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Parametric Study on the Thermal Performance of Beam Screen Samples of the High-Luminosity LHC Upgrade

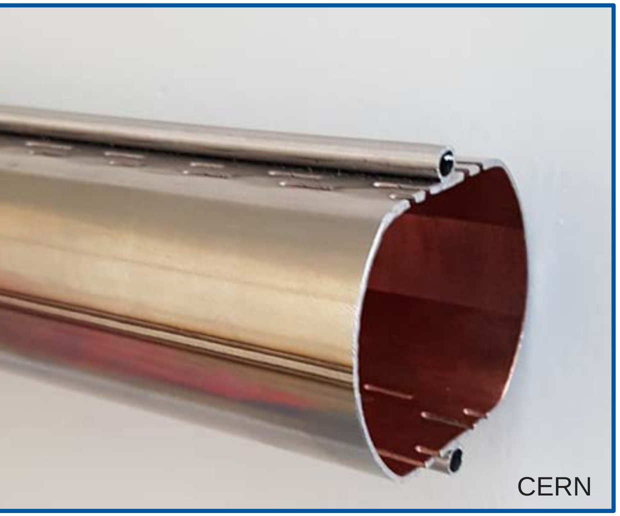
P. Borges de Sousa, M. Morrone, N. Hovenga, C. Garion,
R. van Weelderen, T. Koettig and J. Bremer

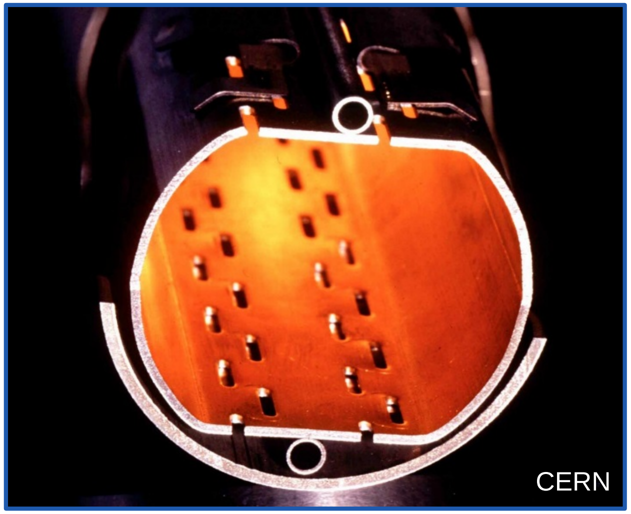
CERN, 1211, Geneva 23, Switzerland

Outline

- High-Luminosity LHC upgrade
- Beam screens for the insertion regions
- Experimental test set-up
- Sample geometry
- Results: beam screen thermal pathways
- Results: supporting structure conductance
- Concluding remarks

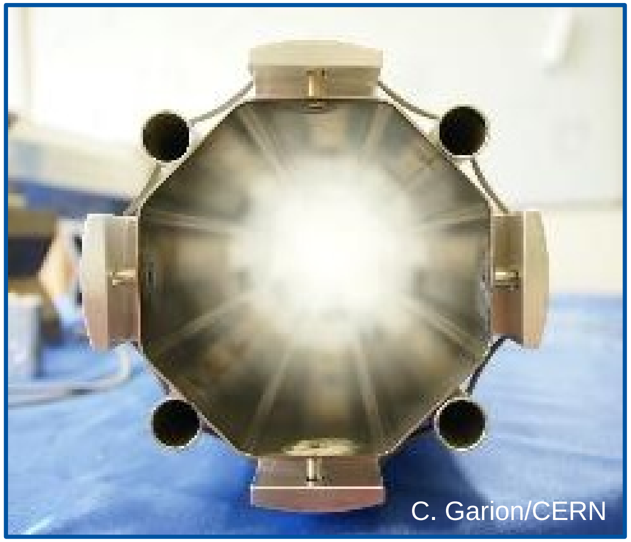
From the LHC to the HL-LHC





LHC beam screen

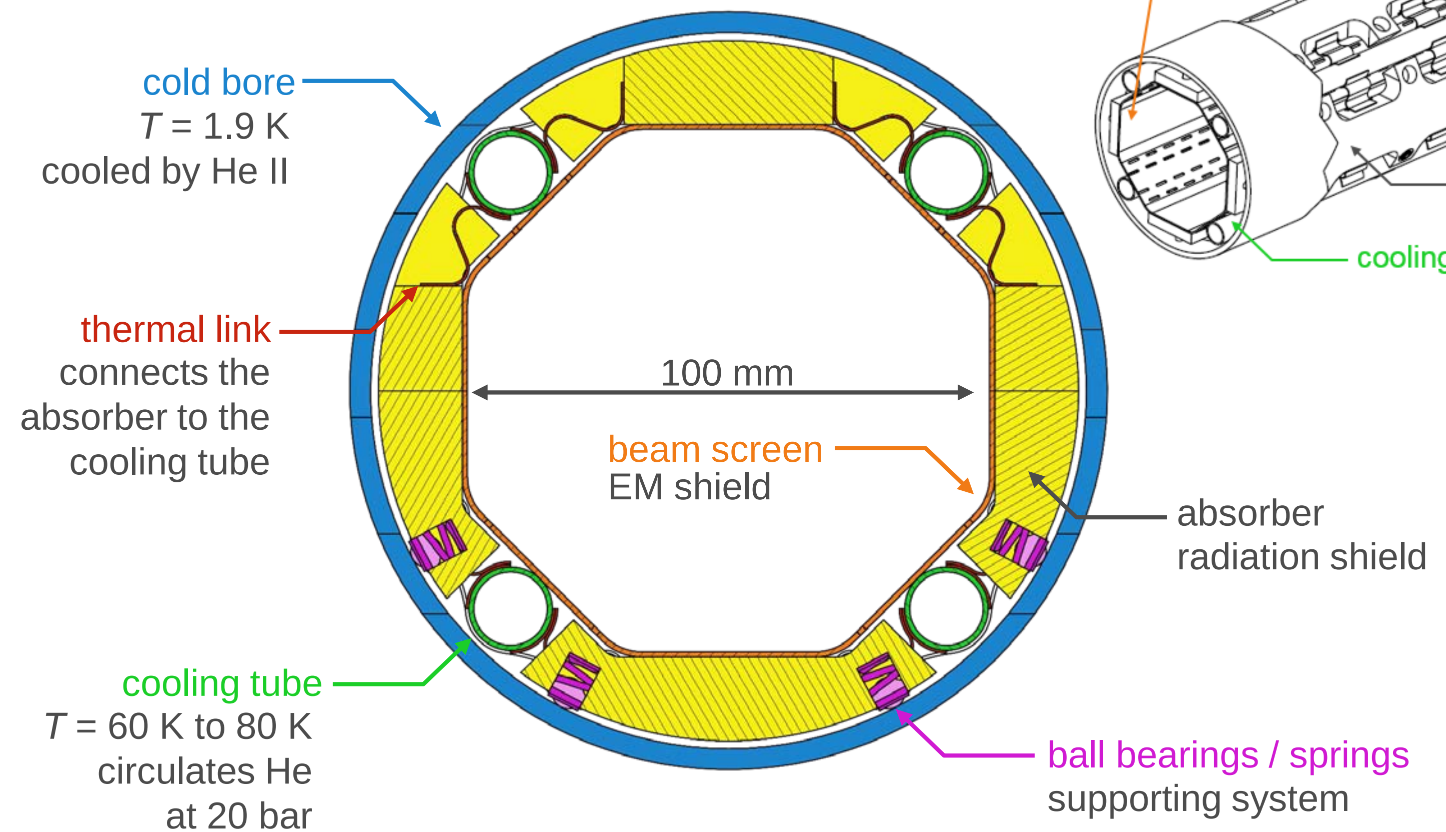
- 4 – 20 K operating *T*
- Low mass flow (1 g/s)
- Supercritical He at 3 bar
- No absorber (just screen)

