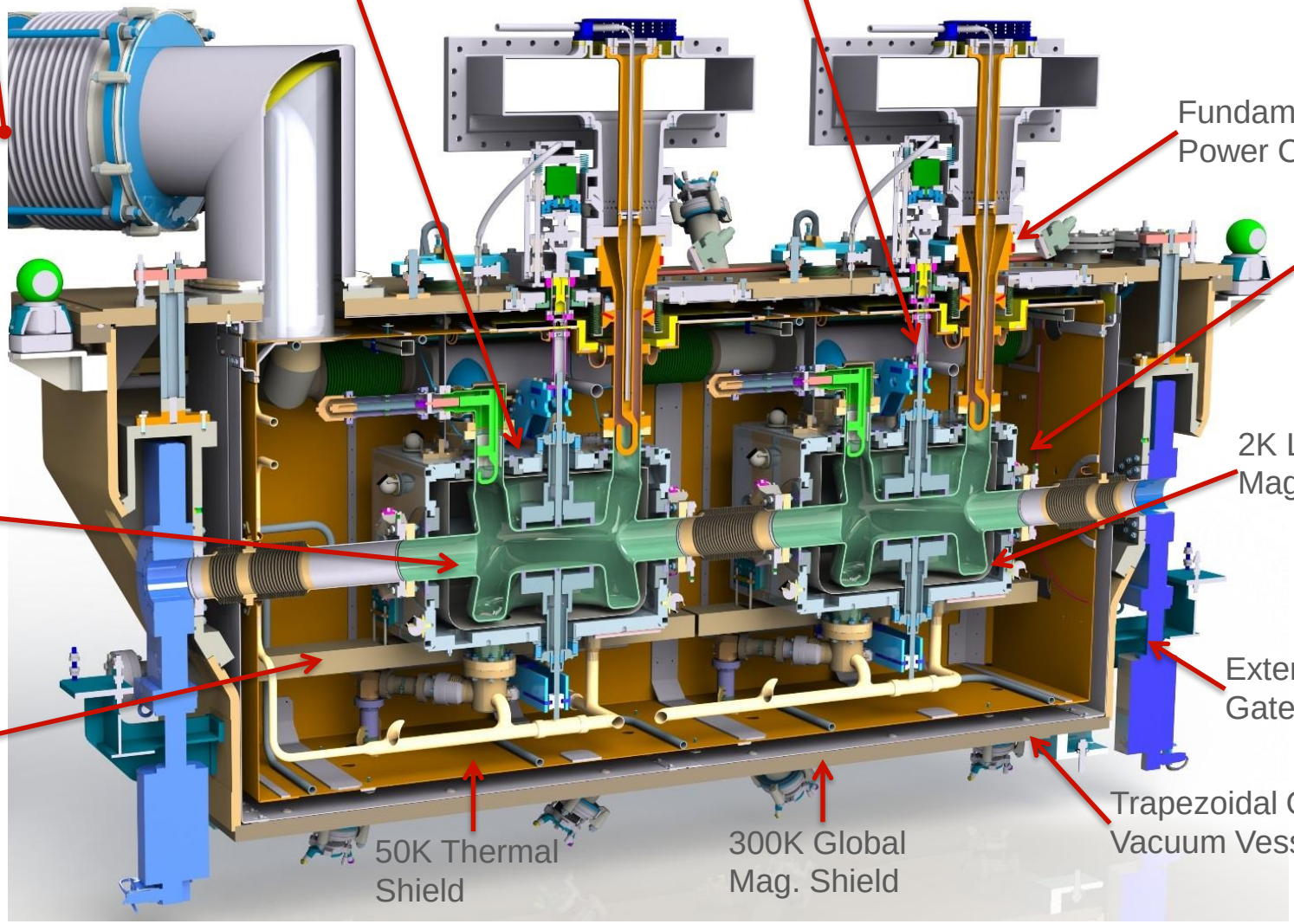
UK HL LHC Plenary Meeting

WP2 - Thermal & Magnetic Shielding for the DQW Crab Cavity Cryomodule

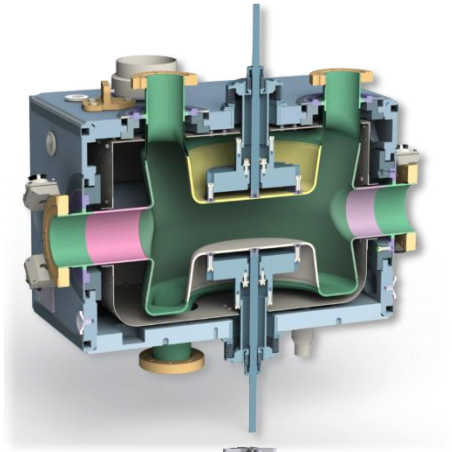
Niklas Templeton – STFC – Daresbury Laboratory

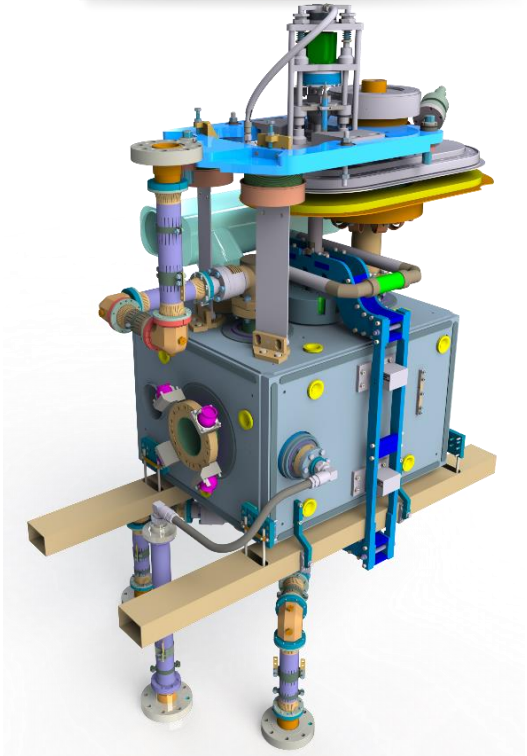
DQW SPS Prototype Cryomodule – Overview



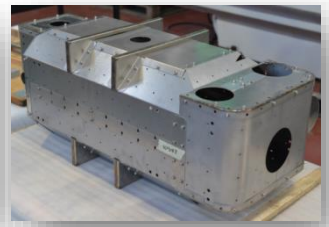
DQW SPS Prototype Cryomodule – Status

- 1st cavity - helium tank successfully cold tested at CERN
  - ✓ 1st SRF Cavity to be manufactured in house by CERN
- 2nd cavity - helium tank assembly complete
- Cleanroom cavity string assembly commencing July ’17
- Cryomodule assembly & preparation progressing in parallel
- To be tests in SPS in 2018

