First thermo-structural Vacuum Barrier design for EU DEMO feeders

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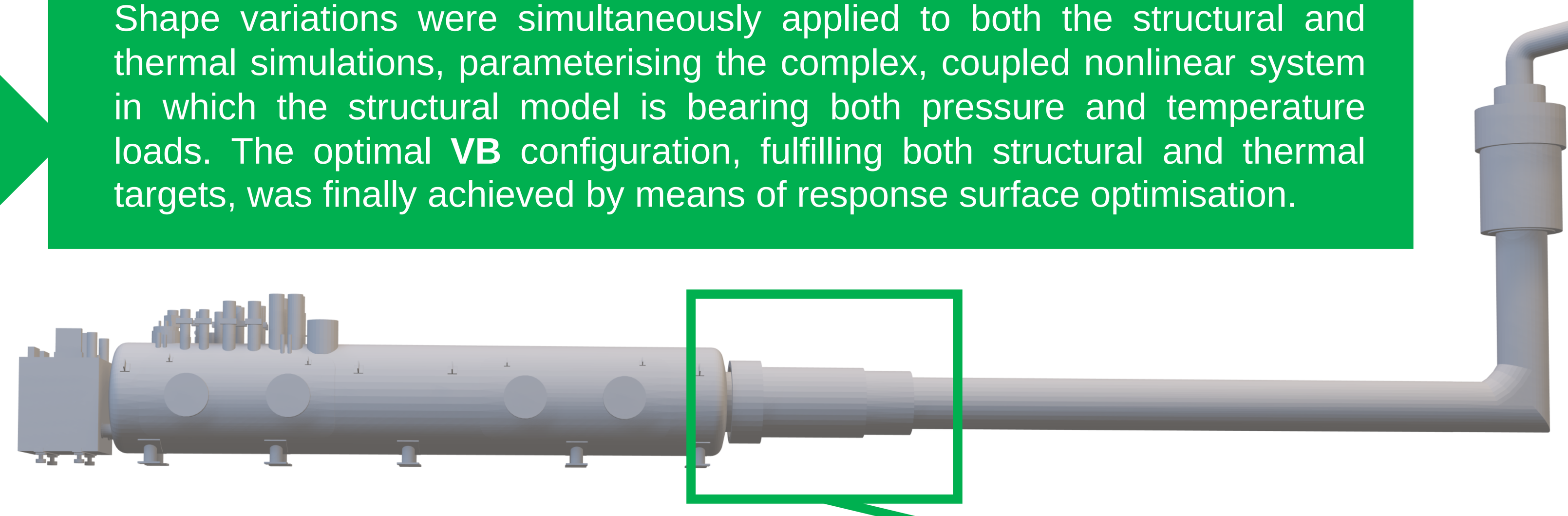
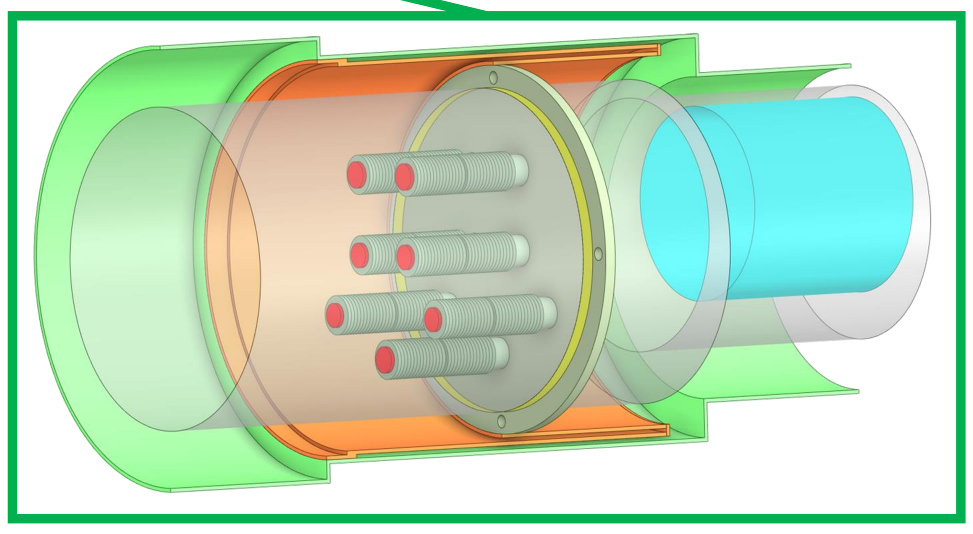
THE GOAL

