ThermoFisher SCIENTIFIC

Thermal path optimization between cryocooler and sample

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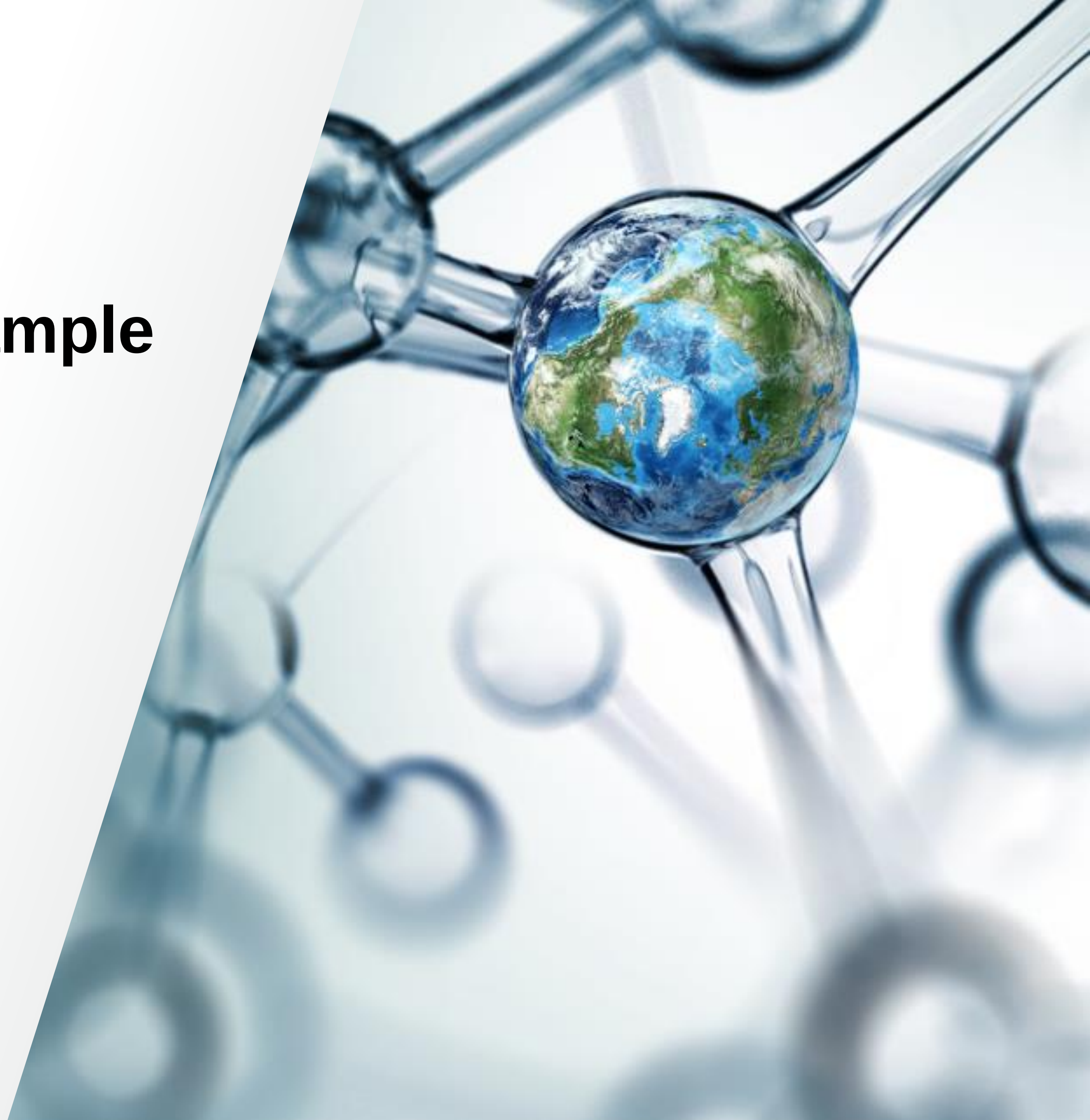

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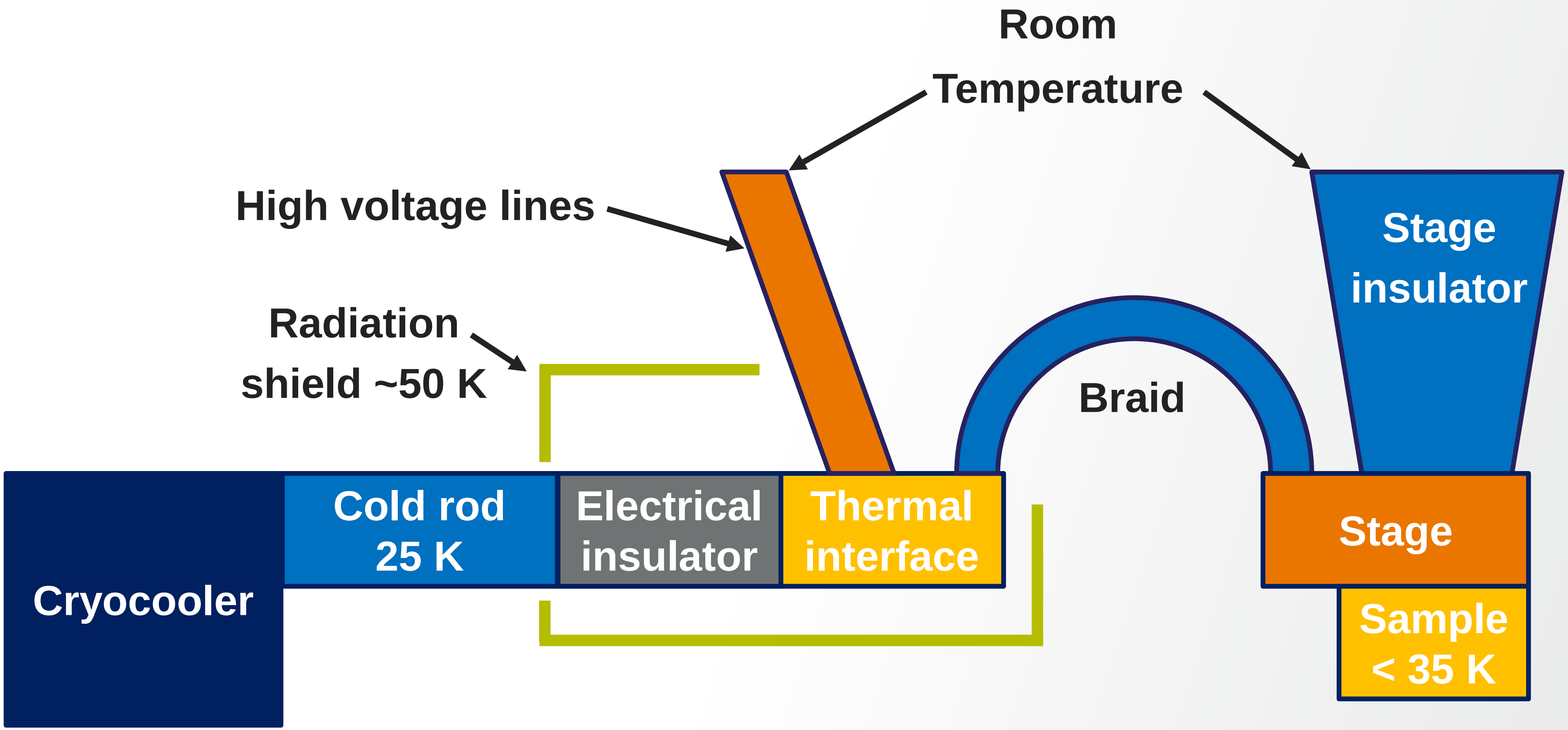
Introduction