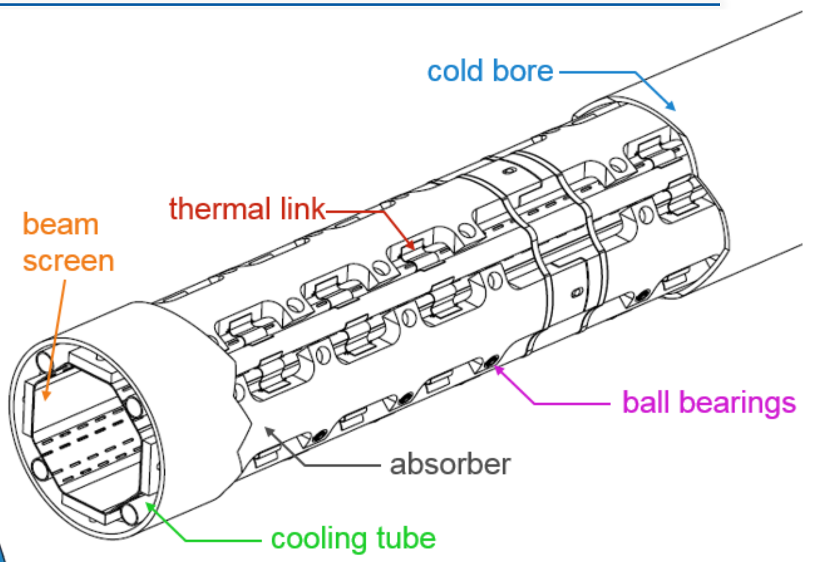


HL-LHC beam screen

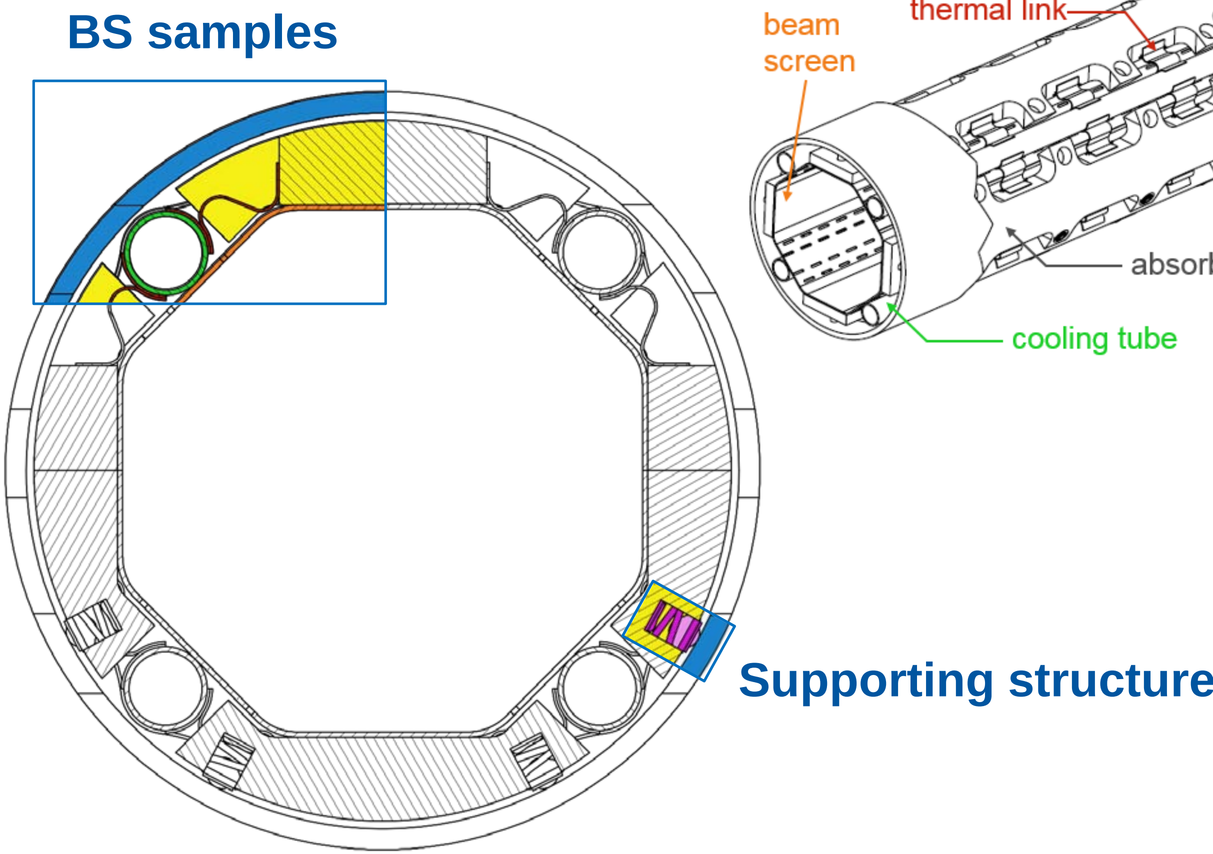
- 60 – 80 K operating *T*
- High mass flow (10 g/s)
- Supercritical He at 20 bar
- Tungsten-based absorber

