Status of RFD Cryomodule Development

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on behalf of Crab Cavity collaboration

14th September 2018

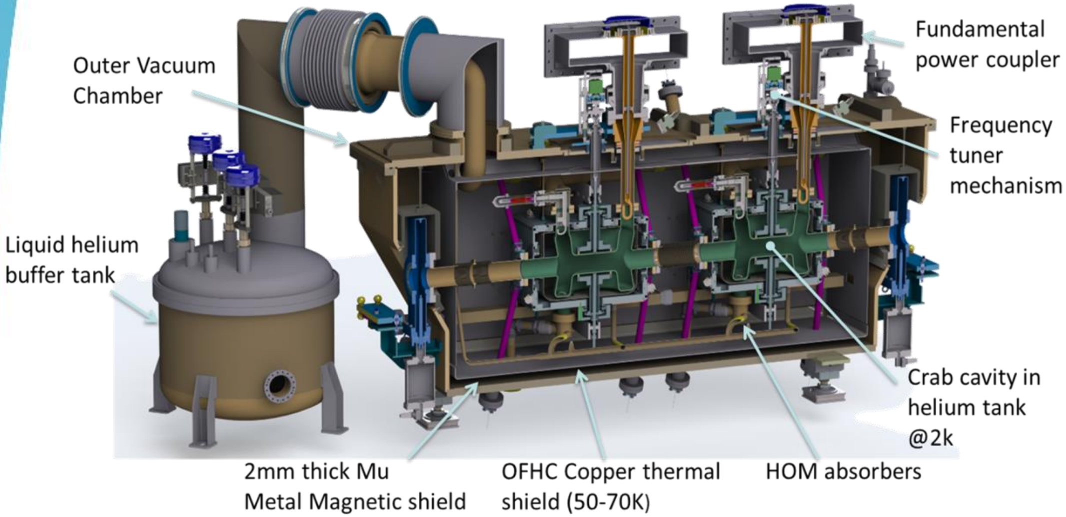
Contents

- Project Planning
- Module Requirements
- Vacuum Specifications
- Cavity String Development
- Cryomodule Design
- Daresbury Laboratory assembly facility development

DQW Cryomodule

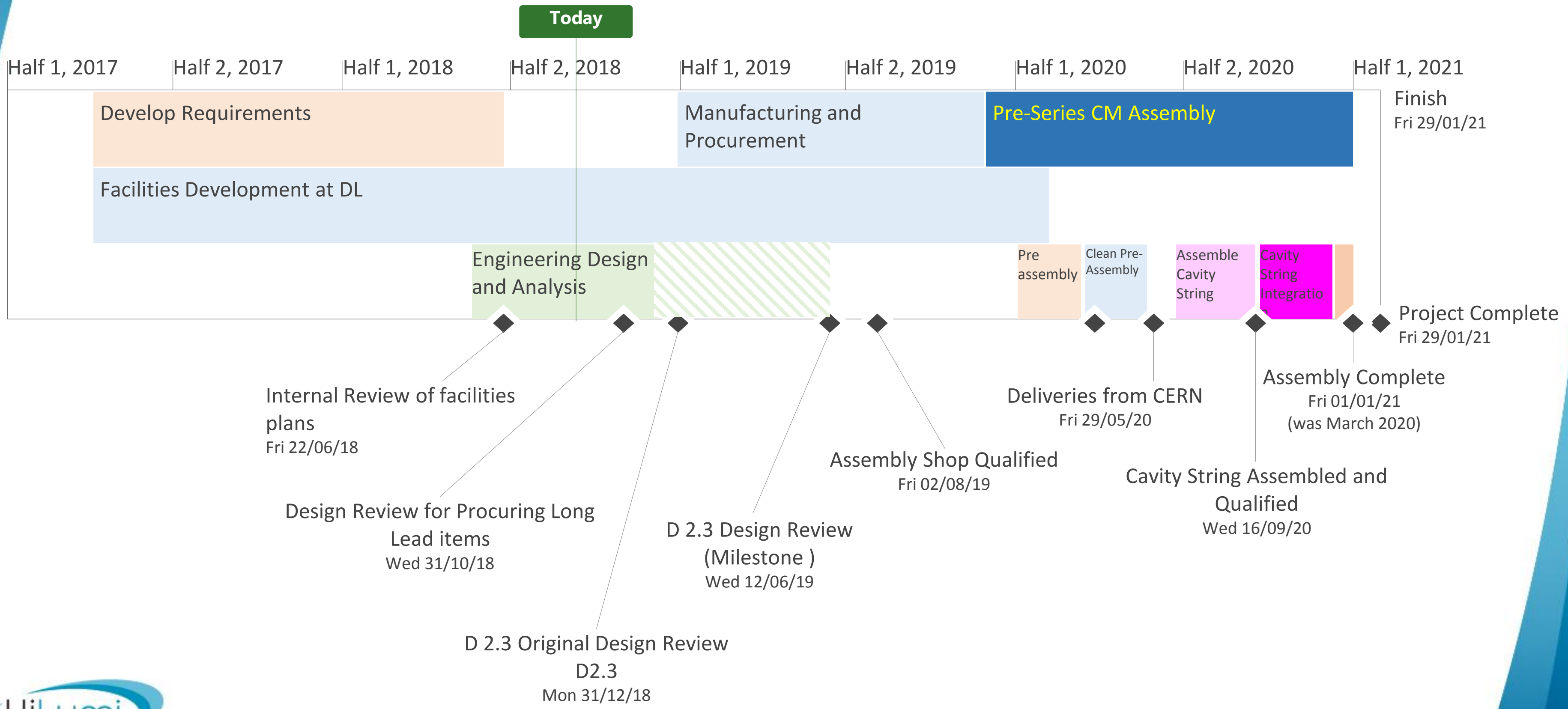
World First Crabbing of a Proton Beam in May 2018!

CERN/STFC/LARP Collaboration.



DQW SPS Prototype Cryomodule

RFD Cryomodule Build Plan



Module Requirements

Fundamental changes to module from DQW SPS;

- Second beam pipe to be introduced.
- Vacuum diagnostic ports to be added to cavity beamline.
- Beam screens will be required in second beam pipe.
- Shielded bellows to be used in both beam lines.
- BCAM system will not be required for LHC.
- Infra-structure and assembly tooling to be updated from DQW SPS to RFD LHC (and modification to suit Daresbury Laboratory facilities).
- Cryomodule length will increase due to longer cavities and addition of vacuum diagnostics, effects OVC, Magnetic and thermal shields.
- Vacuum separation of OVC from service module.
- Cryogenic safety systems to be incorporated into cryomodule.

Module Requirements

Further study is also required in the following areas;

- HOMs designs.
- Cavity design updates required for LHC.

} Led to project delays

- Study of active vs passive positioning of the cryomodule.
- Interchangeable helium level probes
- Cooling capacity of LHe vessels as designed.
- Effect of -1.23% tunnel slope on the cryomodule.
- Support structure analysis for RFD cavity (longer cavity and offset FPC).
- BCP processing of RFD cavity due to potentially increased complexity.
- Material selection for radiation resistance.
- Transportation of module from Daresbury to CERN.

