



Evolution of assembly tooling and procedures for UK Crab Cavity Cryomodules

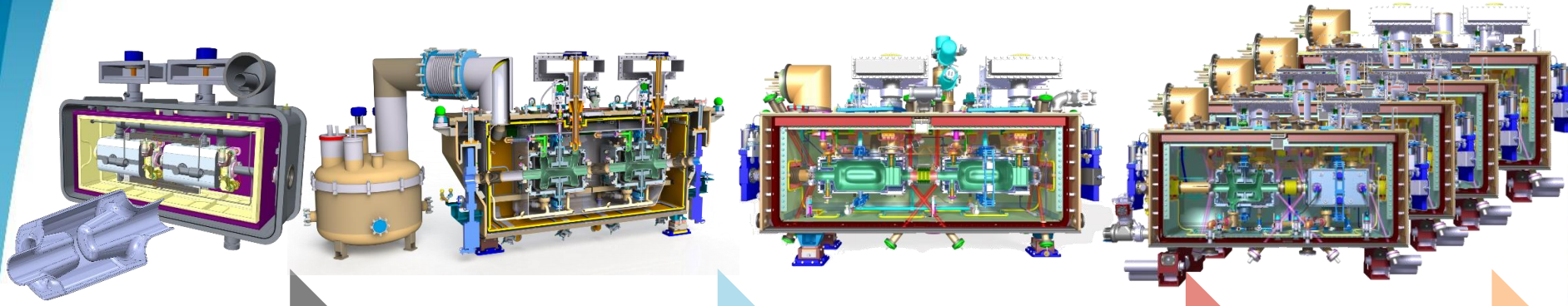
Kavi Chauhan – Mechanical Engineer – STFC Daresbury Laboratory

Early Careers Showcase – CERN – 14th January 2025

DQW-LHC Cryomodules UK

- Build poster overview
- FPC tooling
- Space optimisation
- Vacuum tooling
- Bellows protection
- PIMs processing
- Portable Cleanroom
- Transport
- Procedure bottlenecks
- BOM kitting & parts preparation

Hi Lumi Crab Cavities – UK Collaboration



2011

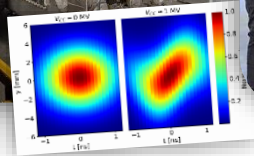
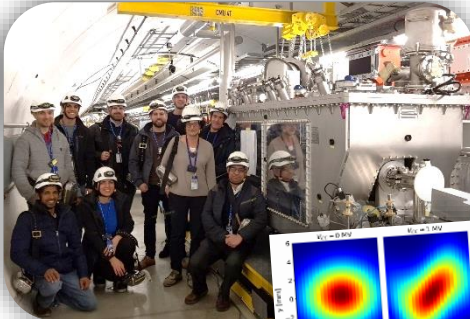
UK 4-Rod
Crab Cavity