- Thermo Fisher Scientific Eindhoven develops and produces Transmission Electron Microscopes (TEM).
- In a new development, TEM and Atom Probe Tomography (APT) will be combined.
- Existing TEM requirements:
  - Tight volume (in the heart of the TEM)
  - Only non-magnetic materials allowed
- For APT, some new system requirements are added:
  - Sample temperature < 35 Kelvin
  - Ultra-High Vacuum around the sample ($1E^{-10}$ mbar)
  - The sample needs to be at high voltage (12 kV)
- A thermal connection between cooler and sample needed to be realized.

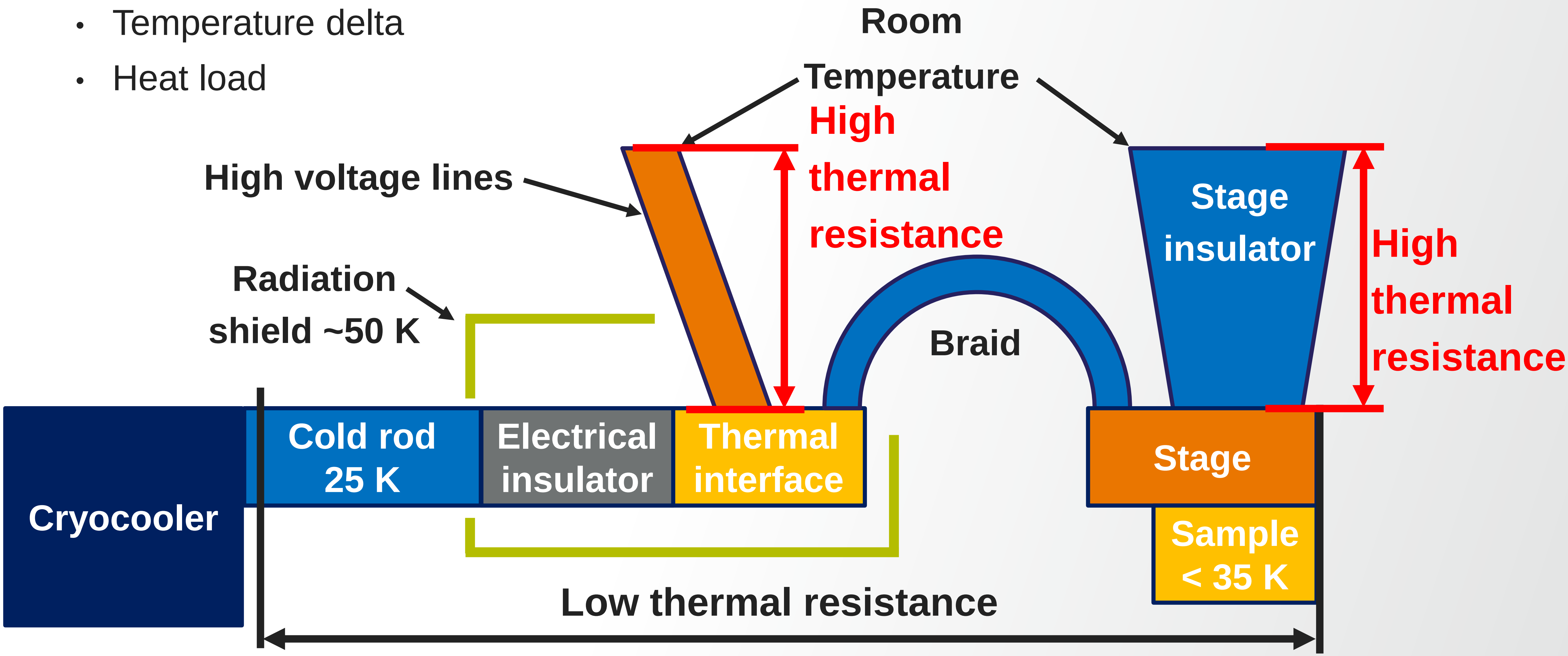
Design and main components

- The main components of the design:



