (EDMS, Smarteam, ARAS)
  - Planning of priorities

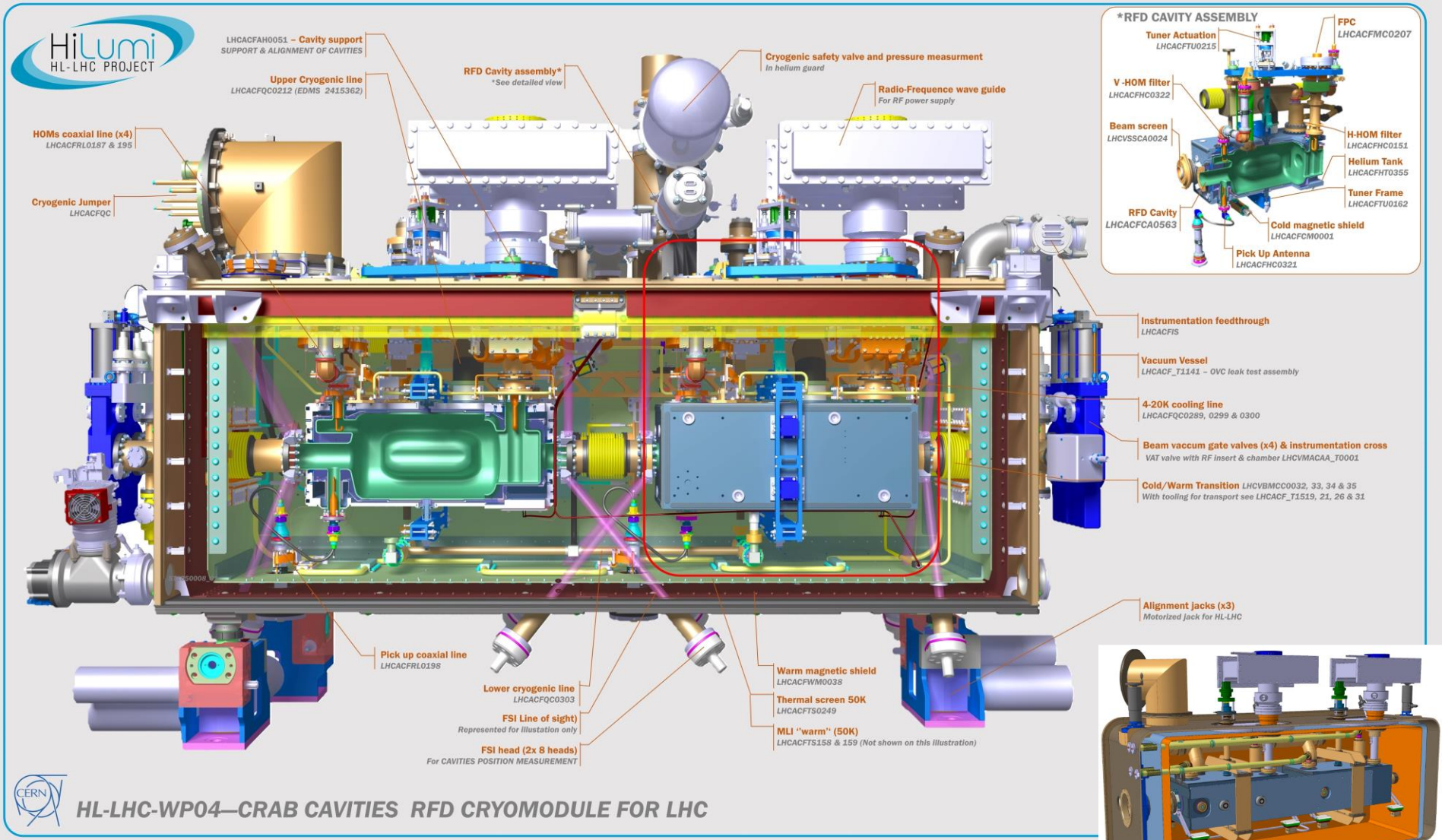


Preview of the new ARAS web access

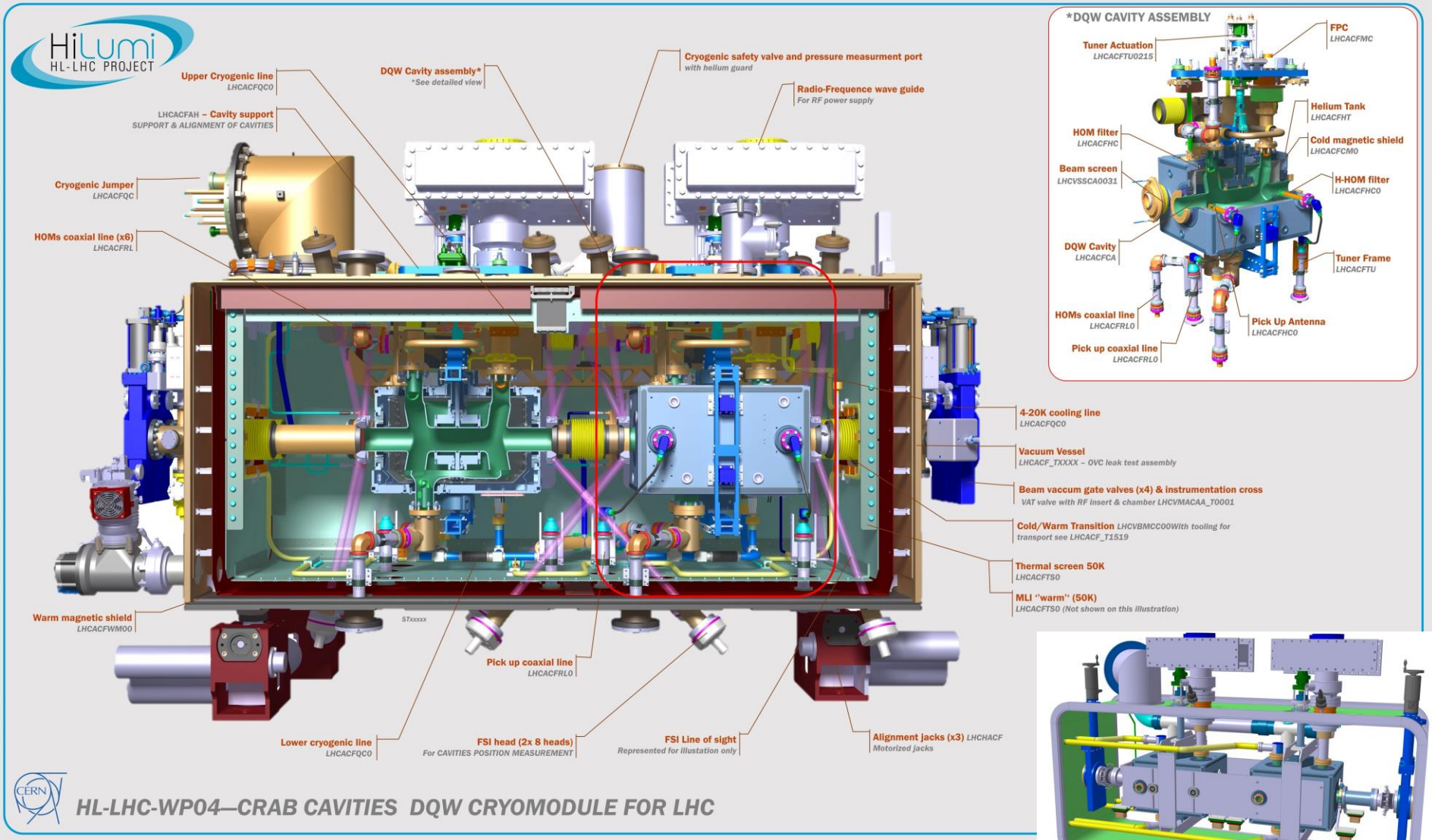
- Environmental constraints :
  - Space for integration in LHC
  - Cold test in SM18
  - Assembly facilities (CERN/STFC/Triumf)
  - Design the tooling needed
  - Transport

