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Design and Manufacturing of the Cryogenic Cooling System for the Rotating Magnetic Validator of the 10 MW SUPRAPOWER Offshore Superconducting Wind Turbine

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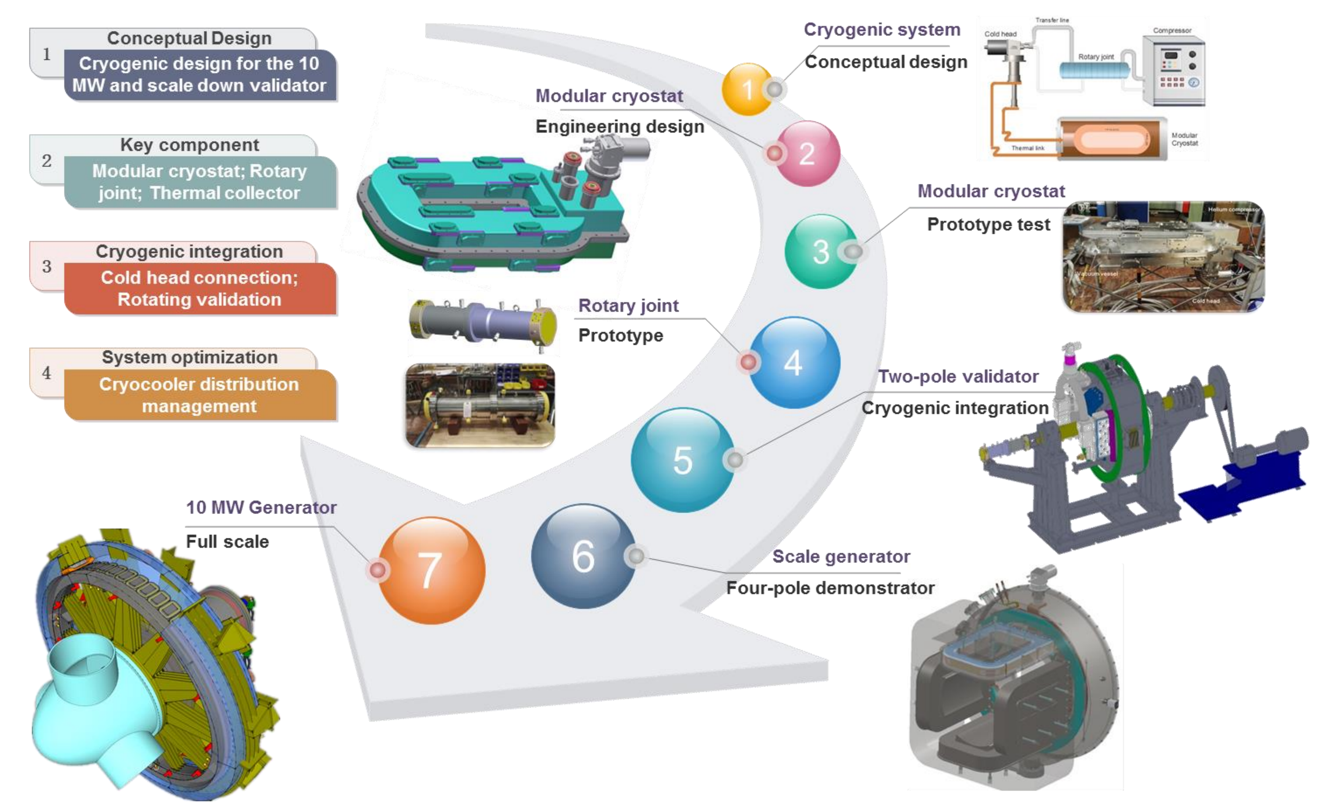
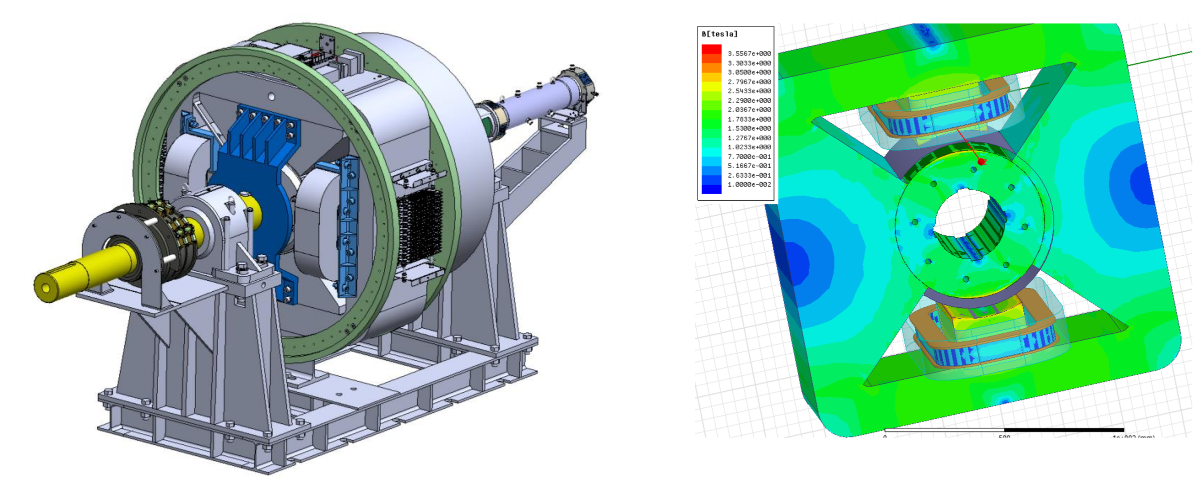
Introduction of the rotating magnetic validator (RMV)