The vacuum barrier (**VB**), located between the Cryostat Feedthrough and the bus bar mid-joint, is a structure conceived to separate the feeder into two vacuum regions: the main cryostat vacuum and the feeder vacuum for the S Bend Box (**SBB**), Cold Terminal Box (**CTB**) and Cryo Distribution Line (**CDL**). The separation into two vacuum zones, required to provide thermal insulation, allows for an easier maintenance and easier access to feeder components. Several feeder key elements, such as the Bus Bars and the cryogenic He lines, penetrate the VB in order to reach the cryostat. Goal of the VB then is not only to sustain the pressure resulting from vacuum either during normal working or in case of malfunctioning, but also to reduce the heat load to low temperature systems from the ambient. In this work the optimisation procedure adopted for a first VB design is described

To reduce the heat loads to low temperature elements the **VB** was equipped with an u-neck structure, whose geometry was optimised recurring to a Radial Basis Functions (**RBF**) based mesh morphing parameterisation. Shape variations were simultaneously applied to both the structural and thermal simulations, parameterising the complex, coupled nonlinear system in which the structural model is bearing both pressure and temperature loads. The optimal **VB** configuration, fulfilling both structural and thermal targets, was finally achieved by means of response surface optimisation.

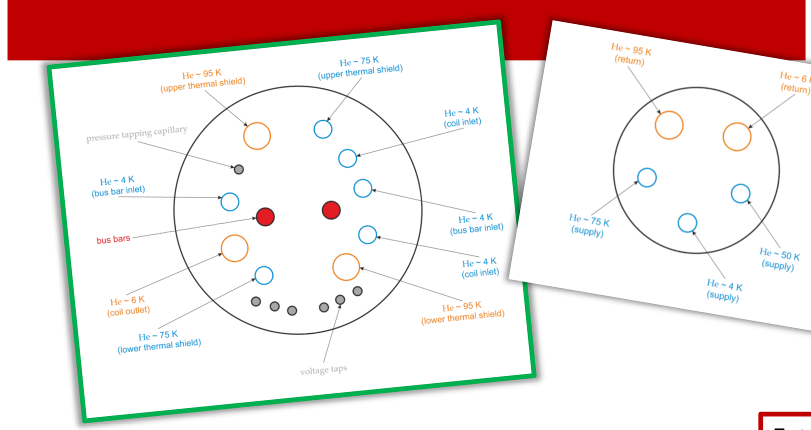




THE GEOMETRY

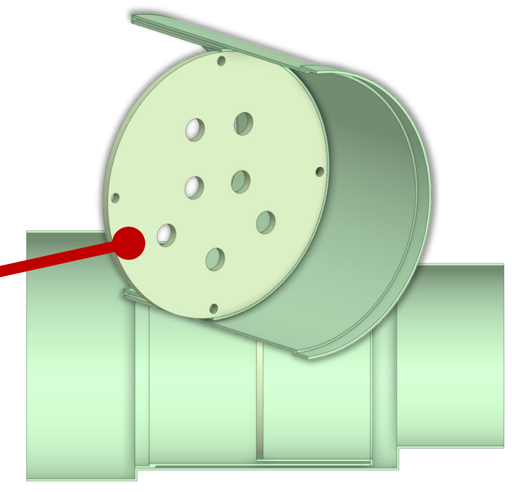
The Process Flow Diagram (**PFD**) of the EU DEMO **TF** magnet feeder allowed to determine the number of penetrations in the main vacuum barrier. 9 Penetrations for the cryogenic lines at the main vacuum barrier:

- 4 for the thermal shield
- 5 for the **He** supply and return lines to the **TF** coil and bus bars.