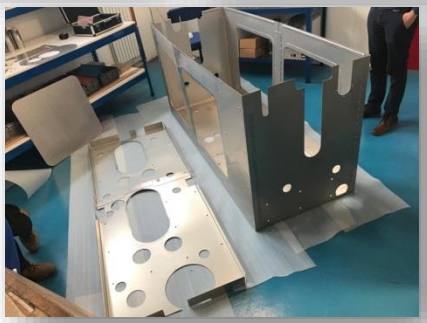


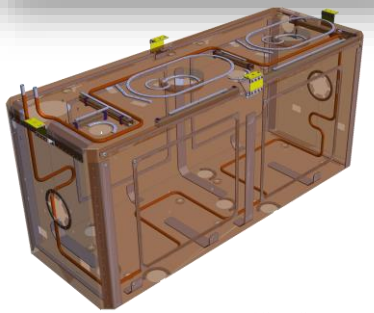


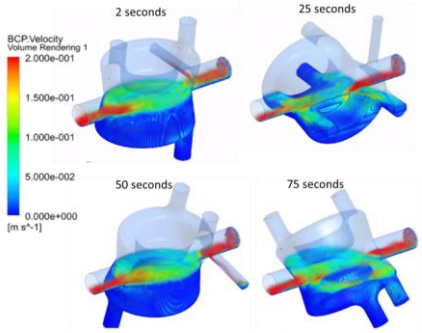
UK Collaboration

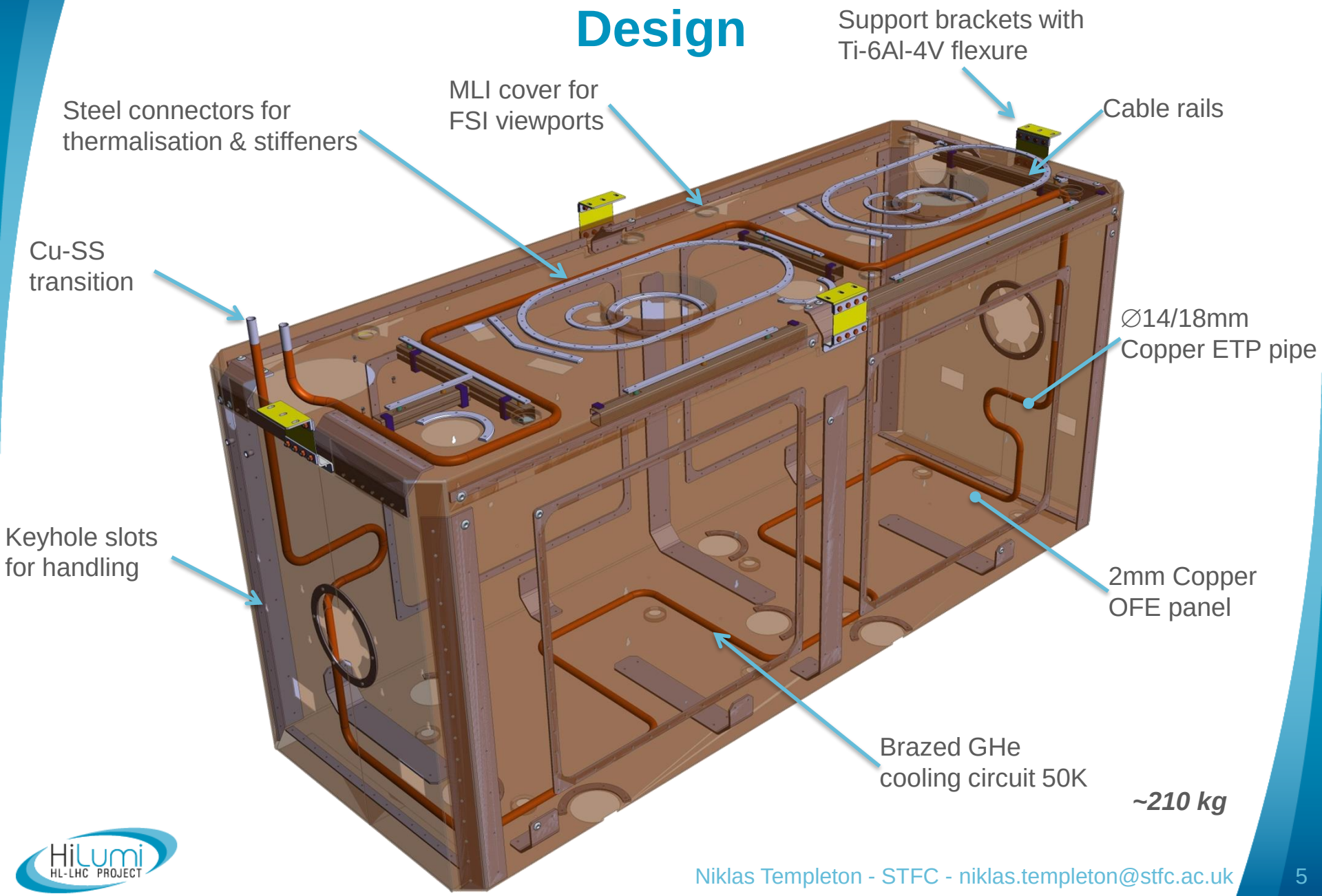
- Crab Cavity Cold Magnetic Shields delivered to CERN April ’16
  - ✓ (1st Hardware for HL LHC CC Project)
- DQW Warm Magnetic Shield Delivered to CERN April ’17
- Thermal Shield Manufacture Launched at CERN May ’17
- Development of Cavity Support System (Paper by Thomas Jones to be published in SRF17)
- Simulation & Optimisation of Cavity BCP (Paper by Thomas Jones to be published in SRF17)
- DQW HOM Coupler for LHC, FPC Test Box, Bulk RRR measurements (see JAM talk)
- *Design & Development of UK RFD Pre-Series Cryomodule*
- *Assembly & Delivery of UK RFD Pre-Series Cryomodule Spring ‘20*





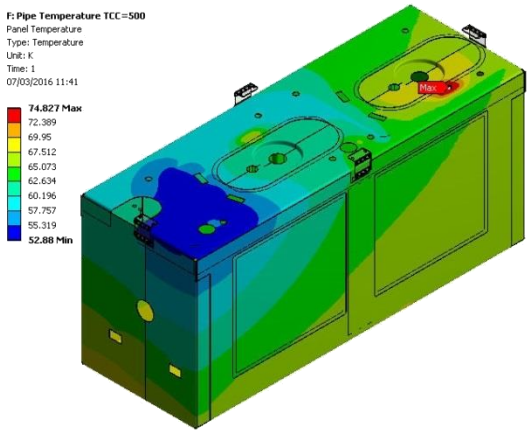


Thermal Shield Design

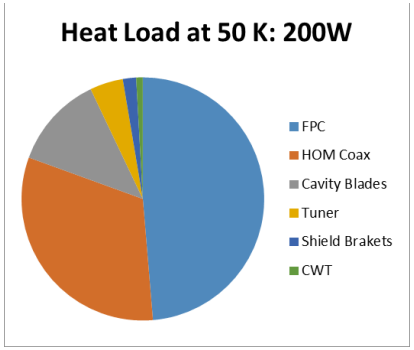


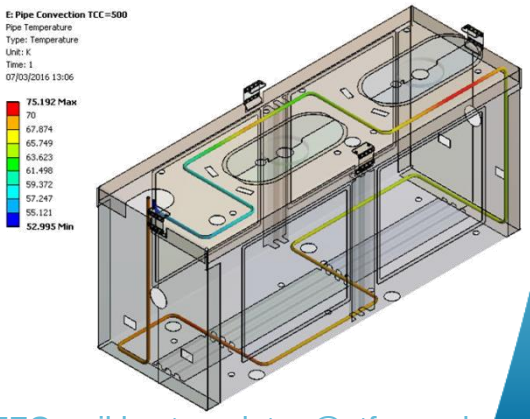
~210 kg

Thermal Shield Calculations



- Material studies - comparing various pipe and panel materials for performance integration and manufacture.
- Thermal contact resistance studies between connections verify passive cooling of panels and components and minimise thermal gradient across shield.
- Cooling Circuit optimisation for homogenous cooling and minimal thermal gradient and cool down stresses
- Thermalisation studies to optimise the conduction path for critical intercepts.
- Self Weight and cool down studies to verify the support brackets.
- Radiation heat leaks check
- *Final iteration required for completed design*

