UK1 RFD Status, CM Transport & Series DQW Cryomodule Planning

Thomas Jones (STFC) on behalf of the UK team

9th HL-LHC Collaboration Meeting,14 to 16 October 2019 FNAL

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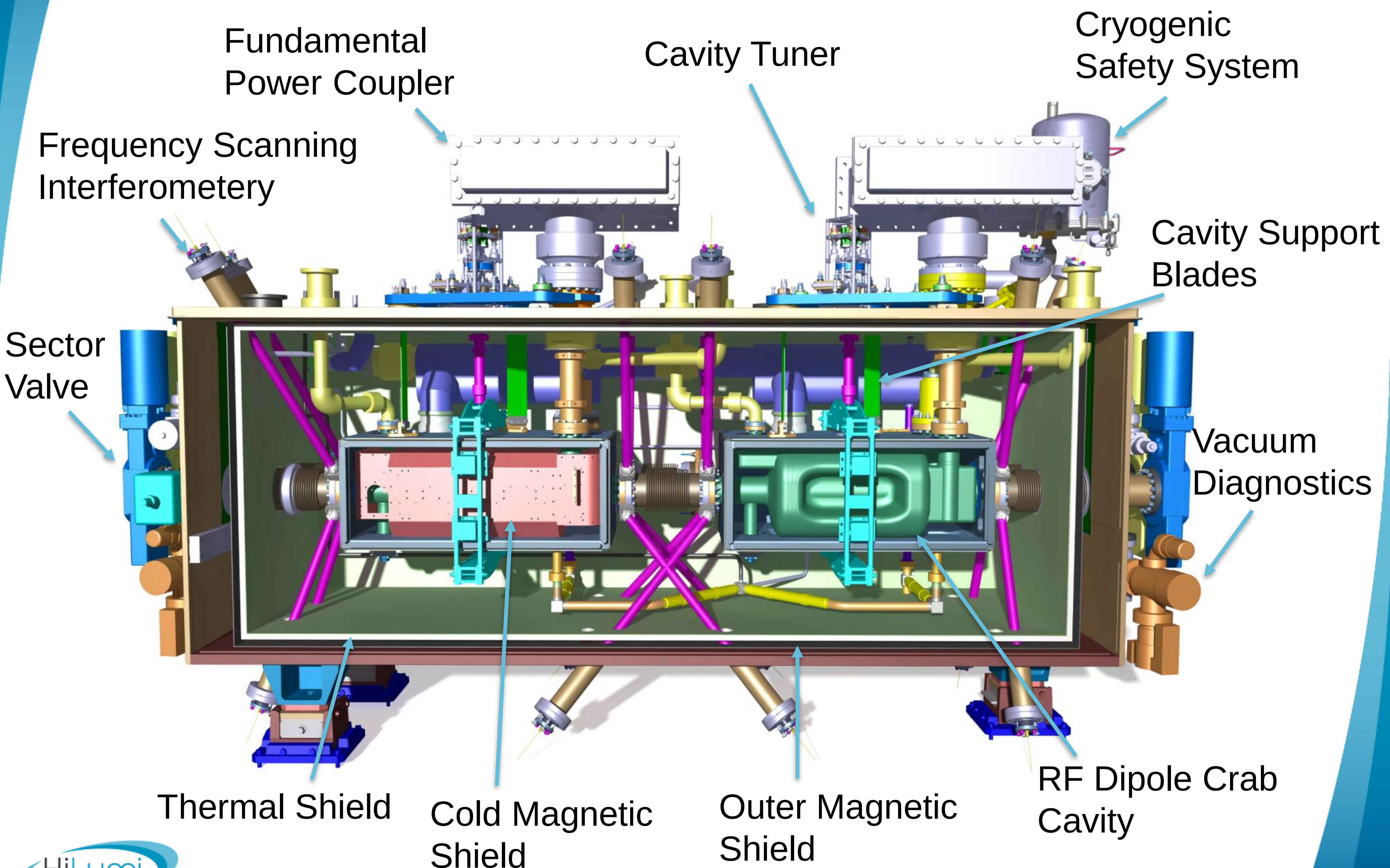
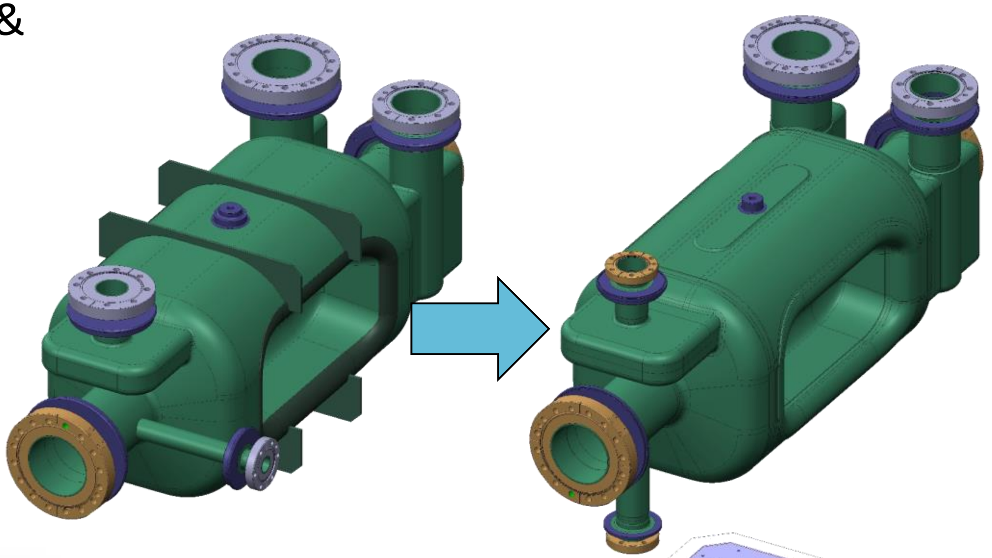
- Scope of WP2, Series Crab Cavity Cryomodule Build in UK
- Schedule for Series Crab Cryomodule Build