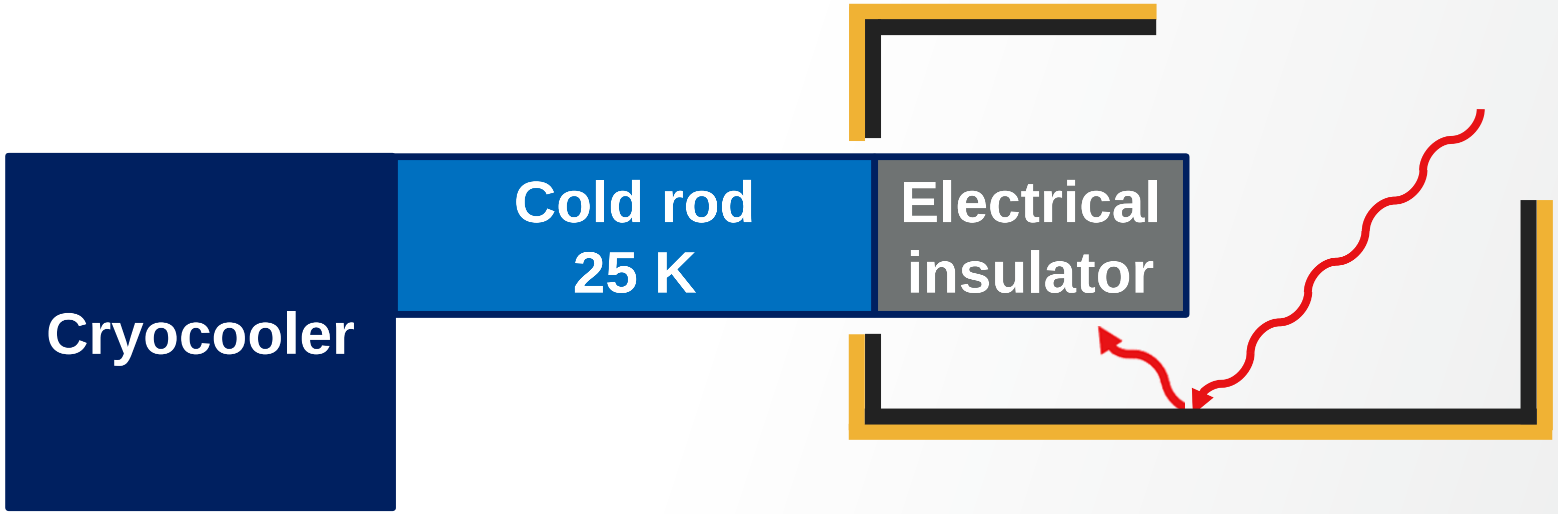
Design and main components

- Thermal requirements:
  - Temperature delta
  - Heat load



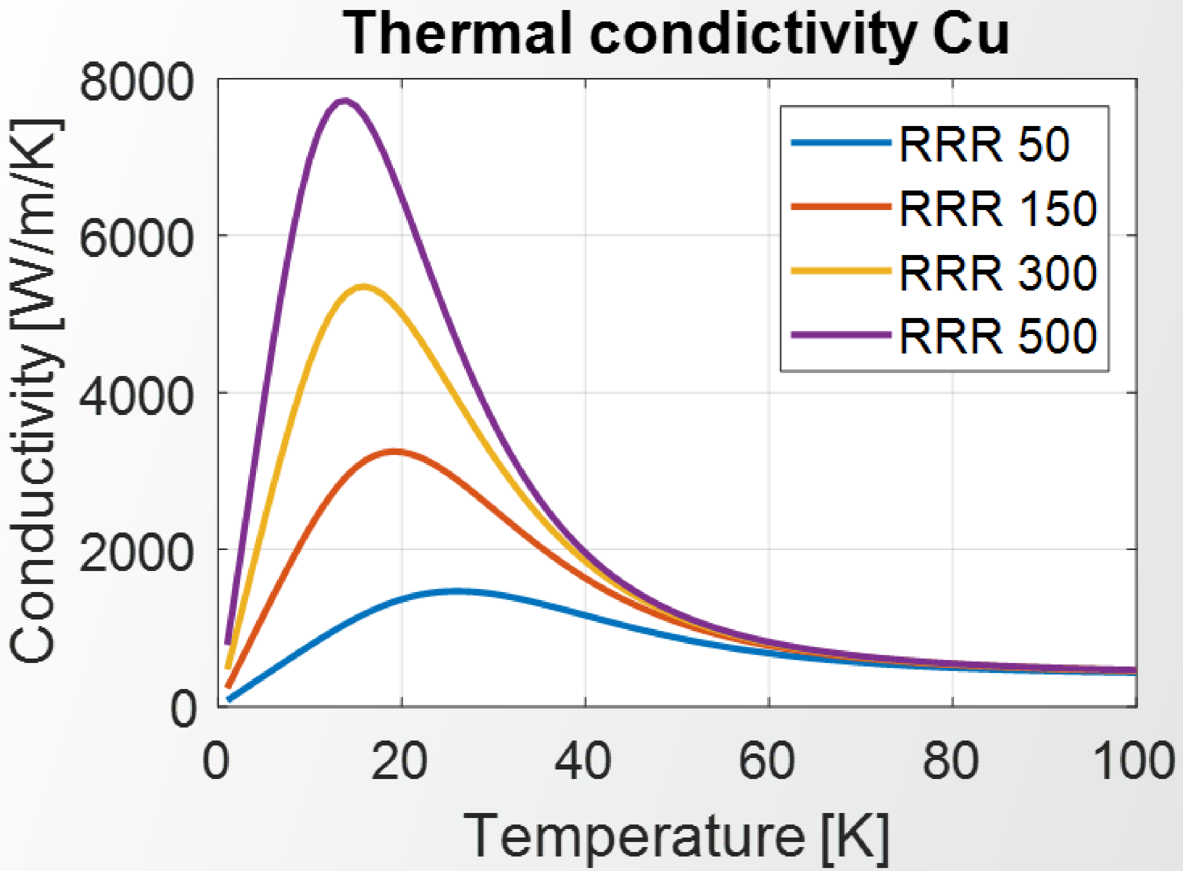
Design – Emissivity & Coatings

- Heat load needs to be minimized.
- Low emissivity (gold) coating.
- Shield with high emissivity coating.