Vacuum Duct (**VD**), Thermal Shields (**TS**) and **VB** modeled. Bellows based on ITER DDD for **VB**.
Bus-bar axial displacements absorbed by S bends and Thermal interception on **VB**.

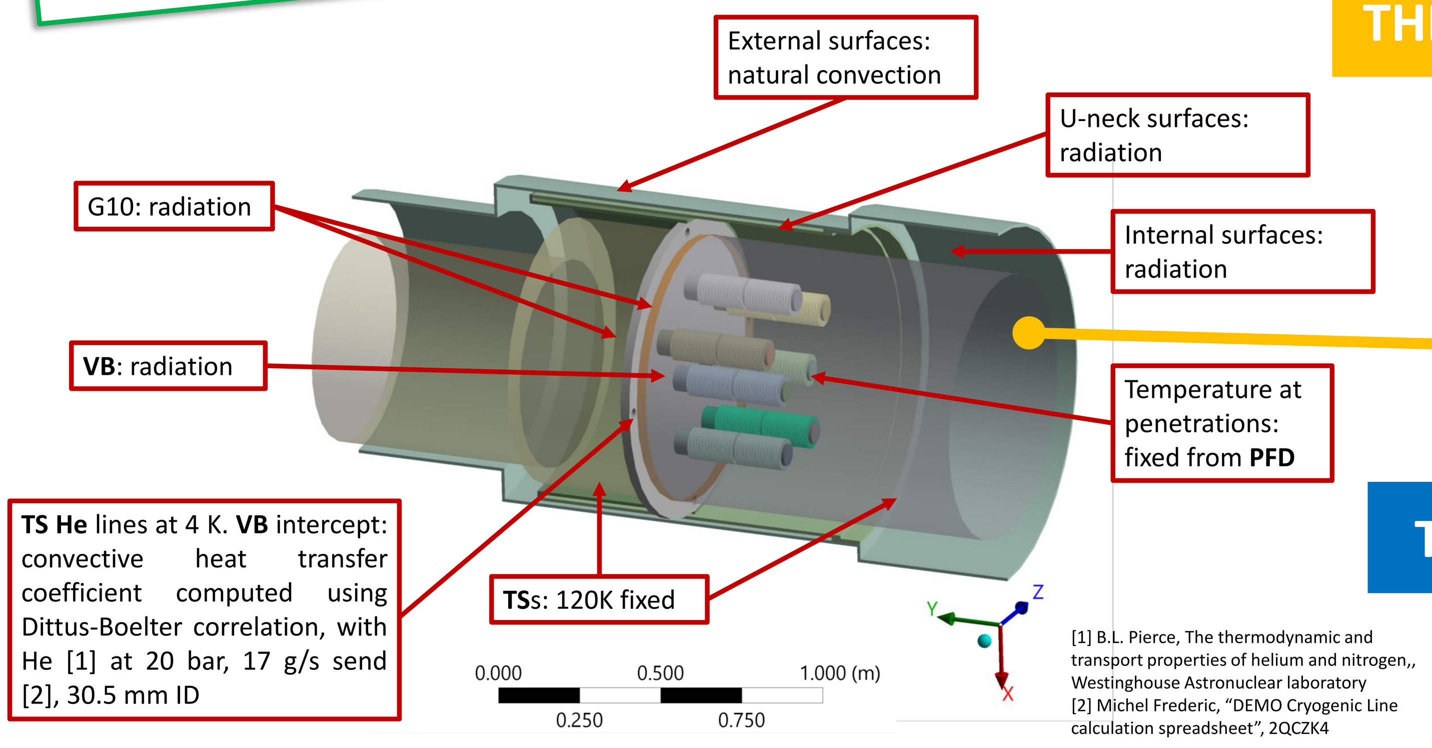
Four **TS** He ducts equally spaced outside the **TS**. Bellow on SBB side for assembly convenience. **TS** connected to **VB** using G10.