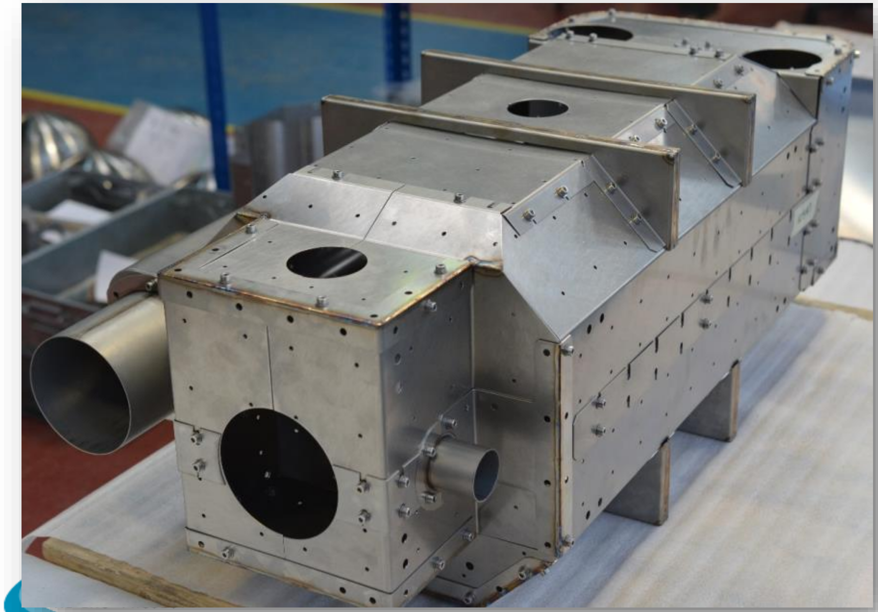
SPS-RFD Cryomodule

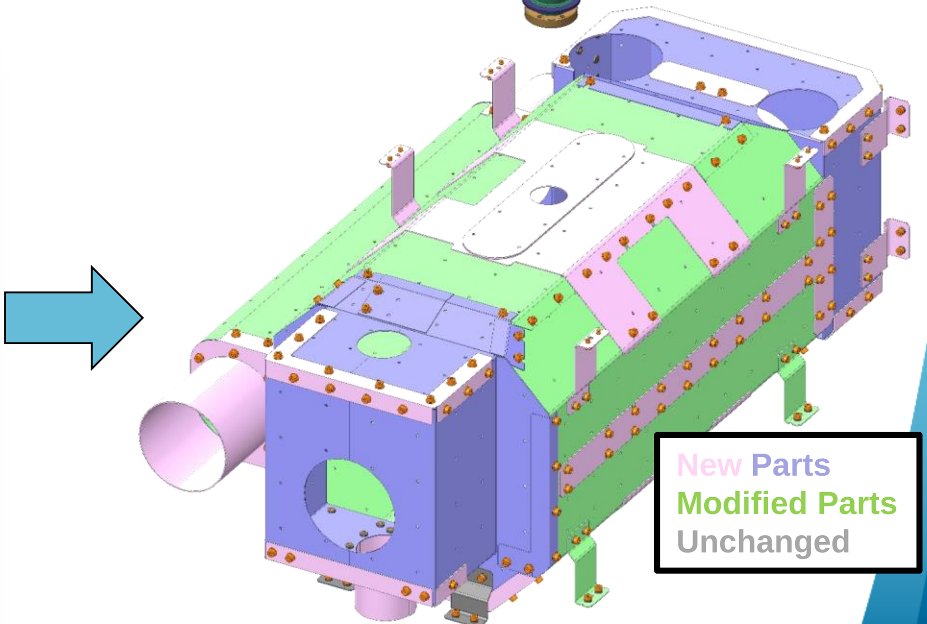


SPS-RFD Cold Magnetic Shield

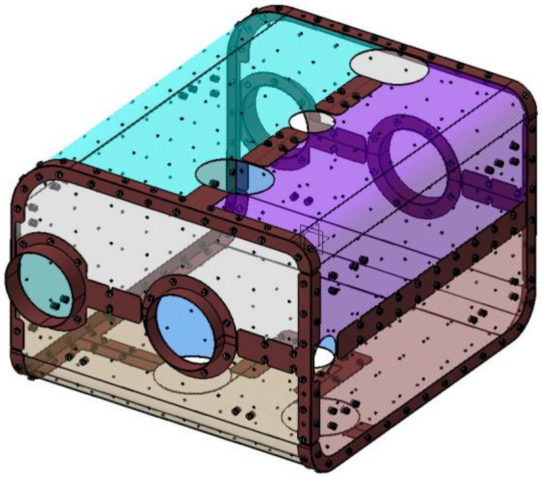
- RFD Cold Magnetic Shields designed & delivered to CERN in Apr '16
- Changes in cavity design mean shield designs require revision
- Approach taken to modify & reuse existing shields (as much as possible)
- Detailed design: Complete
- Integration checks: On-going
- Specification & Tender: On-hold



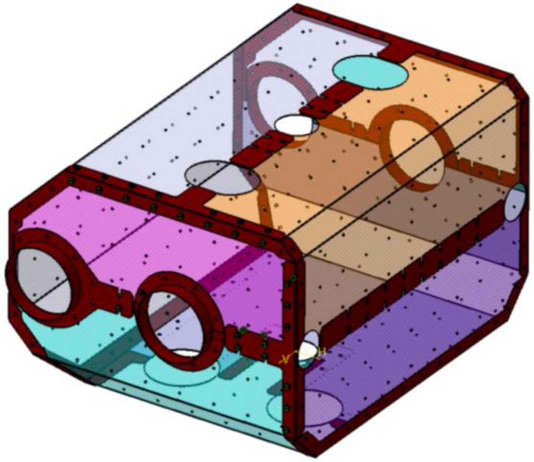




DQW Series Cold Magnetic Shield



Prototype Design



New Design

Status:

- Design and specification complete and drawings issued.
- Tender process complete and order placed for first 2 units.
- Delivery expected in December 2019 to be installed in prototype jacketed cavities.