- Design changes and optimization :
  - Optimization of thermal performances
  - Thermal screen material and modular design for intercepts
  - New HOMs and coaxial lines (see presentation of E.Montesinos)
  - Reduction of cryogenic instrumentation
  - New external safety extension and jumper interface
  - New motorized jacks
  - WPS and inclinometer integration
  - Weight reduction
  - Standardization of component (UHV vacuum, RF coaxial lines, Thermal screen..)
  - Material selection for cost reduction

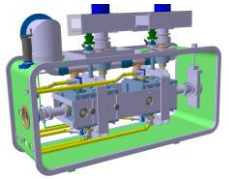
RFD Cryomodules overview

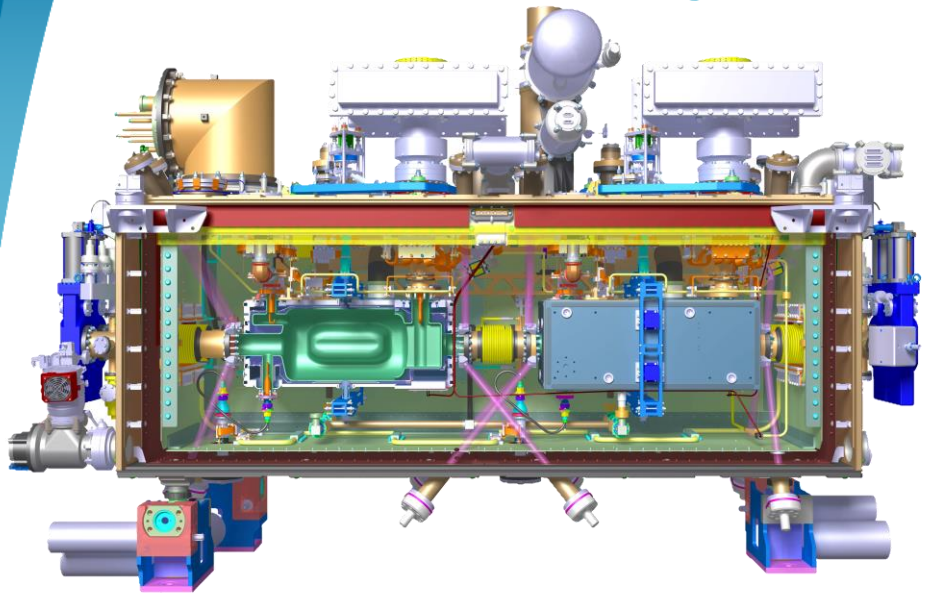


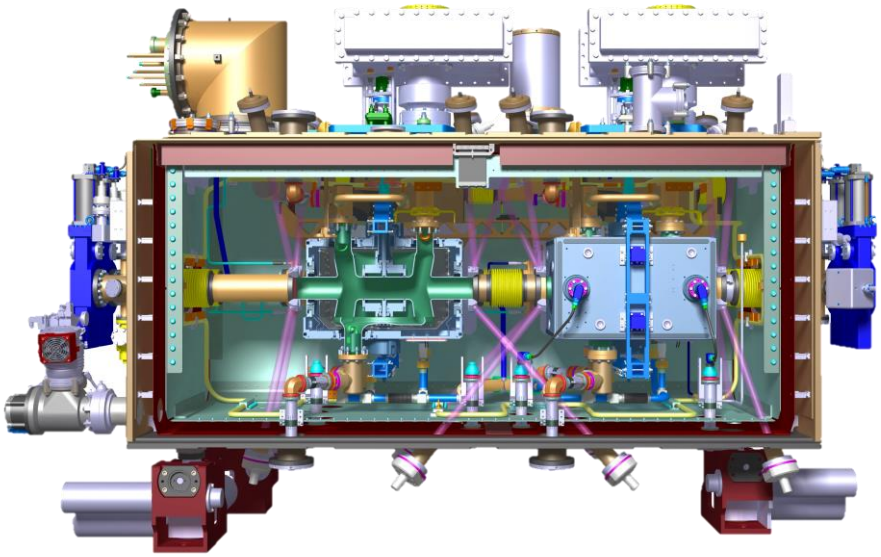
DQW Cryomodules overview



LHC Cryomodules overview





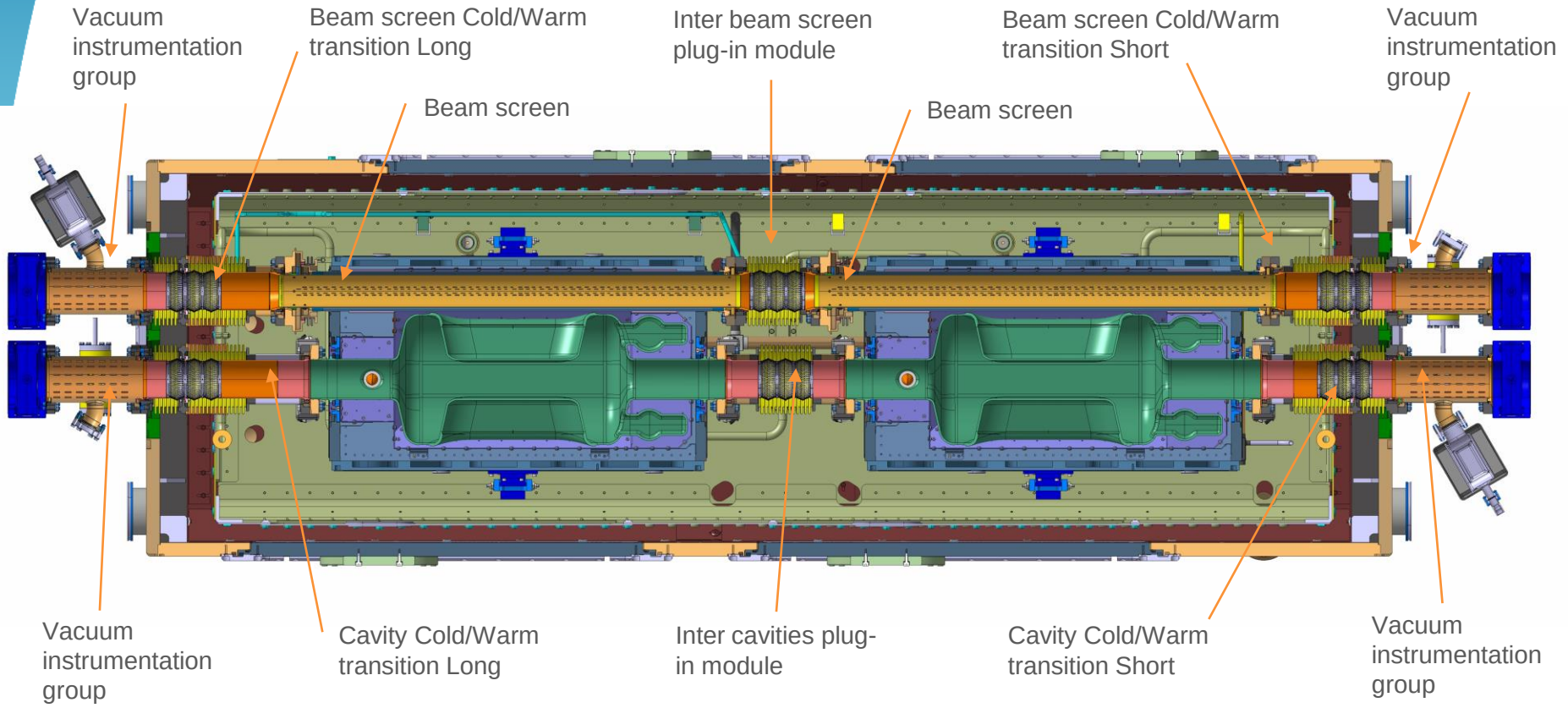


- RFD Cryomodule
  - Overall dimensions (L/l/h): 3350/950/1900mm
  - Mass : ~4400kg (estimation 09-2022)
  - Cavities : Radio-Frequency Dipole (RFD)
  - HOM filters : 4 pces (2 per cavity)
  - Pick Up Antenna : 2 pces (1 per cavity)
  - Position of installation : Point 1 (Before and after ATLAS)
  - 5 cryomodules to be built by Triumf (Canada)

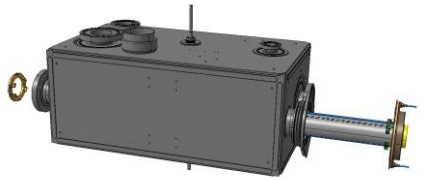
- DQW Cryomodule
  - Overall dimensions (L/l/h): 3120/1000/2000mm
  - Mass : ~4300kg (estimation 09-2022)
  - Cavities : Double Quarter Wave (DQW)
  - HOM filters : 8 pces (4 per cavity)
  - Pick Up Antenna : 2 pces (1 per cavity)
  - Position of installation : Point 5 (Before and after CMS)
  - 1 cryomdule assembled at CERN + 4 cryomodules to be built by STFC (UK)