THE BOUNDARY CONDITIONS

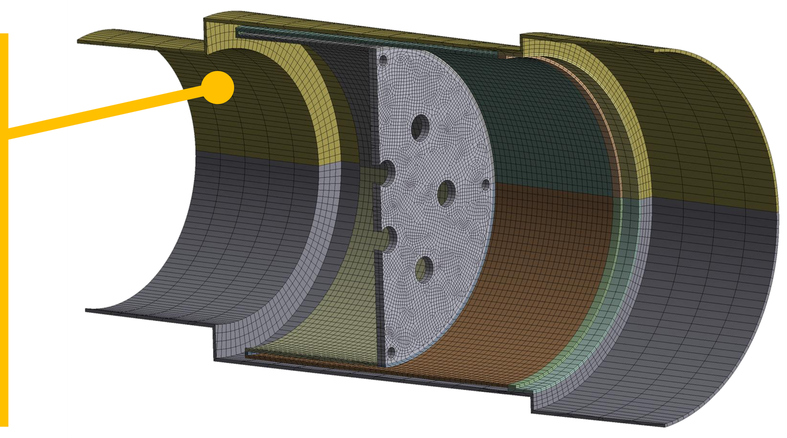
STRUCTURAL SIMULATION

THERMAL SIMULATION



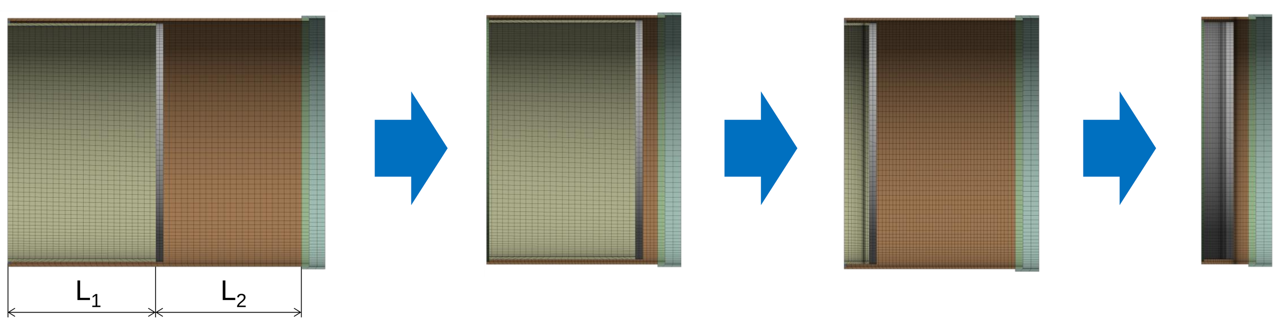
[1] B.L. Pierce, The thermodynamic and transport properties of helium and nitrogen,, Westinghouse Astronuclear laboratory
[2] Michel Frederic, "DEMO Cryogenic Line calculation spreadsheet", 2QCZK4

VD modeled to provide boundary conditions to **VB**. Mesh with two parabolic elements along thickness. E(T) and α(T). Temperature interpolated from previous thermal analysis.