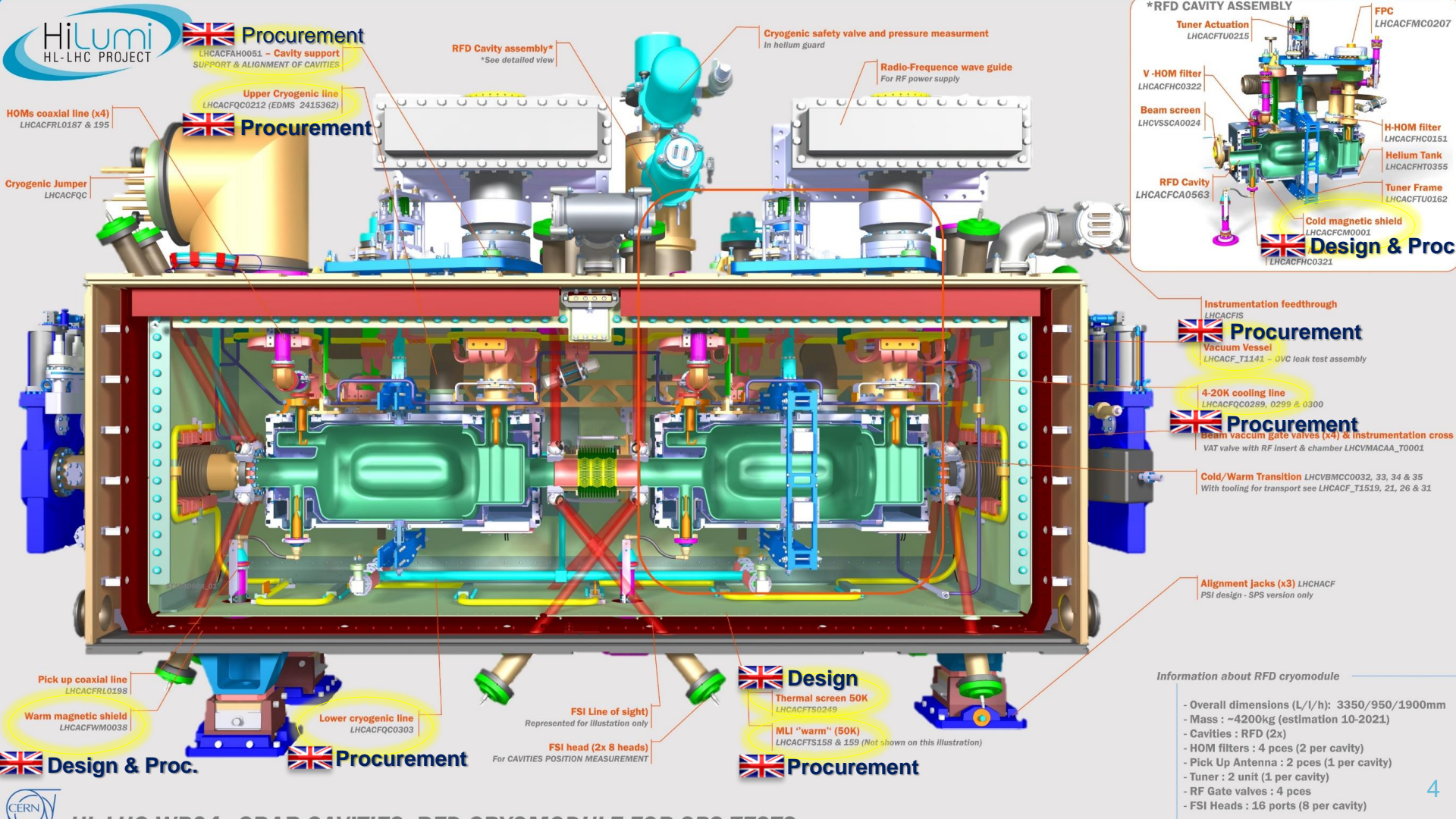
DQW-SPS CM

RFD-SPS CM

DQW-LHC CMs

2027





Procurement
LHCACFAH0051 - Cavity support
SUPPORT & ALIGNMENT OF CAVITIES

Procurement

RFD Cavity assembly*
*See detailed view

Cryogenic safety valve and pressure measurement
In helium guard

Radio-Frequency wave guide
For RF power supply

***RFD CAVITY ASSEMBLY**

Tuner Actuation
LHCACFTU0215

FPC
LHCACFM0207

V-HOM filter
LHCACFH0322

Beam screen
LHCVSSCA0024

H-HOM filter
LHCACFH015

Helium Tank
LHCACFHT0355

Tuner Frame
LHCACFTU0162

RFD Cavity
LHCACFCA0563

Cold magnetic shield
LHCACFM0001

Design & Proc
LHCACFH0321

Instrumentation feedthrough
LHCACFIS

Procurement
Vacuum Vessel
LHCACF_T1141 - QVC leak test assembly

4-20K cooling line
LHCACFC0289, 0299 & 0300

Procurement
Beam vacuum gate valves (x4) & instrumentation cross
VAT valve with RF insert & chamber LHCVMACAA_T0001

Cold/Warm Transition LHCVBMC0032, 33, 34 & 35
With tooling for transport see LHCACF_T1519, 21, 26 & 31

Alignment jacks (x3) LHCACF
PSI design - SPS version only

Pick up coaxial line
LHCACFRL0198

Warm magnetic shield
LHCACFWM0038

Lower cryogenic line
LHCACFC0303

FSI Line of sight
Represented for illustration only

FSI head (2x 8 heads)
For CAVITIES POSITION MEASUREMENT

Design
Thermal screen 50K
LHCACFTS0249

MLI "warm" (50K)
LHCACFTS158 & 159 (Not shown on this illustration)

Procurement

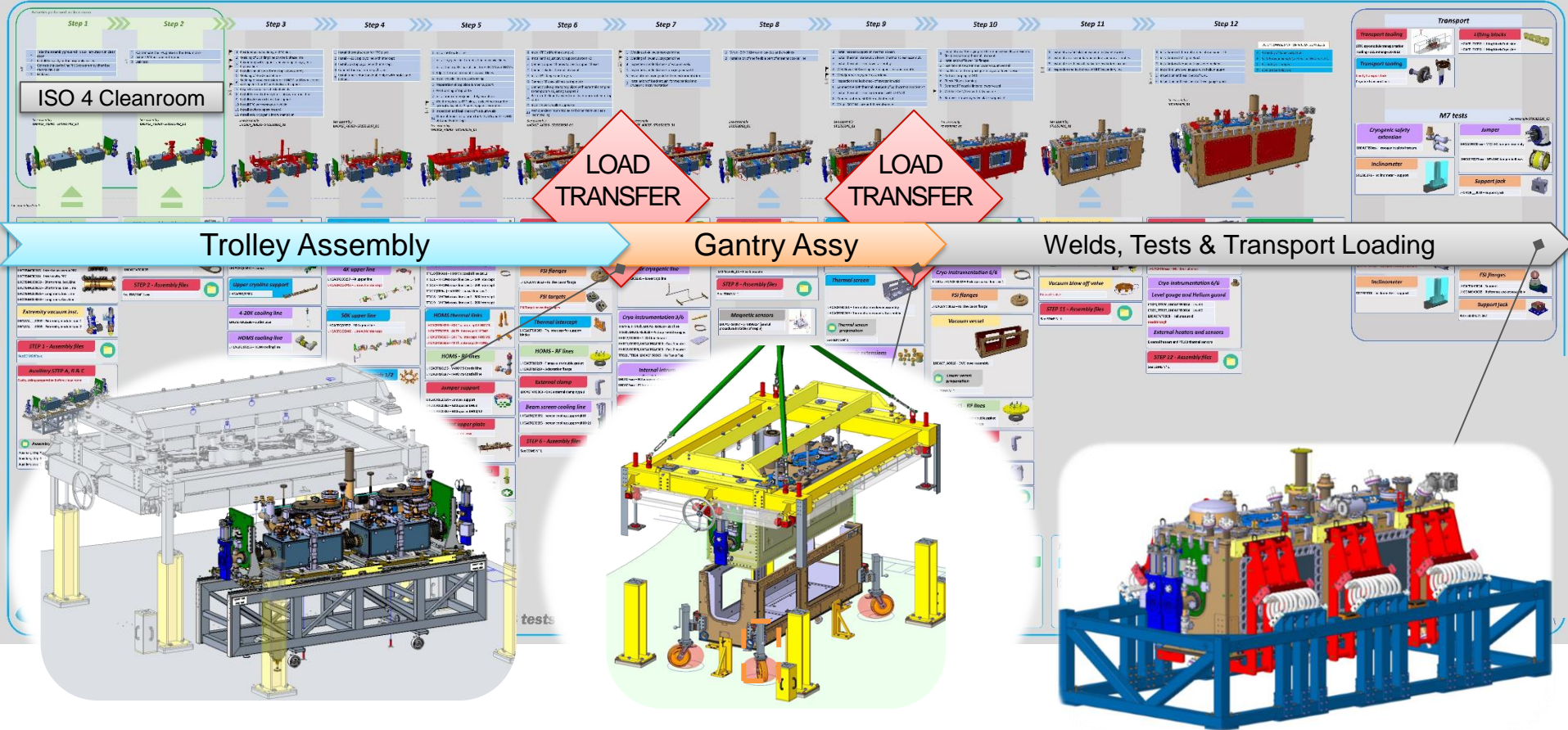
Information about RFD cryomodule

- Overall dimensions (L/I/h): 3350/950/1900mm
- Mass : ~4200kg (estimation 10-2021)
- Cavities : RFD (2x)
- HOM filters : 4 pces (2 per cavity)
- Pick Up Antenna : 2 pces (1 per cavity)
- Tuner : 2 unit (1 per cavity)
- RF Gate valves : 4 pces
- FSI Heads : 16 ports (8 per cavity)

Design & Proc.