The key technology of the 10 MW SUPRAPOWER superconducting generator (SCG) design will be demonstrated through a RMV



Roadmap of SUPRAPOWER cryogenic development

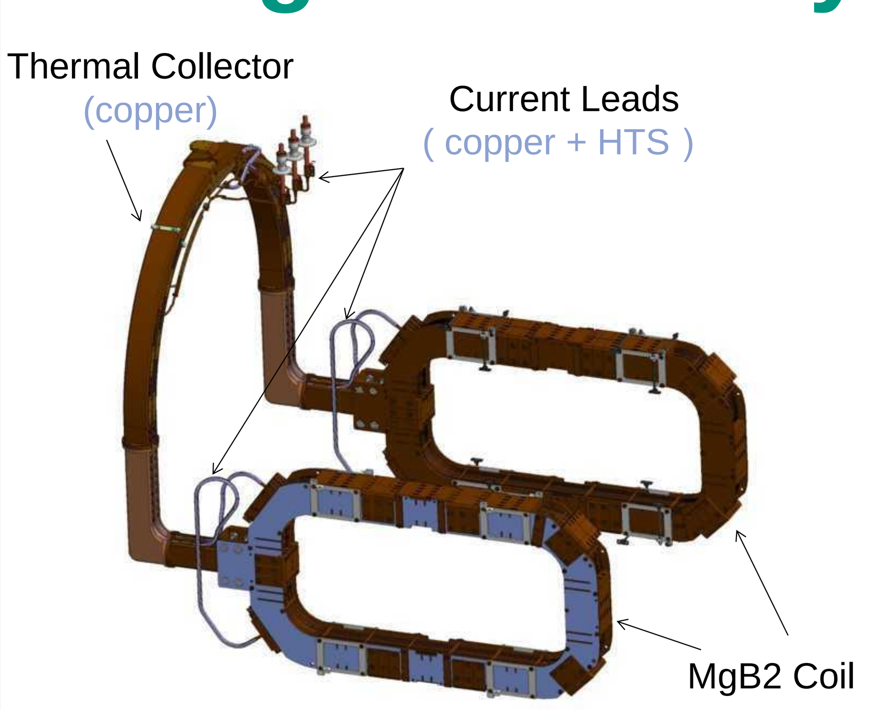
Parameter	10 MW generator	Scale generator	RMV
Power	10 MW	550 kW	-
Speed	8.1 rpm	121.5 rpm	30 rpm
Torque	11.8 MN·m	43.2 kN·m	-
Number of poles	48	4	2
Frequency	3.24 Hz	4.05 Hz	-
Armature location	External	Internal	-
Operating temperature	20 K	20 K	20 K
Armature winding	Copper	Copper	-
Magnetic core length	744 mm	528 mm	528 mm
Armature current density	3 A/mm²	3 A/mm²	-
Induction peak value in airgap	1.5 T	1.5 T	1.5 T
Peak field in the superconductor	1.37 T	1.36 T	1.25 T
Working point in the load line	65 %	65 %	60 %

