Solution for cooling of portcards for CMS Tracker Phase 2

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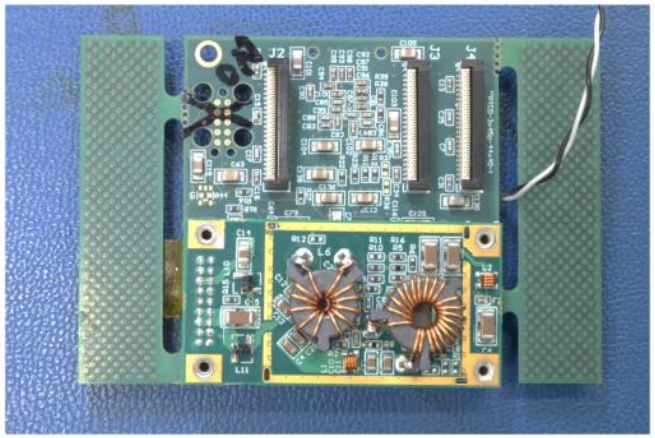
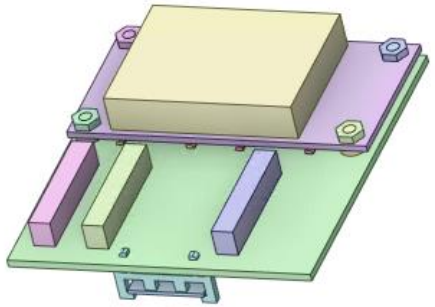
Outline

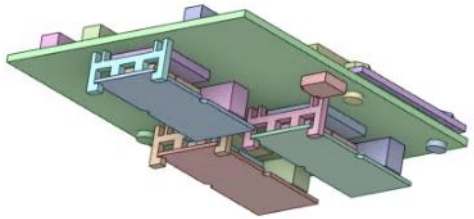
- Introduction
- Validation process
- Active cooling solution
  - Concept
  - Prototyping
- Thermal test
- Conclusions