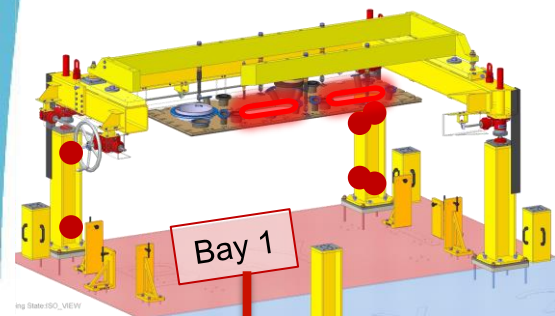
Procurement

RFD Build Poster – Teddy Capelli

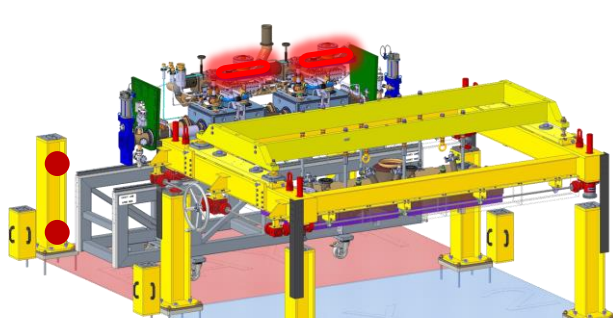


Improved alignment strategy for load transfer

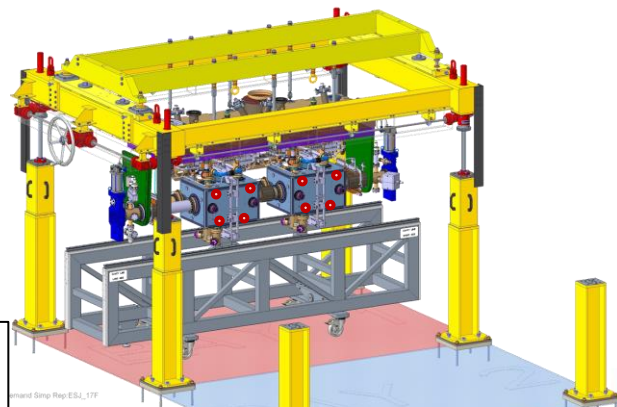
- Improved Survey and Alignment strategy for string & top plate integration
- Intermittent electrical continuity checks on FPC throughout build
- Strain gauges on Blades & FPC can help to identify movement during build



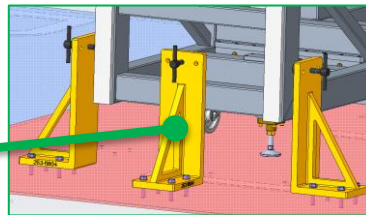
Measure position of FPC interface on top plate in Bay 1



Position string FPC interface accurately to measured position in Bay 1



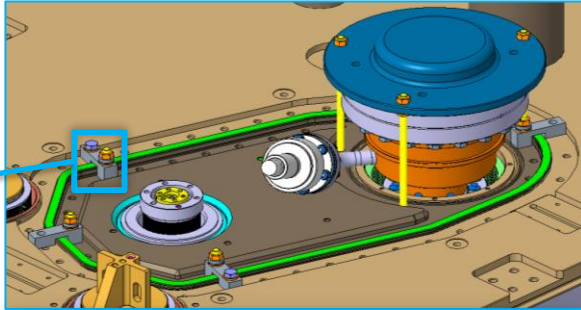
Perform integration of string



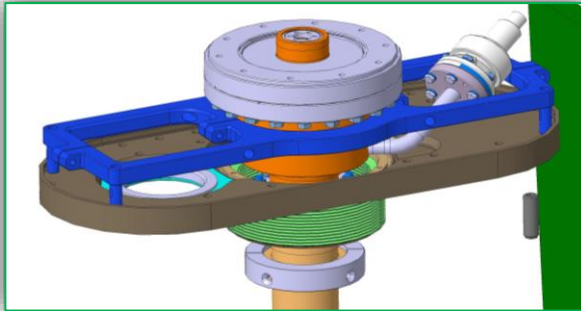
Trolley Positioning Tool

Improvements FPC plate tooling

RFD Tooling

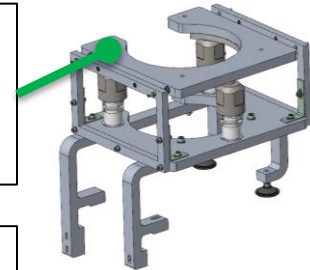


DQW Tooling

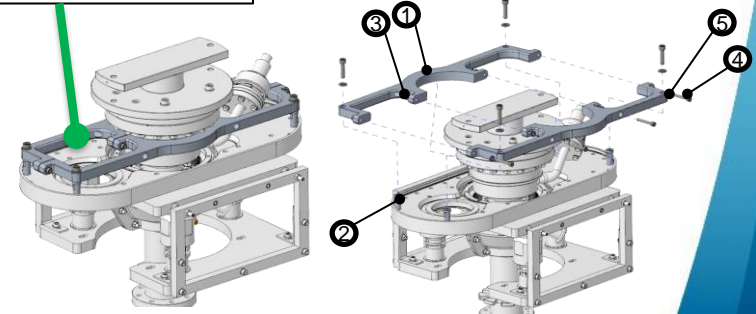


- Improved alignment tooling for welding plate to FPC bellows
- Improved support tooling for FPC plate (mimic interfaces used on Cryomodule)

Alignment support for plate welding, designed for orientation w.r.t centre axis



Fixture to support FPC plate during assembly designed to replicate CM interfaces

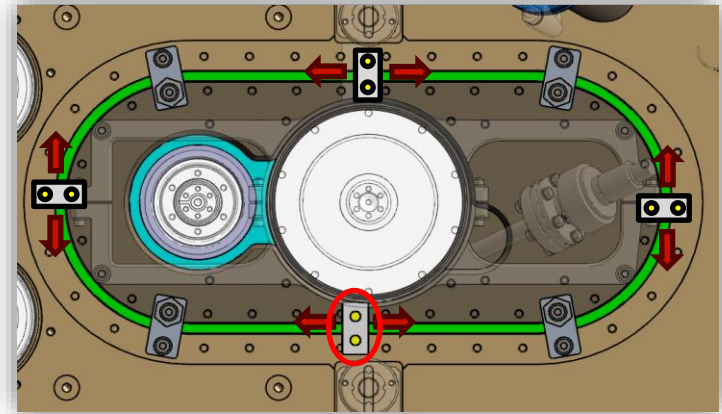


Challenges:

- Needs to pass through OVC top plate
- Support cantilever load
- Height and level adjustment for welding

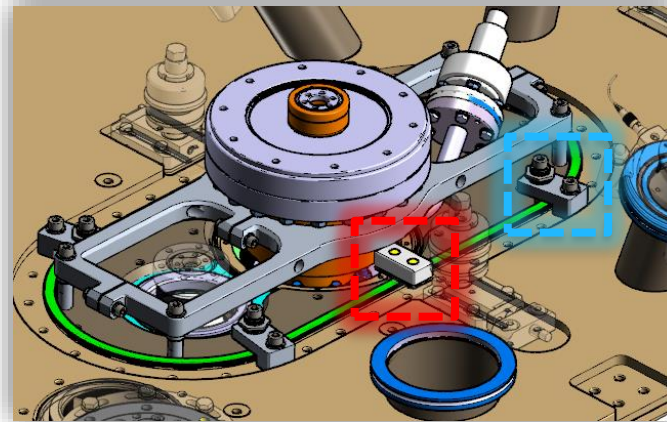
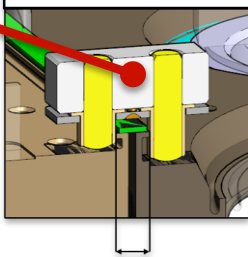
FPC plate welding and installation

- Extra tools designed to check and align FPC plate to OVC
- Load path removed between FPC and plate

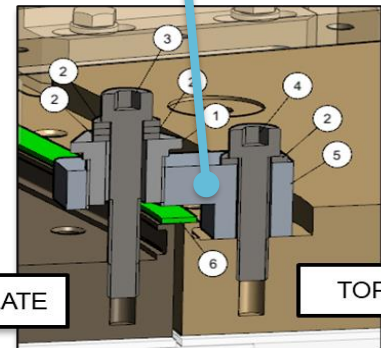


Gauge to align weld features between FPC plate and OVC

FPC TOP PLATE GAUGE



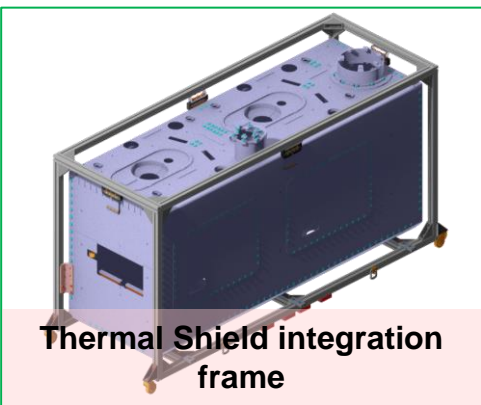
Setting tool to control height of Plate locally



FPC PLATE

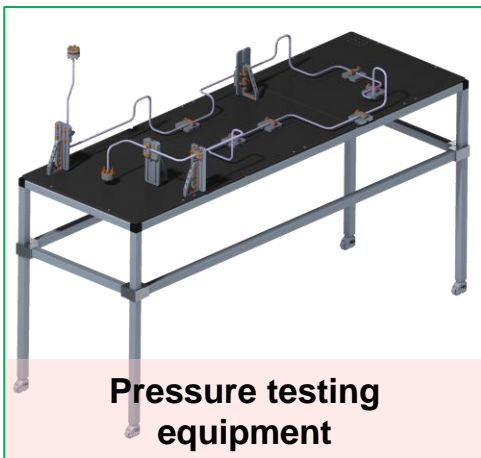
TOP LID

Space saving & design optimisation

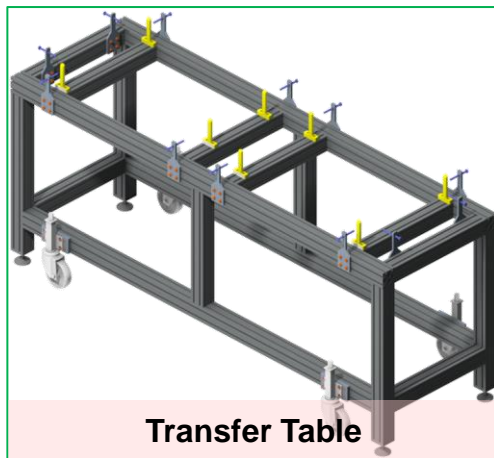


Thermal Shield integration frame

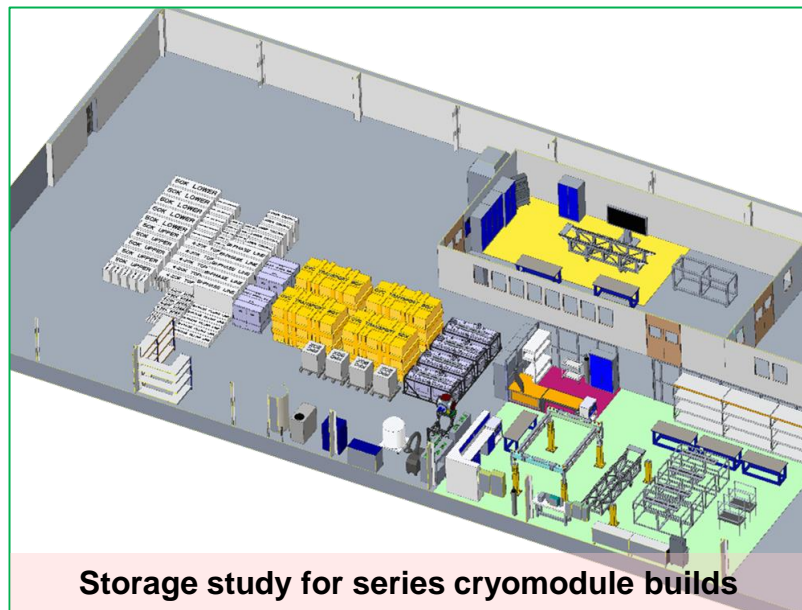
- Improved Cryogenic pressure testing table – includes breadboard for adjusting clamp positions
- Low profile thermal screen integration frame
- Bulky transfer table replaced and dismantled