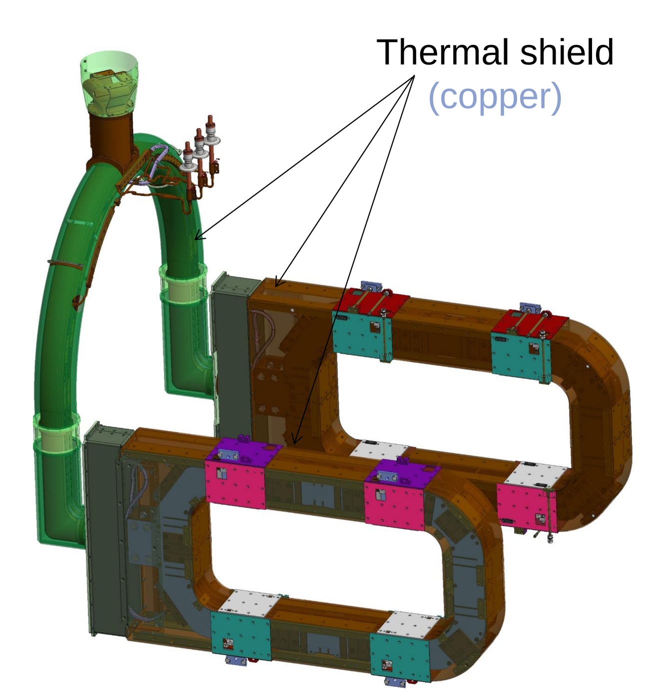


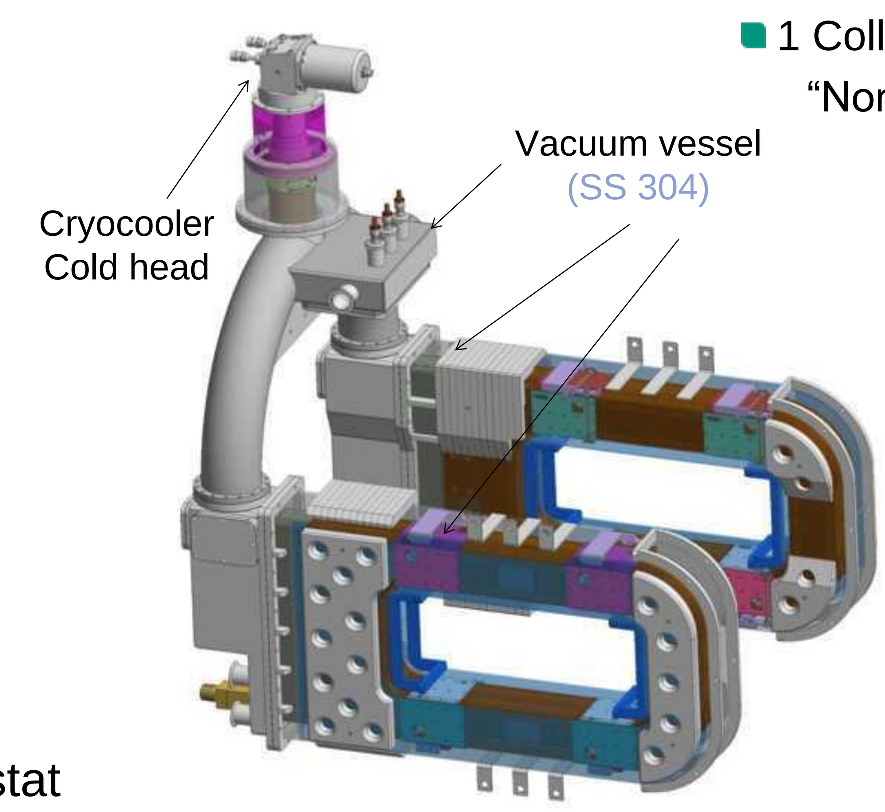
RMV test bench and 3D magnetic analysis

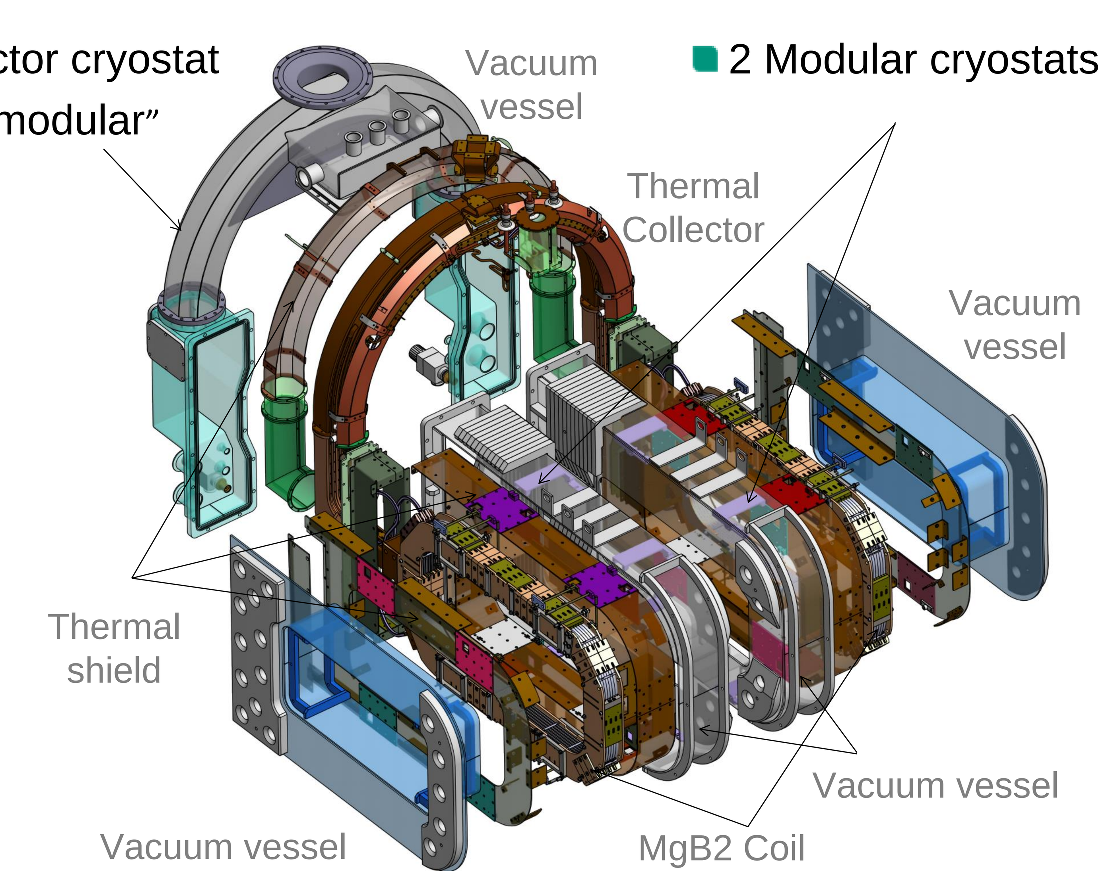
- Consists of only two poles and no armature winding
- Identical air-gap diameter and stack length as the SG
- Same SC coil and modular cryostat as the SG
- Superconducting MgB_2 coil rotates with the rotor