LHC CRAB Cryomodule – Beam section

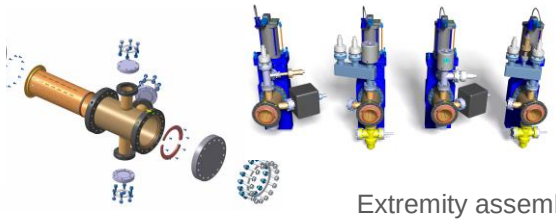
See presentation of Chiara Pasquino



PIMS



Beam screen

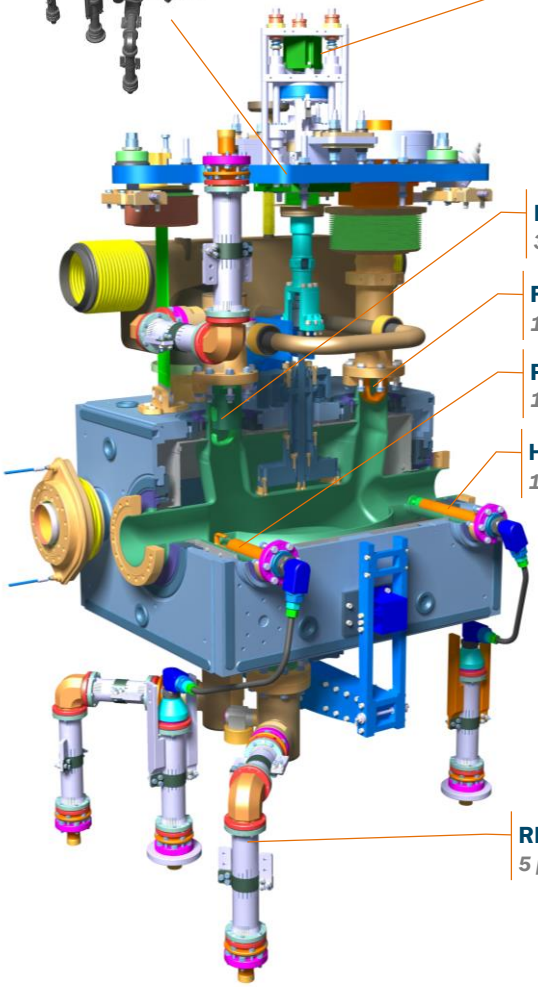


Extremity assemblies

DQW/RFD comparison

DQW cavity support

DQW



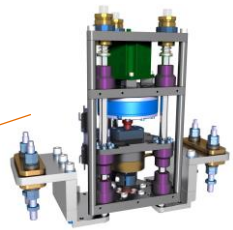
HOM filter
3 per cavity

FPC
1 per cavity

Pick up antenna
1 per cavity

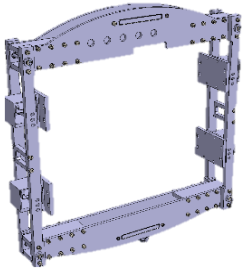
HF HOM filter
1 per cavity

RF coaxial line
5 per cavity

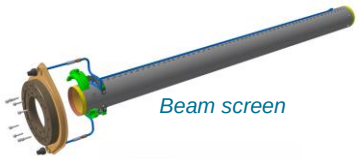


Tuner actuation – courtesy K.Artoos

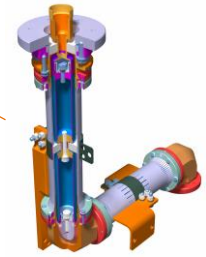
Tuner double tube courtesy K.Artoos



Tuner frame courtesy K.Artoos