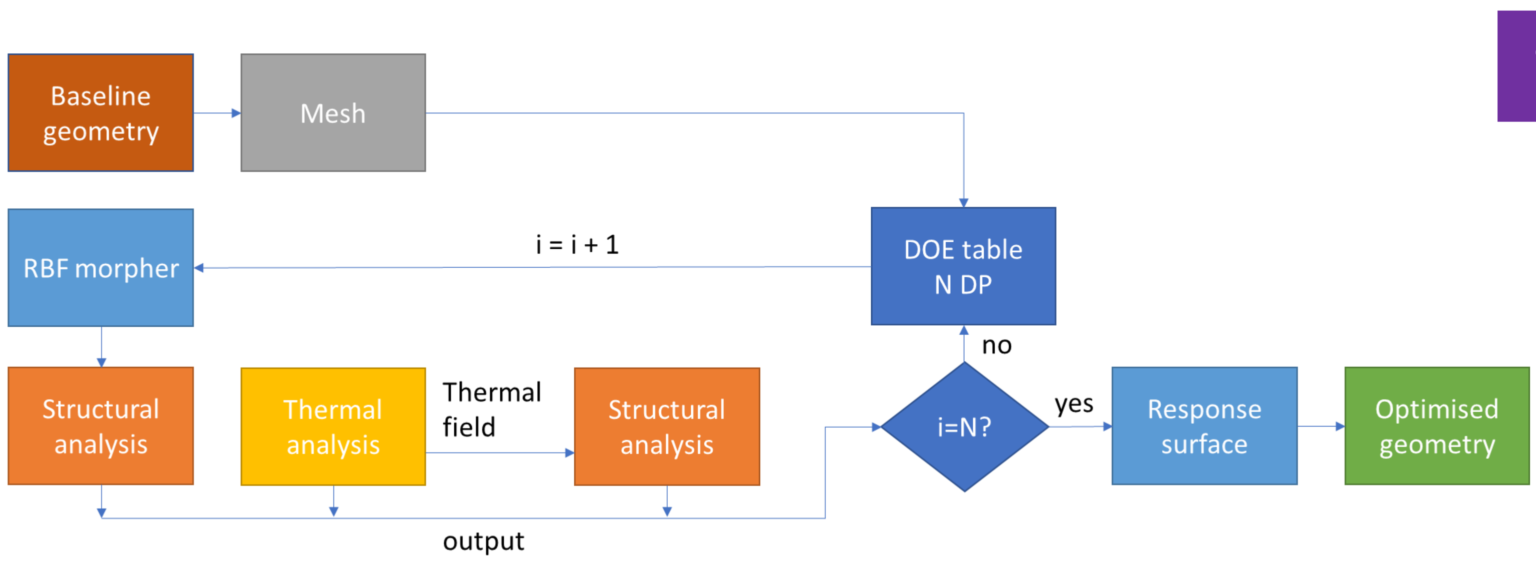


Multistep simulation:
1 - Temperature only
2 - 1.5 bar from CFT side + temperature
3 - 1.5 bar from SBB side + temperature