Design of the cryogenic system





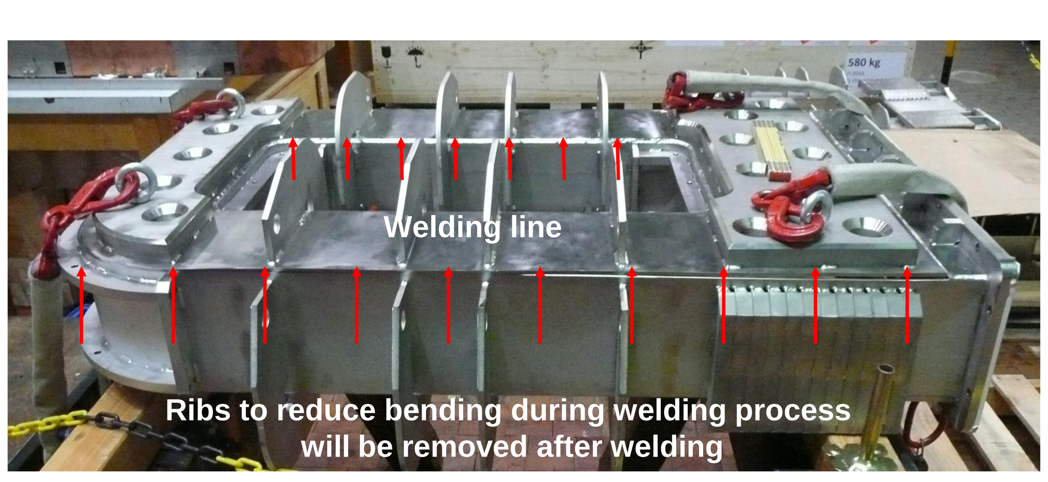




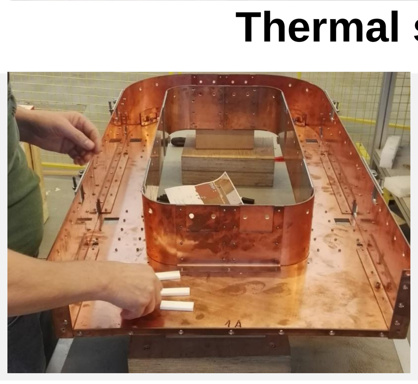
- Cryogenic system includes 2 modular cryostats and 1 non-modular cryostat
- G-M cryocooler with a rotary union provides two-stage cooling through conduction

Modular cryostat

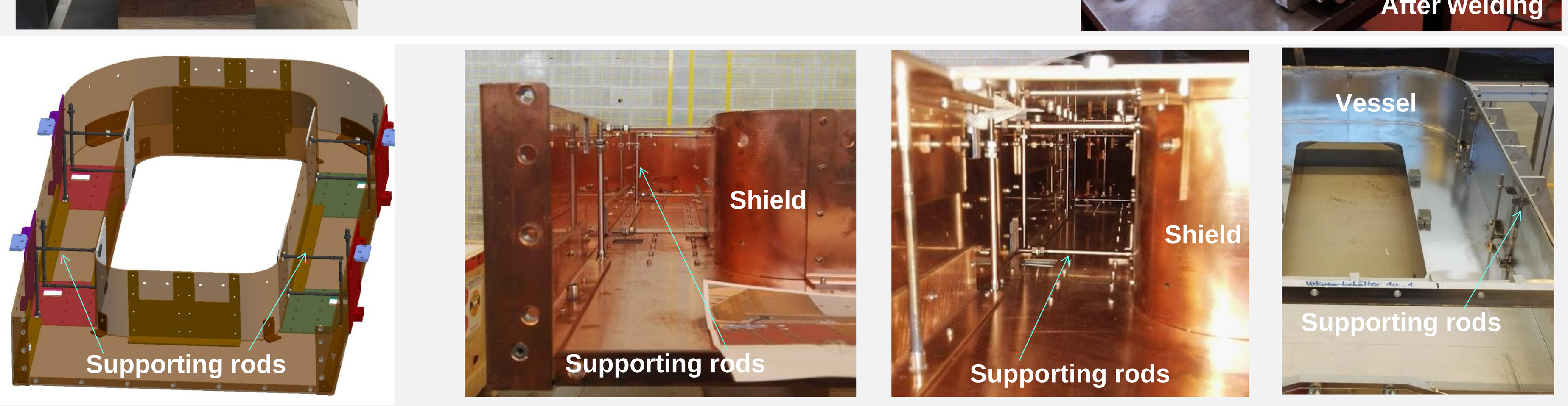
Thermal shield



Vacuum vessel



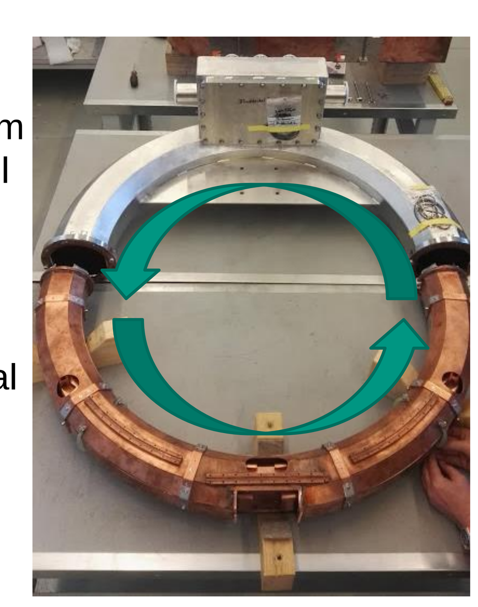
- The vacuum vessel adopts welding approach in order to save space
- Multi-layer insulation (MLI) will be installed on the outer surface of shield