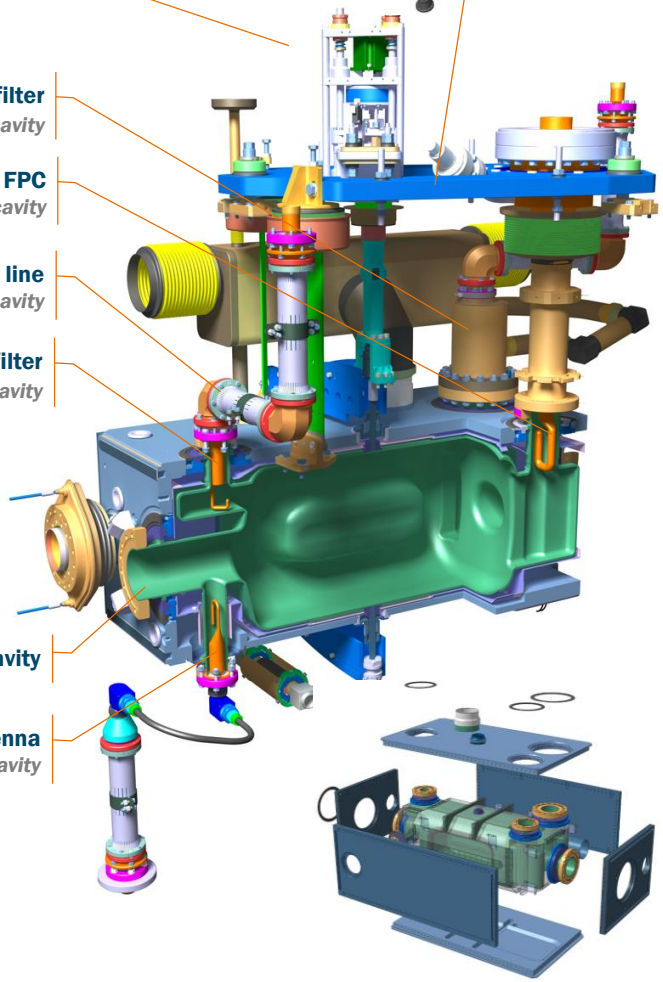
Beam screen



RF coaxial lines – courtesy S.Calvo SY/RF

RFD cavity support

RFD



H-HOM filter
1 per cavity

FPC
1 per cavity

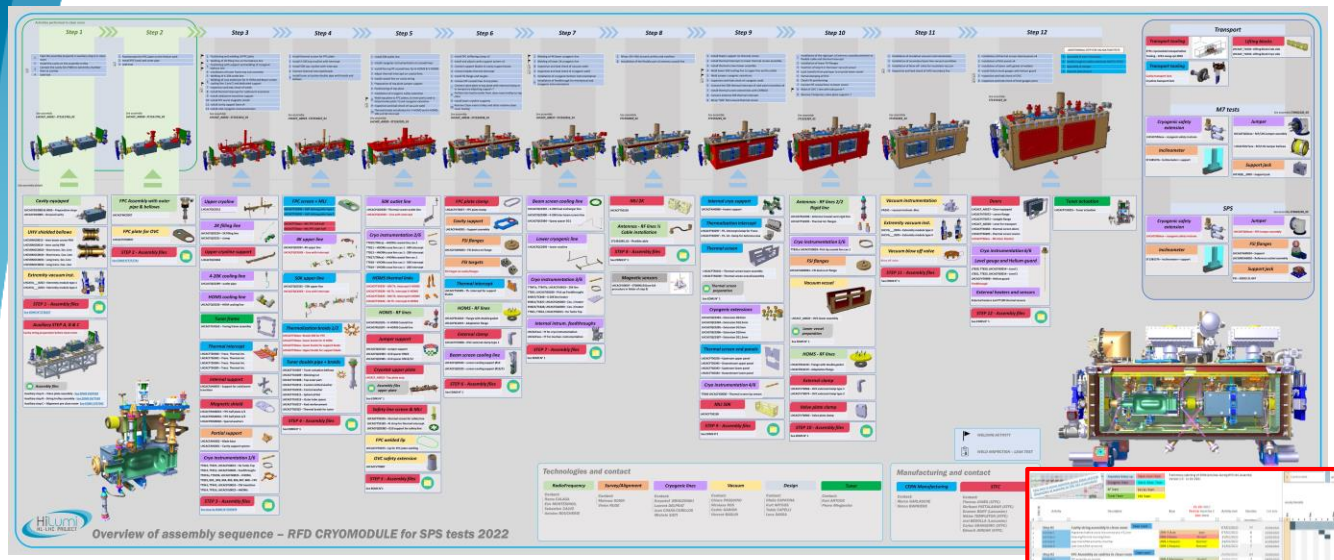
RF Coaxial line
3 per cavity

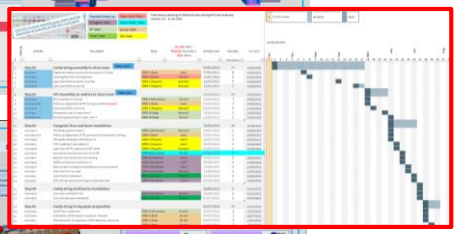
V -HOM filter
1 per cavity

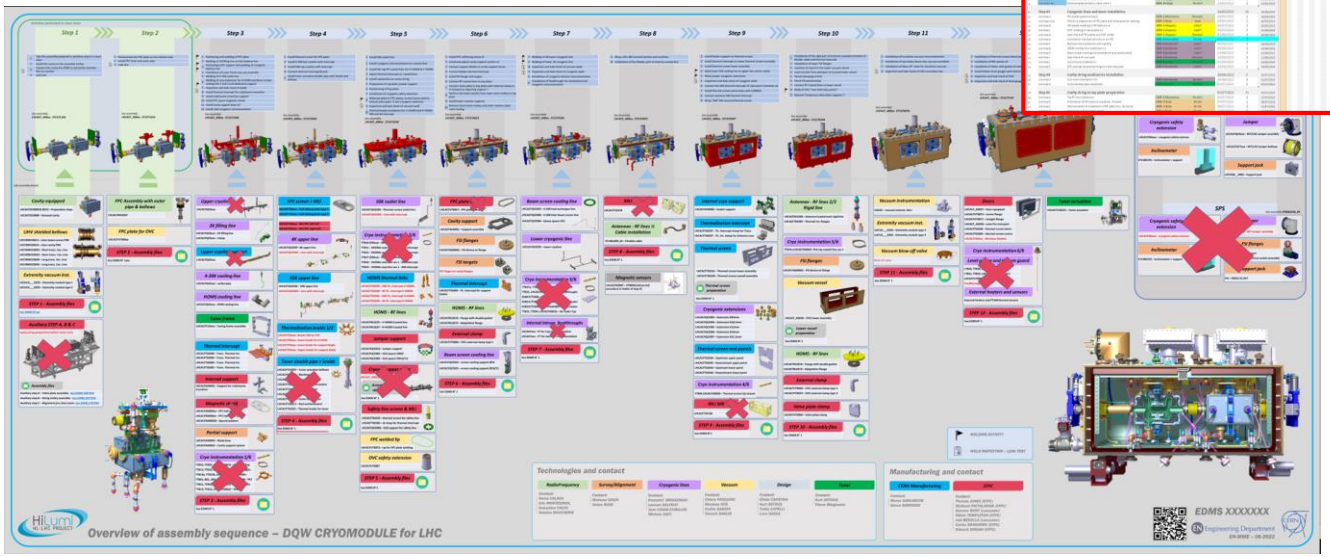
RFD Cavity

Pick up antenna
1 per cavity

Assembly sequence overview



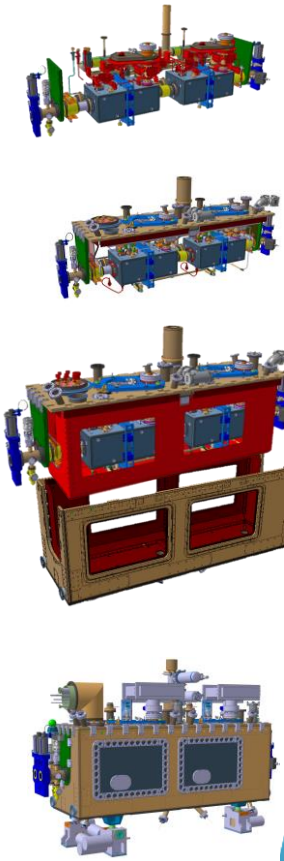




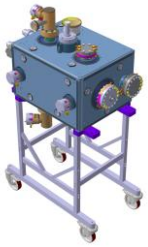
RFD/SPS assembly sequence :

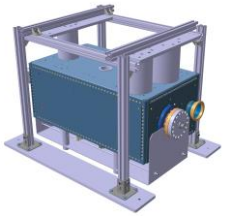
-12 steps cryomodule assembly and additionnal auxialiary steps for preparation

(see presentation of N.Templeton)