Introduction

Portcard



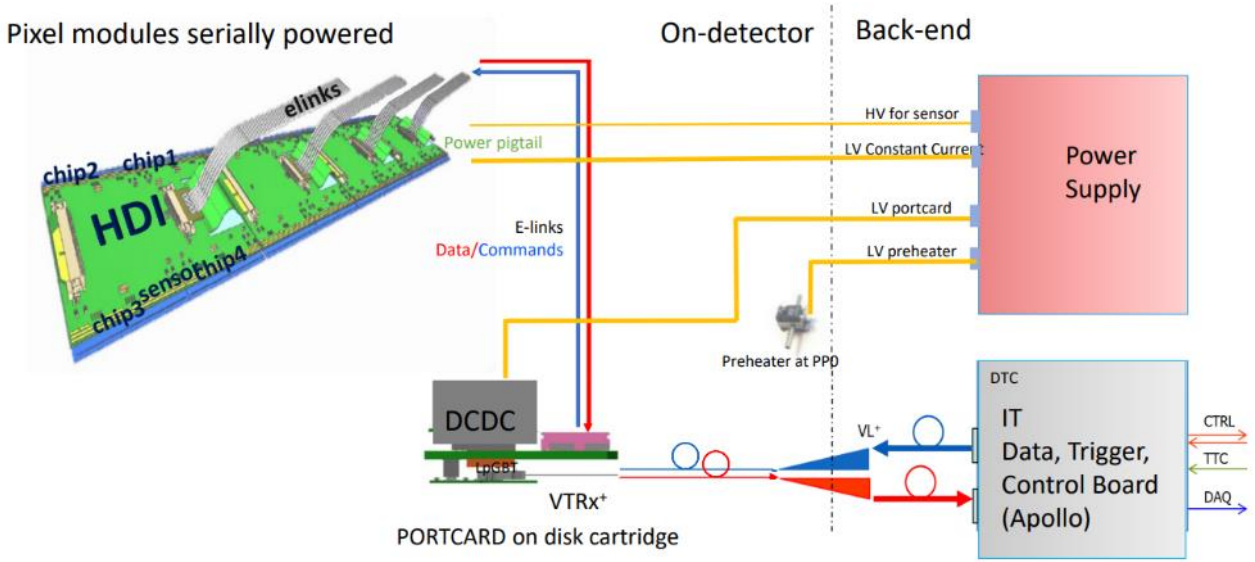




Nominally 2.4 Watt power dissipation

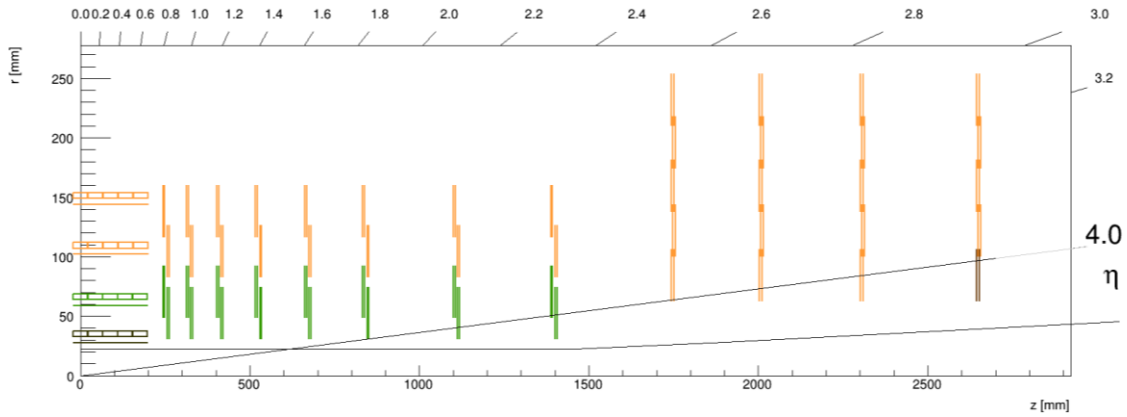
Electrical-optical interface for Inner Tracker