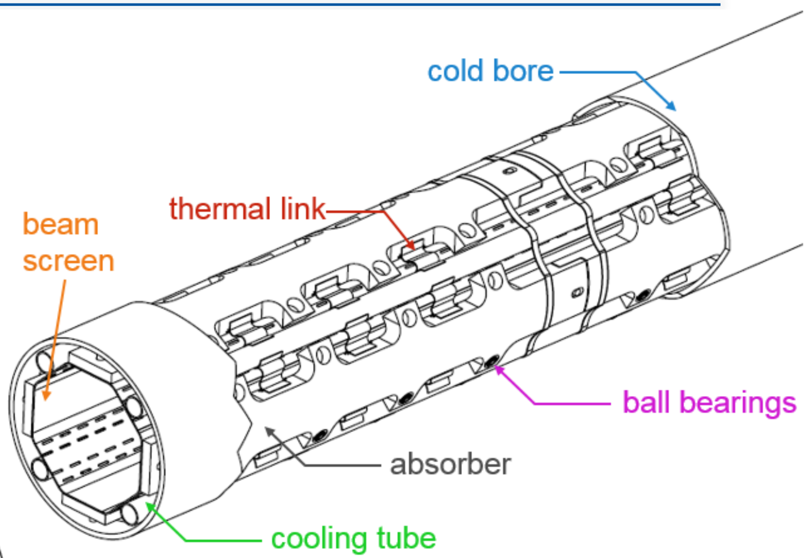
HL-LHC beam screens





HL-LHC beam screens



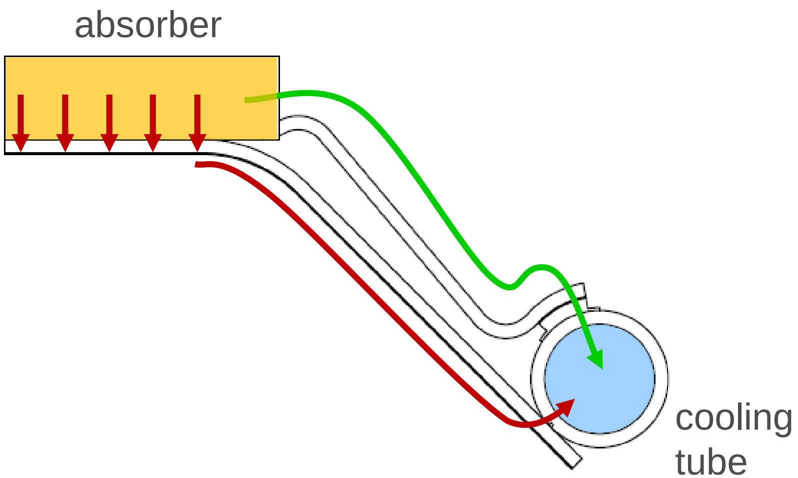


Scope of thermal performance studies

BS samples:

- Characterise two thermal pathways
  - Through the beam screen
  - Through the thermal link

- Requirements:
  - No max. *T* defined for absorber
  - Max Δ*T* between heat sink and inner beam screen surface of 5 K



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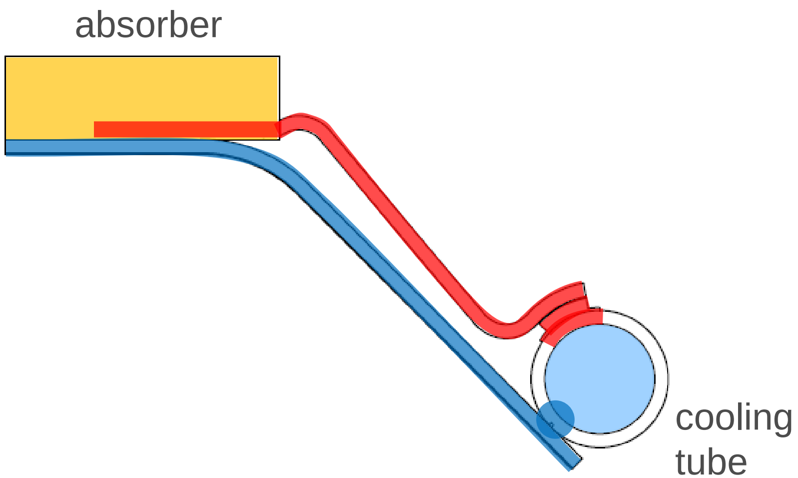

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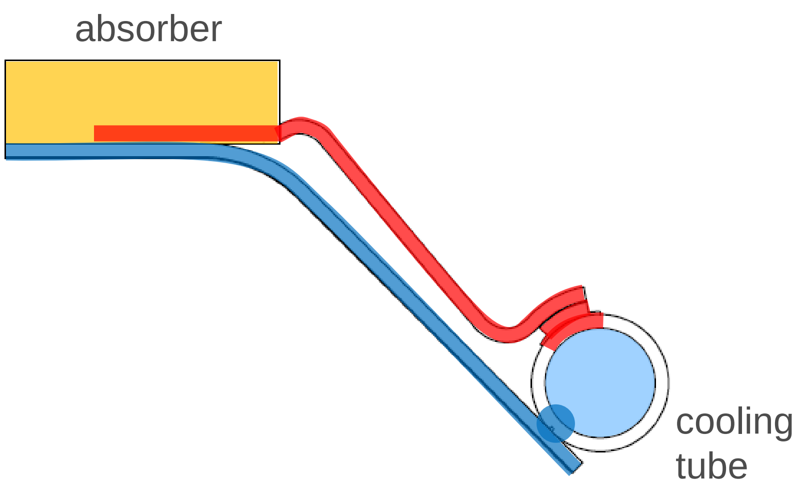
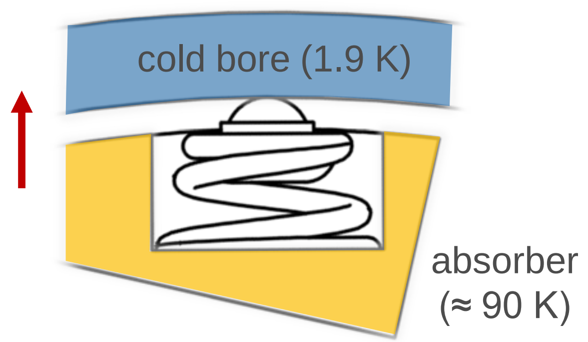
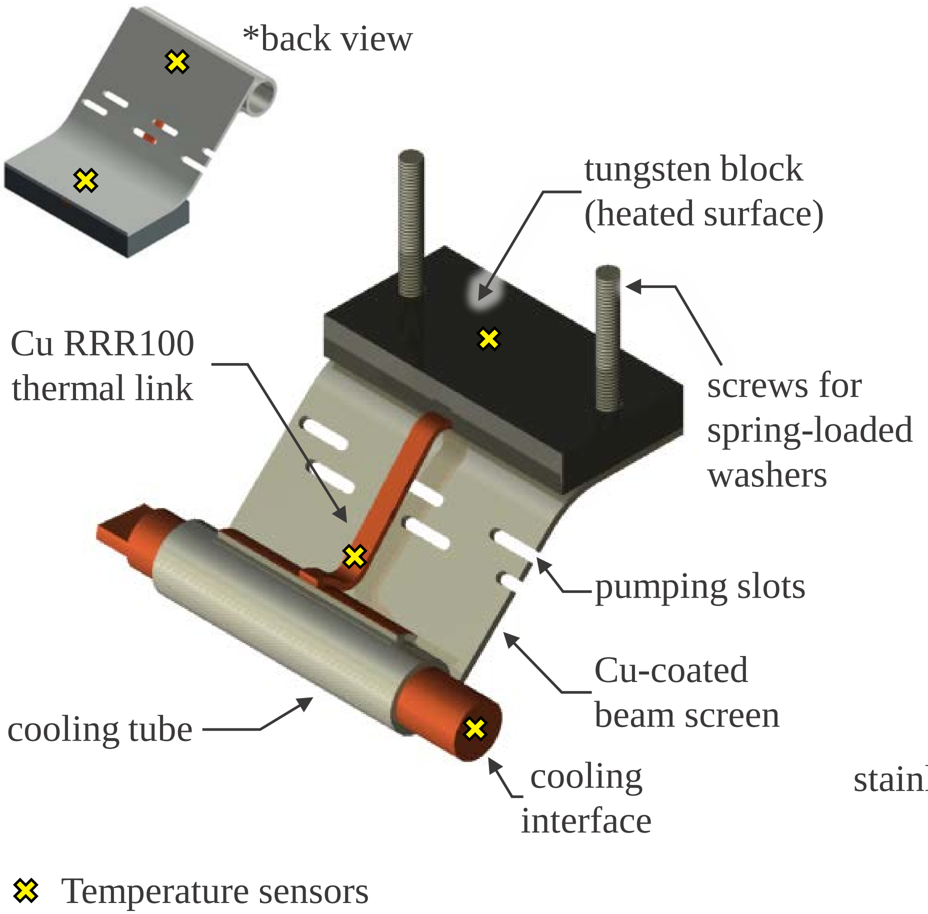