Pressure testing equipment



Transfer Table

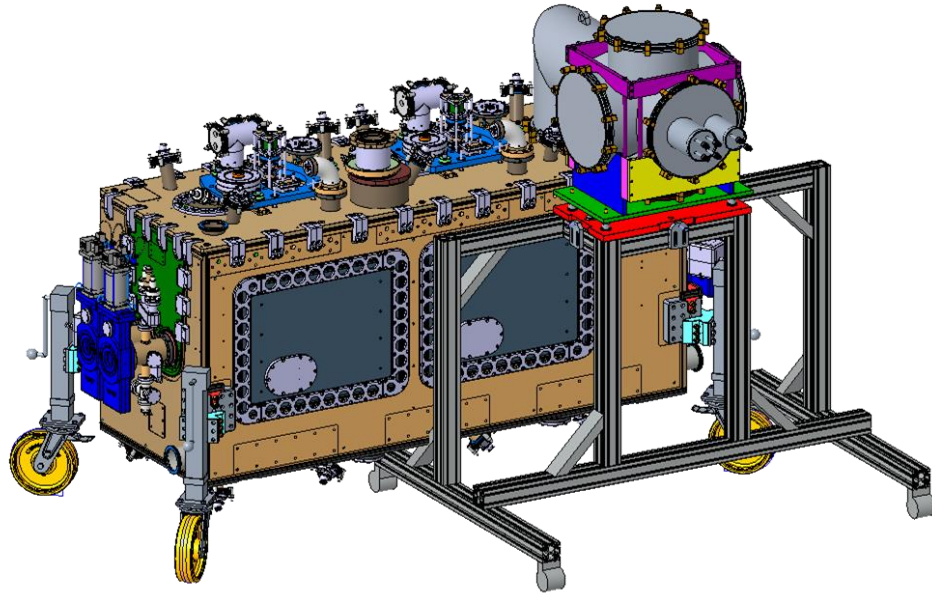


Storage study for series cryomodule builds

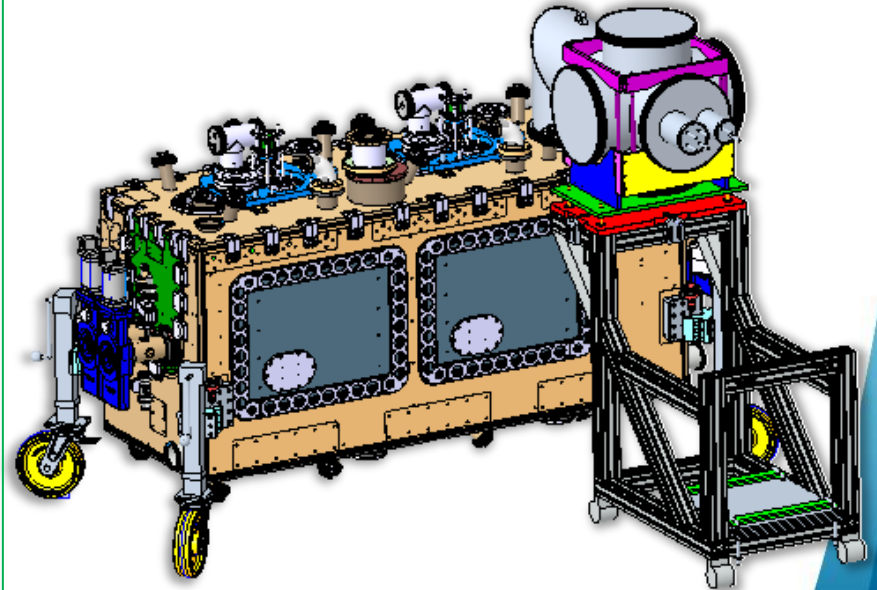
Space saving & design optimisation

- Cold test trolley for outgoing acceptance testing
- New Cantilever frame reduces footprint
- Easier to work around

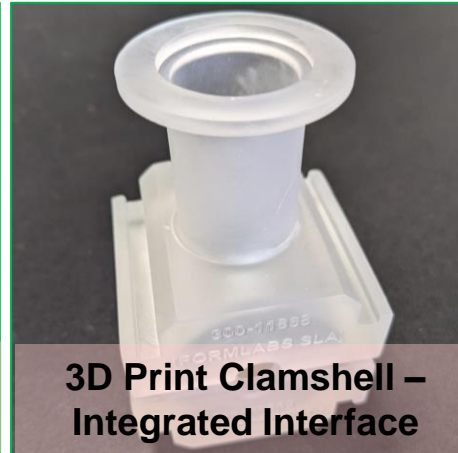
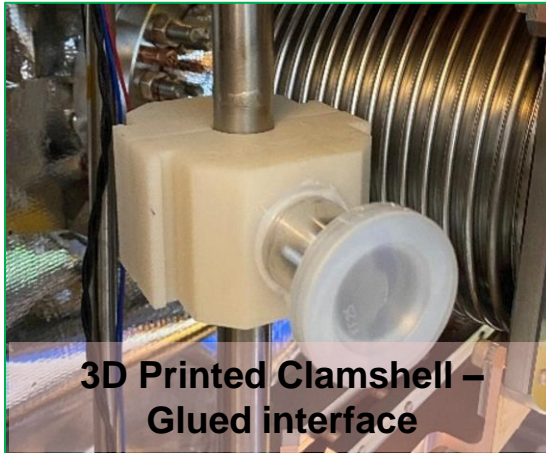
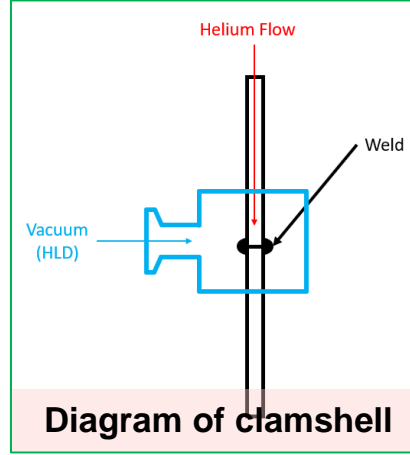
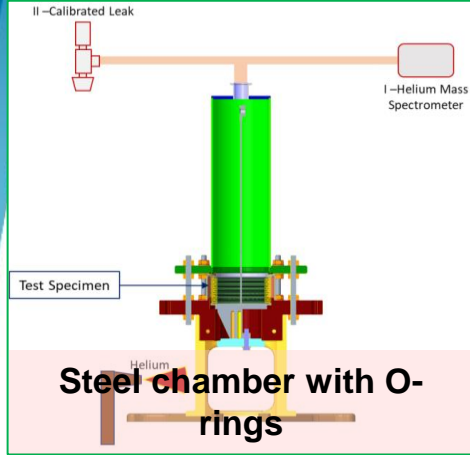
RFD