SPS-RFD Warm Magnetic Shield

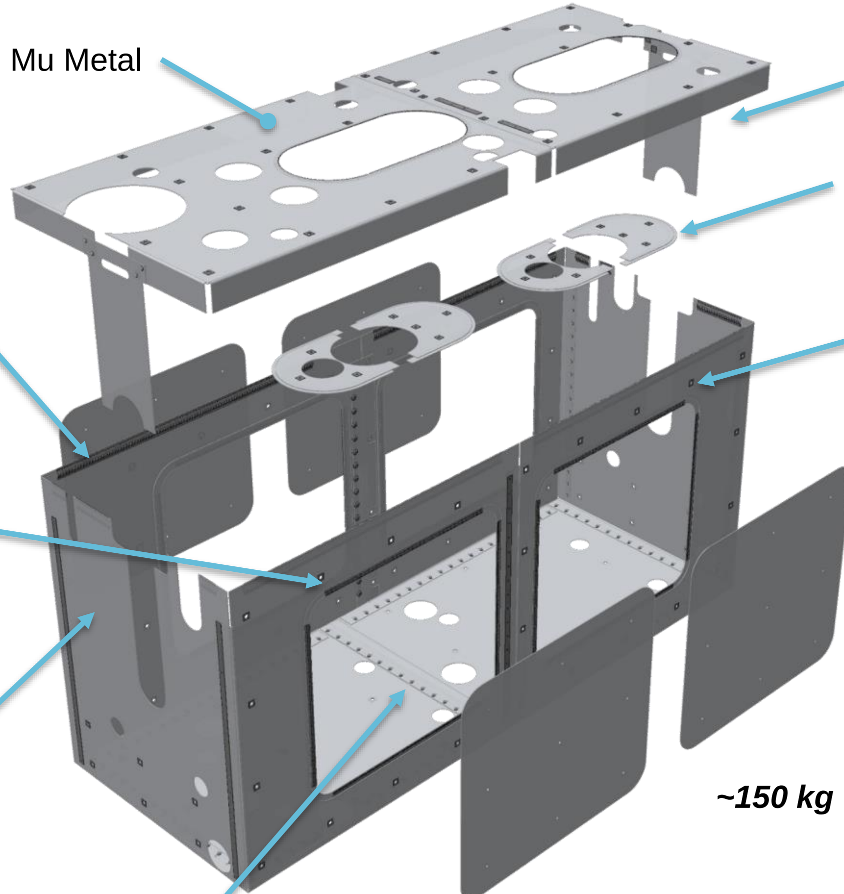
Top Joint EM Gasket

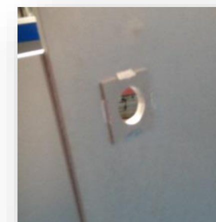
2mm Mu Metal

Top Assembly

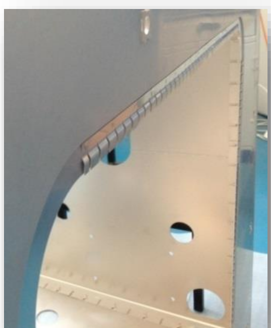
FPC Cover

Tapped OVC Spacers





Window Joint Spring Fingers



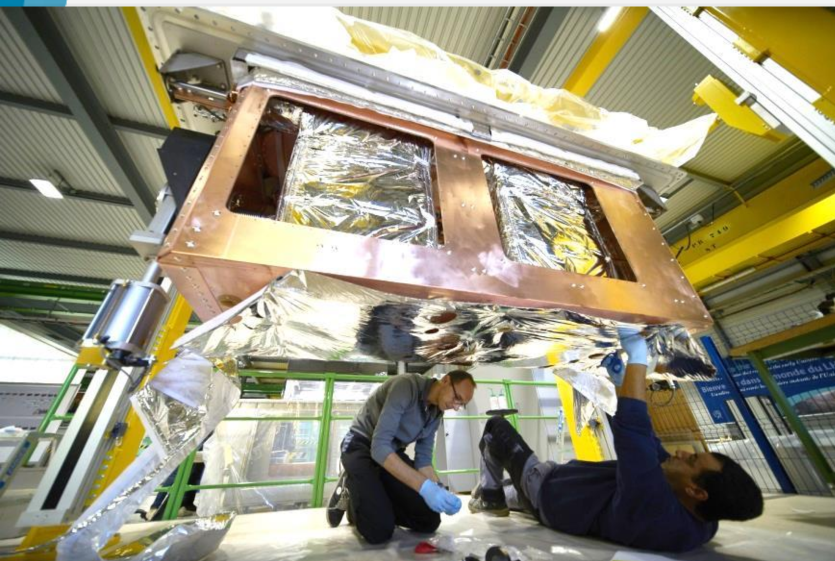
Windows

Lower Assembly

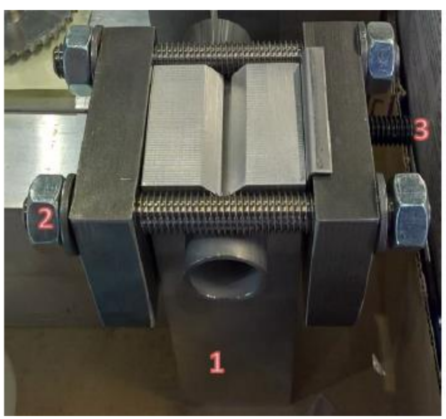
~150 kg

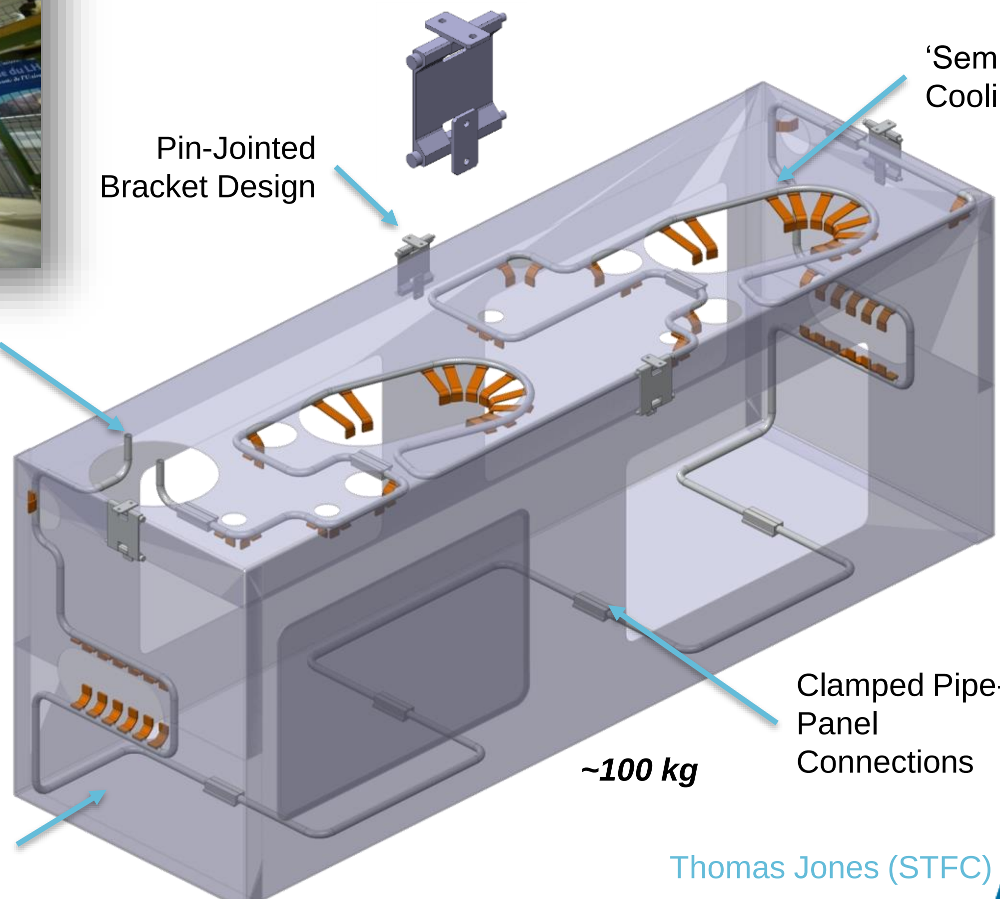
Sliding Joints for OVC Tolerance

Thermal Shield

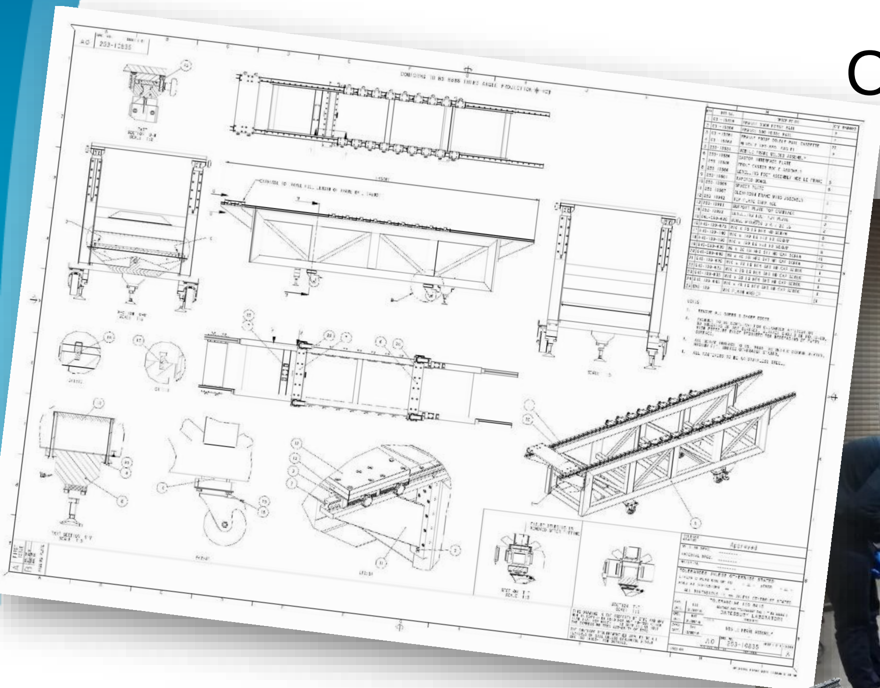


- Al1100 panels give significant cost and weight savings for series production
- SS316 Cooling circuit for cryoline integration and pressure safety

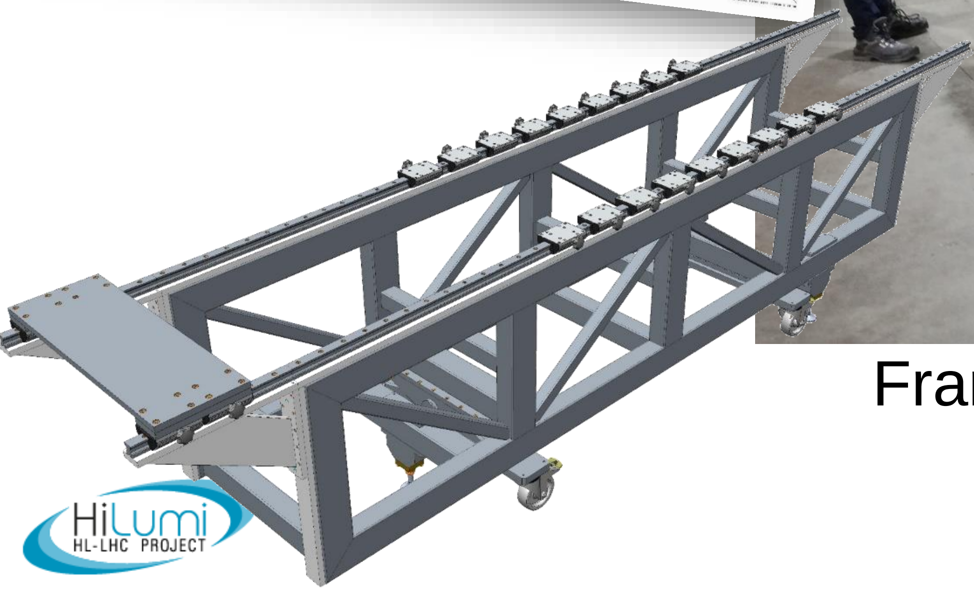




Assembly Tooling



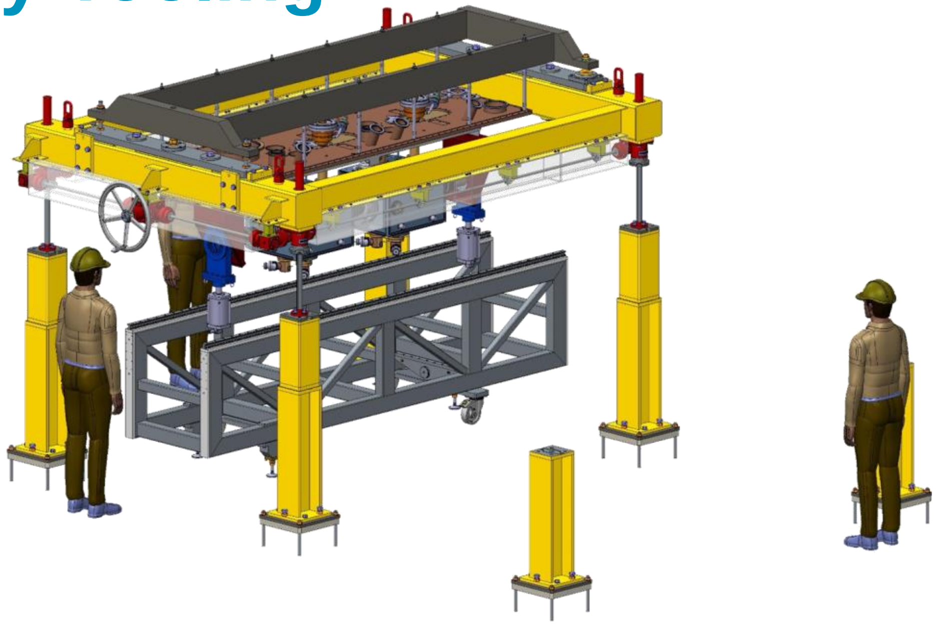
Cleanroom Cavity String Assembly Frame Acceptance Test