Supporting structure:

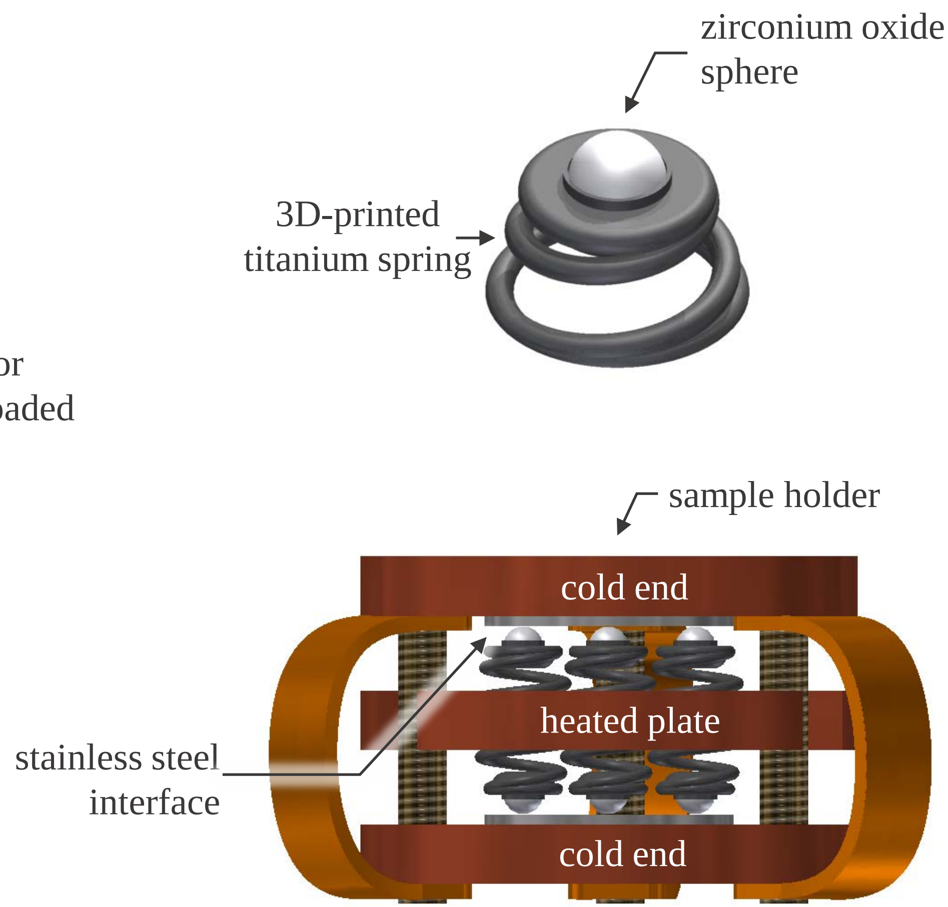
- Characterise heat transfer from beam screen to cold bore by conduction
- Requirements:
  - Total heat load transferred (conduction+ radiation) < 500 mW/m of beam screen