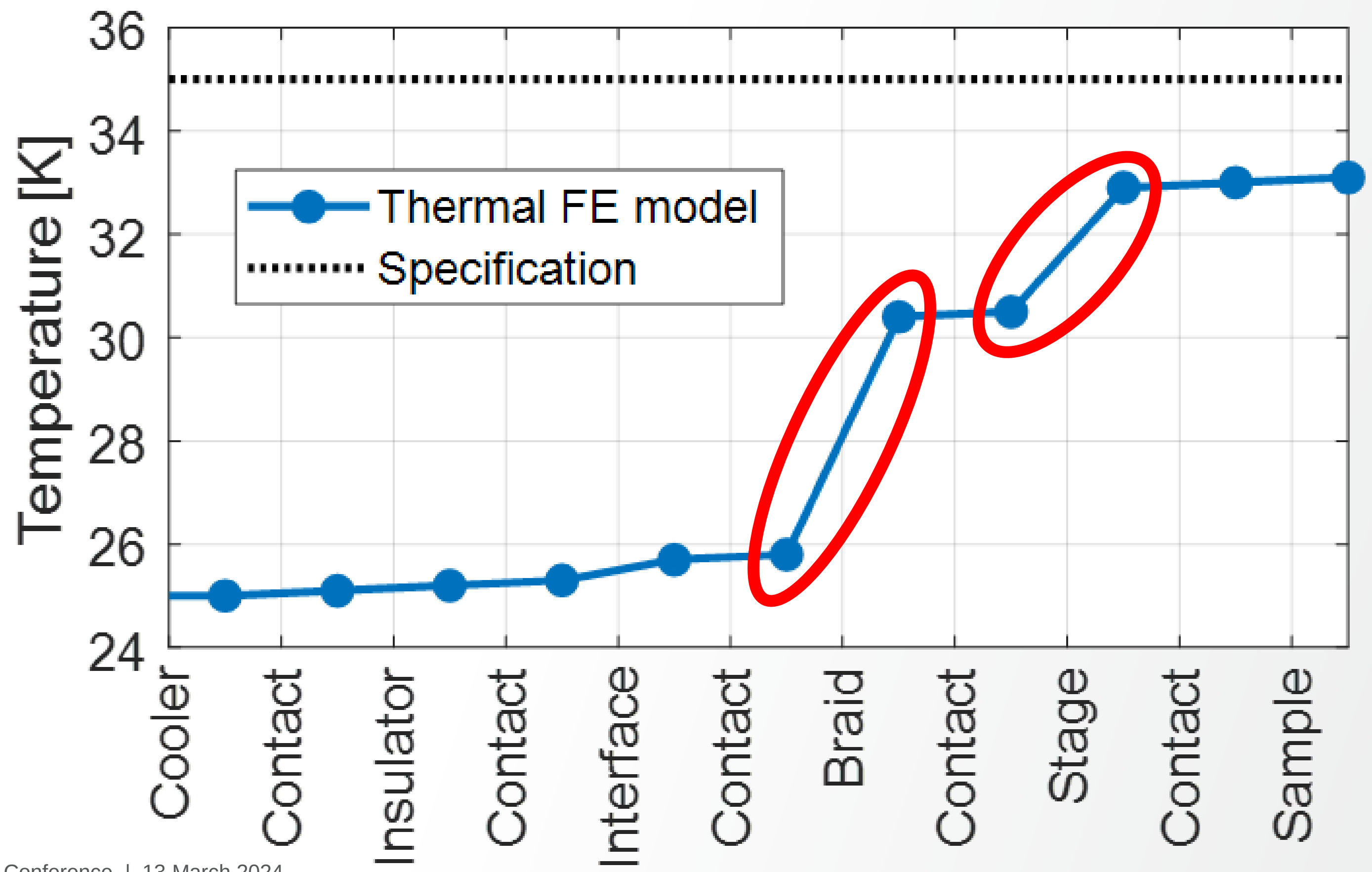
Modelling – Non-linearities

- FE modelling has been used to optimize the design.
- At cryogenic temperatures:
  - Limited data sources
  - Material properties highly non-linear
- Residual-resistance ratio of copper
  - Purity
  - Crystallographic defects
  - Heat treatment
  - Cold deformation
  - Dimensions