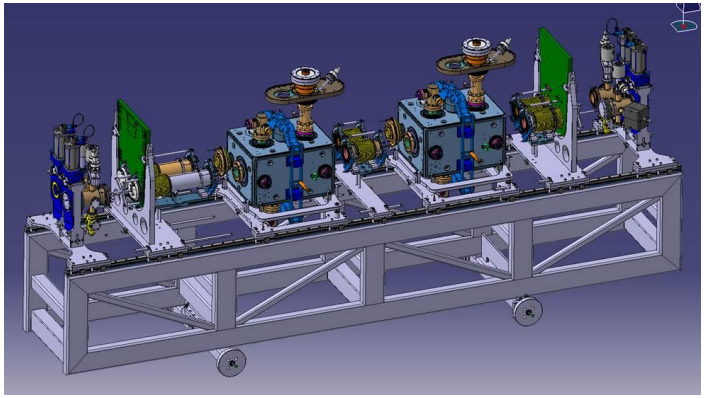


- **Detailled assembly procedure for LHC and planning under definition – Collaboration CERN / STFC / Triumf**





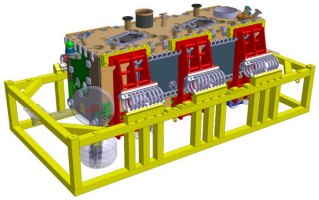
Tooling

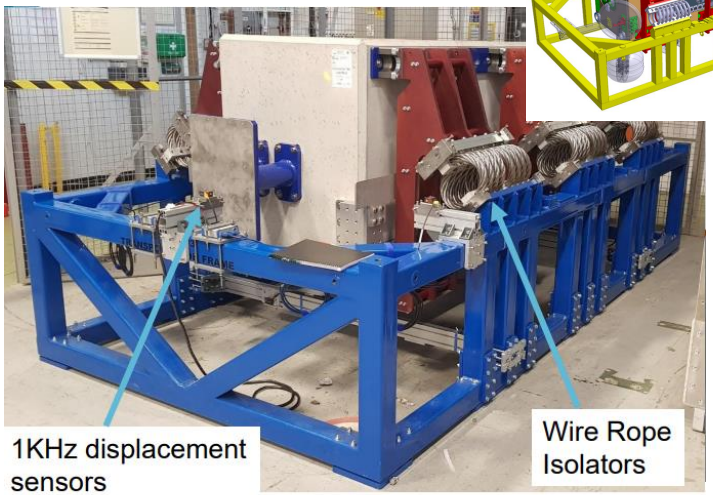


DQW assembly itrolley for clean room designed by P.Minginette (CERN)

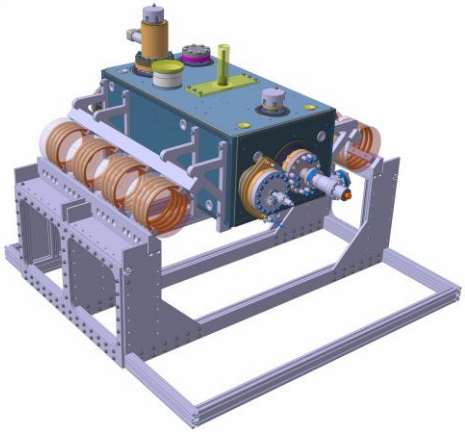
Extensive range of tooling are needed (CERN/STFC/TRIUMF) :

- Welding & machining
- Cleaning and coating
- Assembly (&assembly in clean room)
- Transport & storage
- Test
- Installation

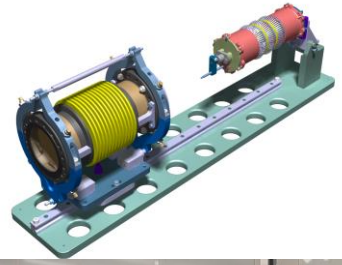




RFD Cryomodule transport tool designed by STFC – courtesy E.Jordan



RFD dressed cavity transport tool designed by K.Artoos & P.Minginette (CERN)



RFD PIM assembly in clean room designed by R.Leuxe & L.Giordanino (CERN)

Status and on-going activities

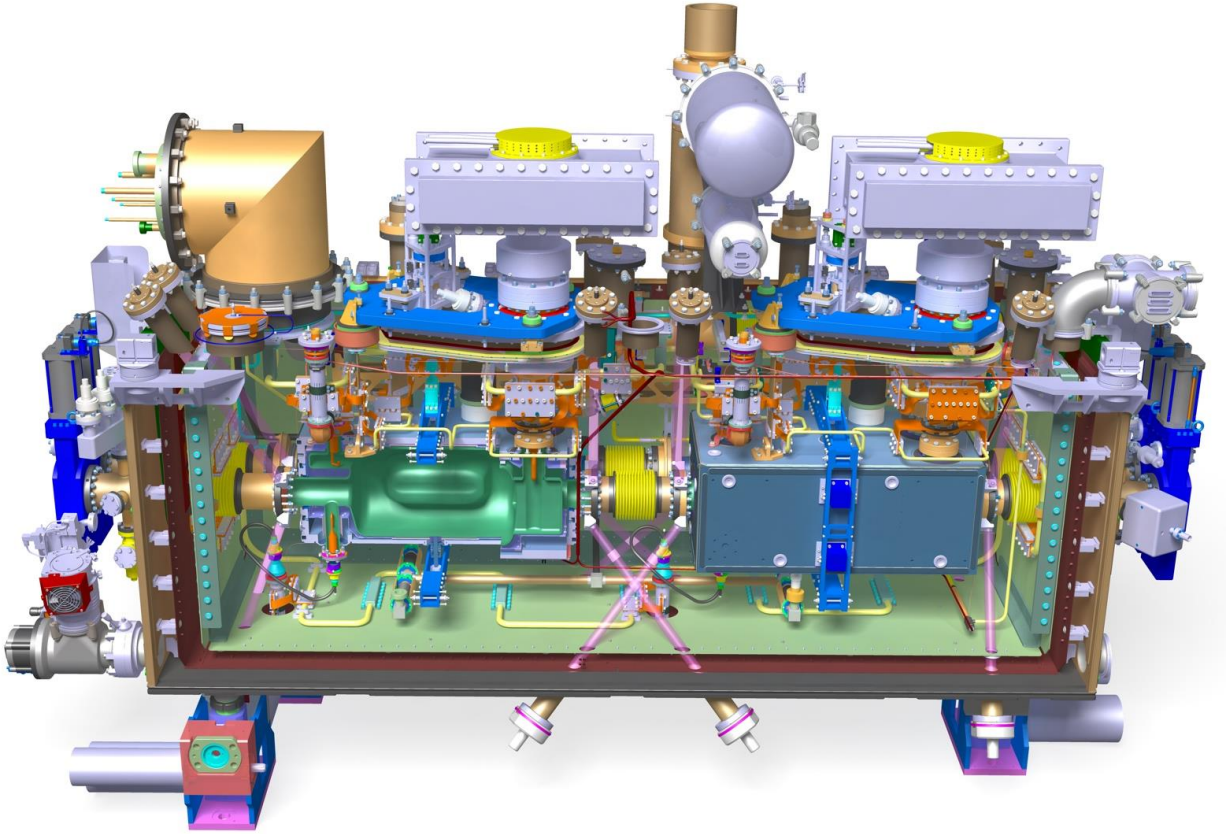
- Design of RFD/SPS cryomodule done – Assembly on-going at STFC

(see Presentation N.Templeton-STFC)