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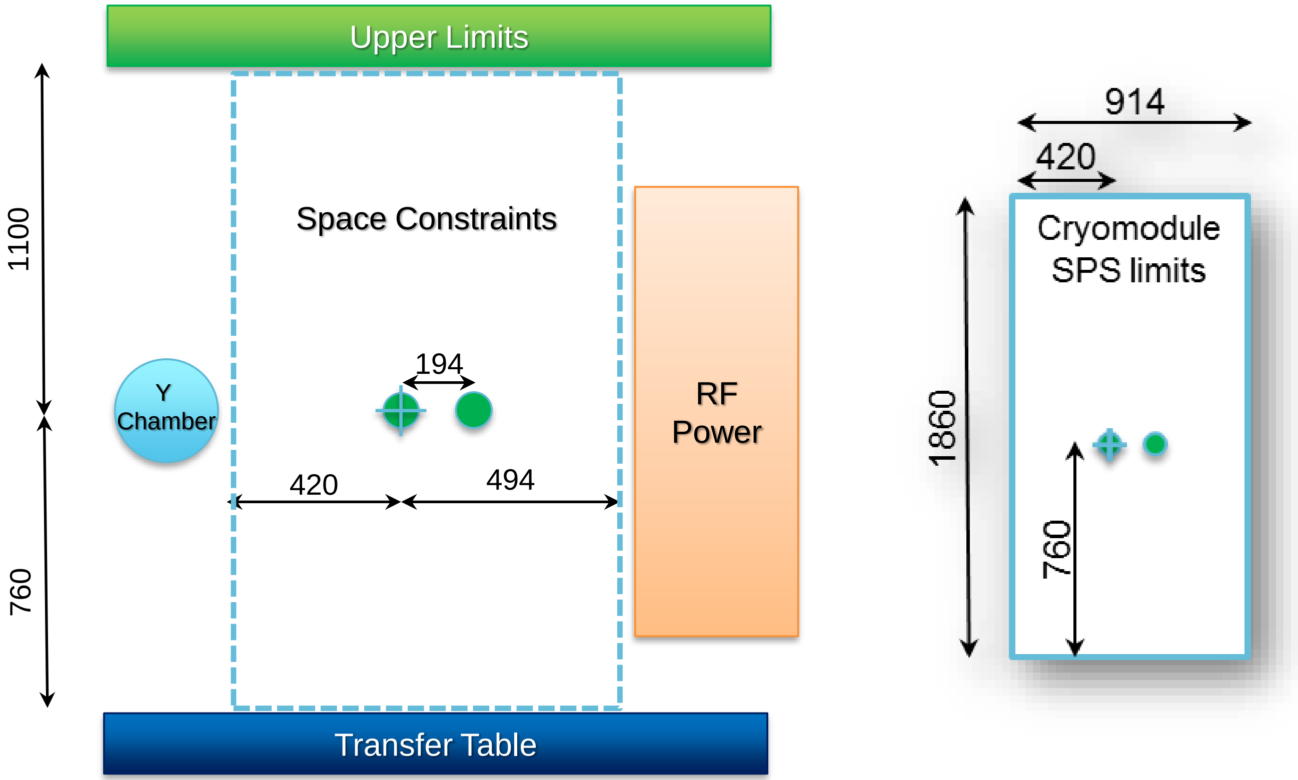
Module Requirements

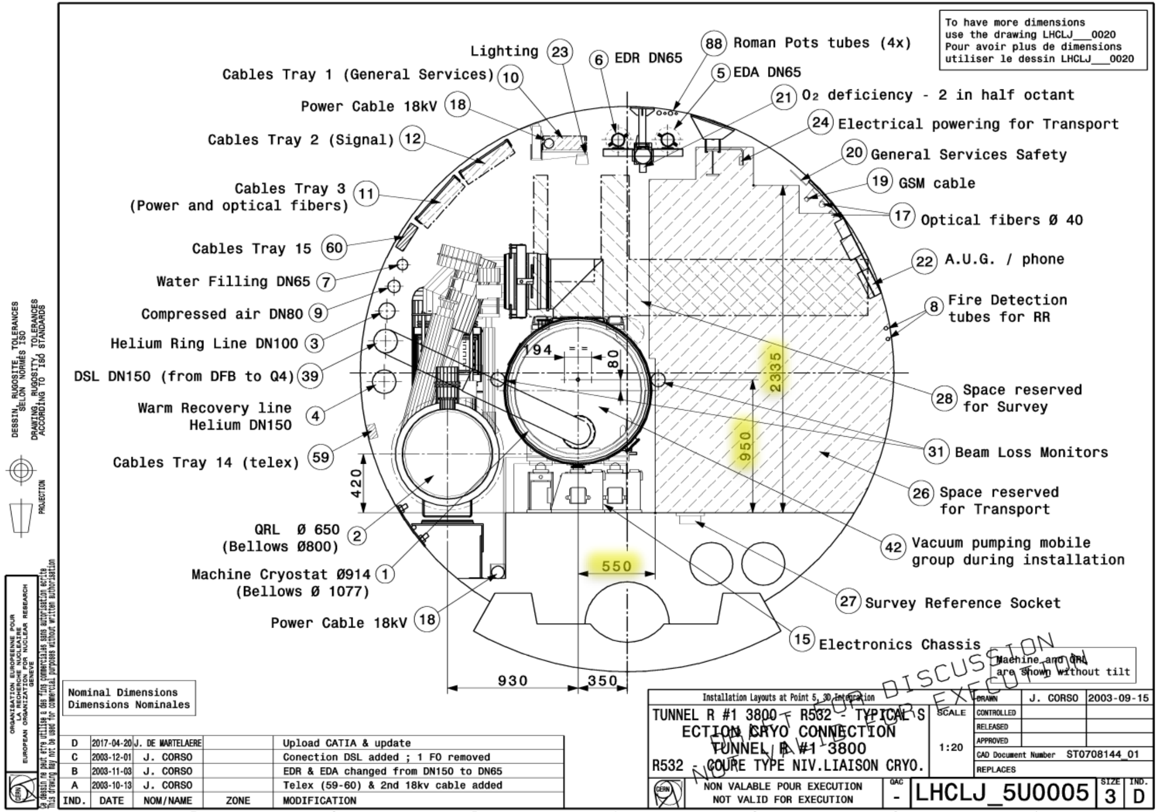
Fixed design areas (will be updated with lessons learned from SPS);

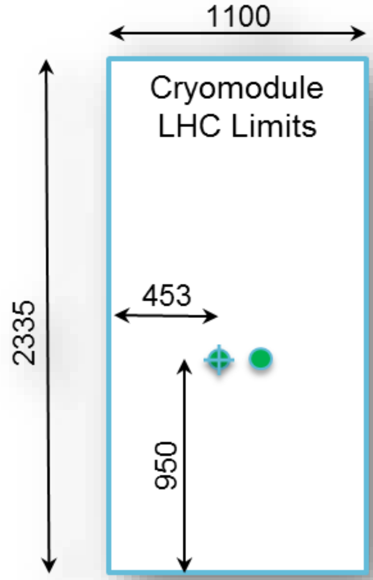
- Cryomodule will contain 2 cavities.
- Cavities will not require active alignment.
- Cavity support system principle (cavities on FPC with additional blade supports).
- Helium tank design should remain fixed.
- Tuner principle (Warm actuation, cold connection).
- Thermal shield design. (Helium gas cooled, copper construction).
- FSI system will remain for LHC, but will not use BCAM.
- Outer vacuum chamber design principle.
- Magnetic Shielding design principle.
- Tooling will be as compatible/similar as practicable to CERN tooling for DQW.