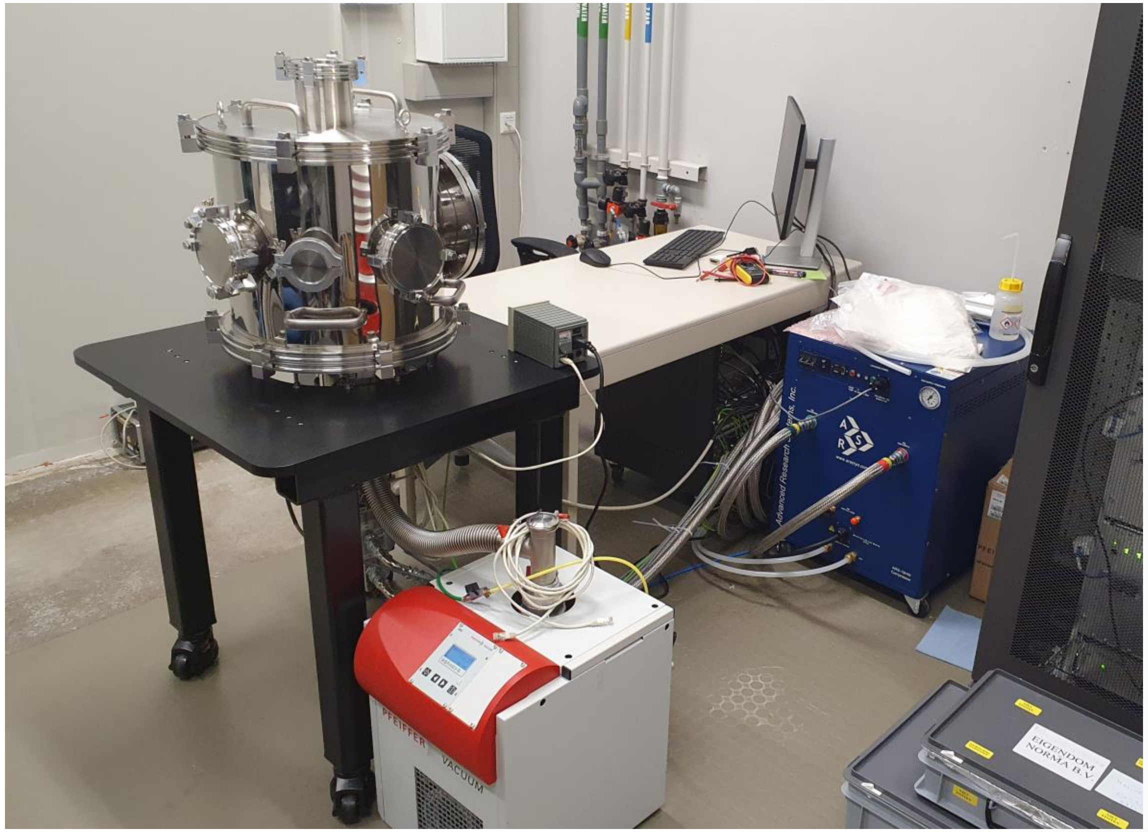
Modelling – Results

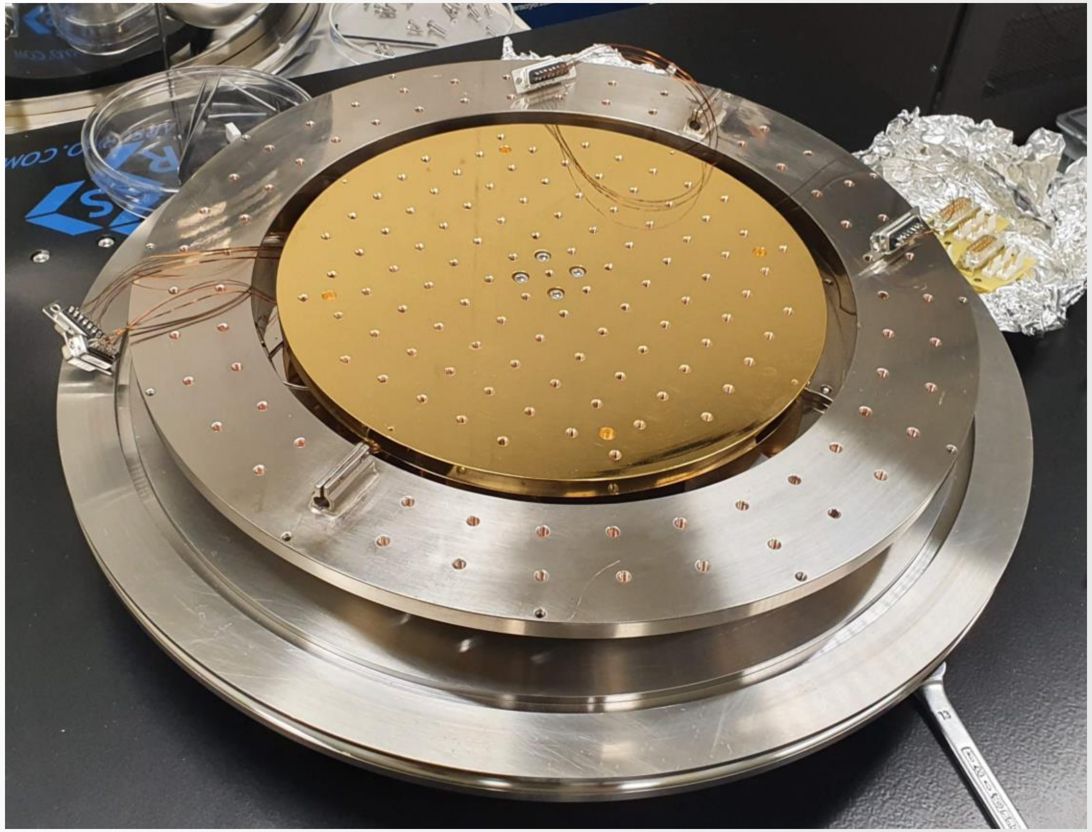
- After several design iterations, a design within specification has been obtained.
- The main temperature gradients are