DQW



Evolution of weld leak test tooling

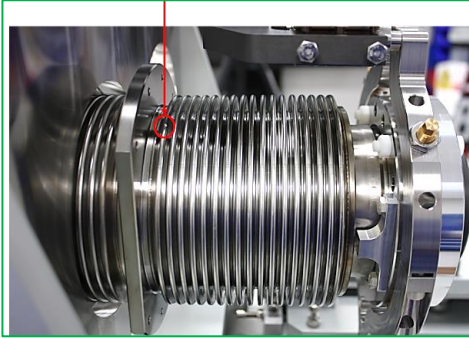
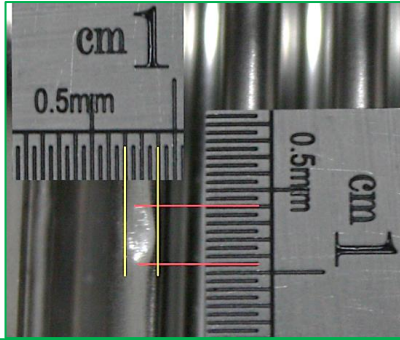


SLA 3D Printed Clamshell

- Cost saving
- Low lead time
- No welding
- Next : No glueing

Credit: Oliver Poynton (STFC)
Luke Farley
Ali Seller et al (CERN)

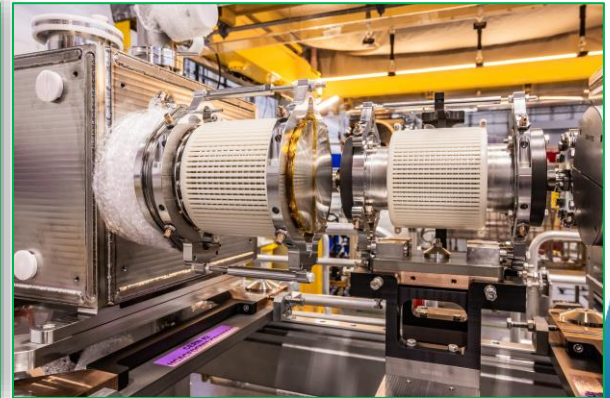
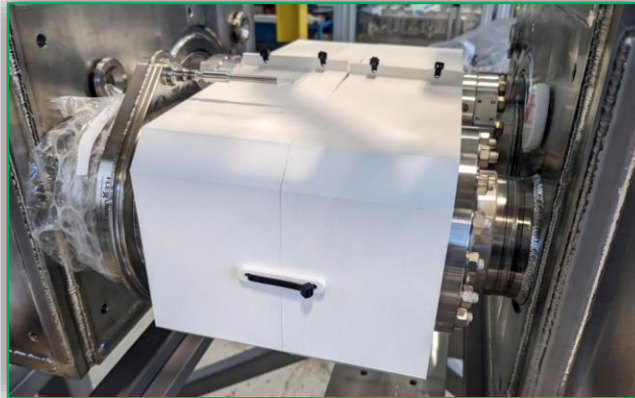
Bellows protection



- Handling errors experienced during RFD SPS build
- Some imperfections are the result of not following procedure correctly, some from suppliers, others unknown.
- Difficult to categorically conclude when damages occurred as travellers were quite lightweight

Improvement

- Bespoke covers design for DQW build for various processing and assembly steps with bellow components



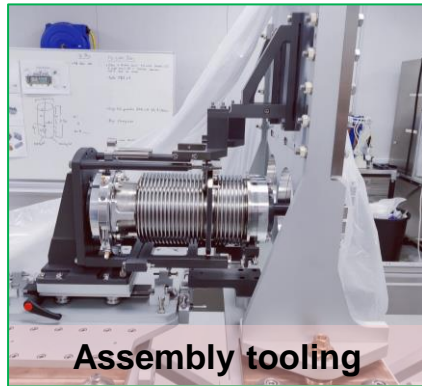
Plug-In-Module Ultra-High Vacuum Processing

Assembly and test tooling for;

- Ultra pure water rinse, Isopropanol bath, and N₂ dry in ISO4
- + RGA & helium leak test, and particle count qualification