Sample geometries and test set-up

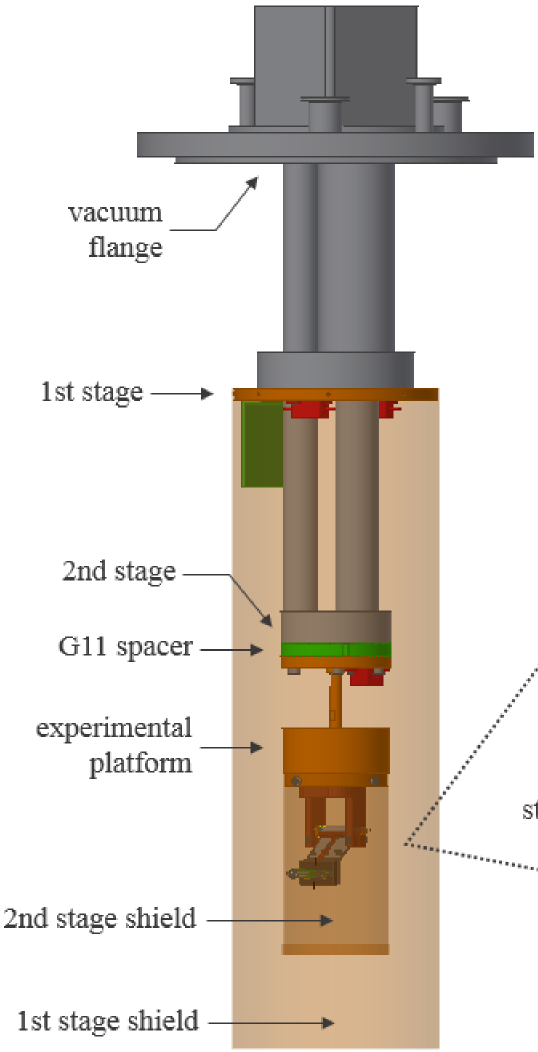


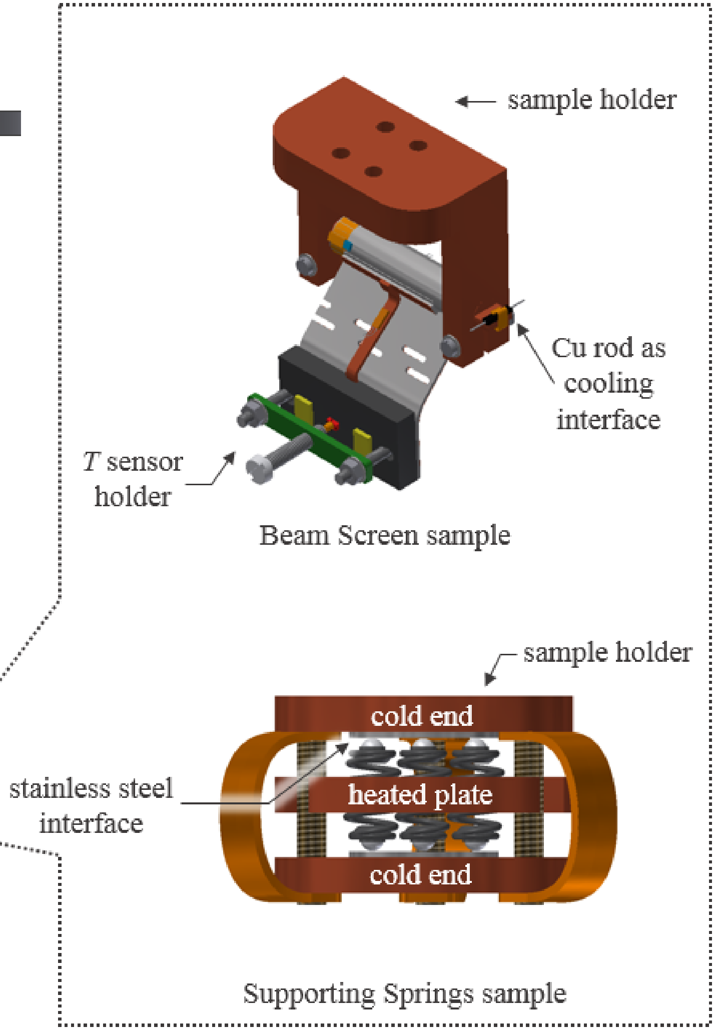
Beam Screen sample



Supporting Springs sample

Experimental set-up





BS samples:

- Base temperature varied from 50 K to 80 K
- Heat load varied from 0 to 400 mW (0 to 25 W/m)
- Tungsten block-beam screen compression 0 and 1.82 N

Supporting structure:

- Base (cold) temperature kept between 2.7 K and 3 K
- Warm end heated up to 100 K
- 7.5 N (nominal) and 15 N compression

Results – Beam screen sample

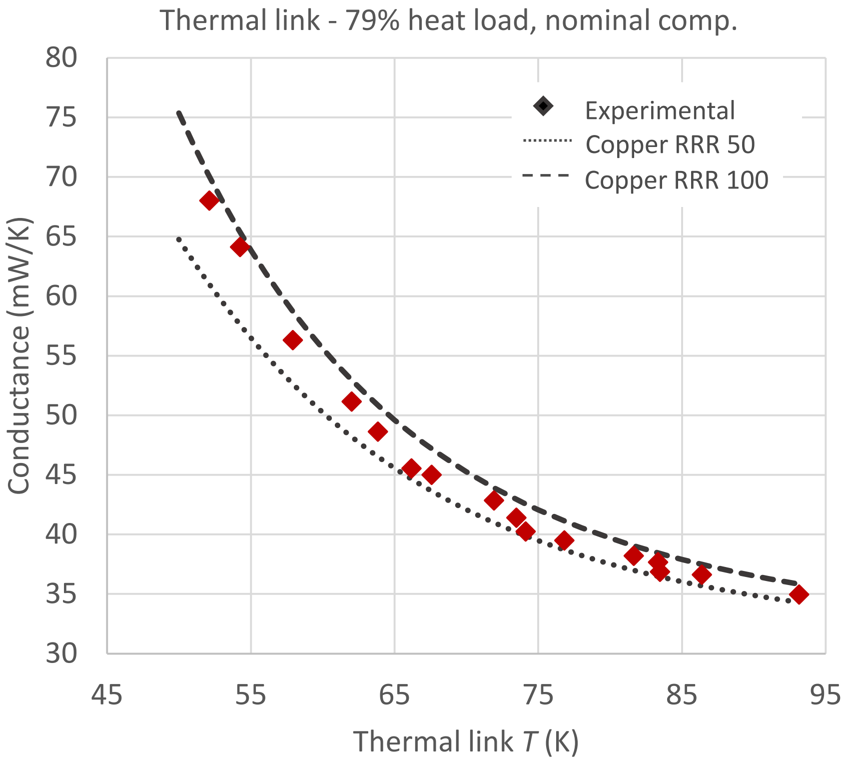
- Maximum temperature increase of relevant beam screen components was measured for a Q2-type magnet, heat load 15 W/m

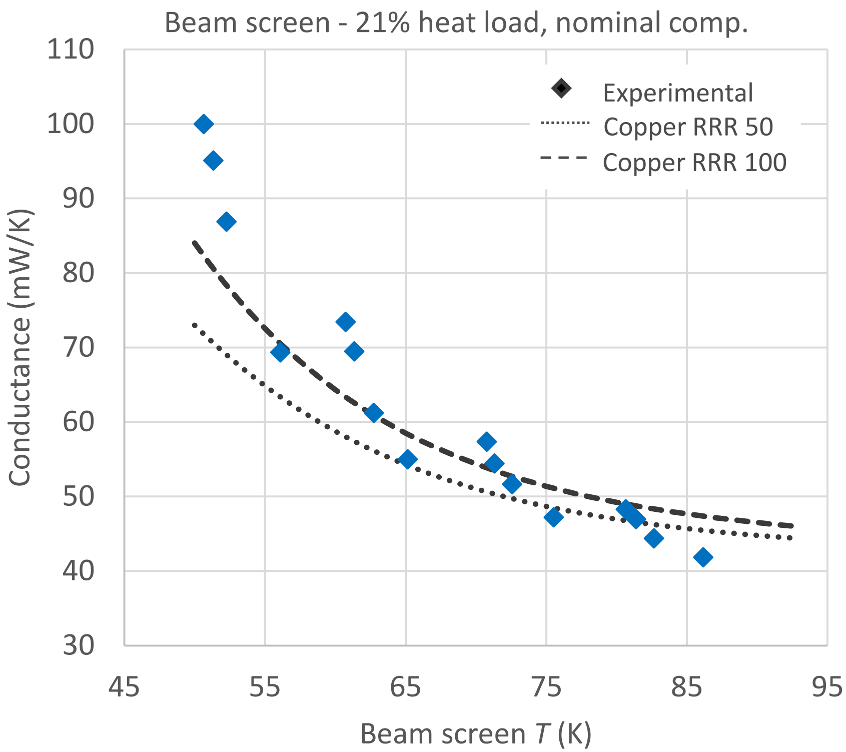
	Nominal compression		No compression	
Base *T* (K)	**W block Δ*T* (K)**	**Beam screen Δ*T* (K)**	**W block Δ*T* (K)**	**Beam screen Δ*T* (K)**
60.00 ± 0.16	14.00 ± 0.06	3.20 ± 0.04	13.50 ± 0.06	2.20 ± 0.04
75.00 ± 0.23	14.00 ± 0.09	3.40 ± 0.03	13.50 ± 0.09	2.30 ± 0.03