over the braid and stage bulk material.



Measurements - Cryostat

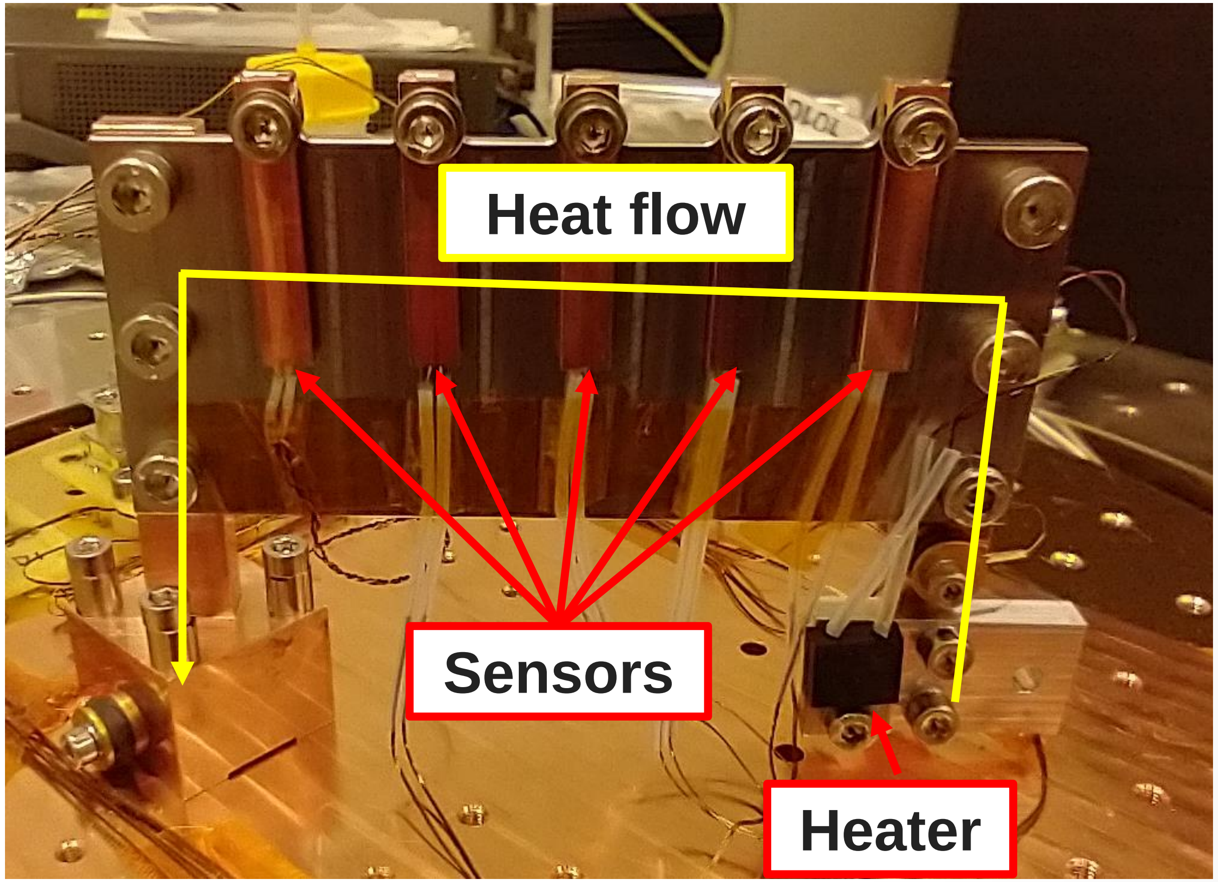
- To verify the model and design, tests have been performed.
- A cryostat has been used to perform cryogenic tests.