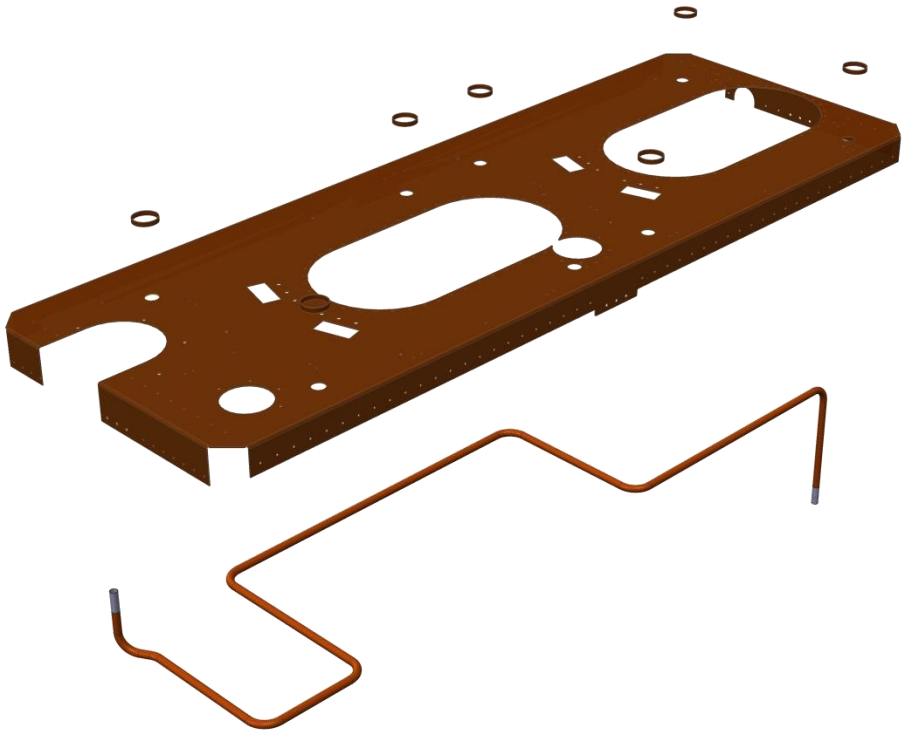




Thermal Shield Manufacture & Assembly

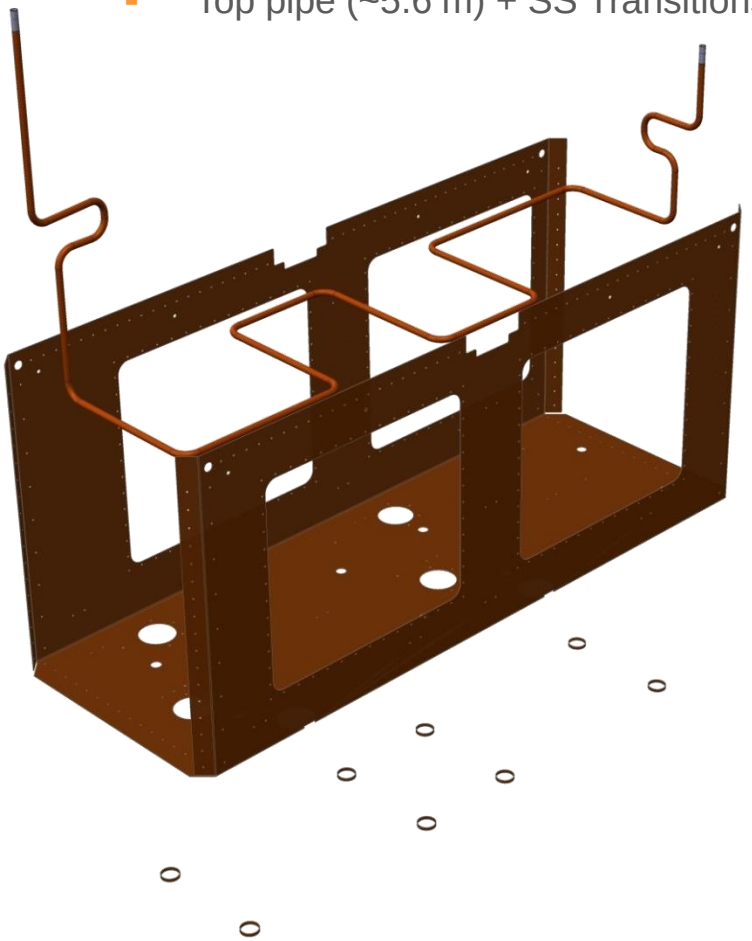
Brazed top assembly:

- Top Panel
- 7 x MLI covers
- Top pipe (~2.5 m) + SS Transitions



Brazed lower assembly:

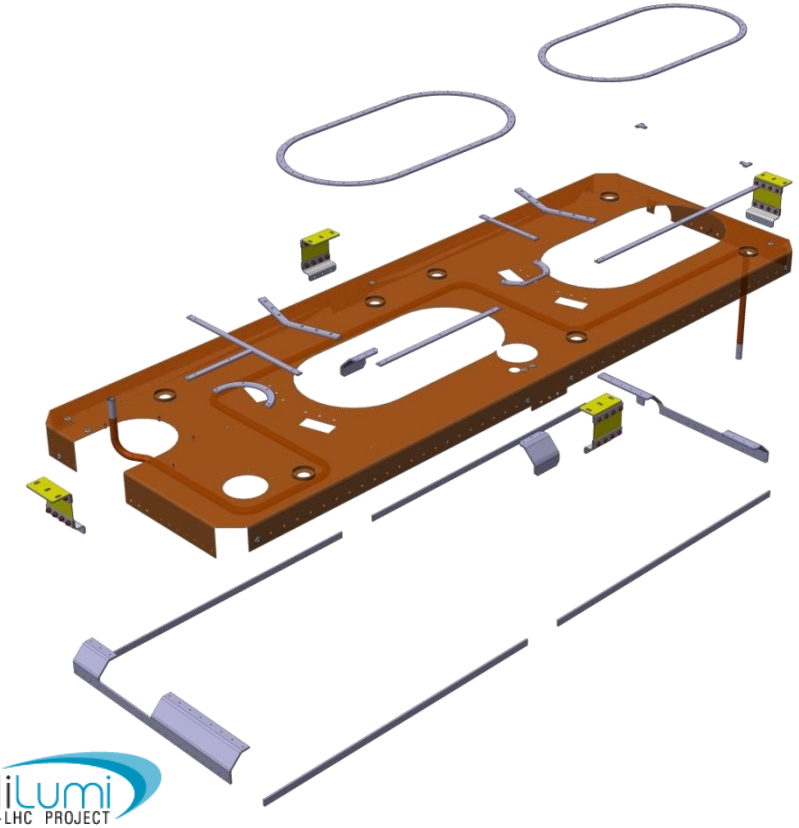
- U Panel
- 8 x MLI covers
- Top pipe (~5.6 m) + SS Transitions