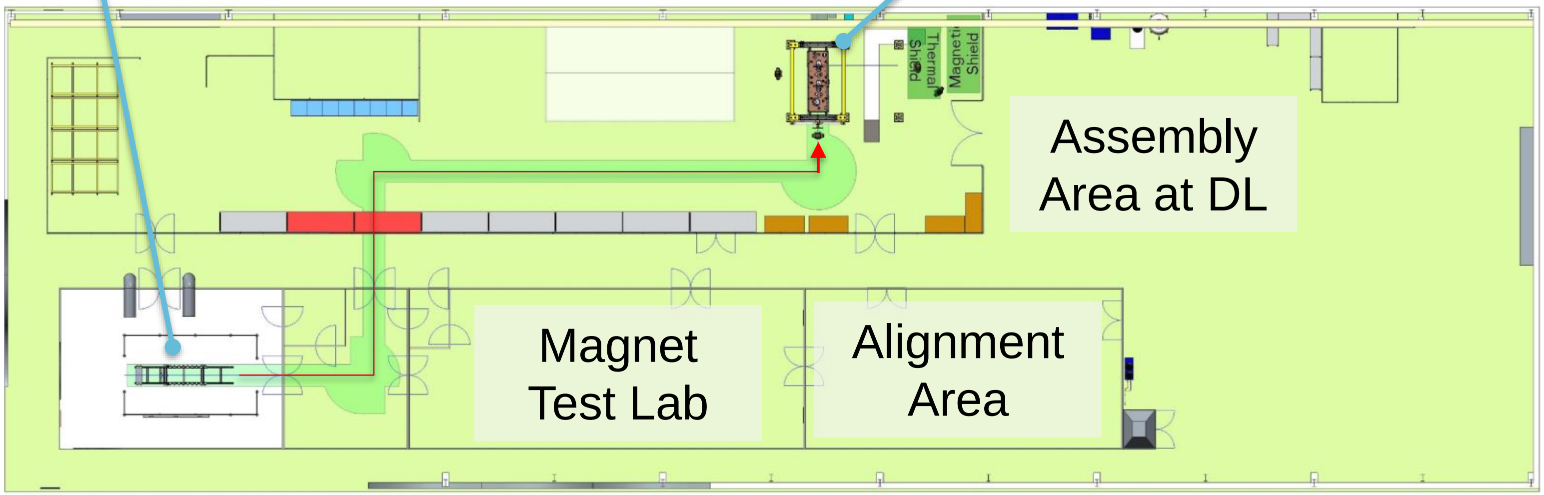
Frame now delivered to DL (First hardware on site)

Assembly Tooling

ISO4 Cleanroom extended to 6m



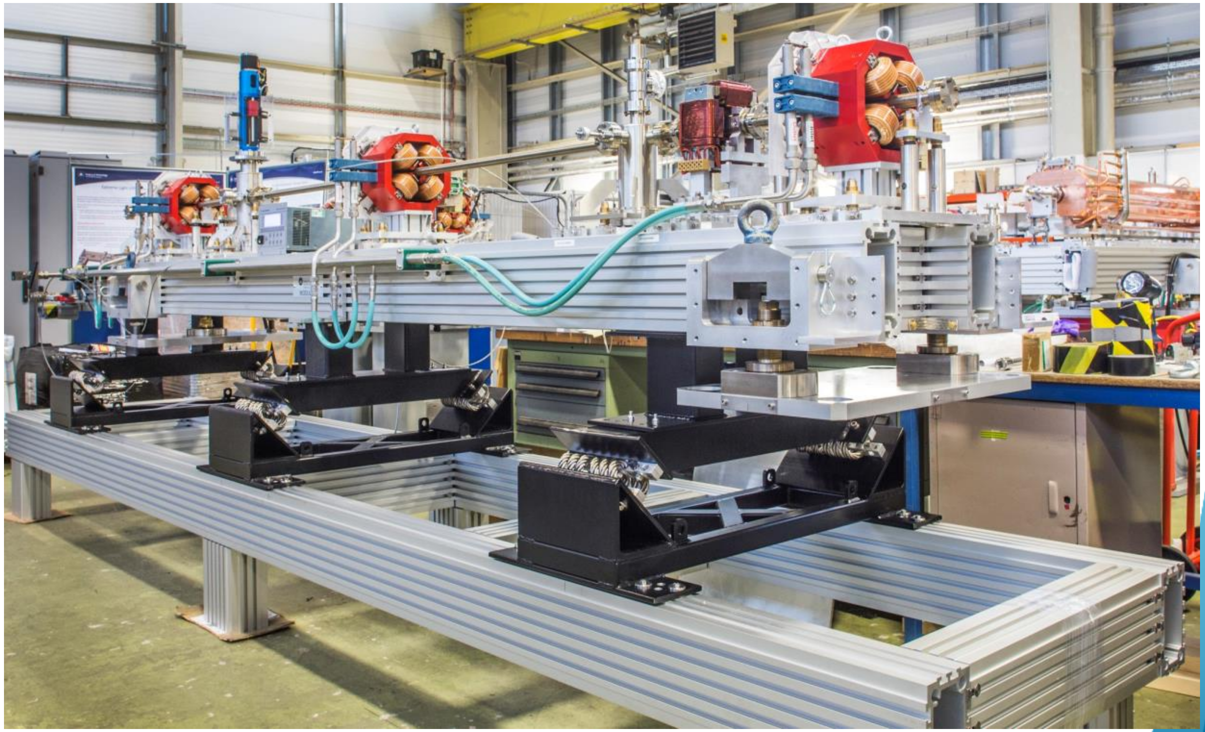
Cavity String Lifter Design Complete



Workflow in assembly area developed

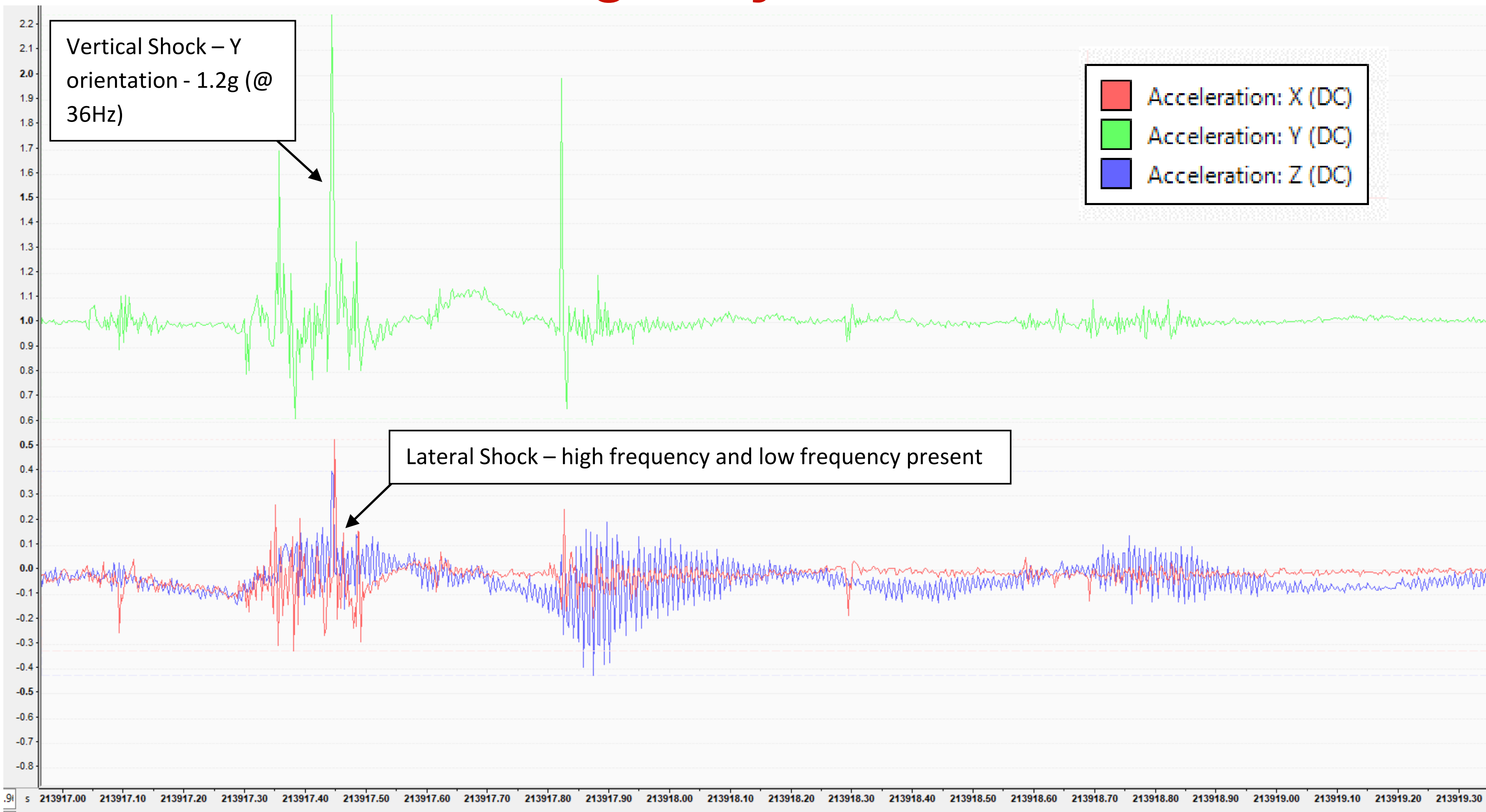
Transportation - STFC Experience

- Wire Rope Isolators proven to reduce shock and random vibration transmission
- Experience (and data) gained at Daresbury through shipment of 2 Cryomodules US to UK and 12 modules to UK to Romania