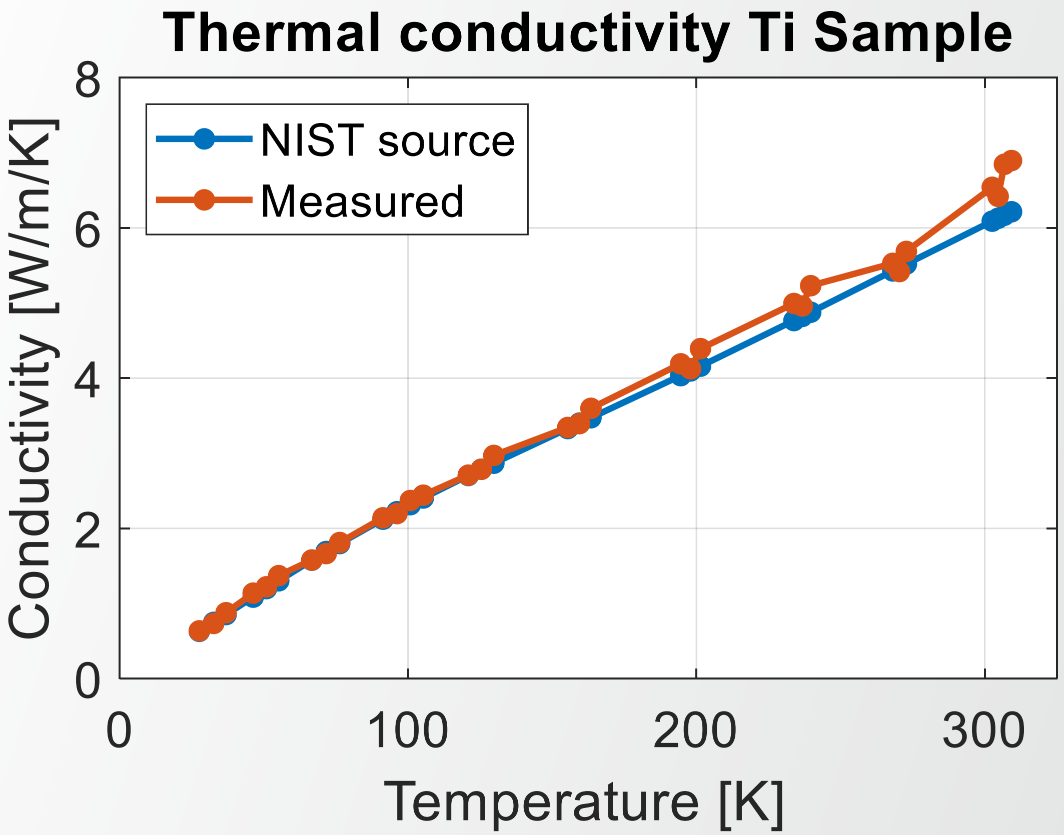




Measurements – Thermal conductivity

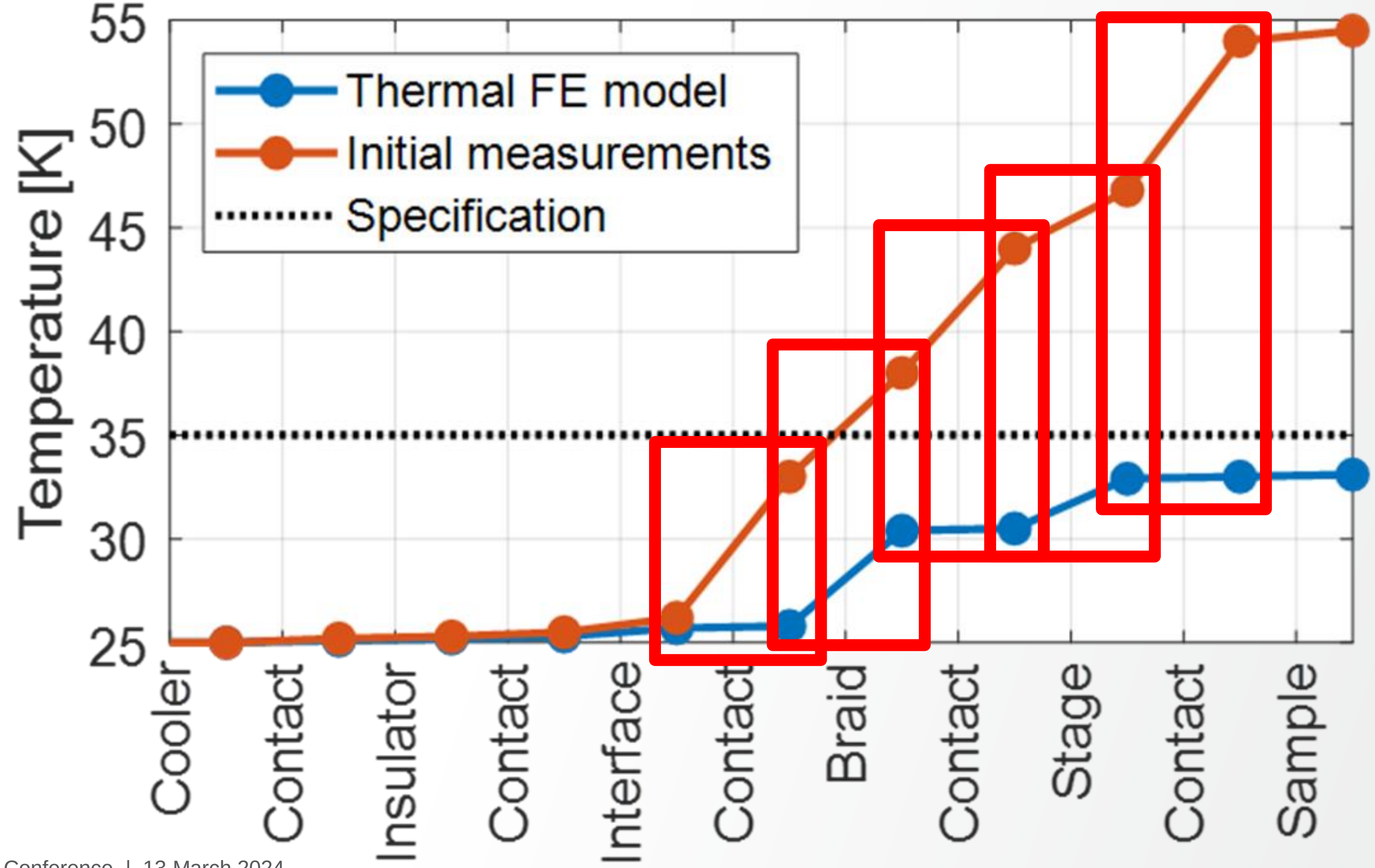
- For multiple material, the thermal conductivity has been measured.
- Below, a low thermal conductivity titanium alloy test setup is shown.





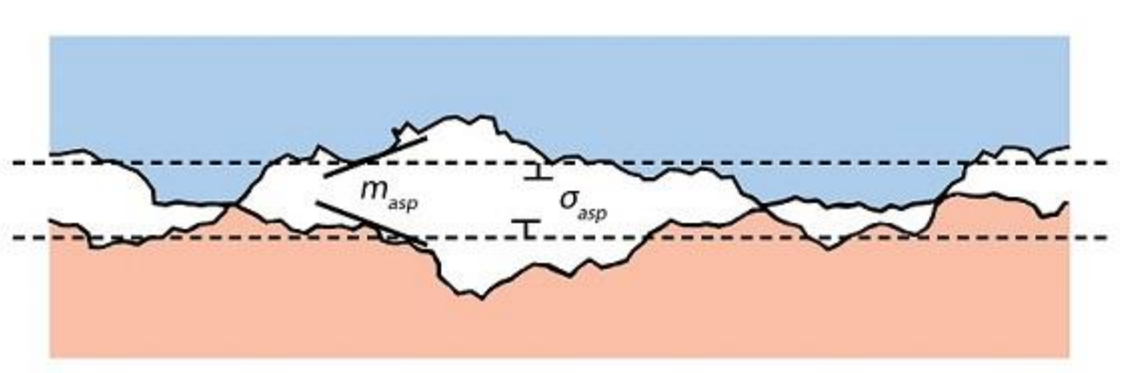
Measurement – Results

- All components have been tested.
- Temperature gradients due to material conductivity are as expected.
- Temperature gradients over contacts are much higher.



Thermal contact resistance

- Equations of Mikic* have been used.
- Some resistances where a factor ~ 10.000 off.
- At cryogenic temperature, no realiable equations.
- Many measurements have been performed.
- Improvement options are available:
  - Increase contact force
  - Applying an intermediate layer or coating
  - Optimizing surface roughness & flatness
  - Soldering
  - Welding