Thermal Shield
Manufacture & Assembly

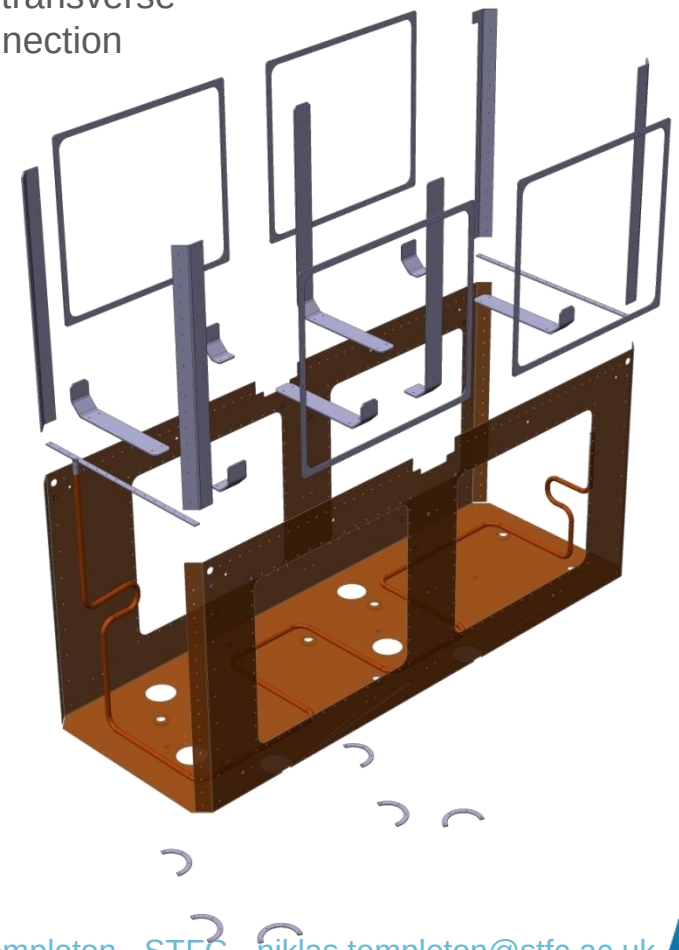
Top assembly:

- 4 x support brackets
- 4 x support stiffener
- 6 x cable rail connection
- 2 x oblong connection
- 2 x blade intercept connection
- 2 x HOM intercept connection
- 4 x longt. connection



Lower assembly:

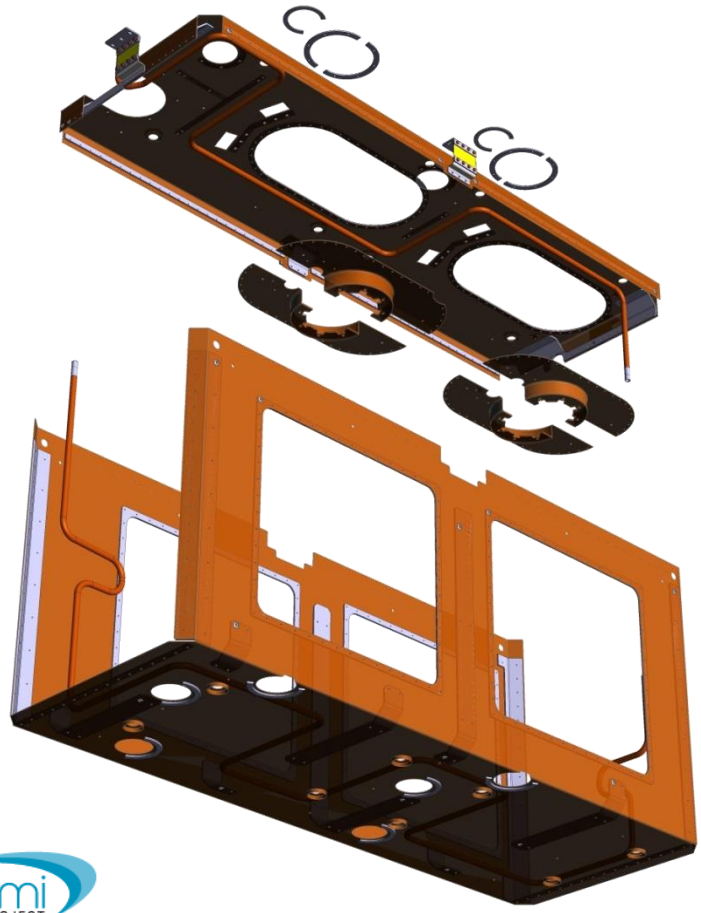
- 4 x window connection
- 4 x vertical connection
- 2 x transverse connection
- 8 x stiffener
- 6 x HOM intercept



Thermal Shield Manufacture & Assembly

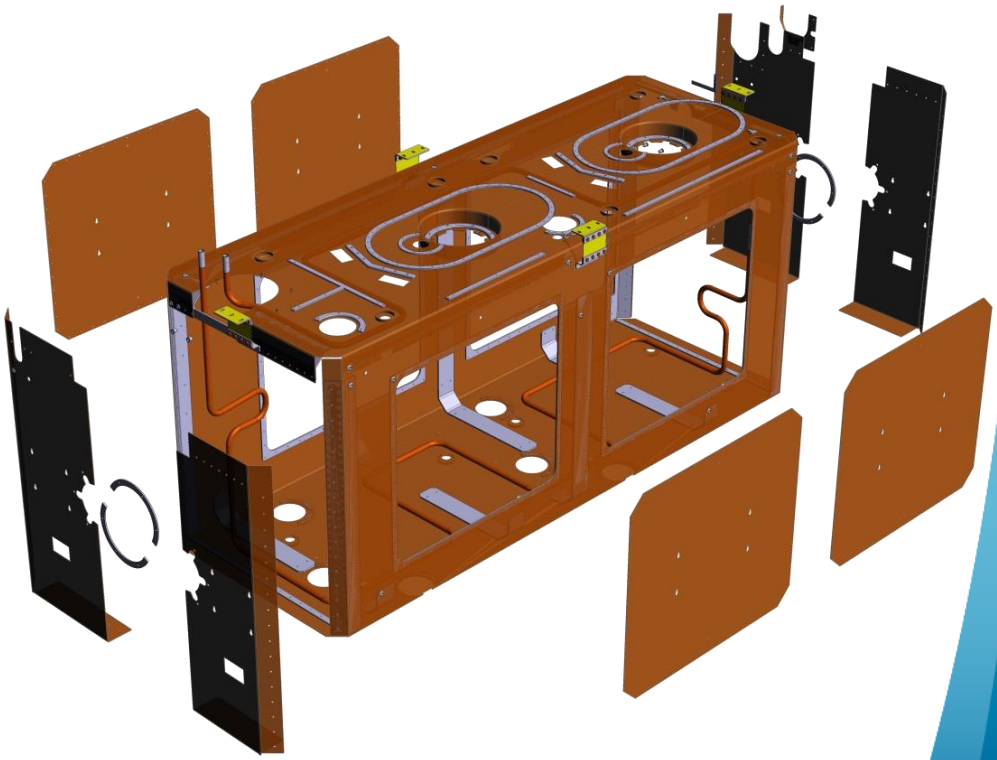
Cavity String Assembly:

- 4 x Support plate cover
- 4 x FPC intercept
- 2 x Tuner intercept



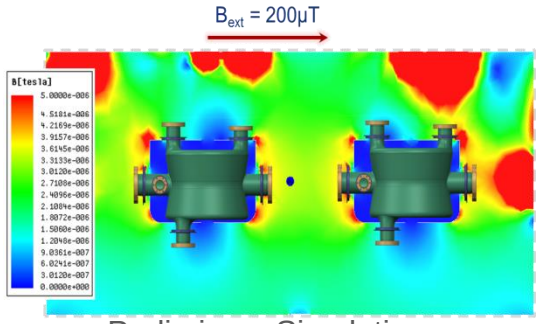
Final Assembly Stages:

- Top & Lower assemblies
- 4 x Beamline cover
- 4 x Beamline thermalisation
- 4 x Windows

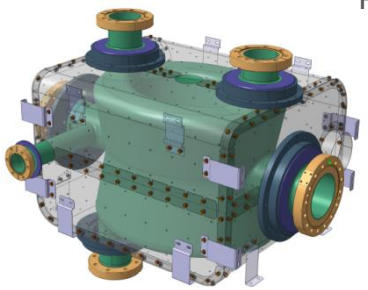


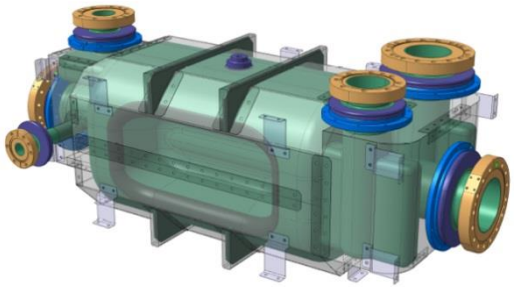
Magnetic Shielding Overview

- Double layer shielding solution
- 1 x global ‘Warm’ shield
- 2 x local ‘Cold’ cavity shields
- Warm Shield: 2mm MuMetal
- Cold Shields: 1mm Cryophy
- Magnetic Survey predicts no more than **60μT** external field in SPS area
- Specification: No more than **1μT** at cavity surface



Preliminary Simulations


DQW Cold Shield

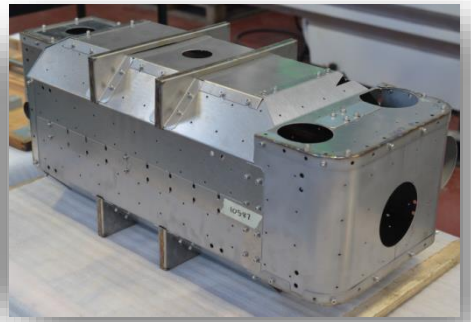

RFD Cold Shield


DQW Warm Shield

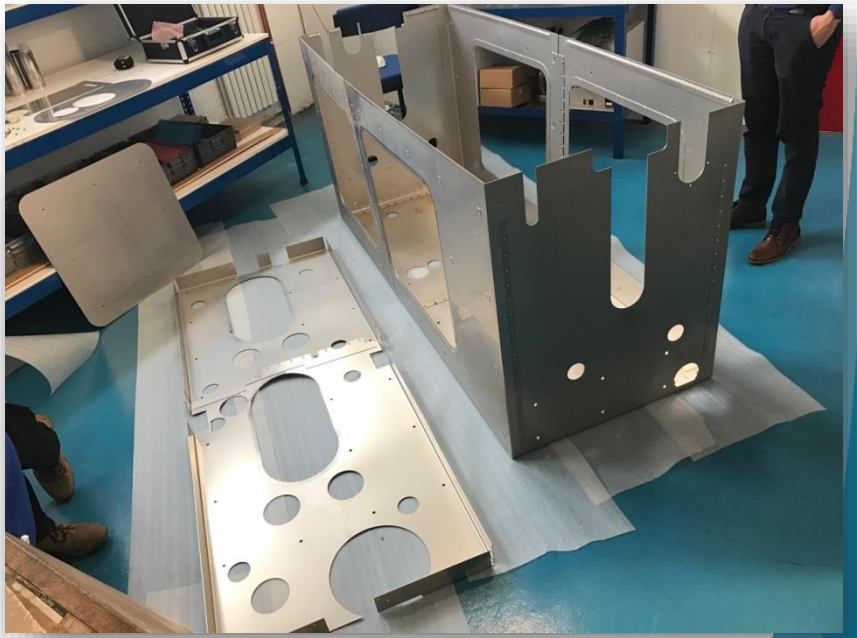
Niklas Templeton - STFC - niklas.templeton@stfc.ac.uk

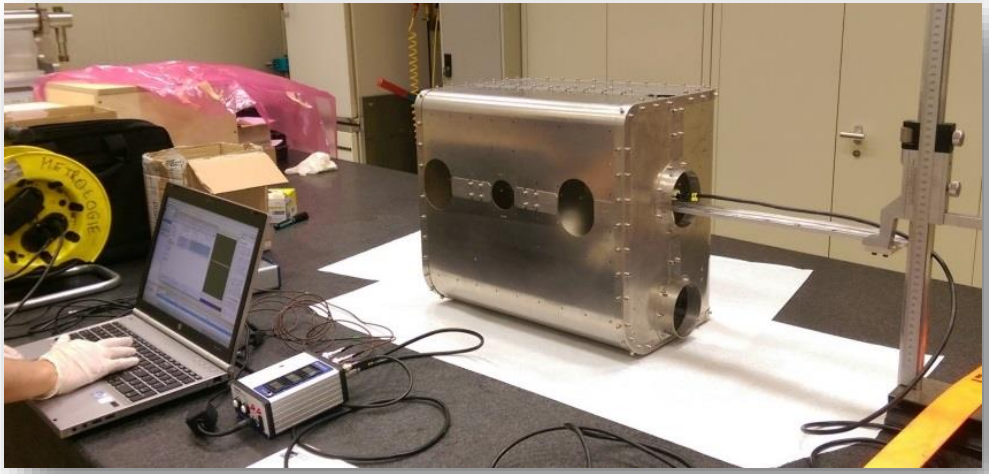
Magnetic Shielding
Status & Activities

- Cold Shields delivered April ’16
- RT magnetic field measurements
- Cryophy material studies
- Inspection & mock assembly