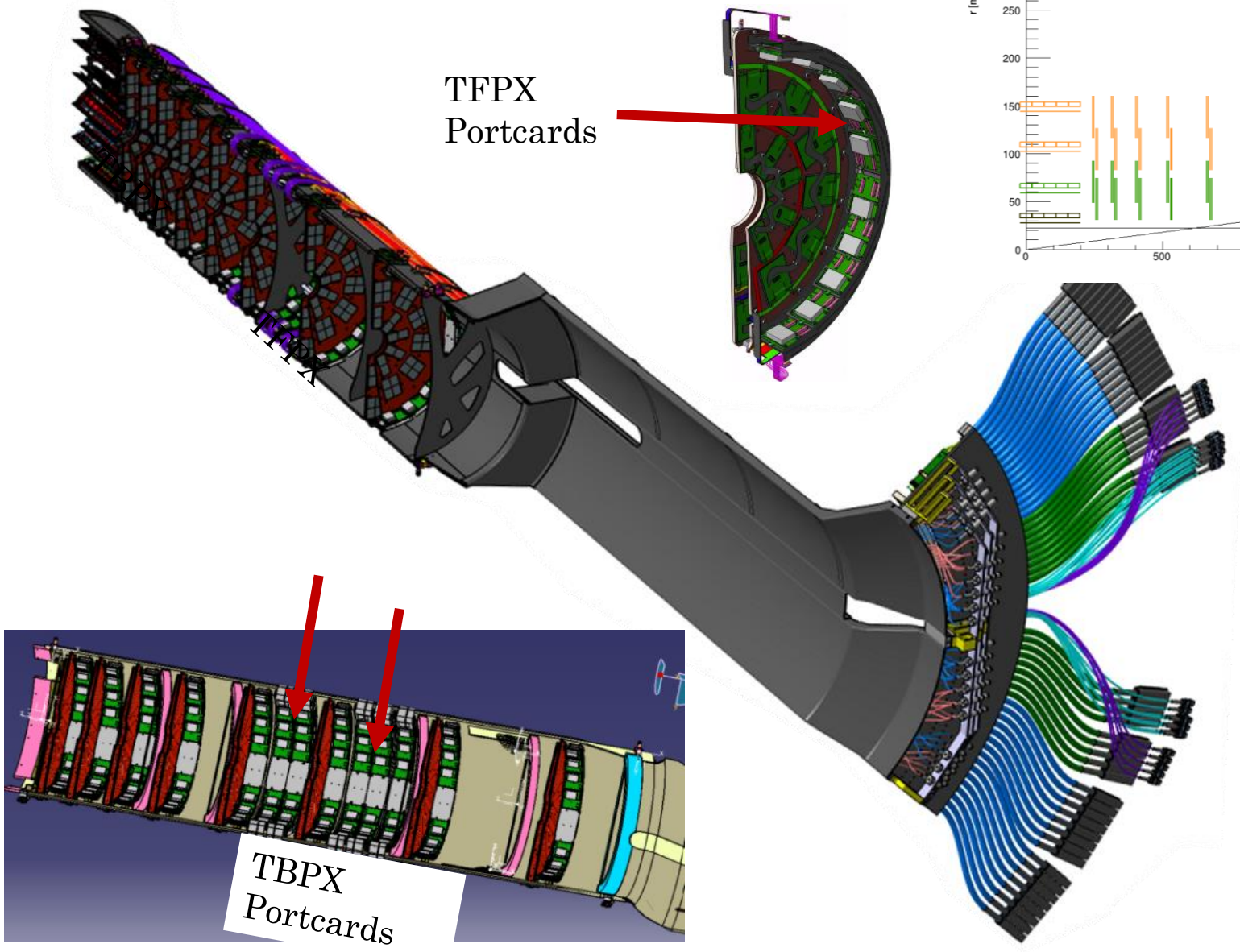
- 40 mm x 44 mm 8-layer PCB
- 3 e-link 45 pin FPC connectors (J2-4)
- DC-DC Mezzanine
  - Toroid inductors installed over bPol12V, bPol2V5 ASICs
- 3 lpGBT
- 3 VTRx+ (Z1-3) (not installed in the picture)
- Test connector footprint (J5)
- Power input DF57 (black/white pair)



Introduction

Location





- TFPX portcards are attached to the disc
- TBPX portcards are far from the barrel. They are located between disks 5 and 7

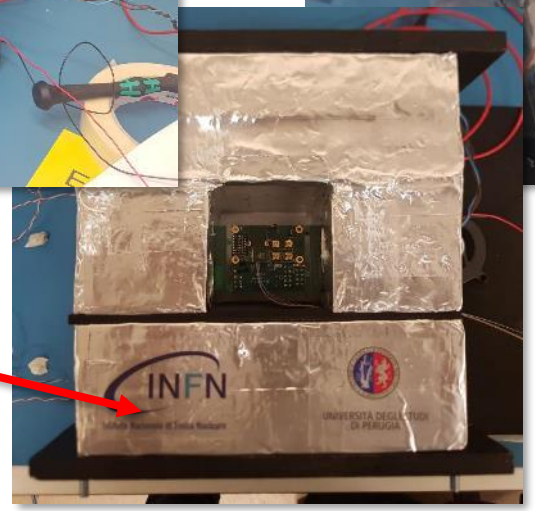
- This talk is focused on the cooling solution for TBPX portcards