THE SHAPE PARAMETERS

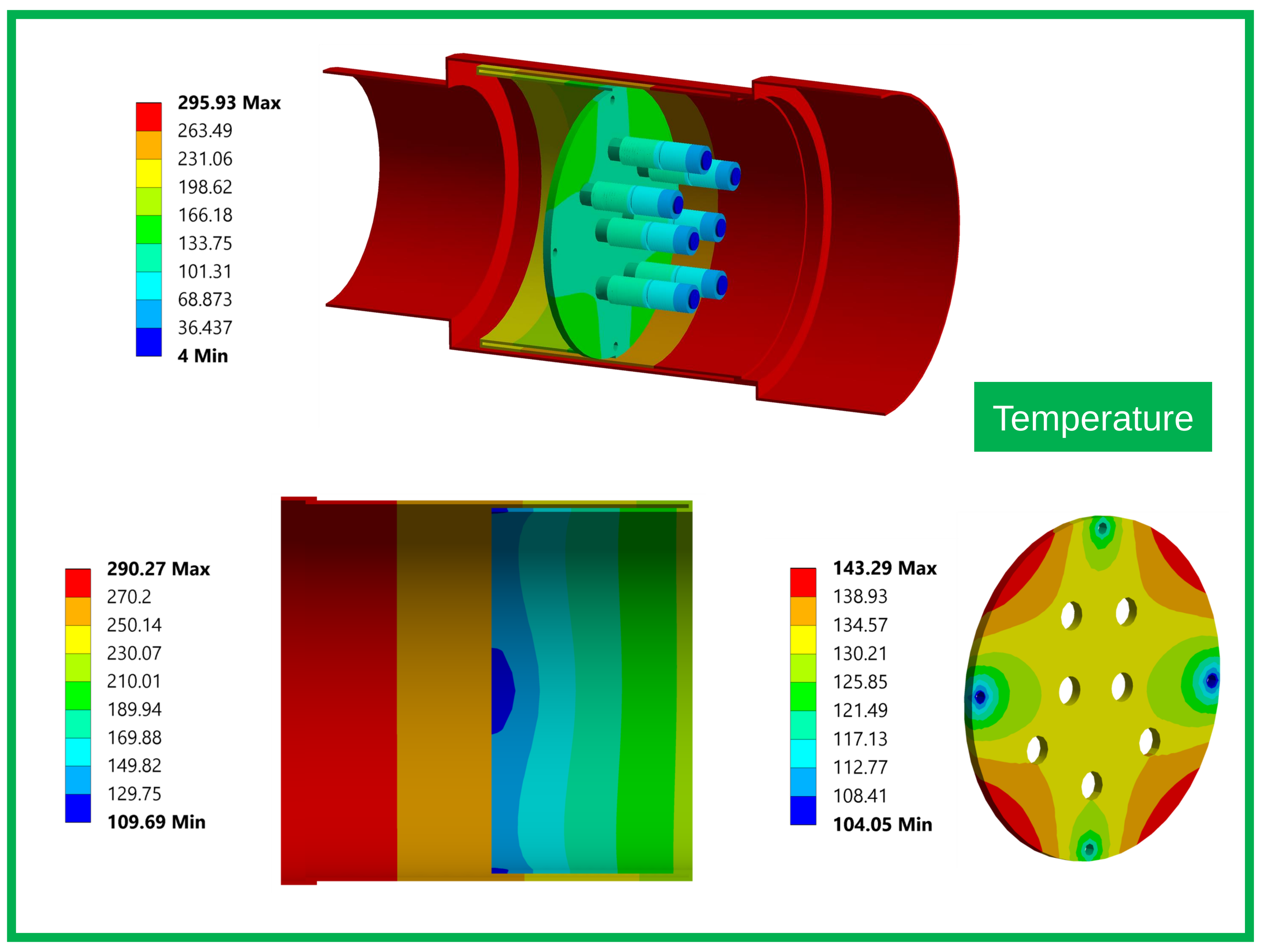


THE WORKFLOW

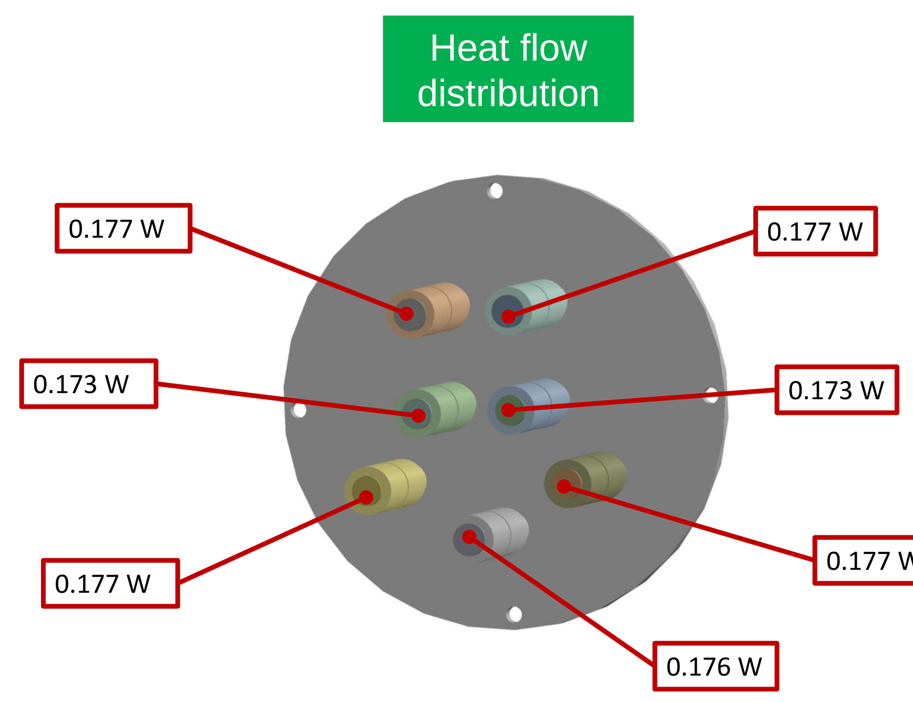


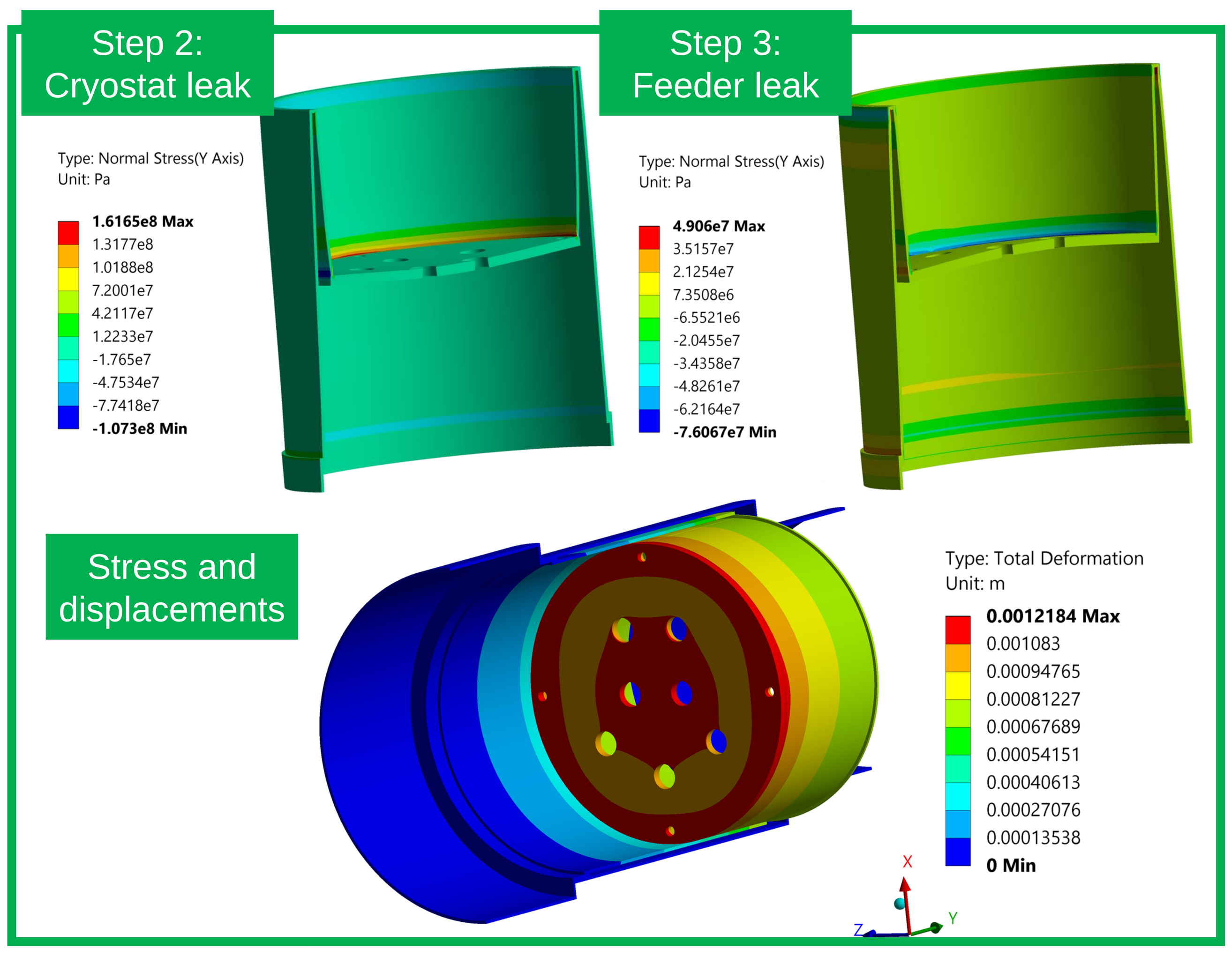
A thermostructural optimization workflow was implemented with 2 parameters changing the length L_1 and L_2 of the u-neck. For each Design Point (**DP**) thermal and static structural simulation were carried, automatically mapping thermal loads. VM stress, normal stress, displacements, heat to He and component volume as output for each **DP** and for each step (thermal only, thermal + pressure **SBB** side, thermal + pressure **ICF** side). 40 **DPs** generated with latin hypercube

THE RESULTS



Optimal Geometry





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