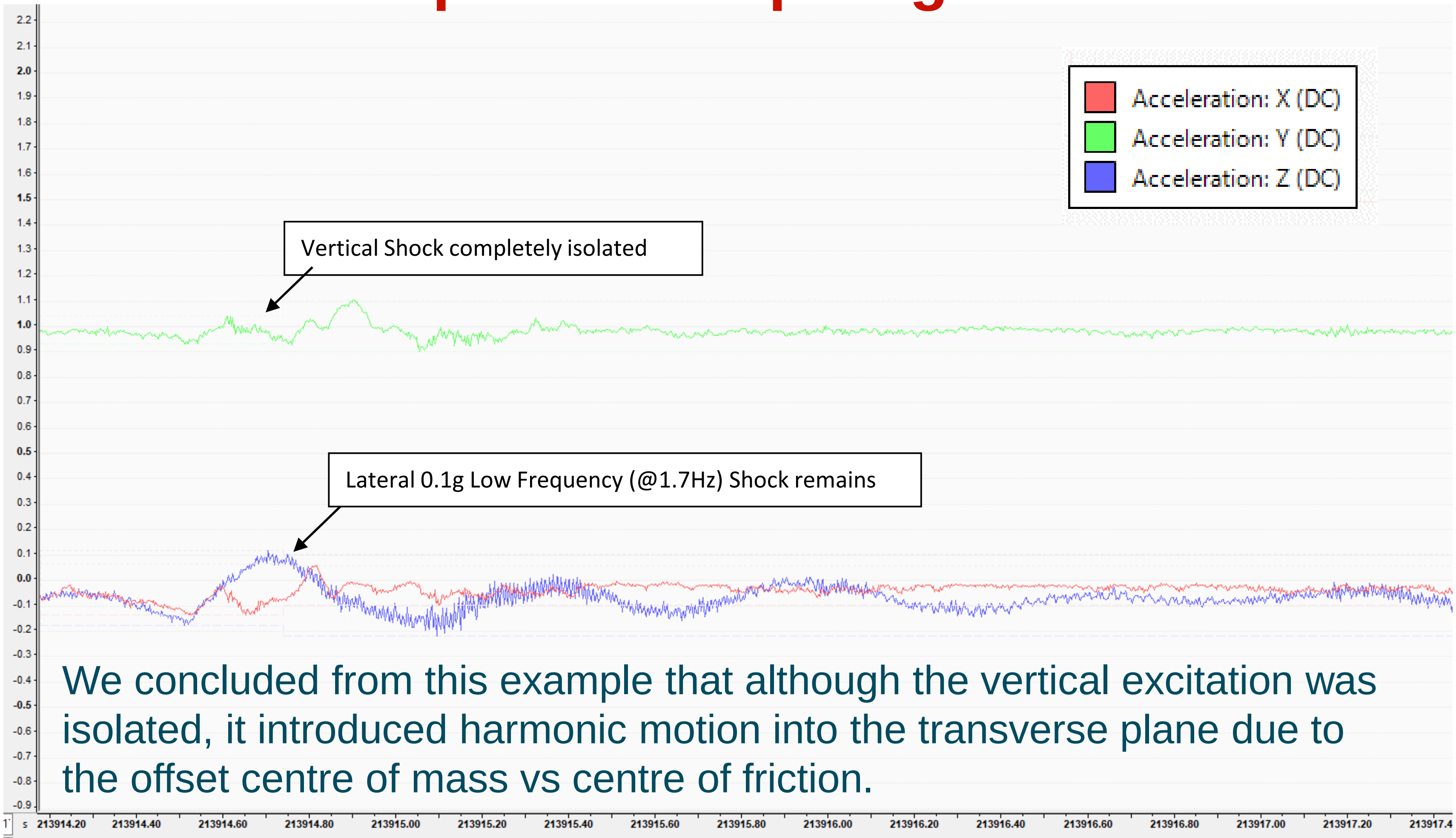
Vertical wire rope isolator performance

Shock from highway event – Truck bed



Vertical wire rope isolator performance

Response on sprung frame



We concluded from this example that although the vertical excitation was isolated, it introduced harmonic motion into the transverse plane due to the offset centre of mass vs centre of friction.

Transportation Specification

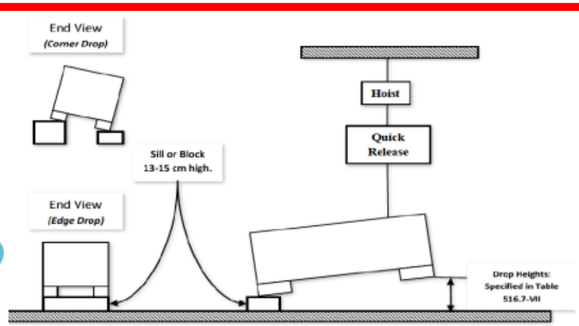
Isolator configuration design to meet test procedures stated in MIL-STD-810H;

"DEPARTMENT OF DEFENSE TEST METHOD STANDARD: ENVIRONMENTAL ENGINEERING CONSIDERATIONS AND LABORATORY TESTS"

Drop Height – 460mm

Table 516.8-IX. Logistic Transit Drop Test[1].

Weight of Test Item & Case kg (lbs)	Largest Dimension cm (in.)	Notes	Height of Drop, h cm (in.)	Number of Drops
Under 45.4 (100) Man-packed or man-portable	Under 91 (36)		122 (48)	Drop on each face, edge and corner; total of 26 drops[5]
	91 (36) & over		76 (30)	
45.4 - 90.8 (100 – 200) inclusive	Under 91		76 (30)	Drop on each corner; total of eight drops
	91 (36) & over		61 (24)	
90.8-454 (200 – 1000) inclusive	Under 91		61 (24)	
	91 – 152 (36 – 60)	2	61 (24)	
	Over 152 (over 60)	2	61 (24)	
Over 454 (1000)	No limit	3 4	46 (18)	Drop on each bottom edge. Drop on bottom face or skids; total of five drops

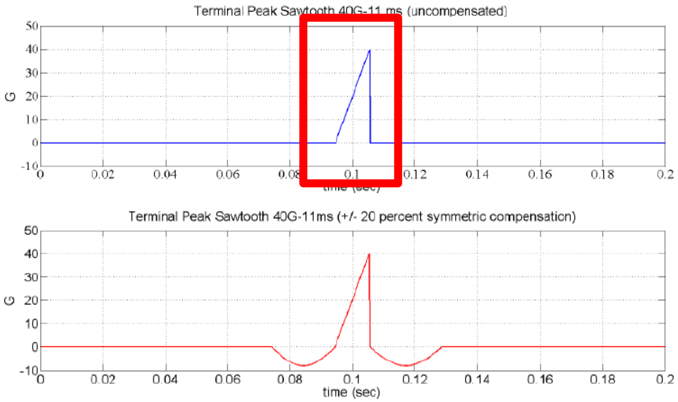


Road Transit (7.6G @ 45Hz Vertical)

Table 516.8-VII Procedure II - Transportation shock test sequence[1, 2, 3].

On Road (5000 km)[4] Terminal Peak Sawtooth Pulse Duration: 11 ms			Off Road (1000 km)[4] Terminal Peak Sawtooth Pulse Duration: 5 ms	
Amplitude (G-Pk)	Number of Shocks		Amplitude (G-Pk)	Number of Shocks
5.1	42		10.2	42
6.4	21		12.8	21
7.6	3		15.2	3

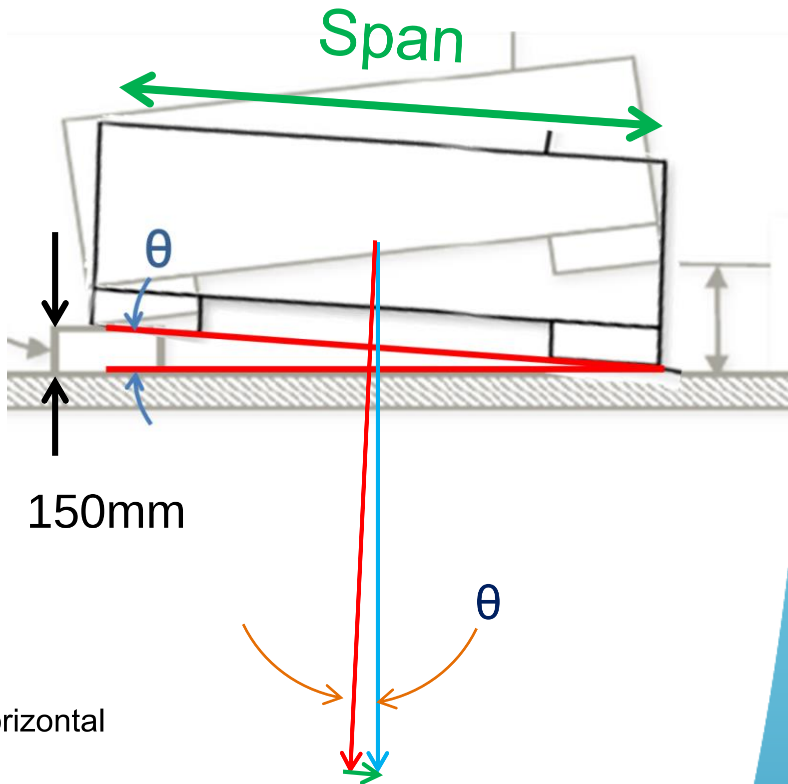
*Calculation uses half sinewave, not saw tooth