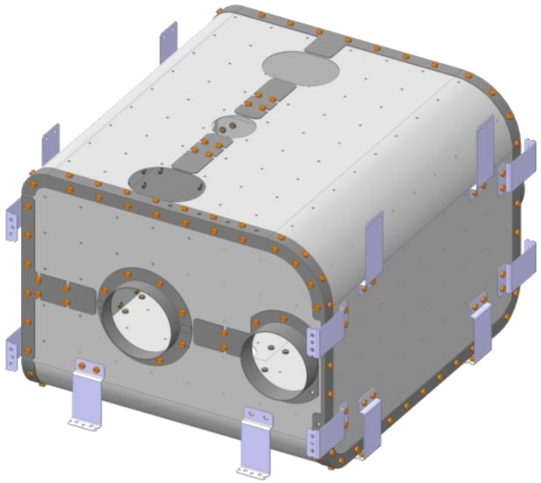
- Warm Shield acceptance visit 30/03/17
- *Delivered April ‘17*



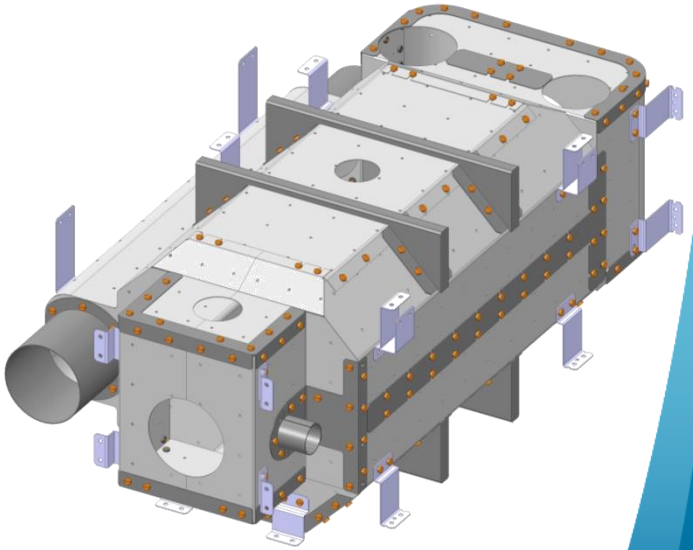


Cold Magnetic Shield Design

- Mounted internal to helium tank – giving several advantages
- Geometry & configuration dictated by cavity, ports, helium tank, stiffeners etc.
- Supported by titanium flexures which eliminate cooldown stresses
- Curvature used (where possible) for stiffness & shielding performance
- Branch tube covers employed around penetrations (where possible)
- Patterned with Ø3 mm holes for helium transfer
- Pre-assebled threaded inserts allow assembly
- 4mm clearance all around cavity
- Curie temperature of cryophy is 400°C, safe limit: 300°C



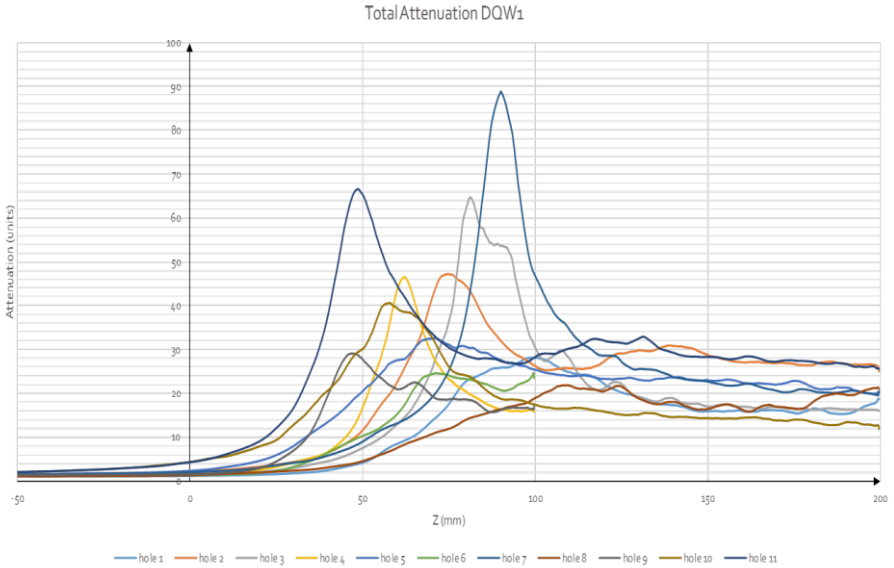
DQW ~10 kg

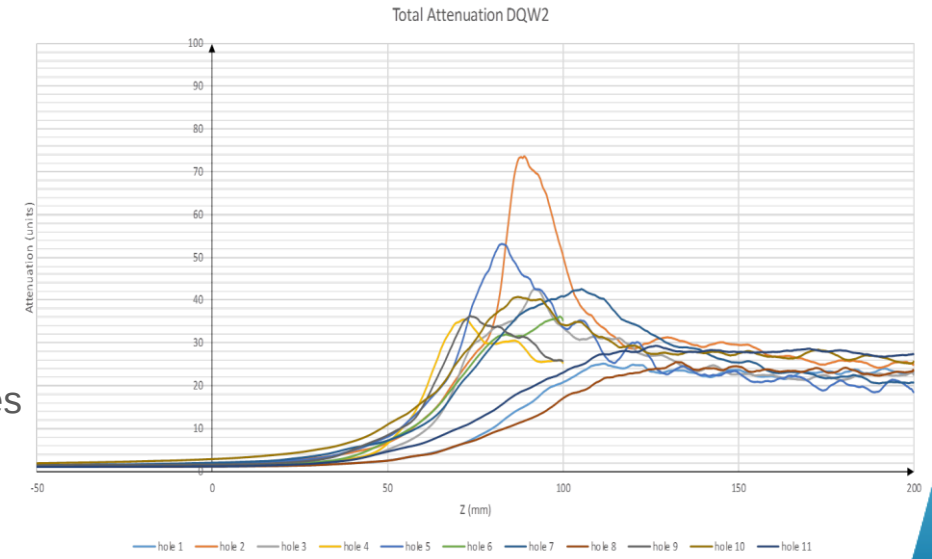


RFD ~12 kg

Cold Mag Shield - Magnetic Measurements
Mathis Lacombe & Marco Buzio TE-MSC-MM

- Performed with Bartington Probe & Magmeter: Fluxgate Mag-03MS1000 (±1µT uncertainty)
- Conducted at Room Temperature with ambient external field
- 2 DQW shields measured and compared with simulations
- Results show an average attenuation (shielding factor) **=23**
- DQW2 shield shows better performance
- Results agree with simulations
- Validates shielding performance and verifies simulations

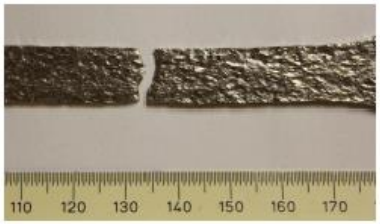


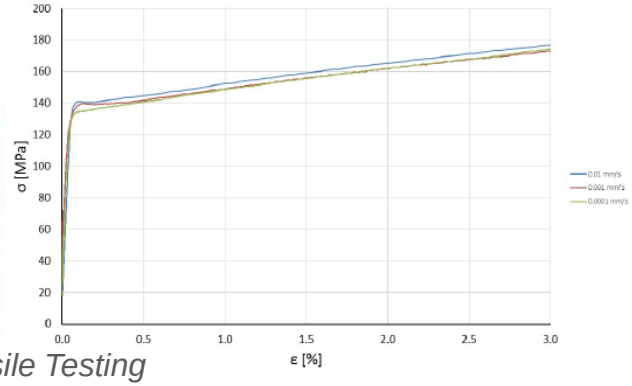


Magnetic characterisation of Cryophy for the crab cavity cold magnetic shield - Konrad Eiler