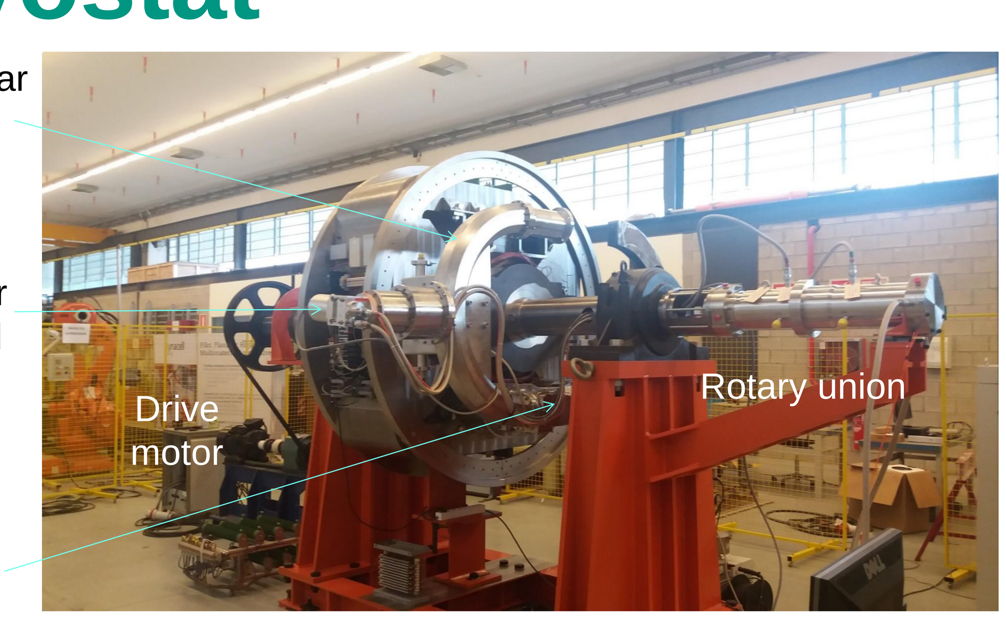


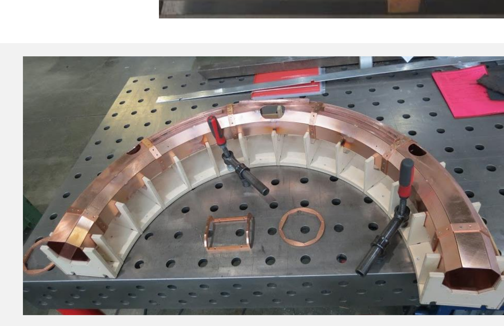
Support structures

- 4 groups of Ti-6Al-4V supporting rods are placed as supporting structure
- Each group include 4 rods per coil support and 4 rods per shield support

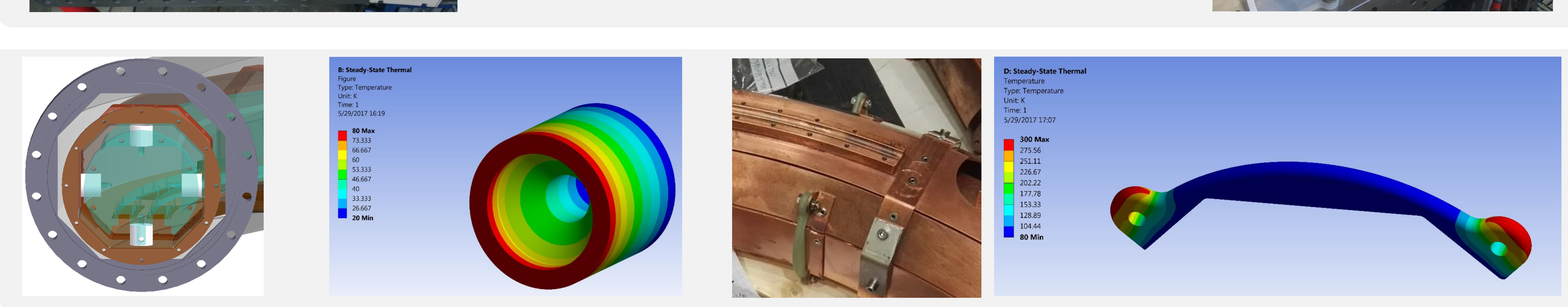
Non-Modular cryostat







- Shield and vessel adopts "tube" design
- Assemble is achieved by circulating shove
- A welding polygon shape is compromised
- Cooler cold head is placed in the middle



- Hollow shape is adapted to reduce conduction between shield & copper bar
- Each Teflon support has a heat load of 0.15 W between 20 K and 80 K
- Point contact is chosen to minimize conduction heat load via shield and vacuum vessel
- Each G10 support has a heat load of 1.59 W between 80 K and 300 K