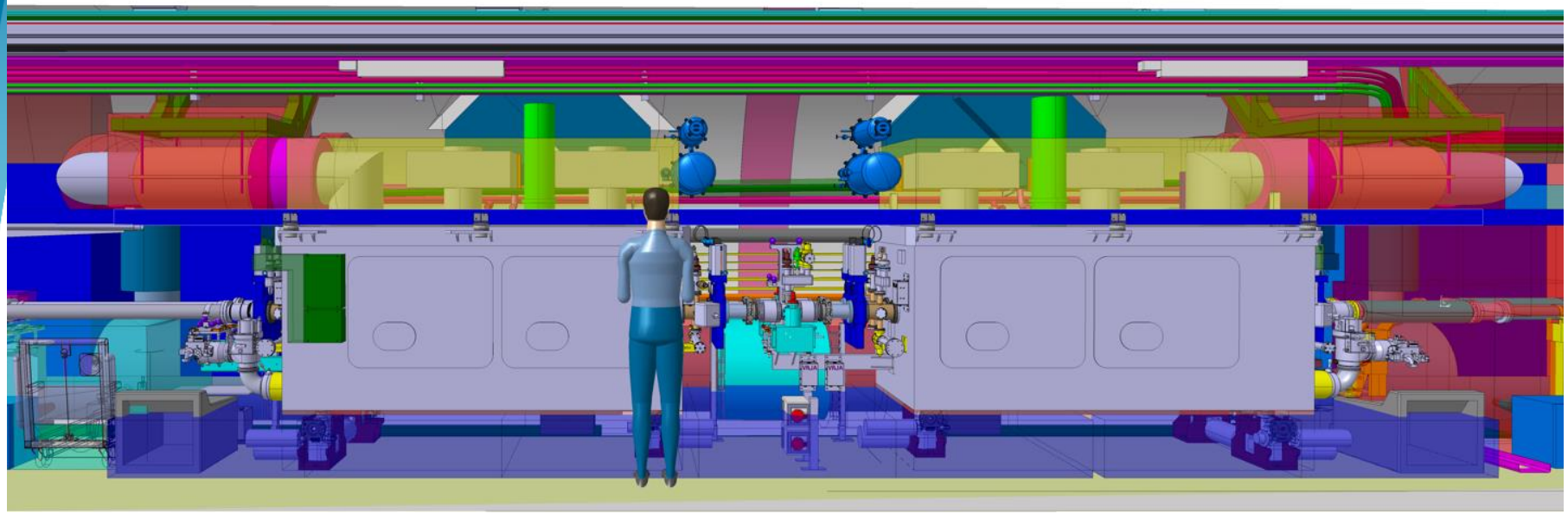
- Follow the assembly on-going at STFC to get the feedback for the next cryomodules
- The design of the UHV equipment and the corresponding tooling for manufacturing and assembly is over and ready for the series production.
- The design and definition of DQW/LHC and RFD/LHC cryomodules is on-going with a focus on :
  - Long lead item (preliminary design and drawing for tender)
  - Defining the assembly process based on the preliminary design in order to work on the tooling needed for the assembly, the manufacturing, the transport and tests.
  - Preparing mechanical and thermal simulation/calculation to check preliminary designs
  - Validation of the integration study done with the integration team to fix the interfaces

HiLumi
HL-LHC PROJECT

Thank you for your attention

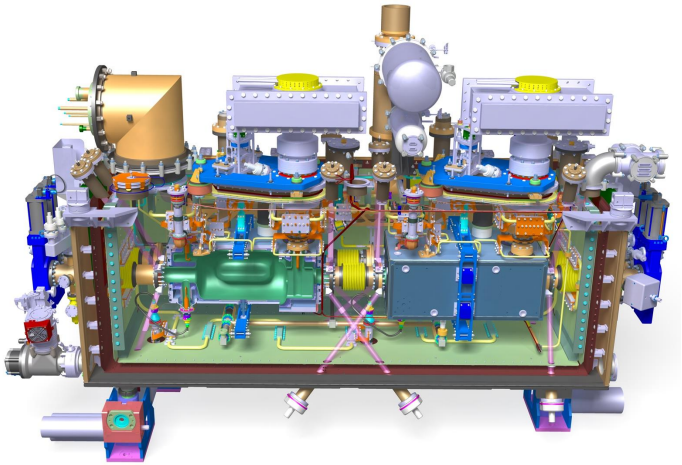


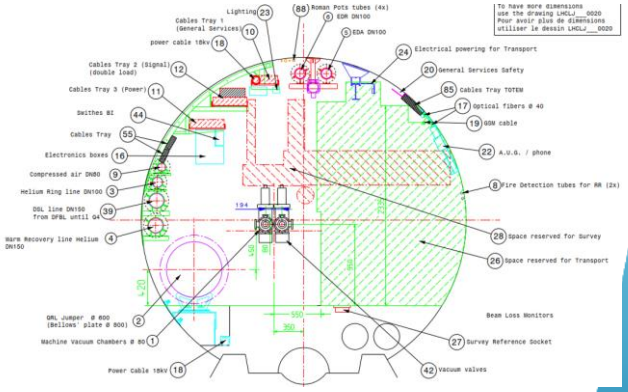
LHC integration



*LHC integration– courtesy **G. Aparicio Cantalapiedra - ATS/DO***

- The space availability is limited
- The accessibility is of paramount importance for maintenance
- Rooting of cables to be added
- Detailed integration in collaboration with the team of P.Fessia



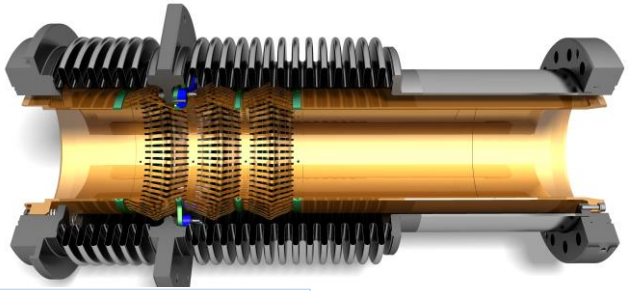


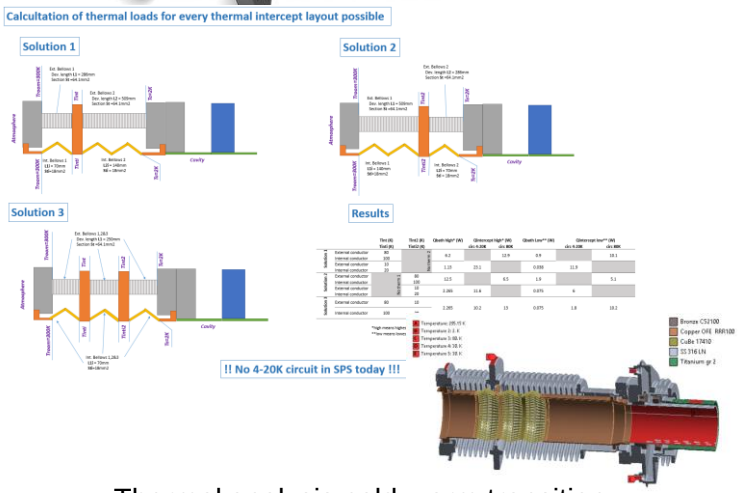
Section view of LHC
More details on drawing LHCLJ___0020

Bellows with internal shield (UHV - PIMS)