Particle Count Test



Assembly tooling

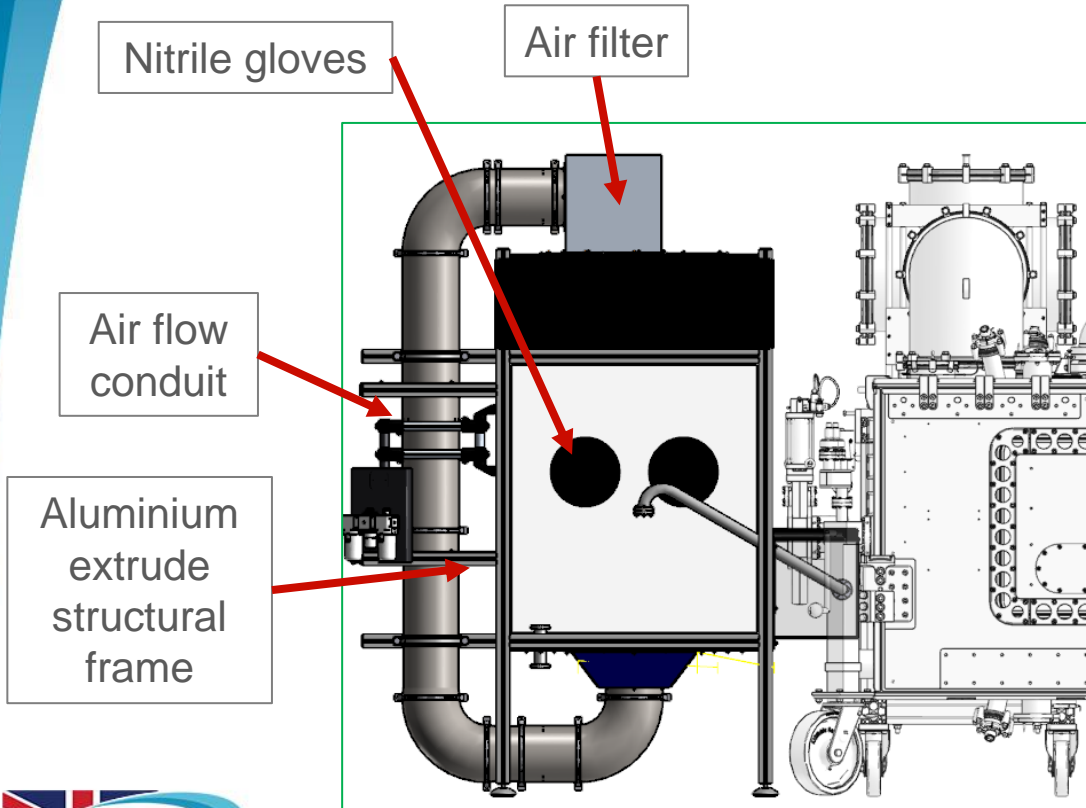


RGA & leak testing



Beamscreen cleaning at Daresbury

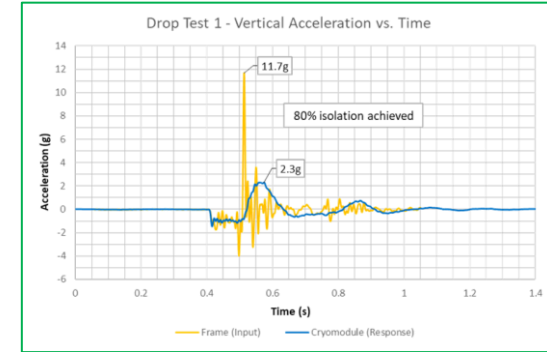
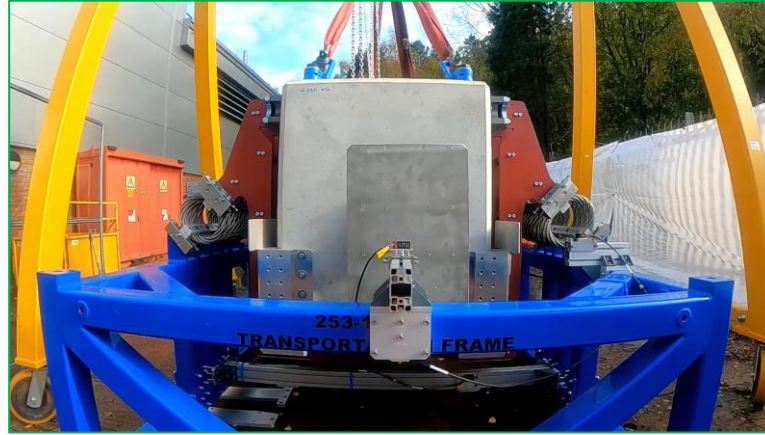
Portable cleanroom for beamline vacuum testing outside of the cleanroom



- Allows for temporary access to critical beamlines
- Final leak and RGA test on beamline outside of cleanroom
- Maintains ISO-4 connections of the beamline throughout the build at Daresbury
- Nitrogen > Vacuum > Nitrogen conversion

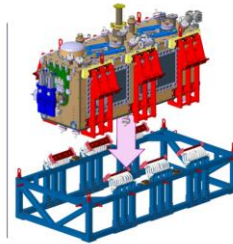
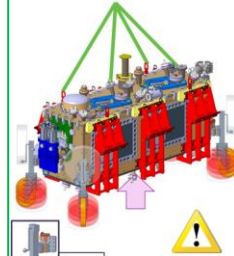
Anti-shock Transport frame & tooling

- STFC design & procurement
- MIL-STD-810H spec.
- 80% isolation



14-2-1 Lift module into frame + remove castors

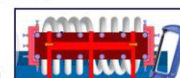
Rigging



Designation	Spec.	QTY	Torque
HHS-120-040	8.8	72	63.7 Nm
Was-120	-	72	-



Remove
x4

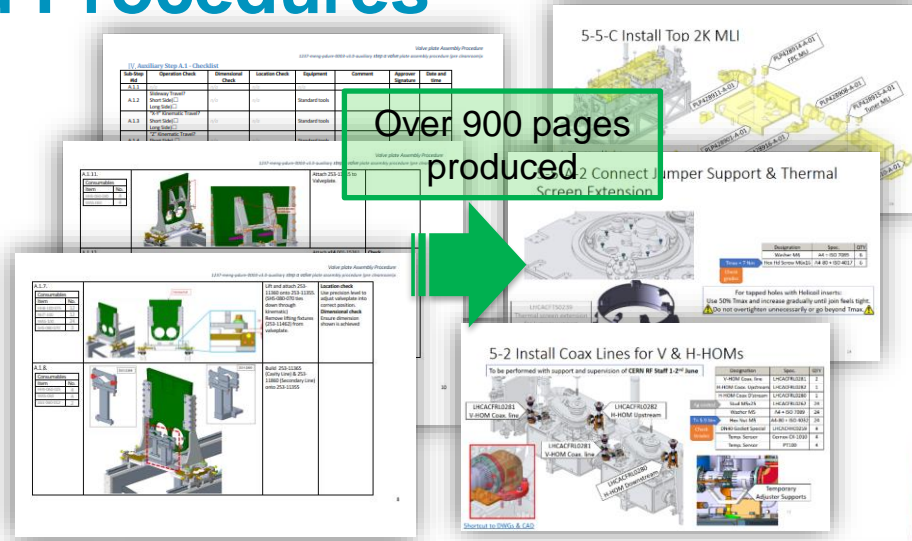


- Lift Module and remove 4x jacking castors
- G-clamps can be used to coarsely manipulate plates face to face at touch down
- Load Cell to measure hoisted Mass
- Load ~ 4800kg

1237-meng-pdure-0044-v1.0 Step 14 Transport Tooling

Detailed Build Procedures

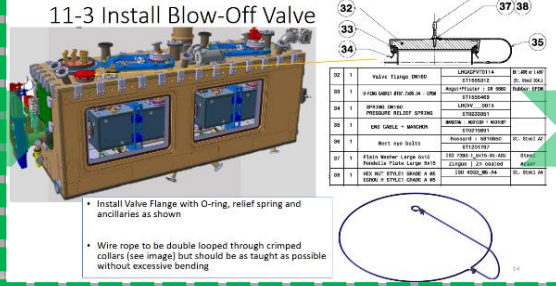
- Poster logic + tooling & infrastructure
- Part of Traveller (QA)
- Troubleshoots & de-risk build
- Captures critical requirements, torques & sign-off
- 'BOM kits' pre-prepared by sub-step



Step 11

- 1 Installation of insulation vacuum instrumentation
- 2 Installation of secondary beam line vacuum assemblies
- 3 Installation of blow-off valve for insulation vacuum
- 4 Inspection and leak check of UHV secondary line