Tests:

- DC Ring measurements at 300, 77 & 4.2 K
- Tensile testing for stress-strain characterization
- Epstein frame measurements on strained samples



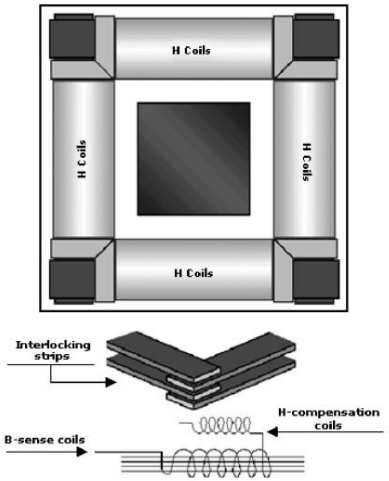


Tensile Testing

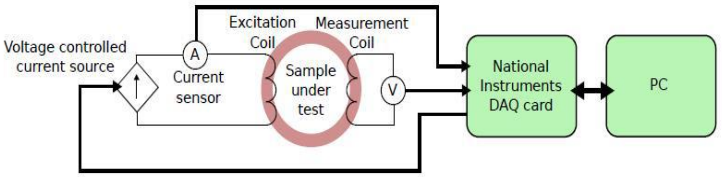
Summary:

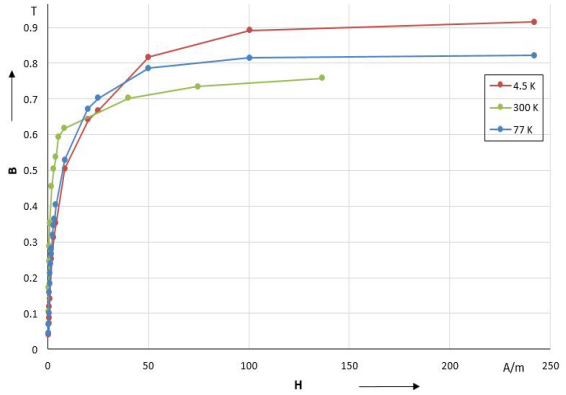
- Magnetisation curves obtained at cryogenic temperatures showing temperature affect
  - Data can be used to refine finite element model
- Tensile tests characterise mechanncial properties
- Yield limit ~140MPa
- Epstein frame tests showed a sharp reduction in permeability for strained samples

Epstein Frame Setup



Ring Sample Measurements

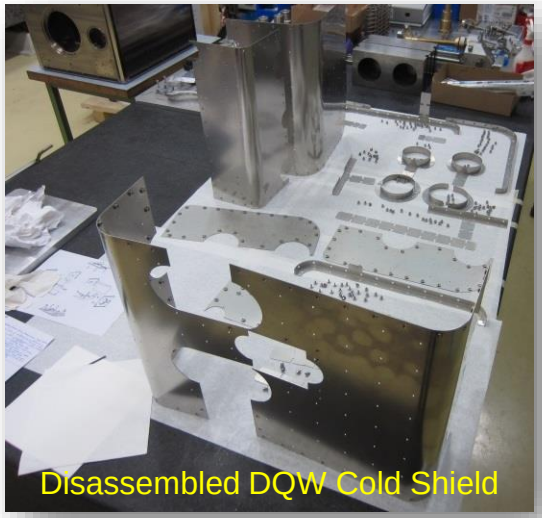


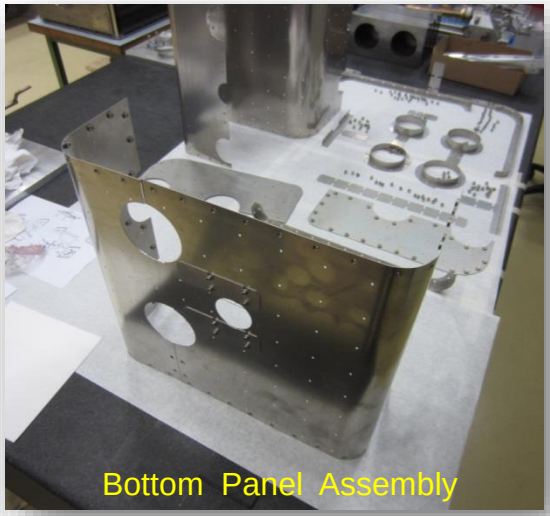


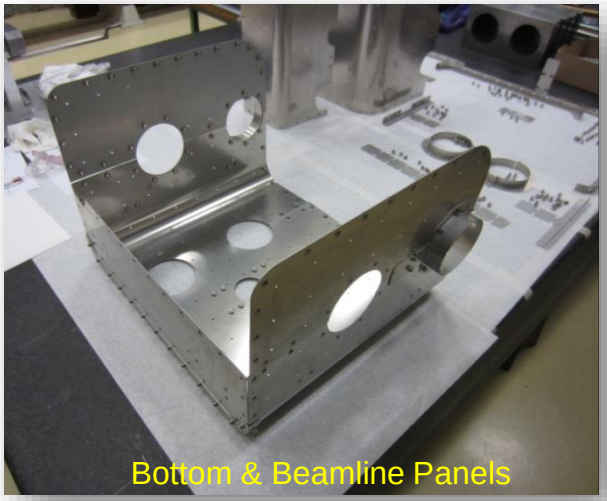
Magnetization curves for Cryophy

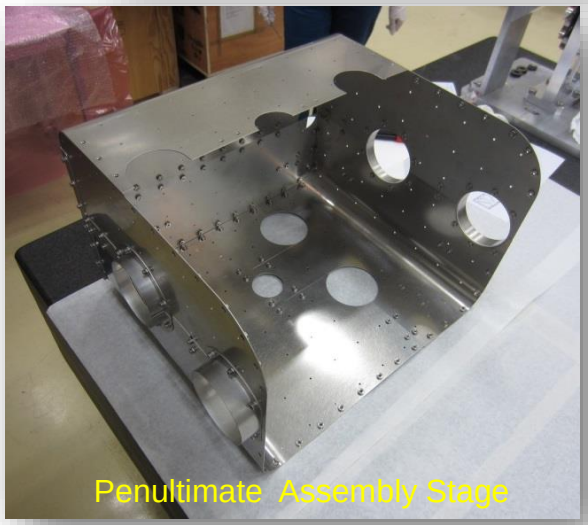
Cold Mag Shield – Inspection & Assembly
Artur Krawczyk

- Detailed inspection report & mock assembly (without cavity-helium tank) performed by workshop.
- Activity serves to familiarise & verify assembly procedure & identify any potential issues or improvements.