SPS LSS6 integration area



LHC Point 5 integration area

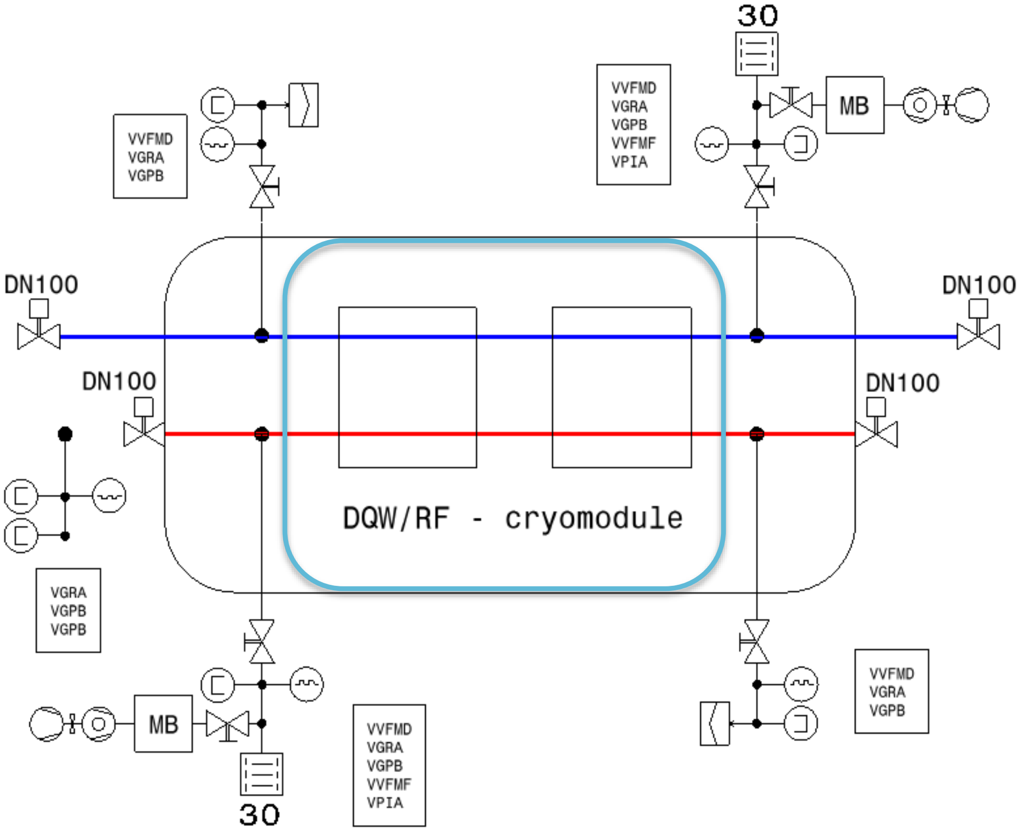




No Additional Space Constraints from LHC

✓ ***Design for SPS***

Vacuum schematic



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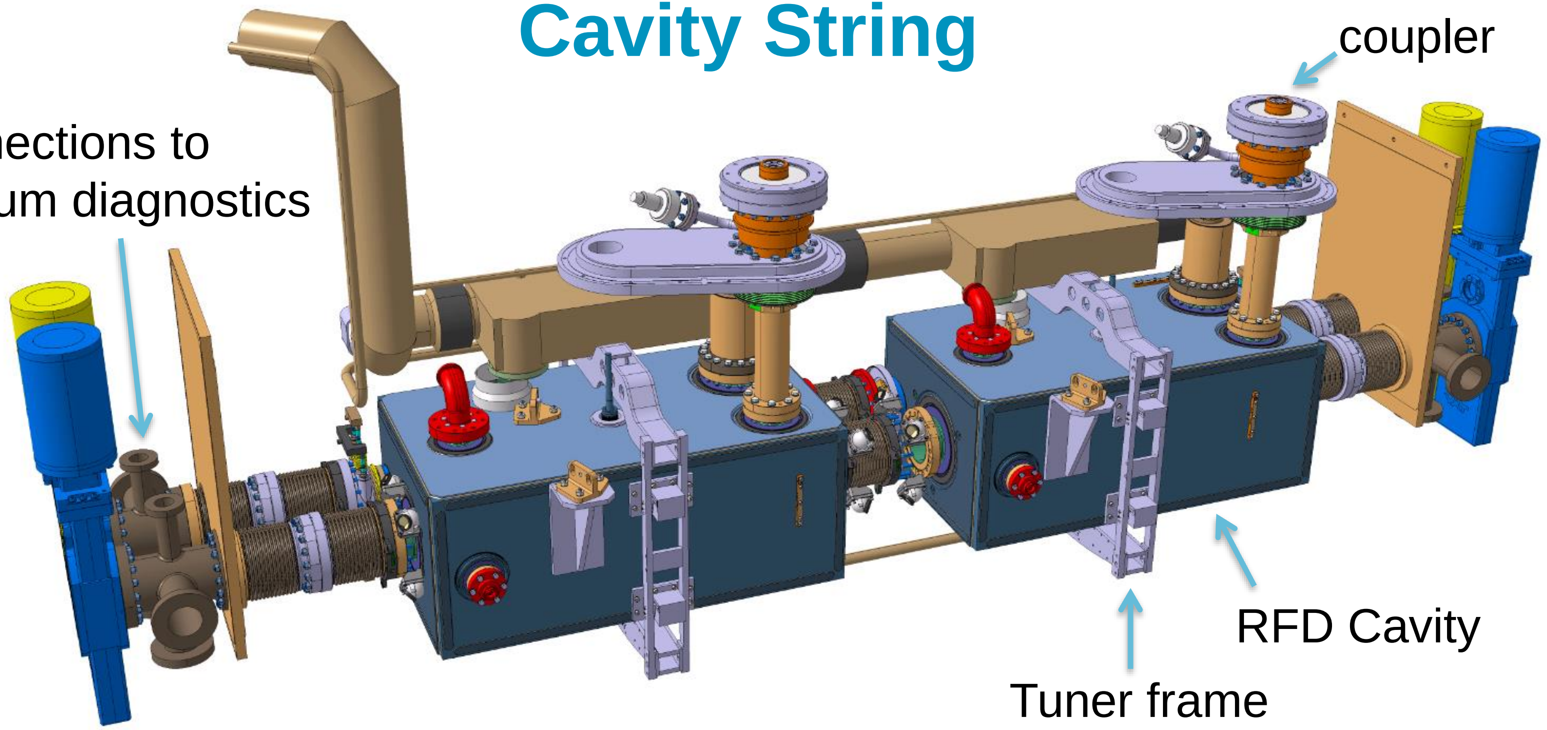
Cavity String



Updates :

-New compact RF valves study (new LHC standard which avoid the staging)

-New RF bridge design on going (see next slide)

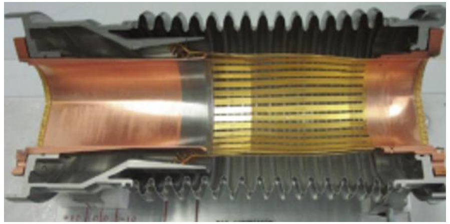
-New Tuner Frame + double actuation pipes