Transportation Specification

Drop Height – Horizontal & Longitudinal Calculation

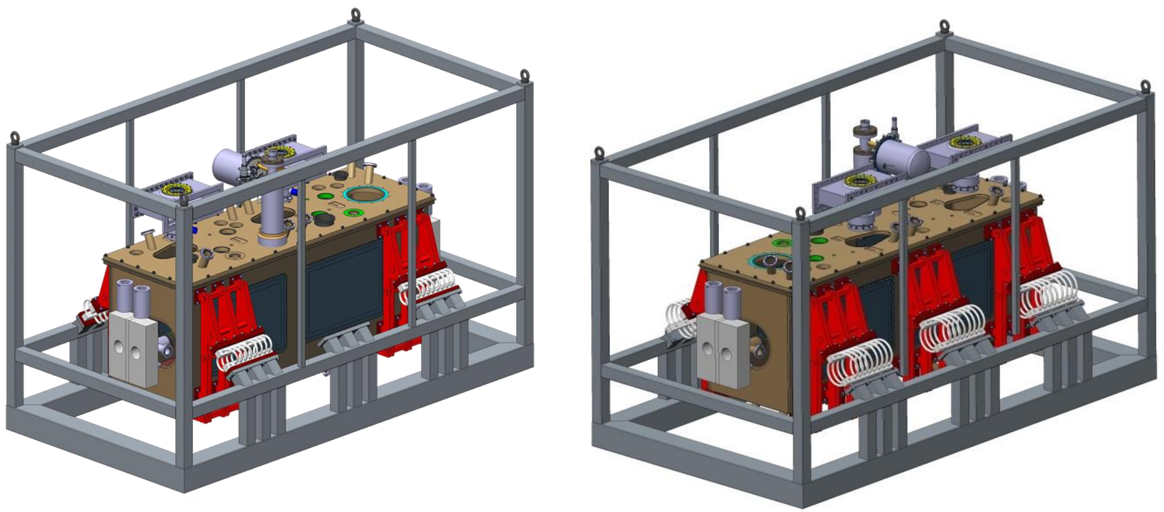
Load Orientation W.r.t CM	Frame Span	θ	Drop Height
	m		m
Vertical	0	0	0.46
Horizontal	2.185	3.93	0.032
Longitudinal	4	2.15	0.017



Horizontal Drop Height = Vertical Drop Height * $\theta_{Horizontal}$

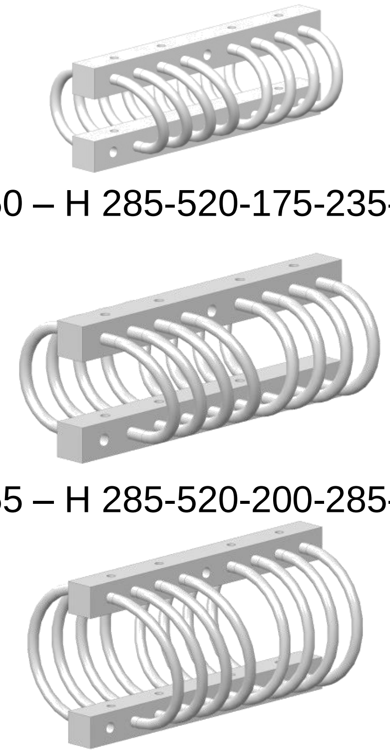
Longitudinal Drop Height = Vertical Drop Height * $\theta_{Longitudinal}$

Configuration options



4 Springs

6 springs



450 – H 285-520-175-235-8

455 – H 285-520-200-285-8

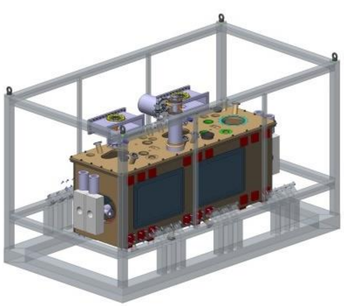
460 – H 285-520-265-315-8

Choose between 4/6 springs, and 3 different spring sizes to compromise between:

- **Deflection,**
- **Spring Capacity Utilised**
- **Resonant Frequency**

Result

			Semi-Sinusoidal shock vertical			Drop Height Shock vertical			Drop Height Shock Horizontal				Drop Height Shock Longitudinal		
Cryomodule Mass	No. Of Springs	Spring Selection	Deflection	Excited Natural Frequency	Spring Stroke Capacity used 1st	Deflection	Excited Natural Frequency	Spring Stroke Capacity used 1st	Deflection	Excited Natural Frequency	Spring Stroke Capacity used 1st	Spring Stroke Capacity used 2nd	Deflection	Excited Natural Frequency	Spring Stroke Capacity used 1st
kg	-	-	mm	hz	%	mm	hz	%	mm	hz	%		mm	hz	%
4228	6	450_H_285_520_175_235-8	18.16	5.09	19.76	-	-	CAPACITY REACHED	-	-	-	-	-	-	-
4228	6	455_H_285_520_200_285-8	26.42	3.91	23.35	-	-	CAPACITY REACHED	-	-	-	-	-	-	-
4228	6	460_H_285_520_265_315-8	37.08	2.96	18.73	178.37	2.67	90.09	50.54	1.70	41.08	25.53	66.38	2.03	47.42
4152	4	450_H_285_520_175_235-8	24.74	4.10	26.91	-	-	CAPACITY REACHED	-	-	-	-	-	-	-
4152	4	455_H_285_520_200_285-8	36.25	3.17	32.04	-	-	CAPACITY REACHED	-	-	-	-	-	-	-
4152	4	460_H_285_520_265_315-8	57.54	2.31	29.06	-	-	CAPACITY REACHED	-	-	-	-	-	-	-



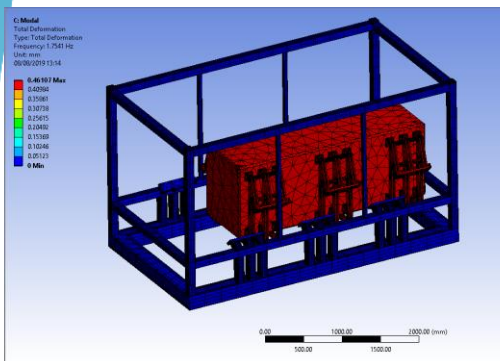
CM Mass 4000kg

Arm Mass (Al) 38kg

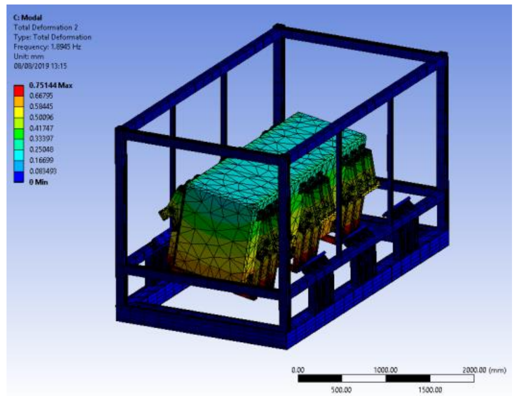
- Only compatible configuration that complies with MIL-STD-810H is 6 x “460 type” isolators, (at current mass estimates)
- Demands:
    1. Vertical stroke clearance of 180mm,
    2. Horizontal stroke clearance of 51mm,
    3. Longitudinal storke clearance of 67mm,

FEA – Resonant Modes

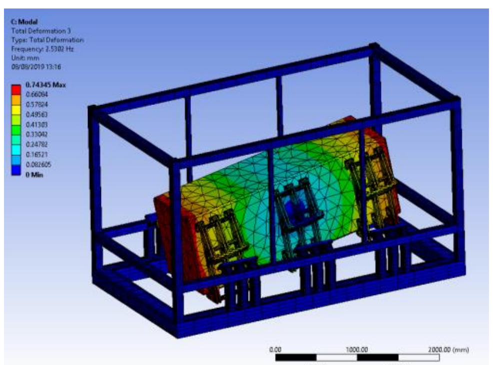
Using the non-linear spring data as an input for springs in Ansys, the initial natural frequencies of the assembled system can be identified.



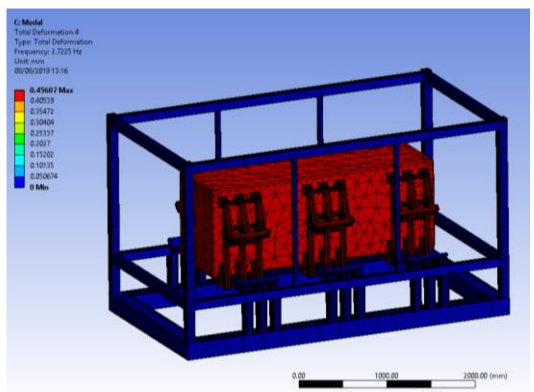
Mode 1



Mode 2



Mode 3



Mode 4

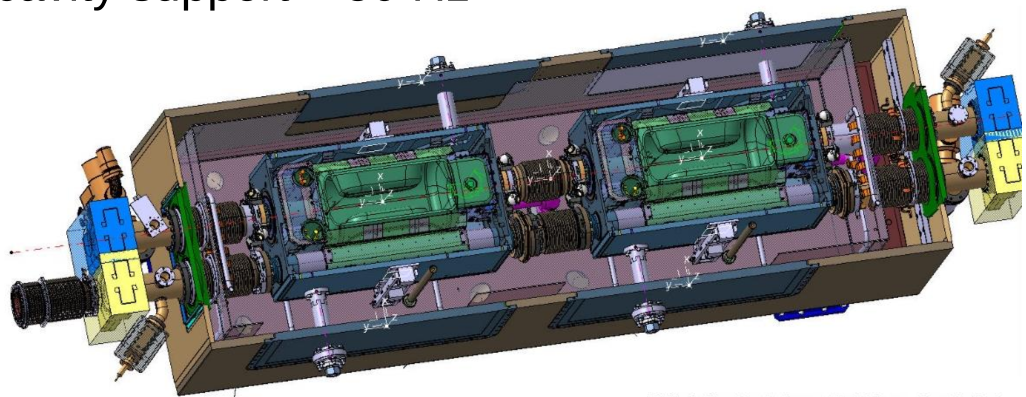
Mode no.	Frequency (hz)
1	1.7541
2	1.8945
3	2.5302
4	2.7225
5	2.7906
6	4.3533
7	18.191
8	21.997