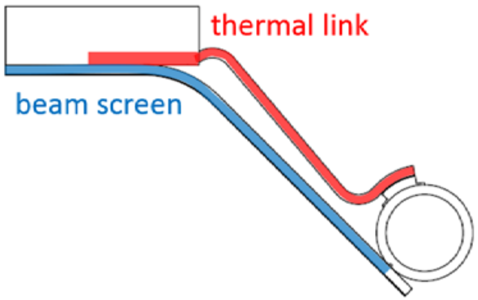
- Temperature difference between the inner surface of beam screen and the cooling source kept below the 5 K threshold

- Tungsten block reaches a maximum temperature of 75 + 14 = 89 K at the nominal heat load towards the high temperature end

Results – Beam screen sample



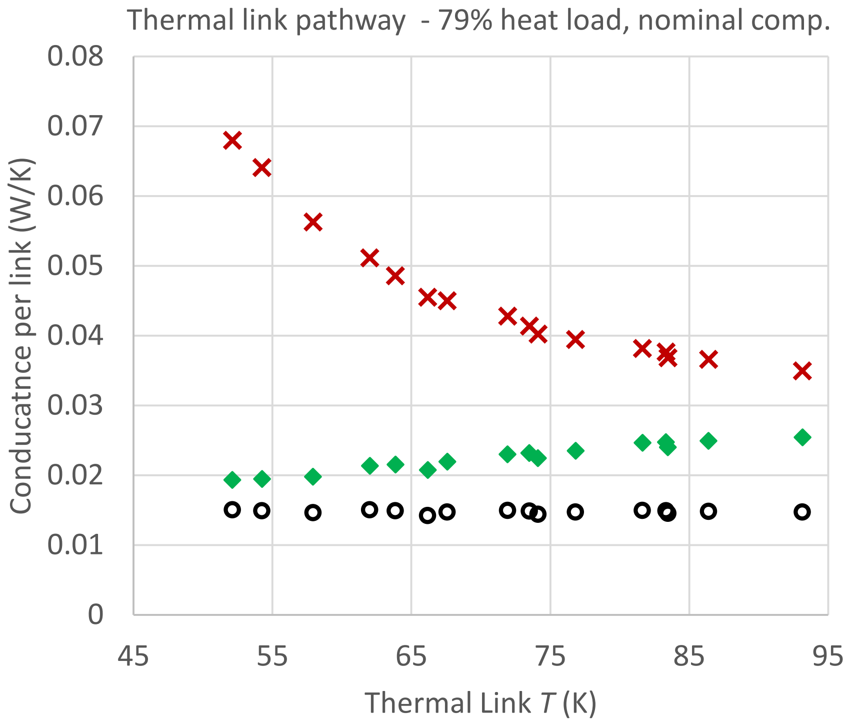


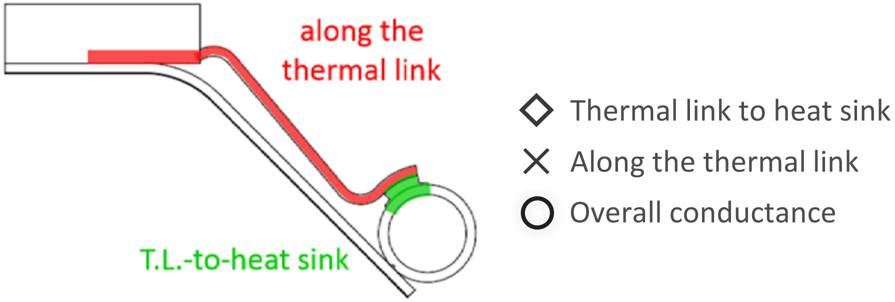


- Nominal compression: 79% heat load flows to the heat sink through the thermal link, 21% through the beam screen

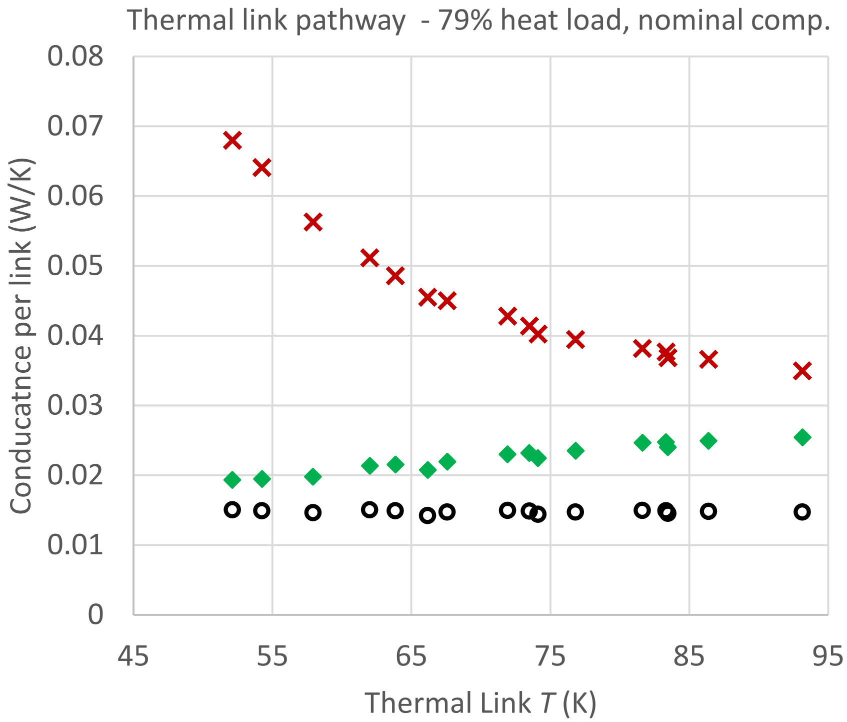
- No compression: 89% through TL, 11% though BS