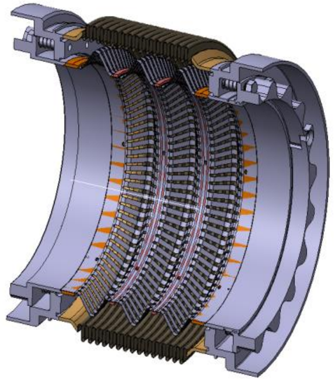
-New vacuum tank fully welded

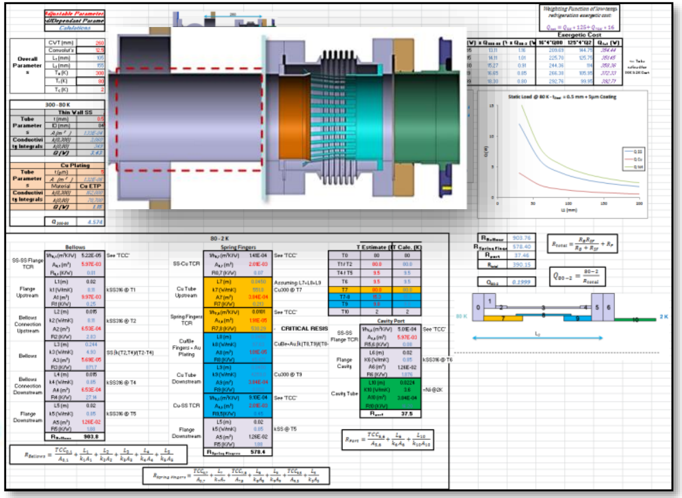
Thanks to T.Capelli

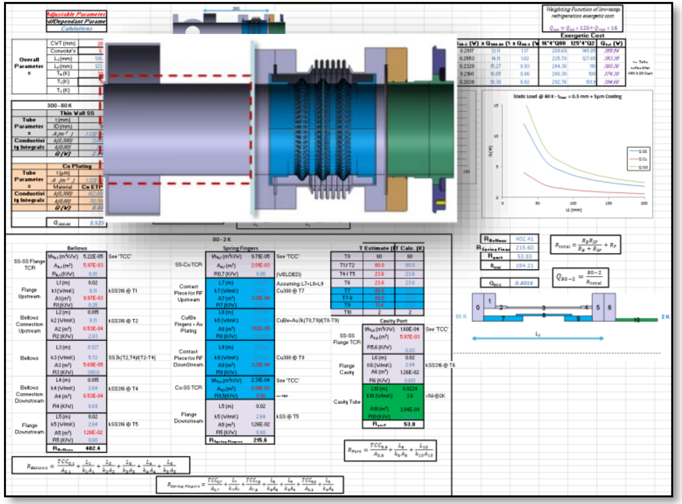
Cold-Warm Transition Calculations

- Analysing the design of Cryomodule CWTs to minimise heat leak to 80 & 2 K
- Calculation developed combines:
  - Thermal resistance networks
  - Non-linear thermal conductivity integrals
  - Thermal contact resistance estimates
  - Iterative temperature convergence



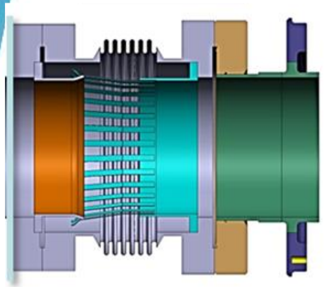




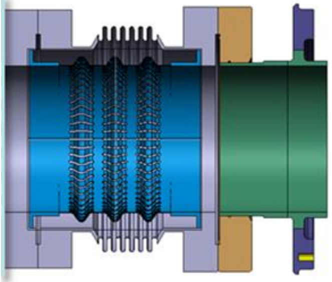


Cold-Warm Transition Calculations

Option 1



Option 2

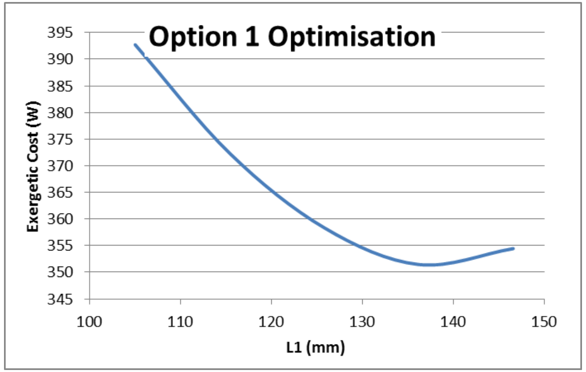


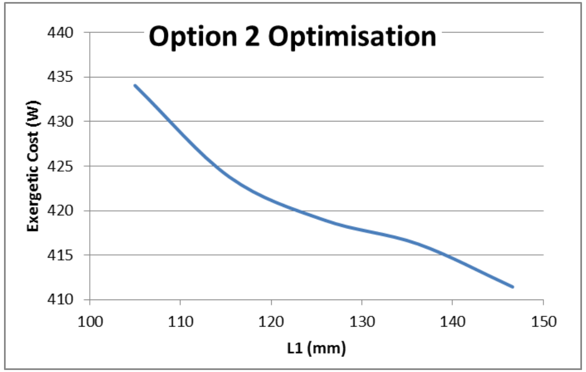
Option	L2 (mm)	Bellows Convol’	4 x Q80 (W)	4 x Q2 (W)
1	123.8	6.5	13.11	1.61
2	113.4*	4.5	14.11	**1.01**

Estimated Total Heat Load @ 80 & 2 K

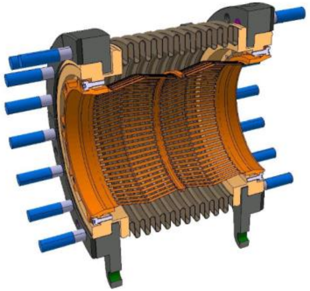
Weighting Function of low-temp. refrigeration exergetic cost:

$$Q_{tot} = Q_{5K} * 125 + Q_{70K} * 16$$

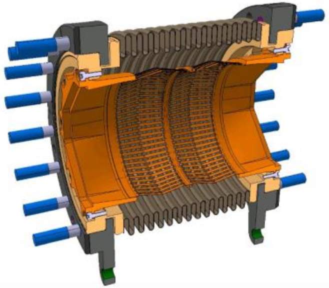




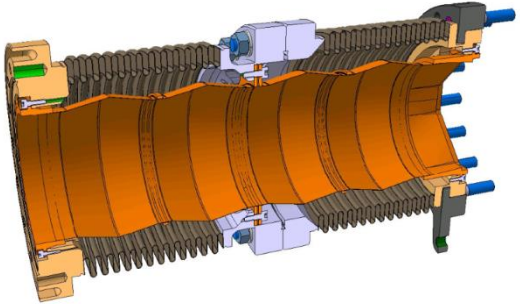
RF bridges (under validation)



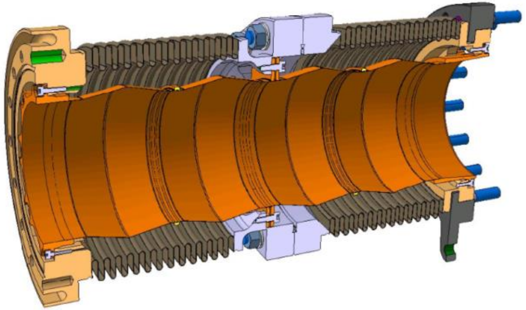
Inter-cavities Circular/Circular



Inter-cavities Octogonal/Octogonal



Cold-Warm Transition Circular/Octogonal



Cold-Warm Transition Circular/Circular

Updates :
-4 configurations in design
-1 prototype to be designed and produced for validation tests (RF and mechanical)