Use this analysis to calculate maximum motion and avoid resonances within the module

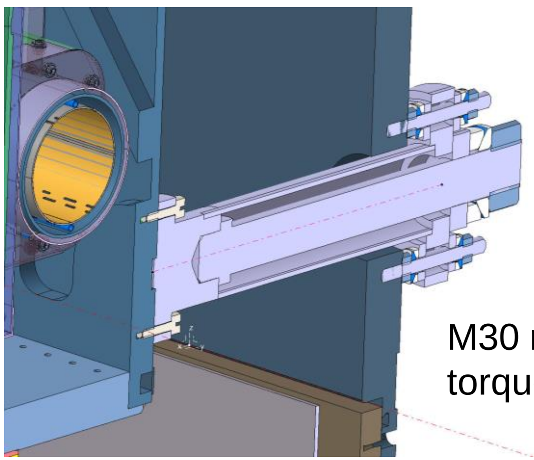
Transport restraint design status

Transport restraints shift modes cavity support > 50 Hz

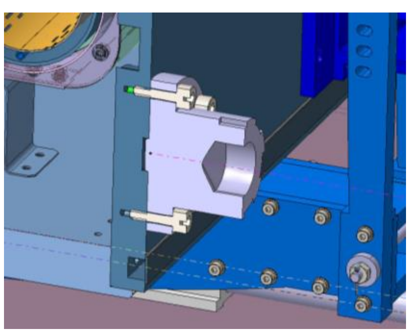
Position layout fixed and implemented in RFD He-tank design



Current design restraint



M30 rod + counter torque tube



Remaining pad after transport

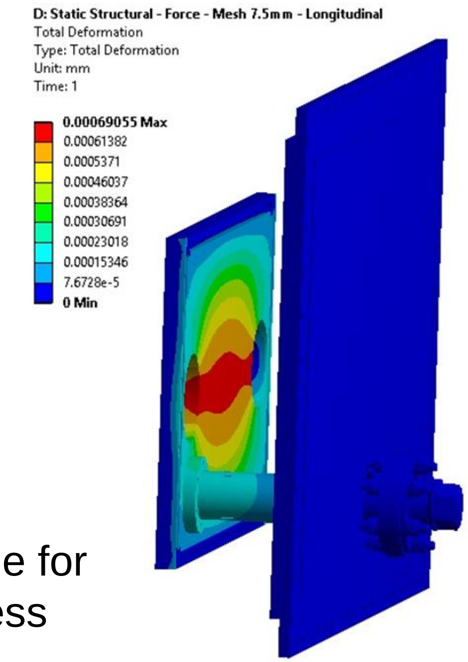
Holes in door and shields covered by flange with inserts

Details not decided as design CM ongoing

Stiffness and stresses verified with 10g reaction forces (on DQW model)

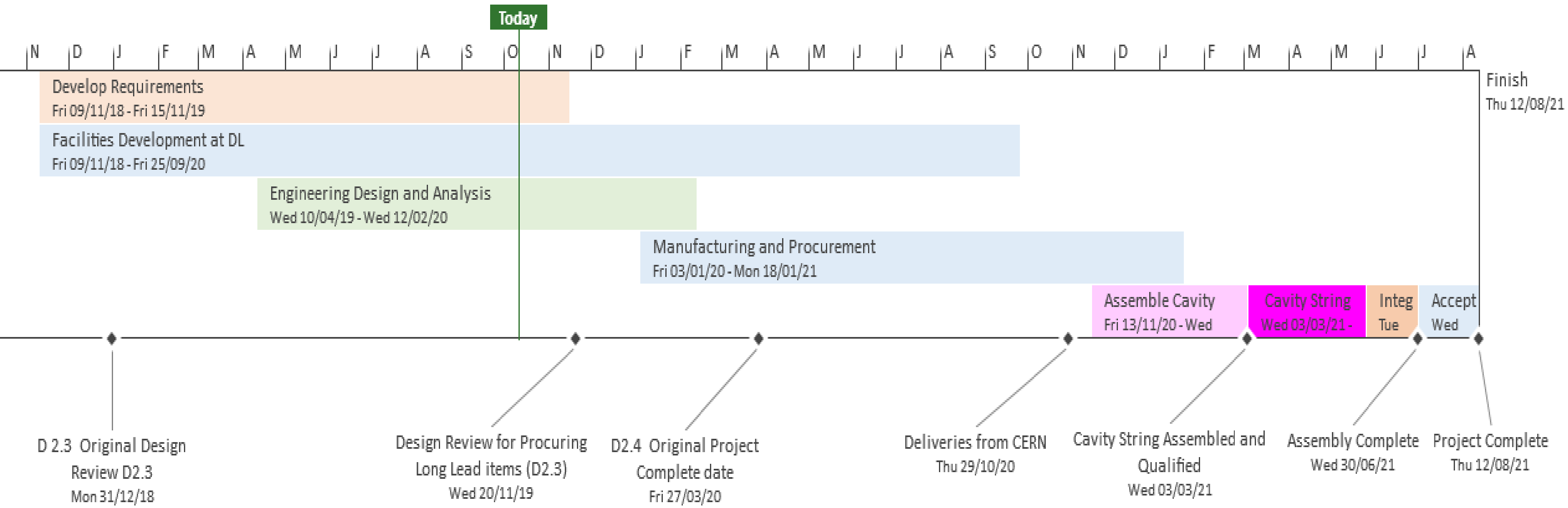
~30 kN/mm longit.

~61 kN/mm vertical



Detailed design to be made for best compromise of stiffness and assembly procedure precision (protection of the cavity support)

SPS-RFD Schedule



HL-LHC-UK2

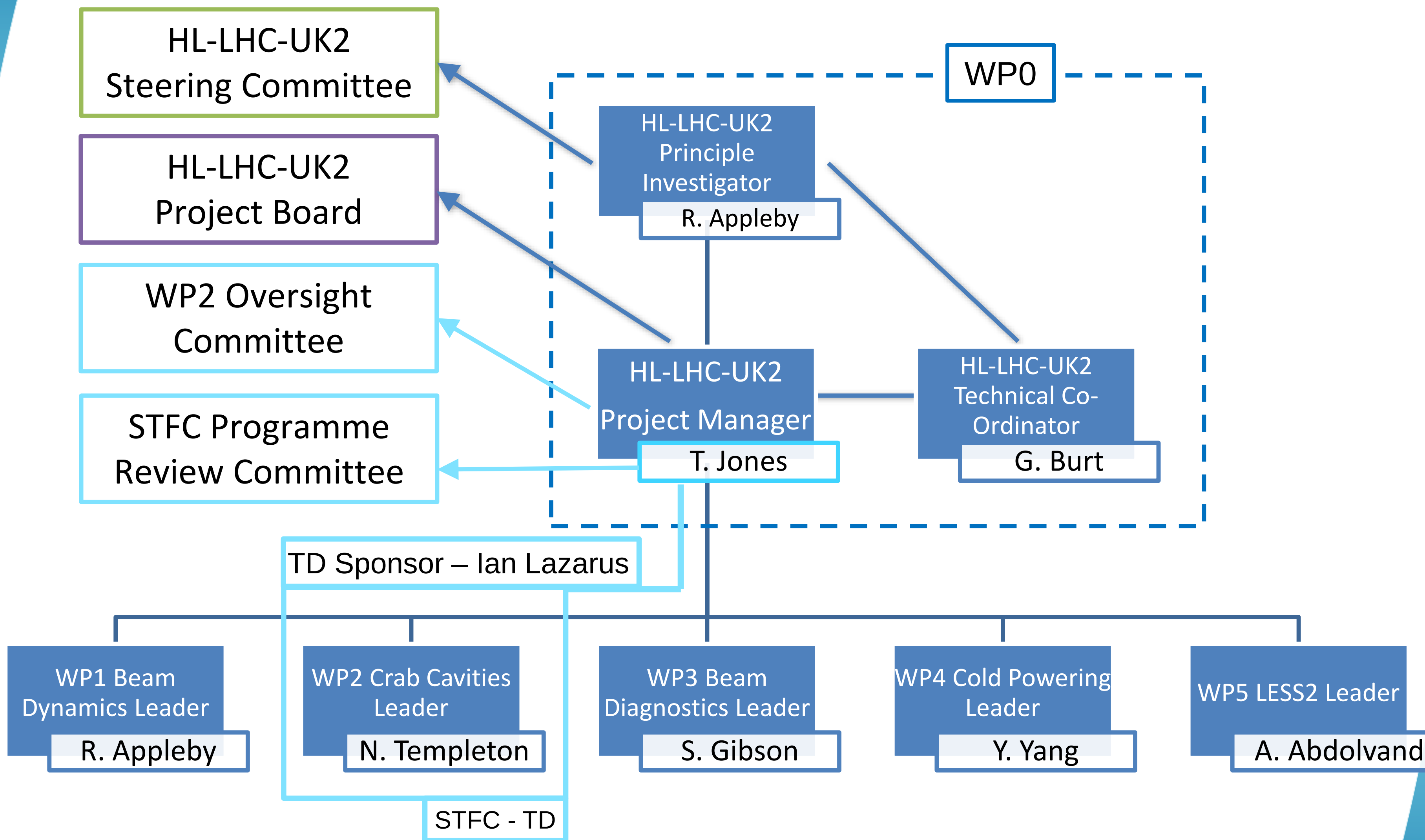
- HL-LHC-UK is a collaboration of UK institutes and Universities delivering hardware for the High Luminosity Upgrade of the Large Hadron Collider at CERN.
- The current collaboration, funded by STFC, has been successful in providing Research and Development into several key areas of the upgrade including;
  - Work Package 1 - Beam Dynamics (led by Manchester University)
  - Work Package 2 - Crab Cavities (STFC-Lancaster)
  - Work Package 3 - Beam Diagnostics (RHUL and Liverpool University)
  - Work Package 4 - Cold Powering (Southampton University).
- In parallel the Laser Engineered Surface Structures (LESS) project has positioned the UK (Dundee University) as a leader in LESS technology for the mitigation of Secondary Electron Yield issues in the LHC.
- LESS will join the HL-LHC-UK collaboration as WP5 for the next phase of the project known as HL-LHC-UK2.
- The project will officially commence on the 1st April 2020, with some pre-work ongoing in 19/20.