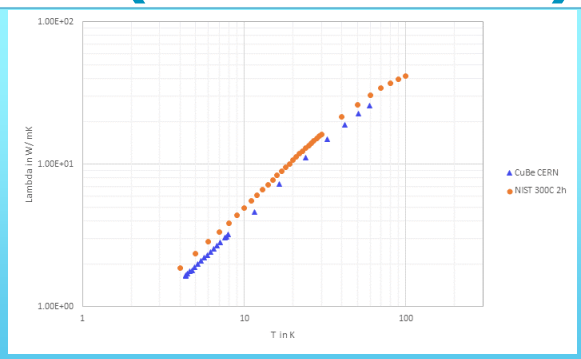
Copper Beryllium deformable RF fingers:

- Circular aperture
- C17410
- 0.1 mm thick, 3 mm width, gap: 1.4 mm
- 3 convolutions
- Thermal conductivity at low temperature checked

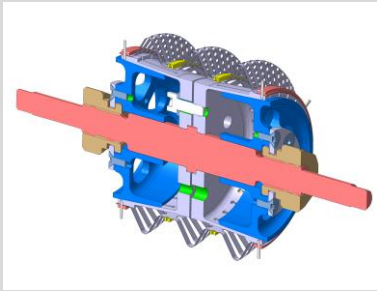




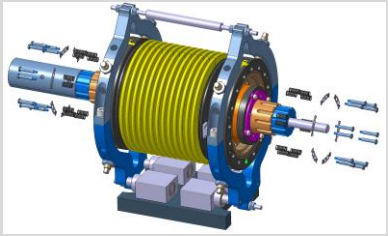
Thermal analysis cold-warm transition
See EDMS 2433067 - J.Swieszek EN-MME



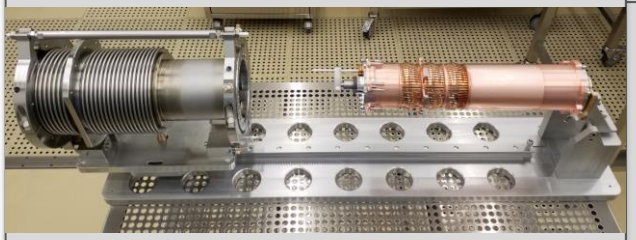
Result of low temp. conductivity measurement
By Torsten Koettig – TE/CRG



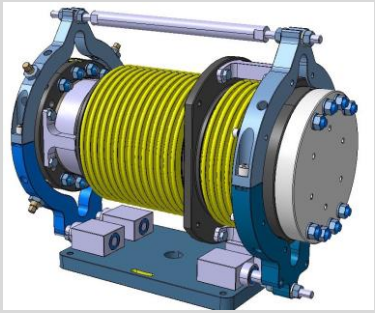
Tooling for manufacturing



Tooling for assembly
Outside clean room
Secondary line



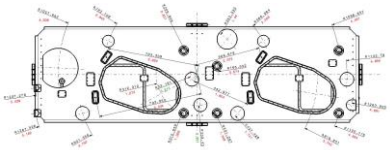
Tooling for assembly
Inside clean room
CRAB line

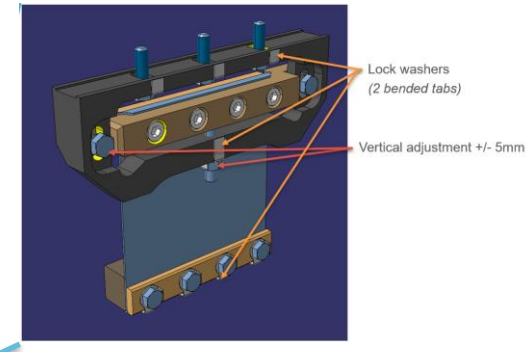


Tooling for transport

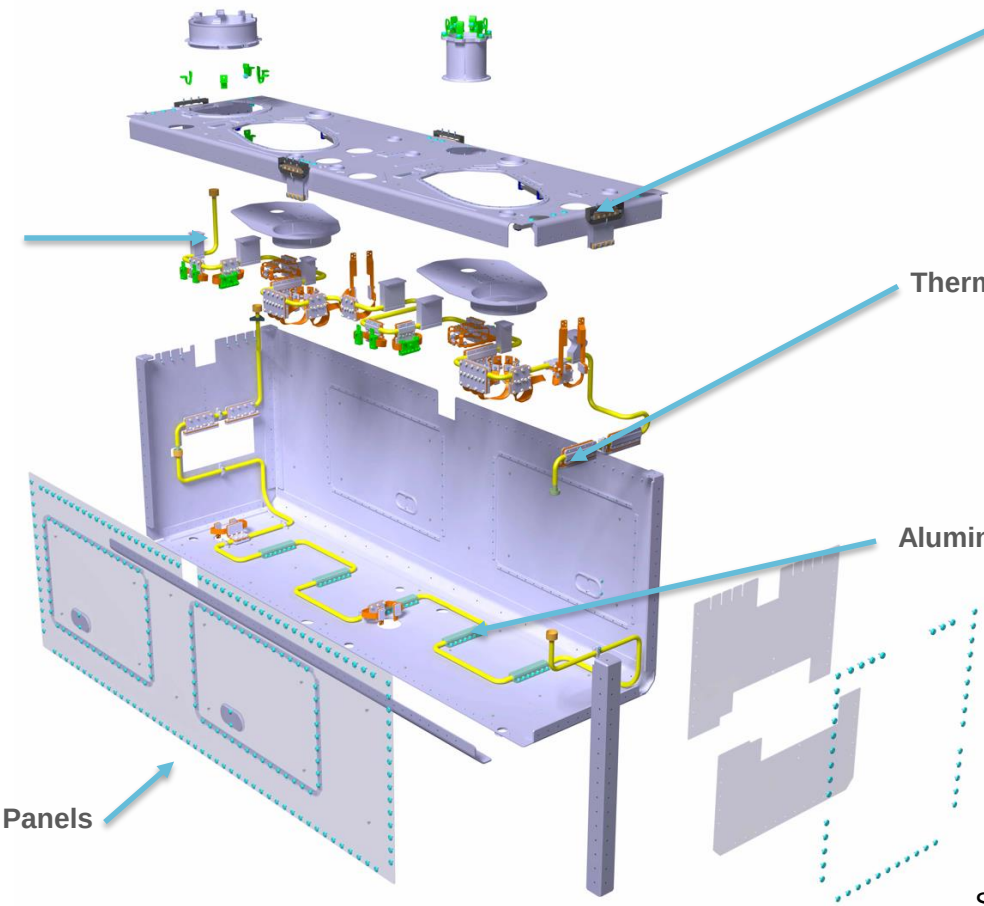
Thermal screen (STFC/CERN)

- Aluminium plates th. 3mm*
- Stainless steel Cooling circuit 316L (1.4435)
- Adjustable support





Screen support



Cooling Circuit

Thermal intercepts

Aluminium Clamp for panel cooling (see next slide)

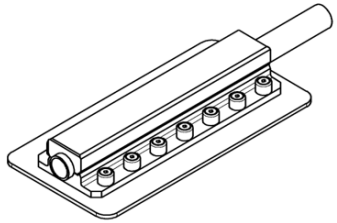
3mm Al 6061-T6 Panels

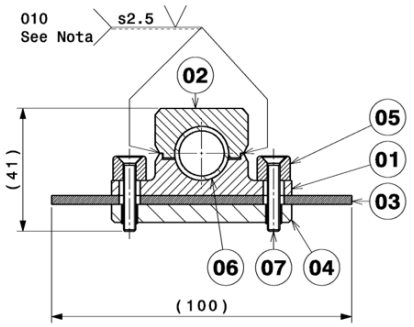
Thermal shield design report and analysis
See EDMS 2369925 - N.TEMPLETON STFC