Thanks to T.Capelli

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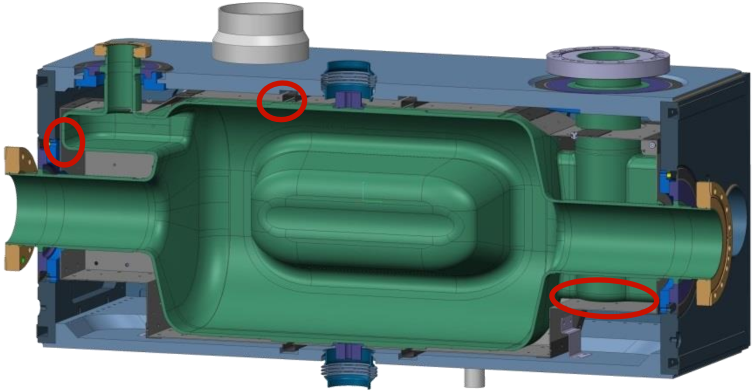
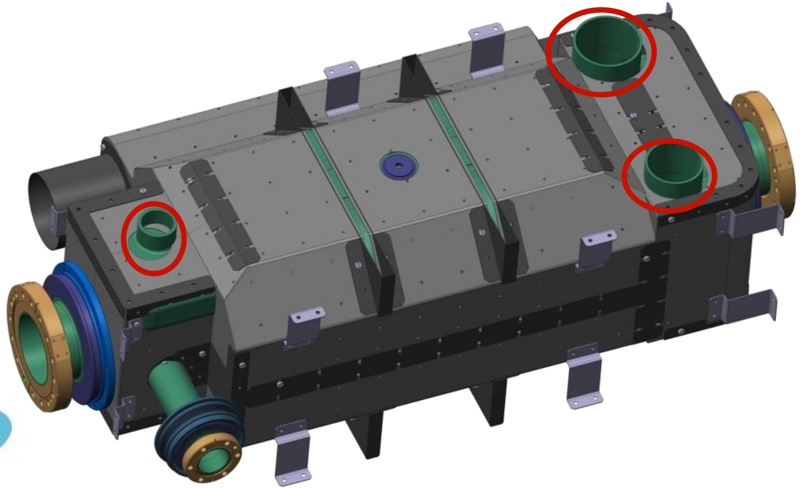
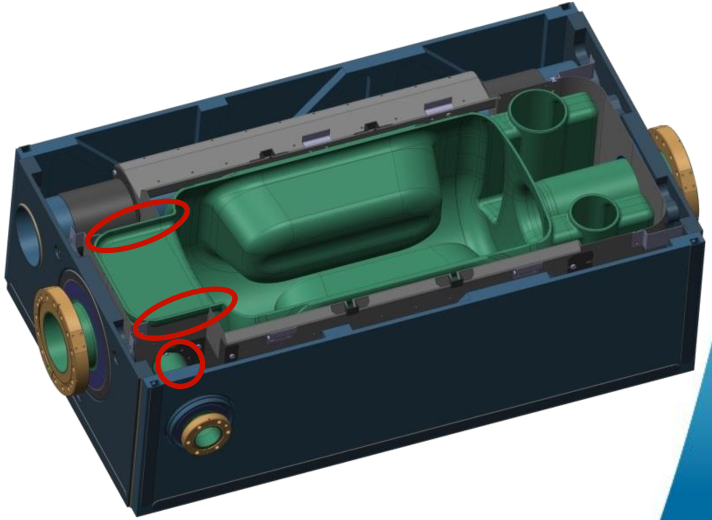
Cold Magnetic Shield Modifications

- New cavity geometry clashes with existing shield design
- Cold magnetic shield modified to suit updated cavity-helium vessel