Disassembled DQW Cold Shield

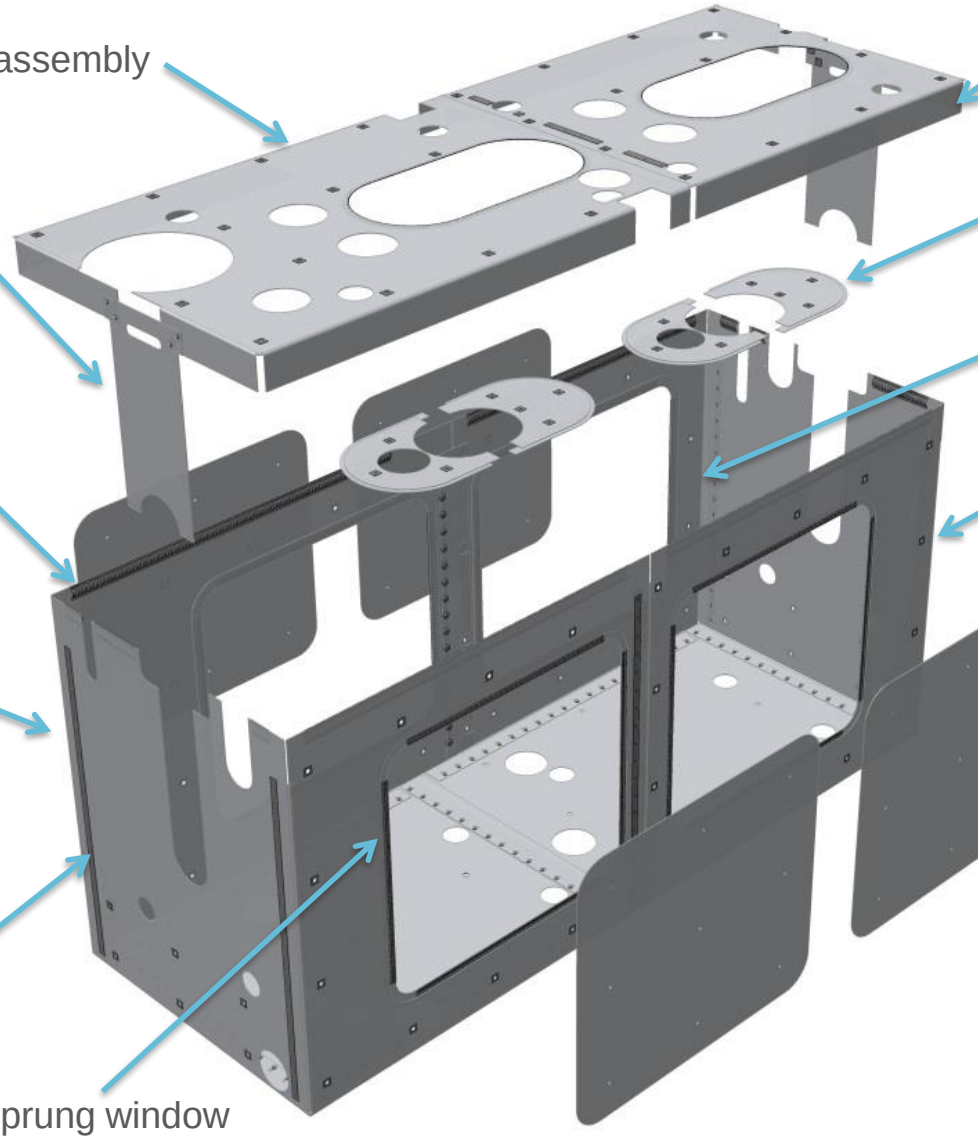

Bottom Panel Assembly


Bottom & Beamline Panels


Penultimate Assembly Stage


Re-assembled Shield

Warm Magnetic Shield Design



Drop down underlapping configuration

Top assembly

Split support plate cover

Beamline cover

Integrated flanges

Spring fingers between lid

1mm Spacers at vessel connection

Lower assembly

Windows

1mm additional boss for tapped connection

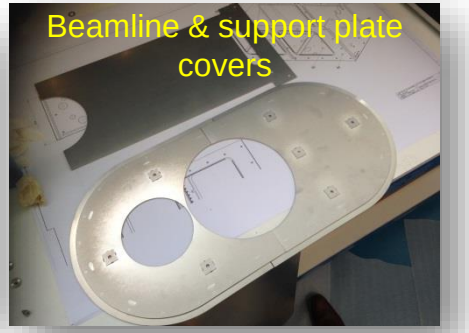
~150 kg

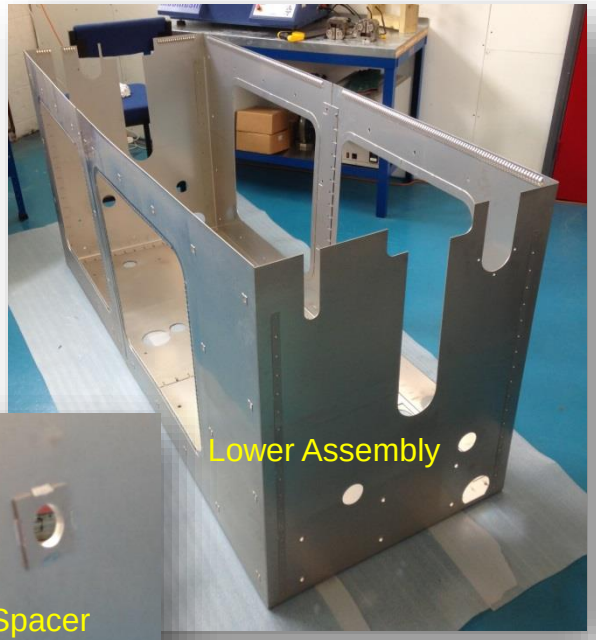
Sprung window connection

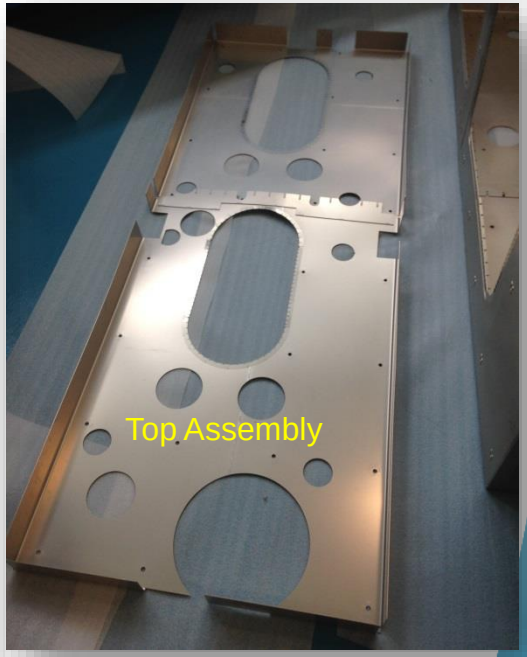
Warm Magnetic Shield Acceptance Visit

- Dimensional reports inspected
- Mock assembly performed
- Assembly measurements
- Permeability checks

- Non-compliant panel
- *Full assembly & magnetic measurement not feasible without vacuum vessel*







Thanks for your attention!