Pipe Panel Connections (STFC/CERN)

- Ss 316 Pipes pre-assembled with Al. block (6061-T6)
- Pipes are pre-loaded with clamp
- Al block welded in sequence
- Pipe-block is integrated into cooling circuit
- Al blocks are fastened to panel

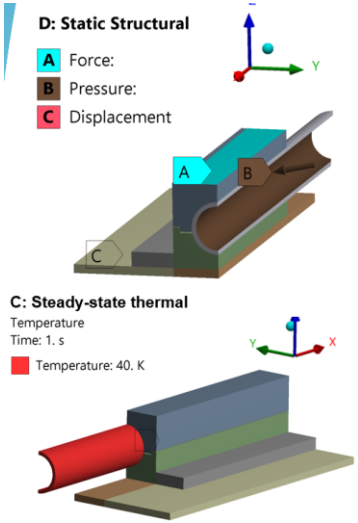
LHCACFTS0192





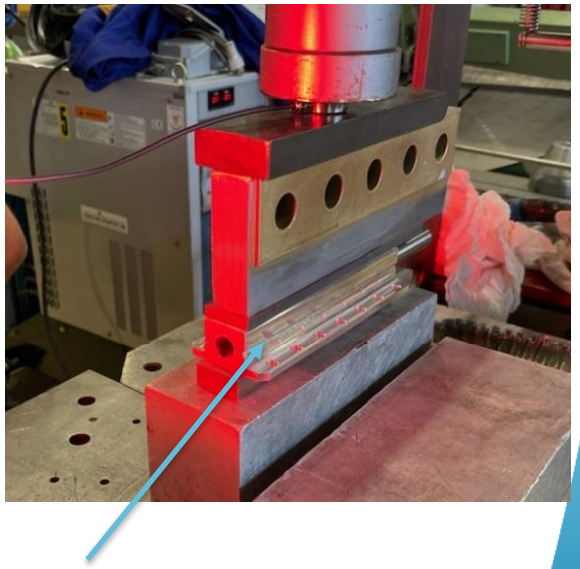
Mechanical analysis

See EDMS 2569527 - T. GUILLEN HERNANDEZ EN-MME



Load case	Preload/Force [N]	Displacement [mm]	Pressure inside pipe [MPa]	Temperature [K]
LC 1	-1625	Uz = 0	-	-
LC 2	-1625	Uz = 0	-	-
LC 3	-	Uz = 0	-	-
LC 4	-	Uz = 0	2.5	-
LC 5	-	Uz = 0	2.5	Yes
LC 6	-	Uz = 0	-	Yes

Welding test with optical mechanical measurement



Cryostat vessel design

- Large gaskets avoided
- Overall dimensions : 2800x950x1300
- Mass : 3100kg
- St. Steel welded assembly

Mechanical analysis
See EDMS 2272855 - L. DASSA EN-MME

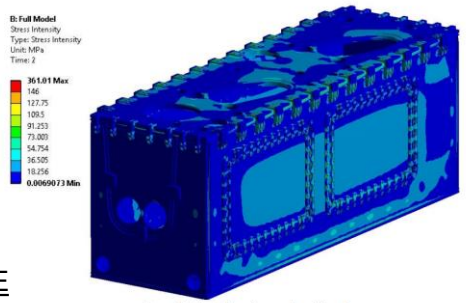
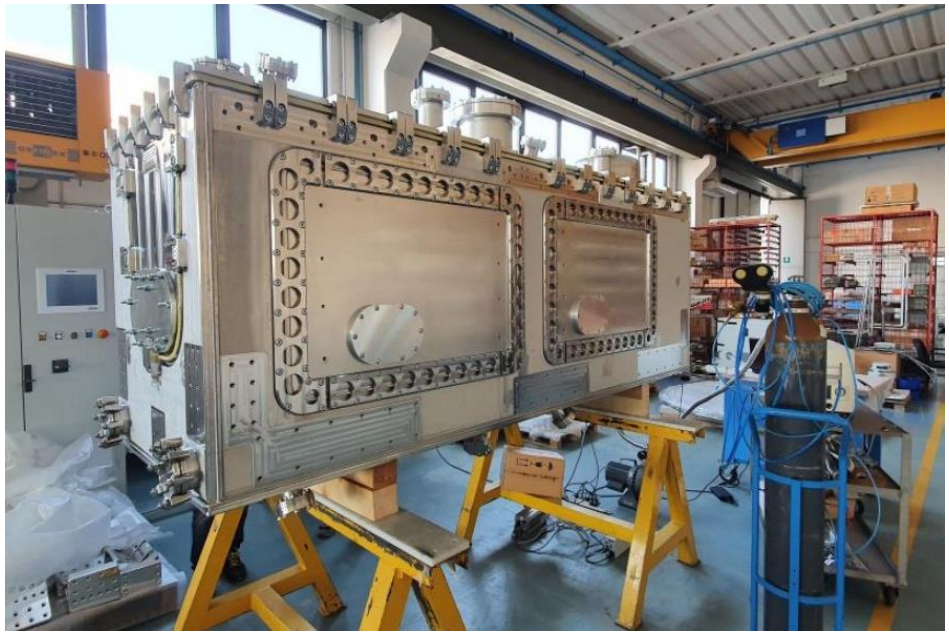
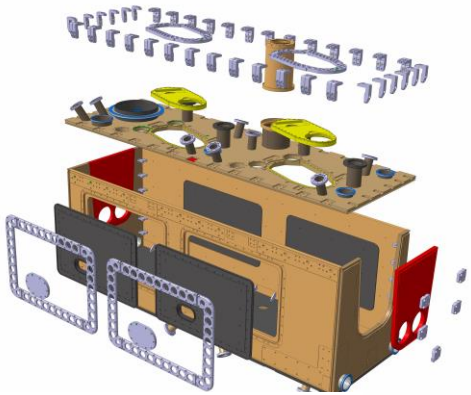
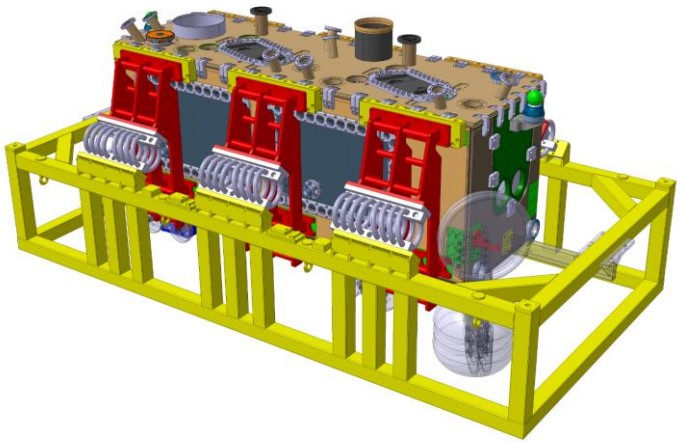


Figure 31: Von-Mises Stress – Load Case 1


RFD OVC manufacturing – Courtesy J.Sauza Bedolla - Lancaster

- Manufacturing is over and leak test has been done and validated




Tooling for cryomodule transport – courtesy E.Jordan - STFC