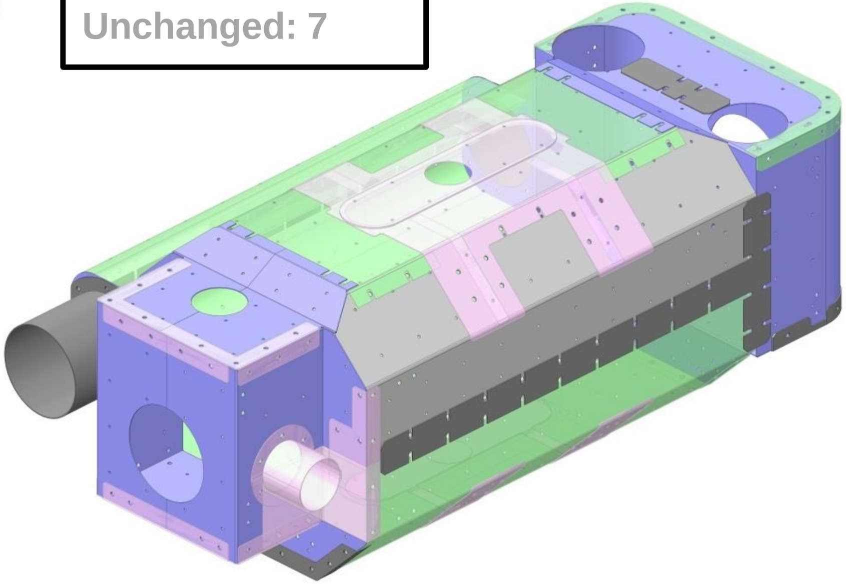


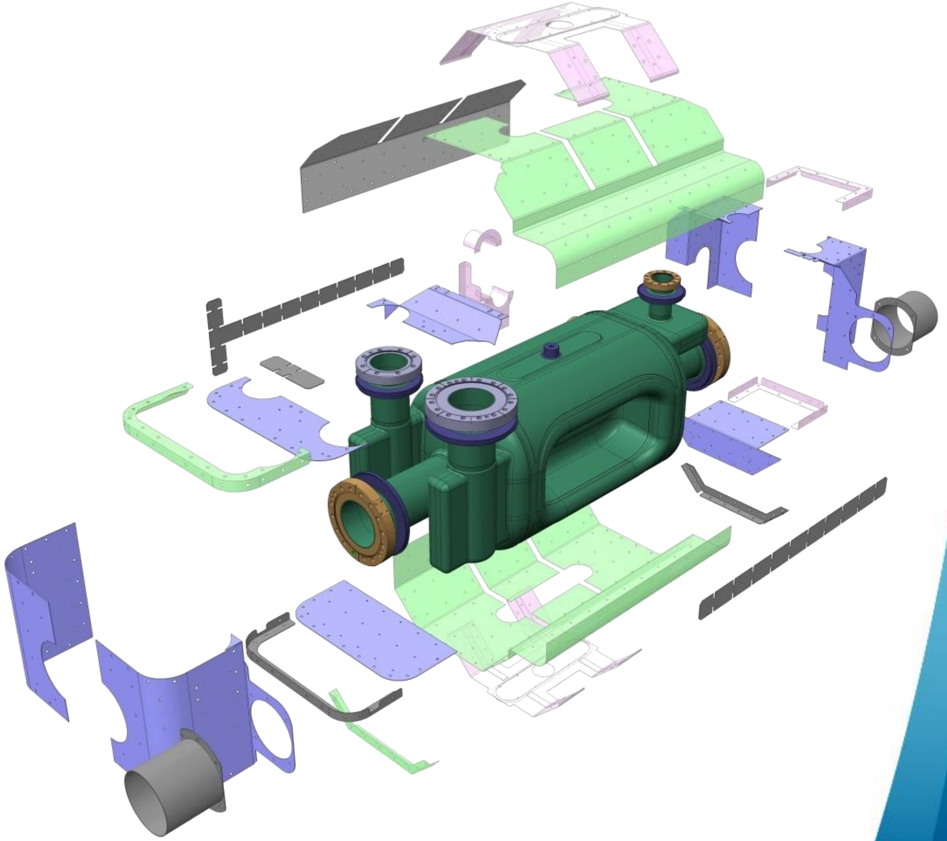
Cold Magnetic Shield Modifications

New Parts: 14

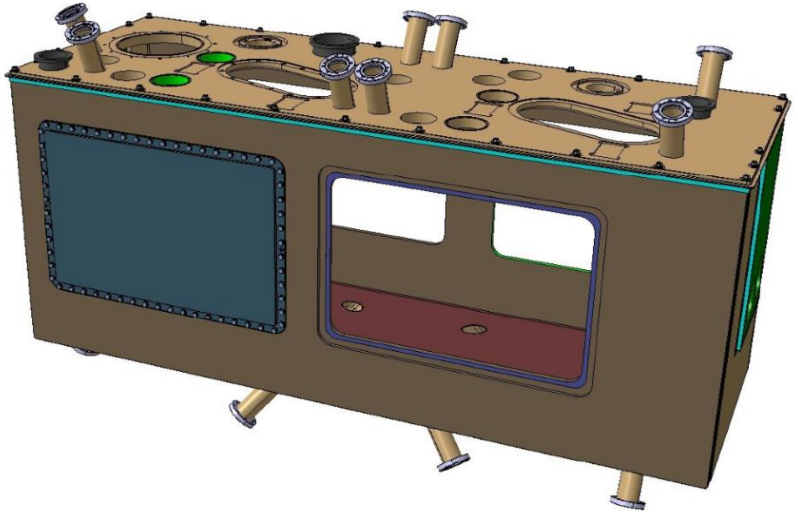
Modified Parts: 3

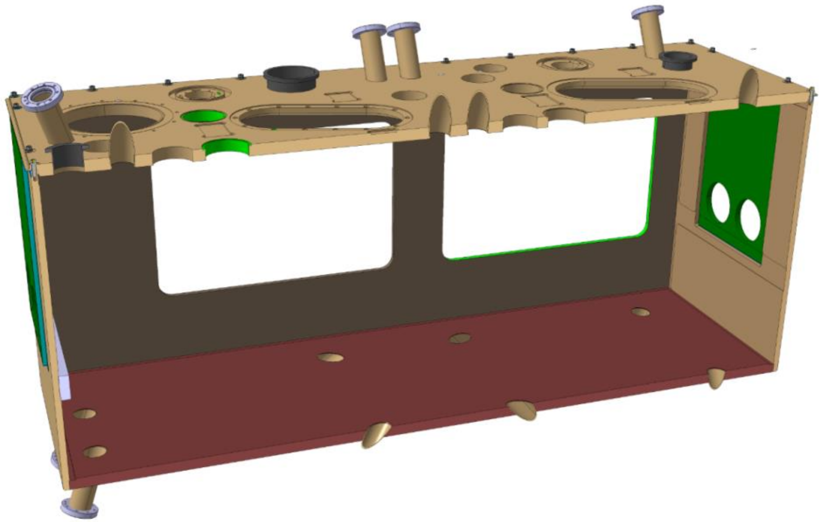
Unchanged: 7





Outer vacuum chamber



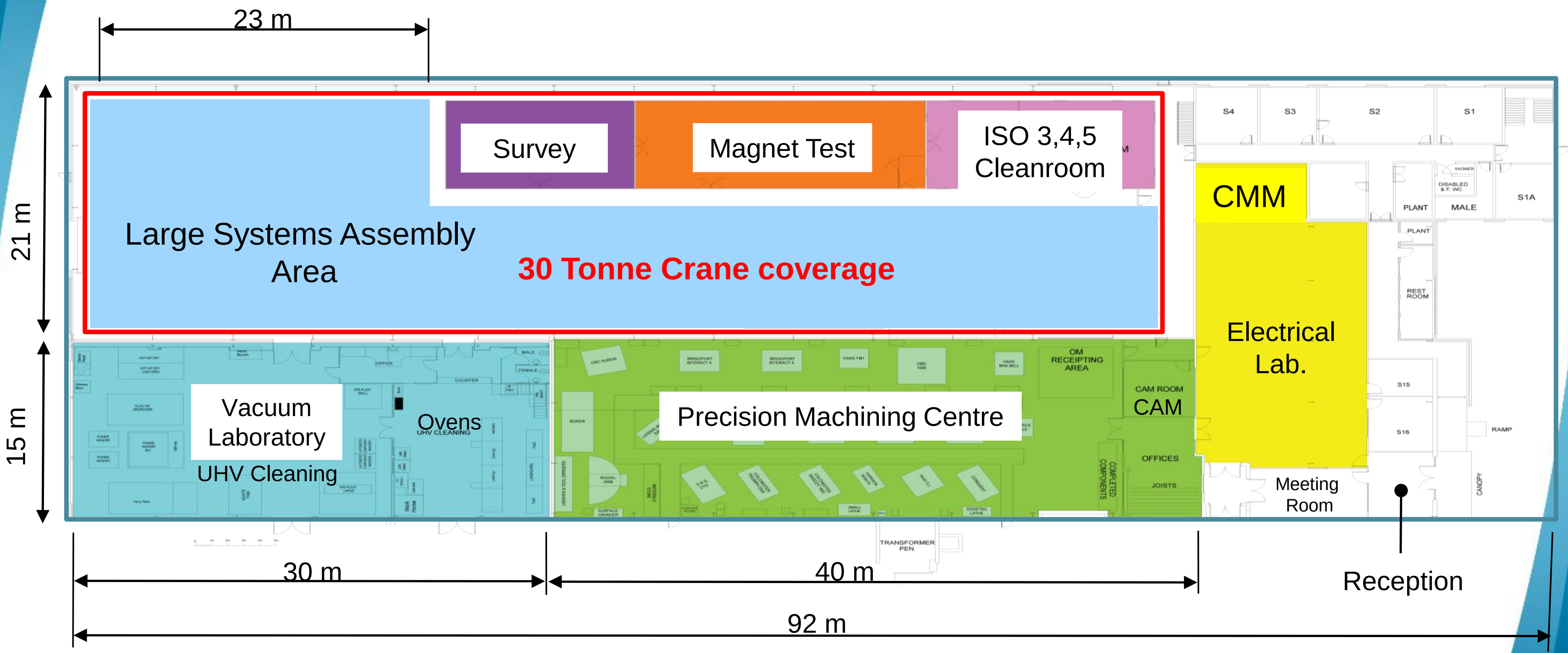


Updates :

-New welded interfaces in order to reduce the work in case of dismantling
-Remove rubber gaskets which couldn’t be repaired in the tunnel
-New length (increase of cold/warm transition length and inter cavities length)
-FSI ports with new location and CF flanges (metal gaskets)
-Doors with rubber gasket, with the possibility to weld them if needed

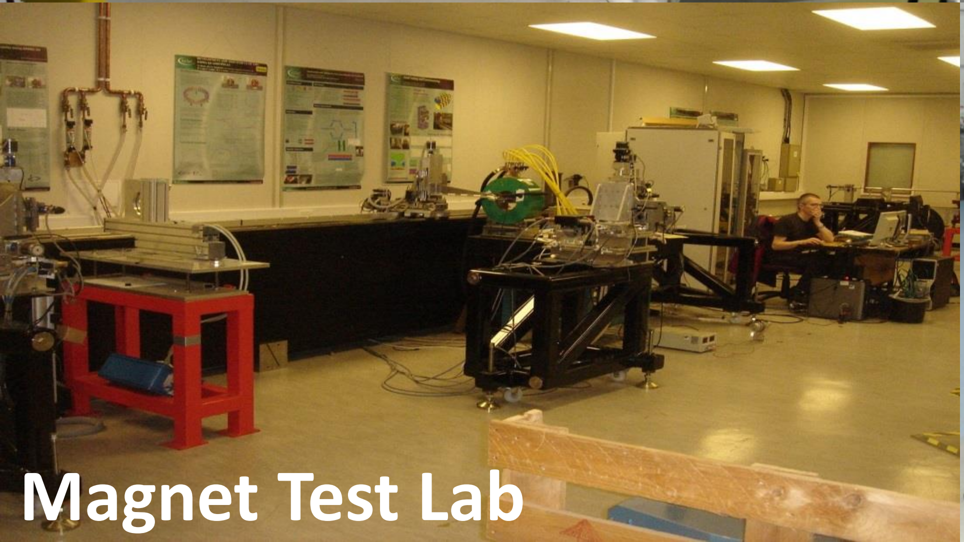
Daresbury Lab Engineering Technology Centre
Systems Integration Building