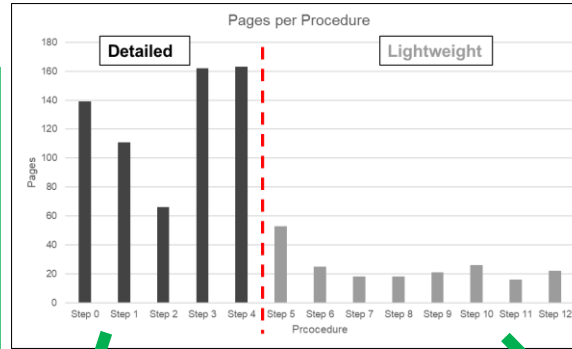
11-3 Install Blow-Off Valve



RFD Procedure Bottleneck

Mitigation

- DQW procedure development progressing well. Need to maintain buffer between publication & execution to allow information digestion beforehand



Lite Procedure approach

4.4.1 Sub-Step 4.4.1 - Installation

Image	Description	Checks
	Install the tuner bellows protection/ installation tool on the flanges of the tuner	
	Measure lateral distance of tuning frame to helium tank	
	Apply MoS2 on the thread M27 of the inner tube of the tuner actuator before (LHCACFTU0007) and let it dry.	
	If the vertical alignment is good, tighten the two times three M16x20 screws of the outer tube spacer on the second beam line side to the torque indicated in Table 8 (11 Nm).	Microscope value of 11 Nm
	At this point, the double tube is connected and aligned with the tuner frame.	
	Remove the outer tube spacer on the cavity side (not tightened side).	

4.4.2 Consumables

Item	No.	Unit
MS10-001	3	
MS10-002	3	

4.4.3 Consumables

Item	No.	Unit
MS10-001	3	
MS10-002	3	

4.4.4 Consumables

Item	No.	Unit
MS10-001	3	
MS10-002	3	

4.4.5 Consumables

Item	No.	Unit
MS10-001	3	
MS10-002	3	

9-2-10

On the Secondary line SHORT side, release the bolts holding the braids down on LHCACFRL0261. Do not fully remove the clamp.

1206-meng-plans-002-v0.4 Step 9 Procedure

Step-5.4

- From below the frame, bolt LHCACFTQ0553 to LHCACFTS0429 using LHCACFTS0501 (9.4mm tall) and CSK-050-025-A4 (Ag COATED)
- Hand tighten all bolts.

DO NOT TIGHTEN THIS CLAMP

1206-meng-plans-002 Aux D Thermal shield integration (v0.4)

Step-7.2

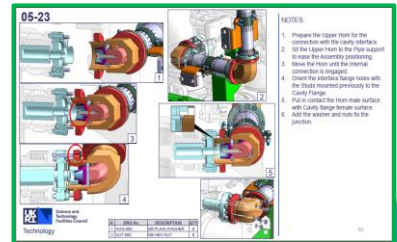
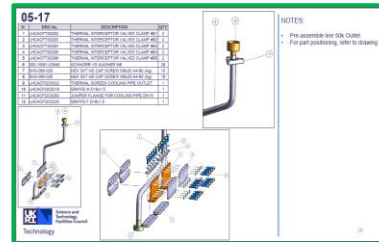
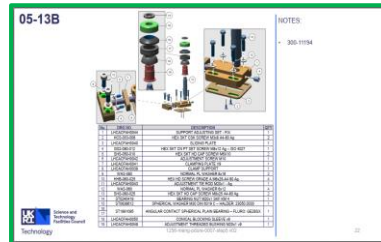
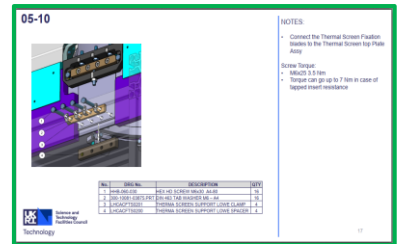
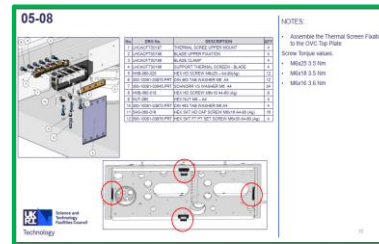
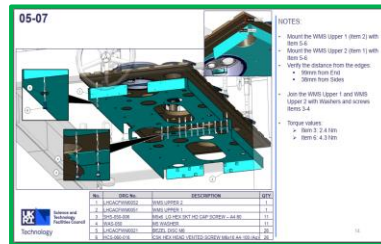
- Attach two LHCACFTS0447 to LHCACFTS0392 using CSK-050-014-A4 (Ag COATED) and LHCACFTS0208 (4.15mm tall). Conform to engineering drawing LHCACFTS0425 to ensure correct alignment. Hand tighten all bolts.

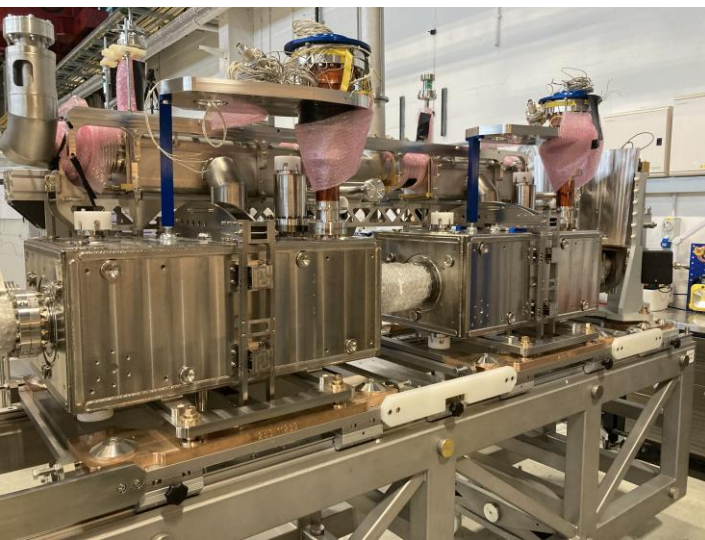
1206-meng-plans-002 Aux D Thermal shield integration (v0.4)

Where to next?



- 5 years of procedure progression so far
- Effort should match risk and reward
- VR/AR considered for future cryomodules
- Current procedures are viable for Hi-Lumi





Questions?