HL-LHC-UK2 Key Dates

Project subject to review through STFC Projects Peer Review Panel (PPRP).

- 13th September 2018 – Statement of Interest (SoI) reviewed by STFC Accelerator Strategy Board (ASB)
- 16th October 2018 – Feedback received from ASB
- 4th June 2019 – PPRP Documentation Submission
- 4th September 2019 – PPRP Review Meeting
- 31st October 2019 – STFC PPRP Visiting Panel meeting
- 16th to 17th December 2019 - STFC Science board
- 1st January 2020 – WP5 project start
- 1st April 2020 – WP1 to WP4 Start.
- Start Q1 2024 to end Q2 2026 – Long Shutdown 3

HL-LHC-UK2 Project Organisation



RACI Matrix

Project Requirement	Principal Investigator	Project Manager	Technical Co-Ordinator	WP Leads	CERN CM Collaboration Manager	CERN WP leads
CERN Collaboration Agreement	A	C	C	C	R	C
Project Organisation	A	R	C	I	I	I
Project Management Plan	A	R	C	C	I	I
Change Control Management	A	R	C	C	C	C
Risk Management	A	R	C	C	C	C
Quality Management	A	C	R	C	C	I
Project Financial Management	A	R	C	C	C	I
Work Package Financial Management	C	A	C	R	I	C
Work Package Scheduling	C	A	C	R	I	C
Deliverable Specifications	I	C	A	R	I	C
Deliverable Acceptance Criteria	C	C	A	R	I	C

Responsible: The person who does the work to achieve the task. They have responsibility for getting the work done or decision made. This should be one person.
Accountable: The person who is accountable for the correct and thorough completion of the task. This must be one person and is often the project executive or project sponsor. This is the role that responsible is accountable to and approves the work.
Consulted: The people who provide information for the project and with whom there is two-way communication. This is usually several people, often subject matter experts.
Informed: The people kept informed of progress and with whom there is one-way communication. These are people that are affected by the outcome of the tasks, so need to be kept up-to-date.

Ref: https://www.projectsmart.co.uk/raci-matrix.php

WP2 Scope of Work

Goal: Design and procure necessary components and then to assemble **4 Double Quarter Wave Crab Cavity Cryomodules**

Included;

- Review the design of pre-series cryomodule and undertake any design modifications.
- The procurement from industry of the required components to produce 4 cryomodules.
- Assembly of 4 x Double Quarter Wave cavity strings and associated ancillaries in ISO-4 clean room.
- Assembly of the cryomodules (cryostating).
- Undertake vacuum leak tests after thermal cycling with liquid nitrogen.
- Design and fabrication of the transport frame.
- Shipment of Cryomodules to CERN.
- QA management for all the above.

WP2 Scope of Work

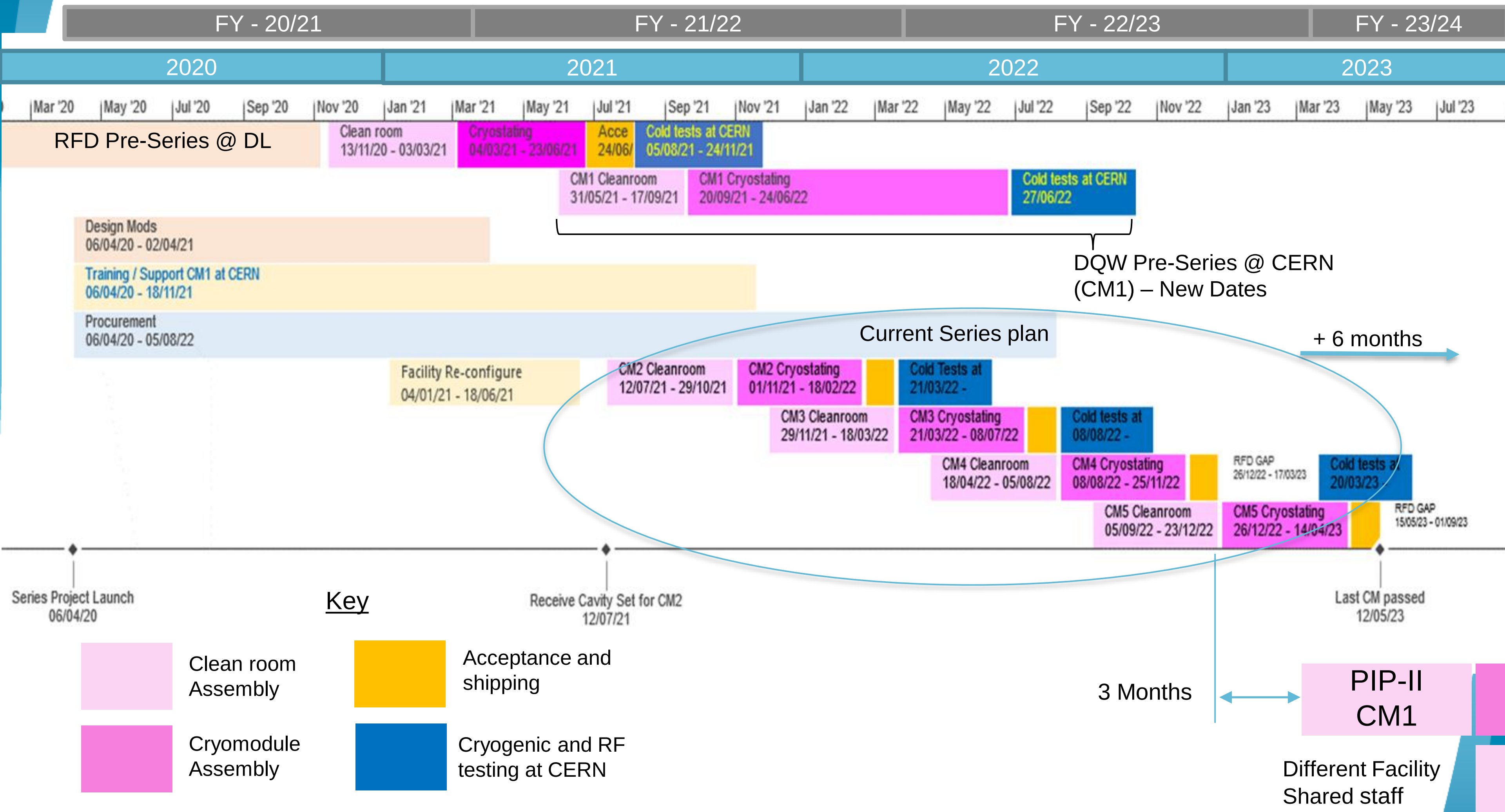
Excluded

- Design and procurement of cavities, tuners, HOMs, RF Couplers, RF Probes, beam line components and Cryogenic Safety equipment.
- Conducting Cryogenic and/or RF performance tests at 4K and 2K.
- The conditioning and testing of the RF input couplers (It is assumed that the conditioning and testing of the RF input couplers will be performed at and by CERN).
- Any-reprocessing of the cavities or RF Couplers in case of contamination at any stage between arrival, assembly and transport.

Facilities

The project will utilise the infrastructure developed for the RFD-prototype cryomodule located within ETC at Daresbury Laboratory.

Series Crab Cavities High Level Schedule



- To be revised, reviewed and finalised in time for HL-LHC cost and schedule review.

Thank you for your attention