ETC Floor Plan




Machine Centre


Cleaning in Vacuum Lab


Magnet Test Lab


Ovens in Vacuum Lab


30 Tonne Crane
Assembly Hall


Softwall cleanroom


Magnet Test Room
ISO 4 Cleanroom
Assembly Hall

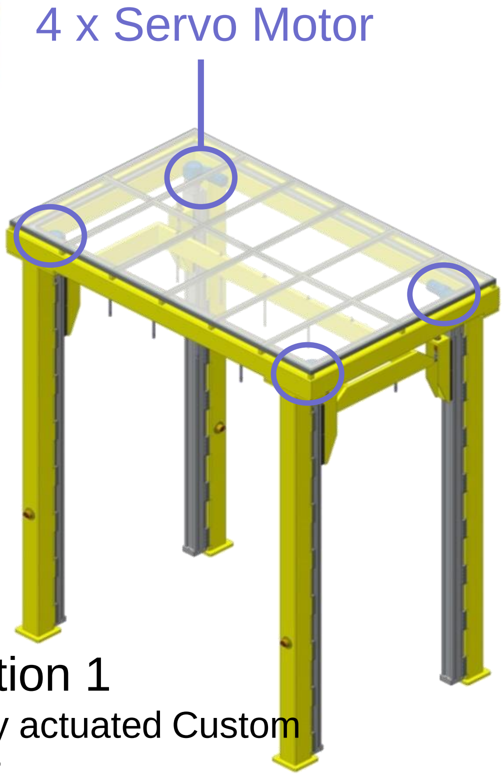

ISO 4 Cleanroom

Facility reconfiguration

Engineering Technology Centre 3D Layout

ETC ISO 4 Cleanroom

Cavity String lifter selection

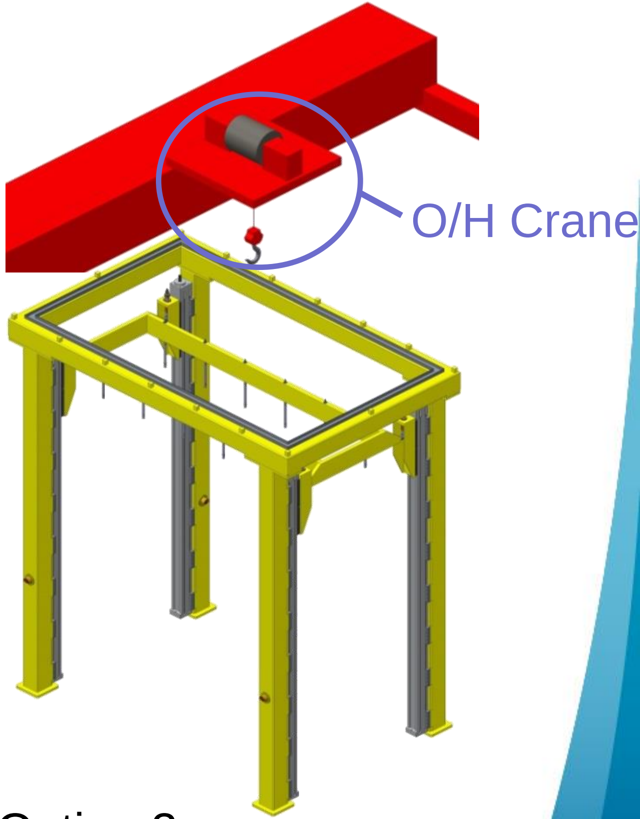


Option 1

Fully actuated Custom lifter

Option 2

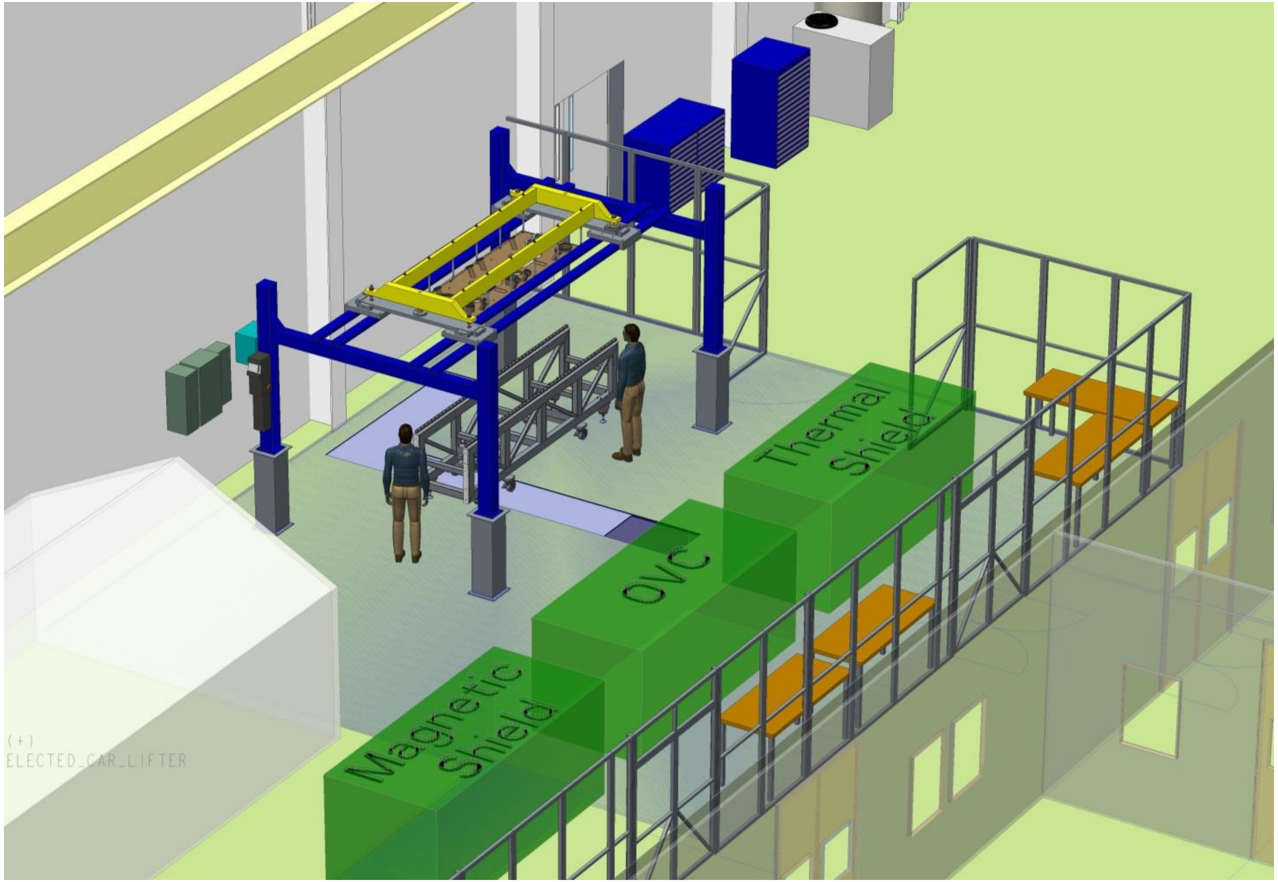
Modified commercial car lifter



Option 3

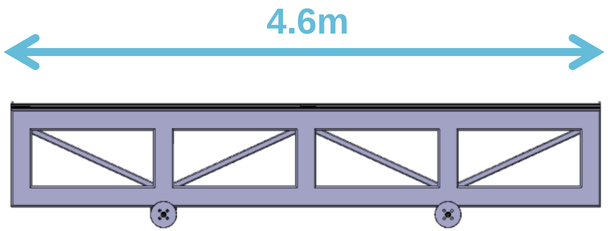
Use overhead crane and guidance frame

Lifter Integration

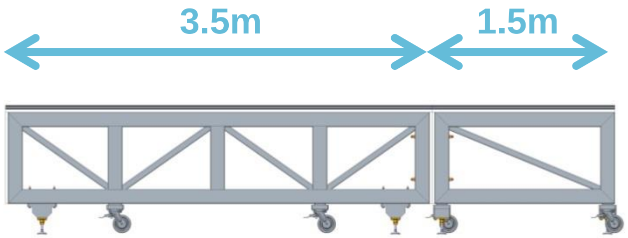


Cavity String Mobile (Trolley)