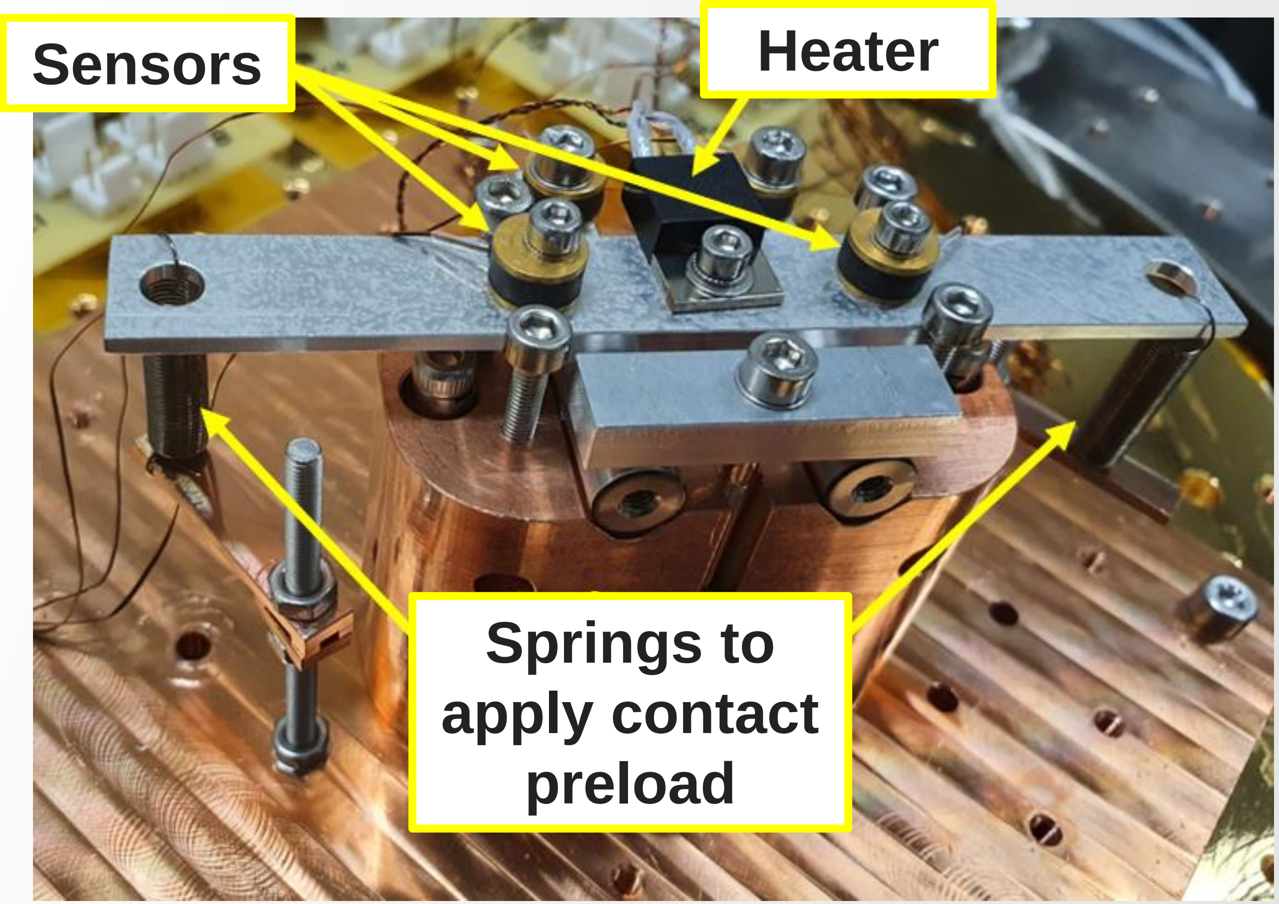


Source: Comsol

*B.B. Mikic, Thermal contact conductance; theoretical considerations, 1974, International Journal of Heat and Mass Transfer. 17.2: 205-217

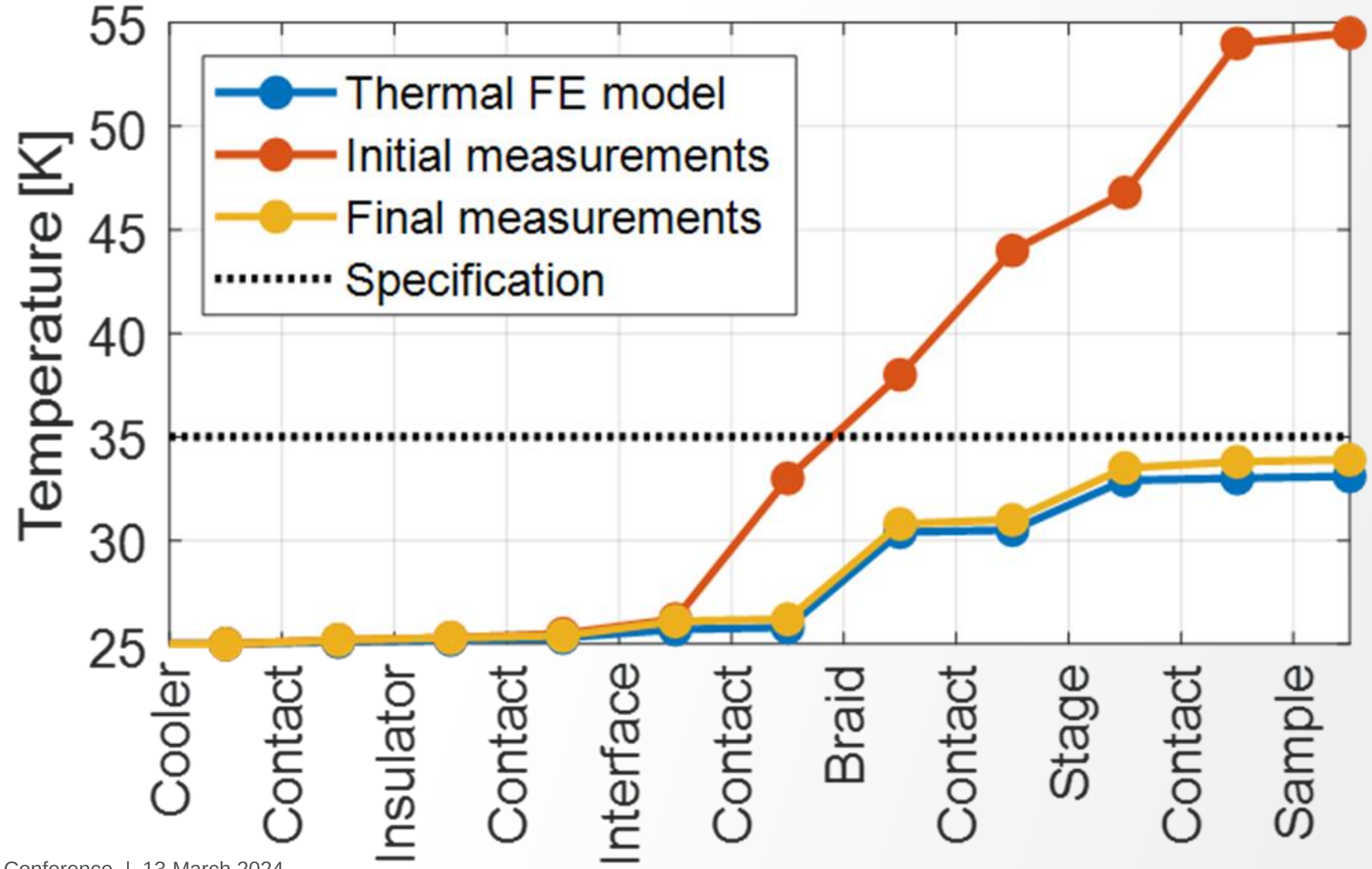
Thermal contact resistance

- Multiple test setups for thermal contact resistance.
- Test performed with:
  - Contact force variations
  - (Thick) gold coating
  - Tin and indium interface layers
  - Soldering / welding



Final results

- After all improvements of the contacts have been applied, the following results have been obtained.
  - Soldering and indium gave the main improvements



Summary and conclusions

- Many thermal challenges
  - Material properties
  - Thermal contact resistance
  - Testing is of major importance
- System within the specification!

End

Thank you for listening!