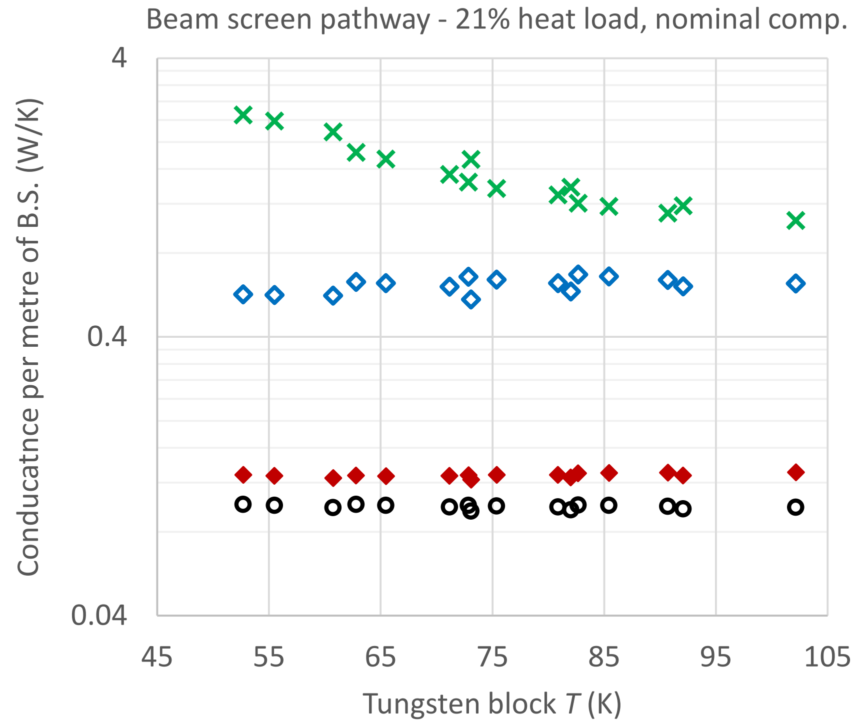
Results – Beam screen sample

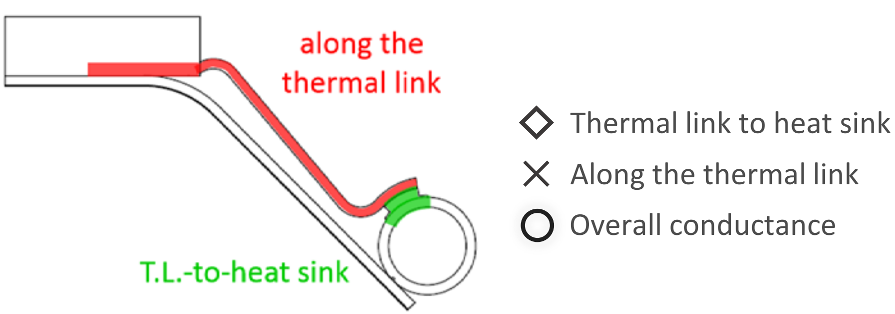


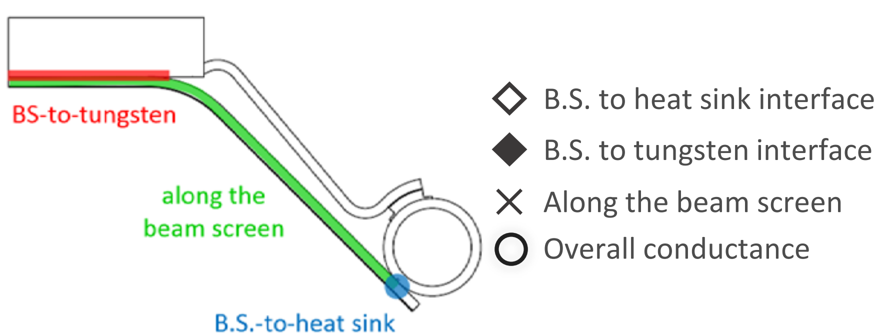


Results – Beam screen sample

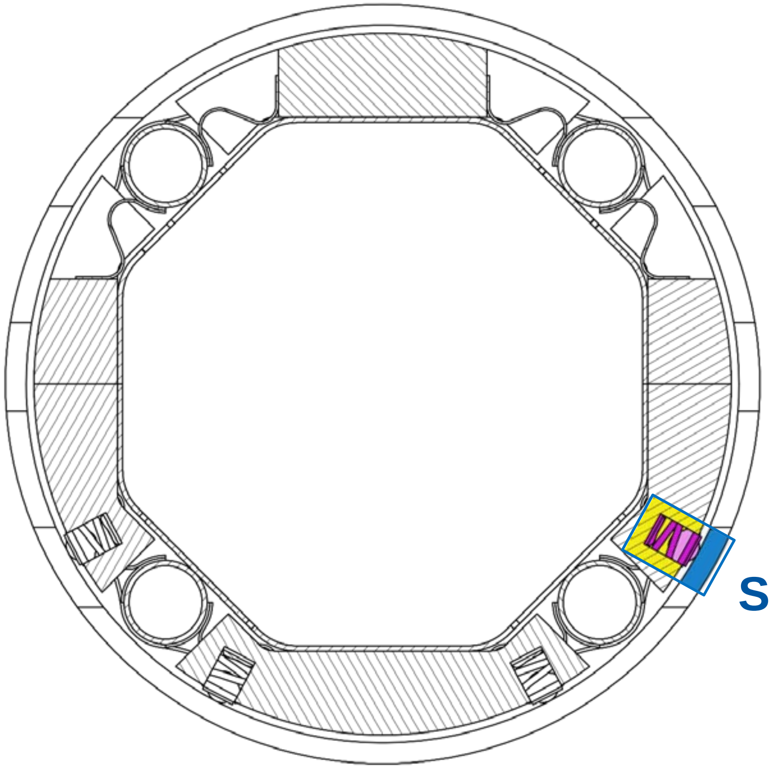




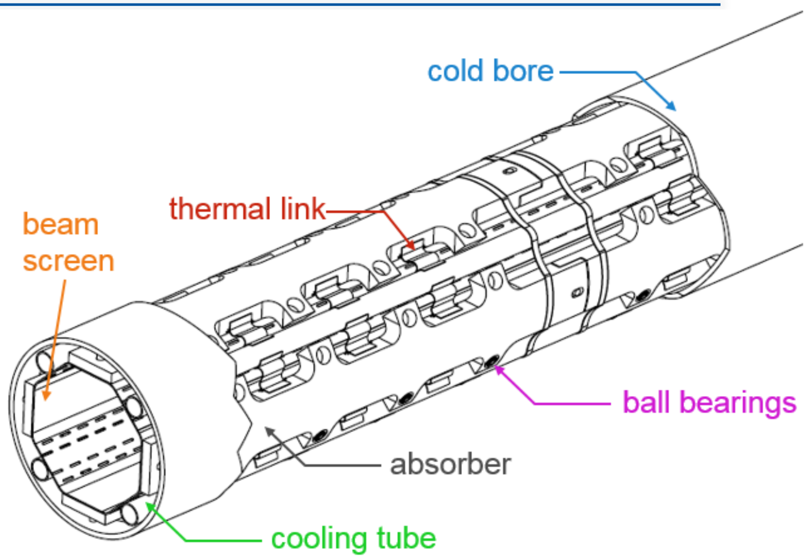




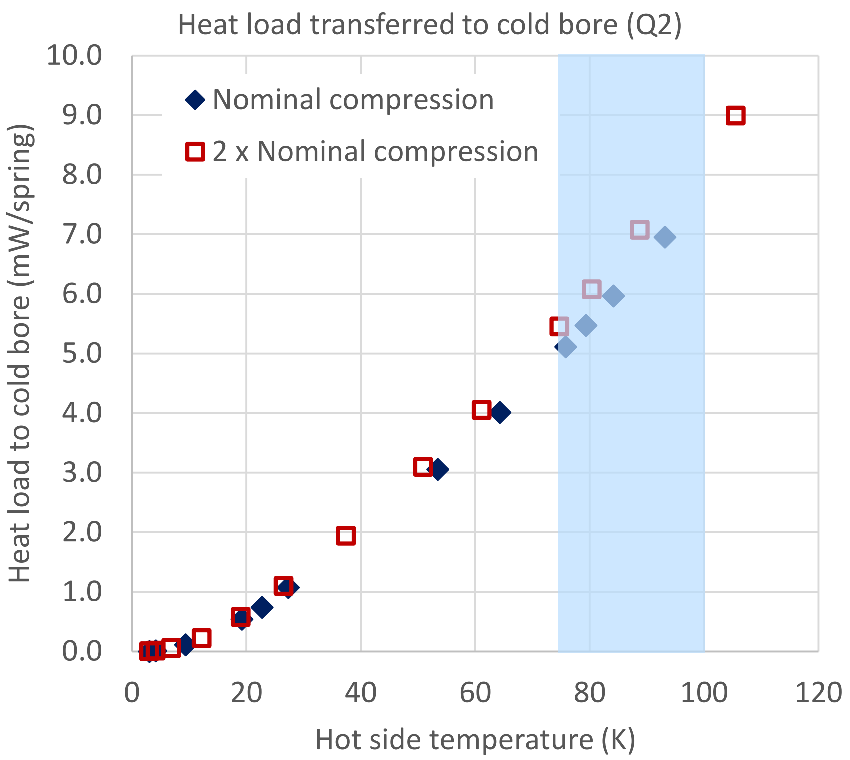
Supporting structure – Q2 assembly



Supporting structure

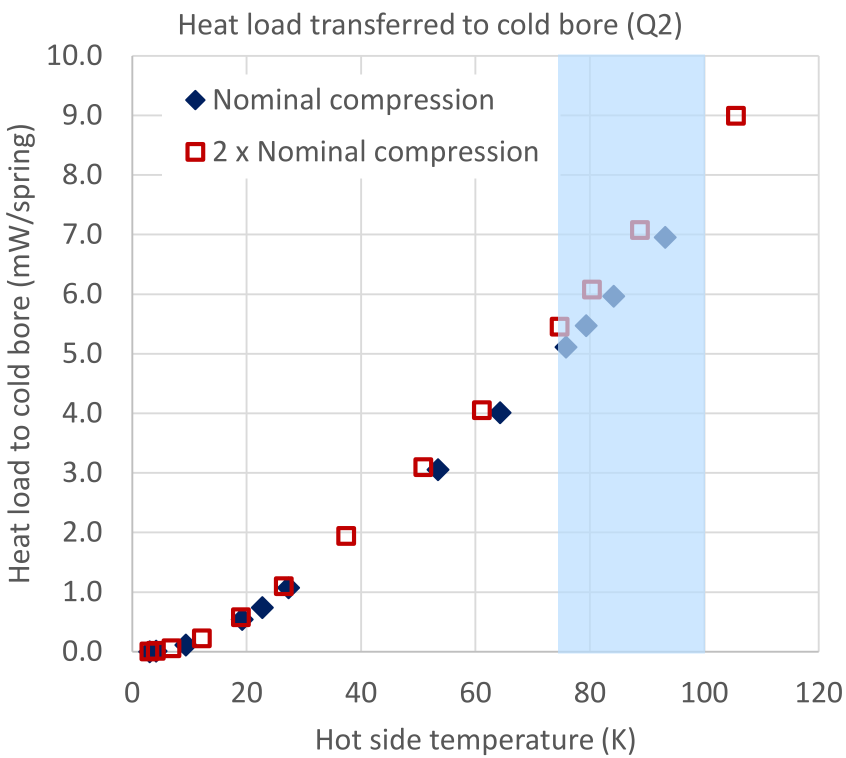


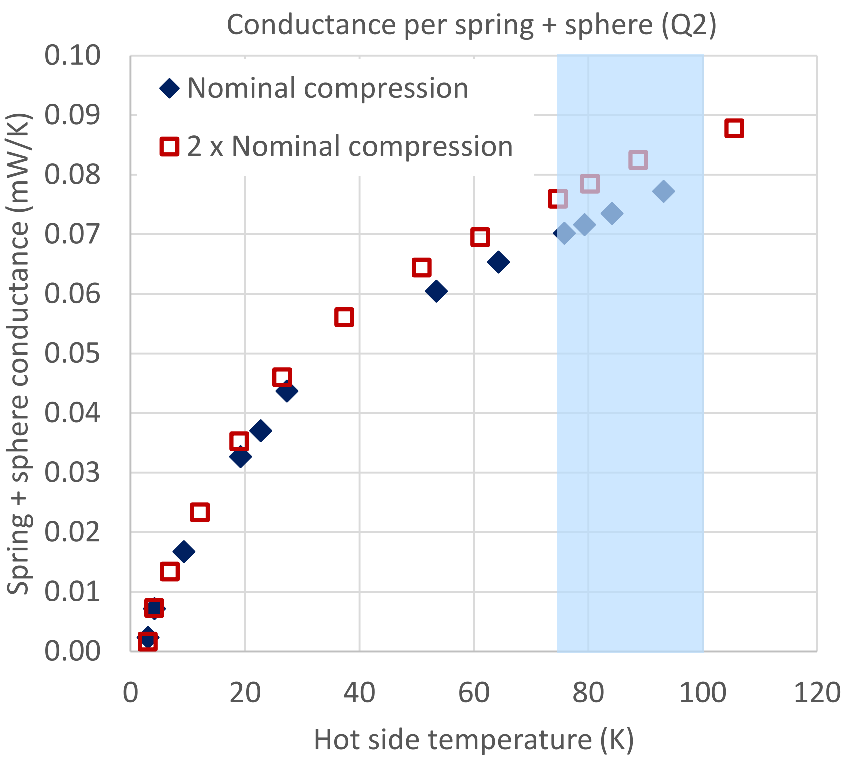
Supporting structure – Results for Q2 assembly



- Nominal compression: 7.5 N
- 80 spring+sphere sets per metre of beam screen → 560 mW/m

Supporting structure – Results for Q2 assembly





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Summary

Beam screen thermal link at the nominal heat load of 15 W/m:

- Maximum *T* of tungsten block is 89 K (14 K gradient to cooling tube)
- Δ*T* between the cooling fluid and the inner surface of the beam screen kept below 5 K
- Results similar for nominal (1.82 N) and no compression
- Major thermal pathways have been analysed and design validated, and agree with simulations

Spring support structure to cold bore:

- Conductance around 0.08 mW/K for the 75 K – 95 K range to 3 K
- An average of 560 mW per metre of beam screen needs to be considered
- Little influence of compression force (less than 10%)

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