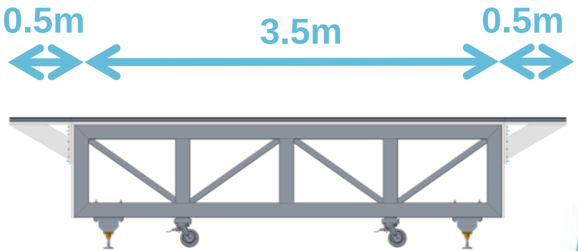
Cavity String Option 1



Cavity String Option 2



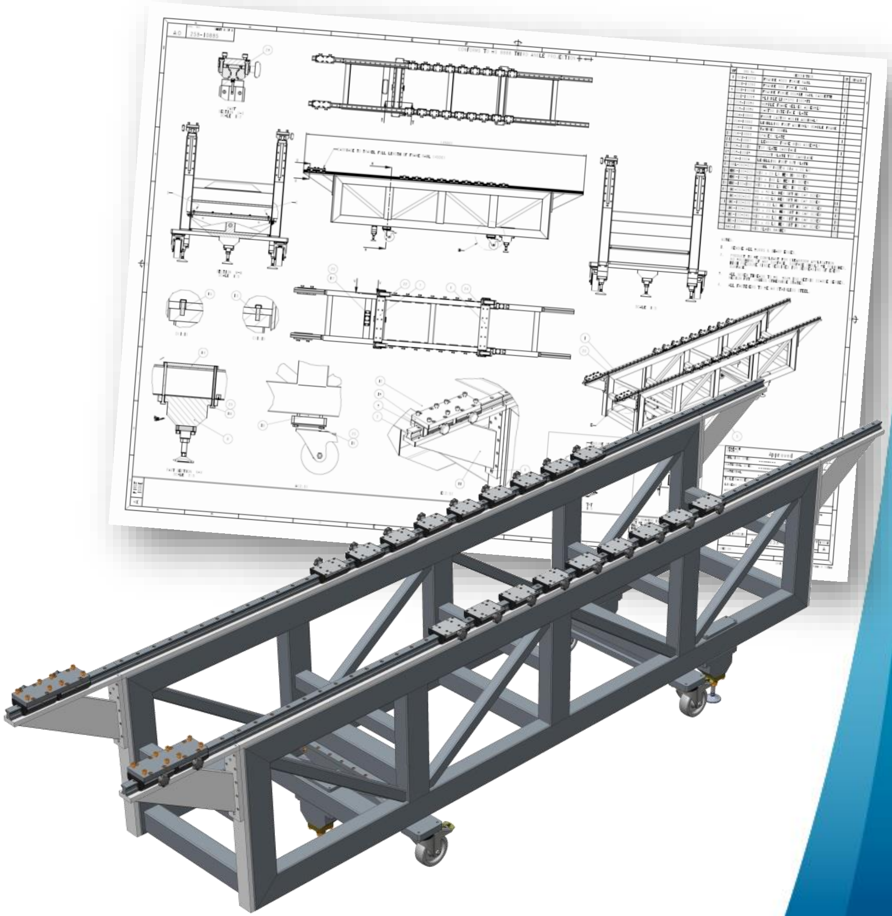
Cavity String Option 3



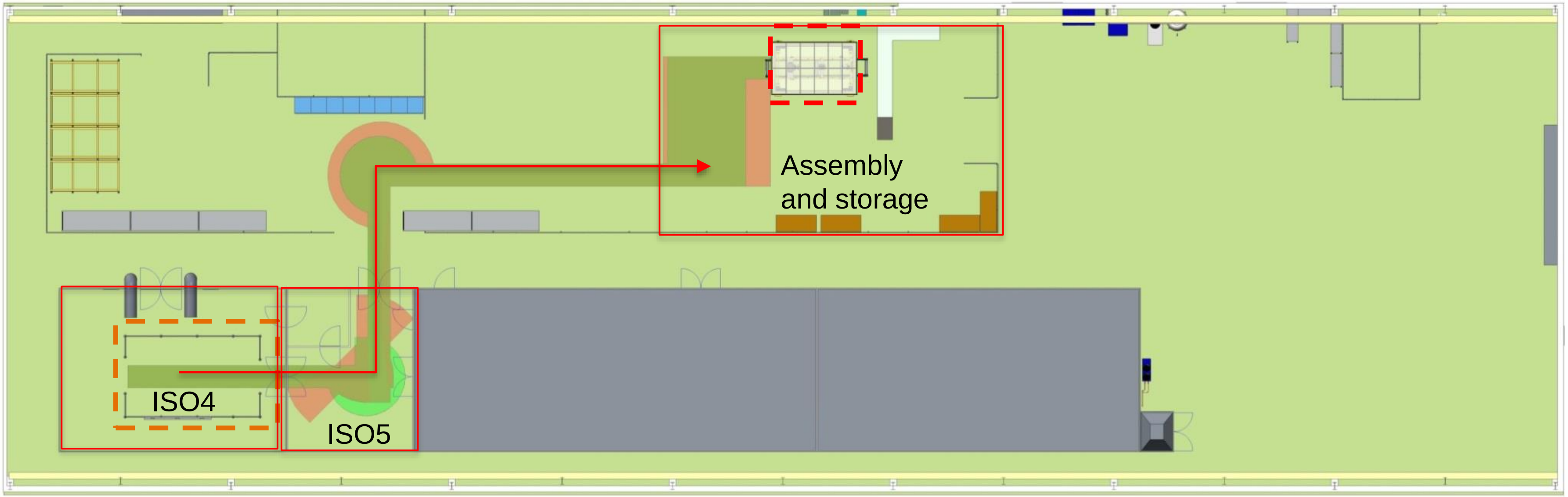
Now on order

Mobile Cleanroom Assembly Frame

- 3.4 – 4.5 m Mobile Cleanroom Assembly Frame
- Contract Placed with ESE Engineering Aug ’18
- Cost: £40k
- Expected Feb ‘19



Cavity String Mobile (Trolley)



- Green route is for shorter trolley.
- Reduced turning area required, increase in ease of transport gives less risk of damage.
- More space to work around the string on the assembly frame.

Summary

- Cryomodule requirements and design ongoing.
- UK team focussed on Magnetic Shielding, Thermal Shielding and Assembly tooling.
- Facility development at Daresbury has begun.
- Placed order for RFD cleanroom assembly frame.

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Questions?

CERN

Science & Technology Facilities Council

The Cockcroft Institute of Accelerator Science and Technology

Lancaster University

US HL-LHC AUP