Validation Process

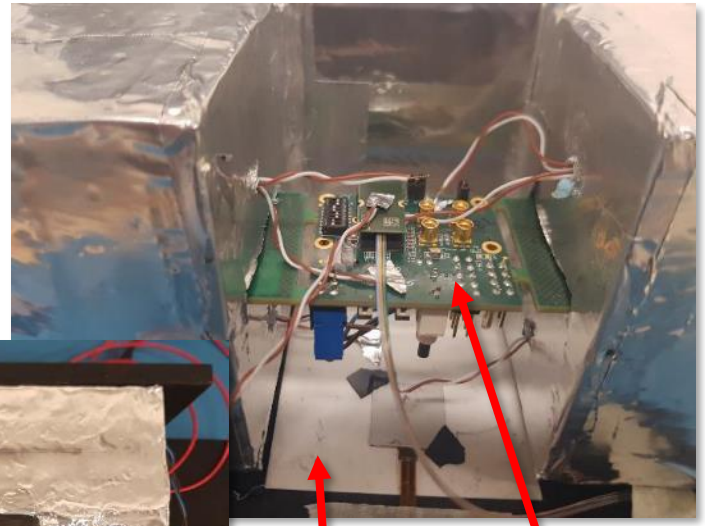
Thermal Test Setup

A DEMO portcard has been thermally analysed to validate the thermal simulations.

The DEMO portcard was inserted in an enclosure to test its thermal behavior in a confined environment.



Removable wall



Demo Portcard

Peltier cell

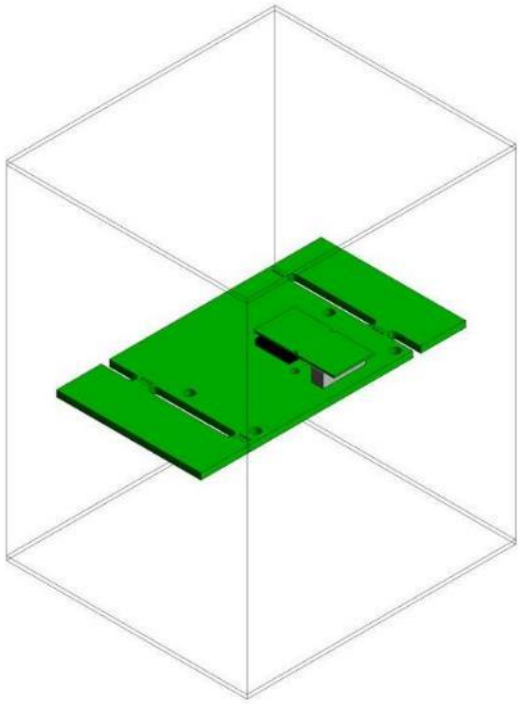
It can be positioned on the top or on the bottom of the enclosure

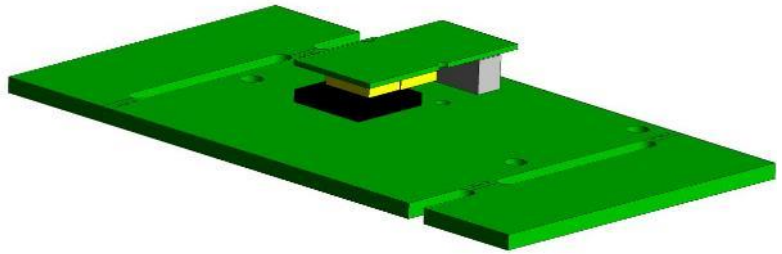
IR window

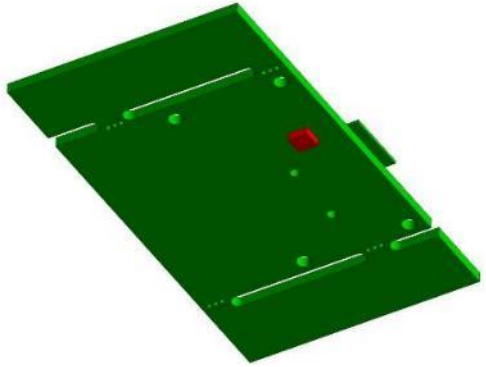
Thermographic survey

Validation Process

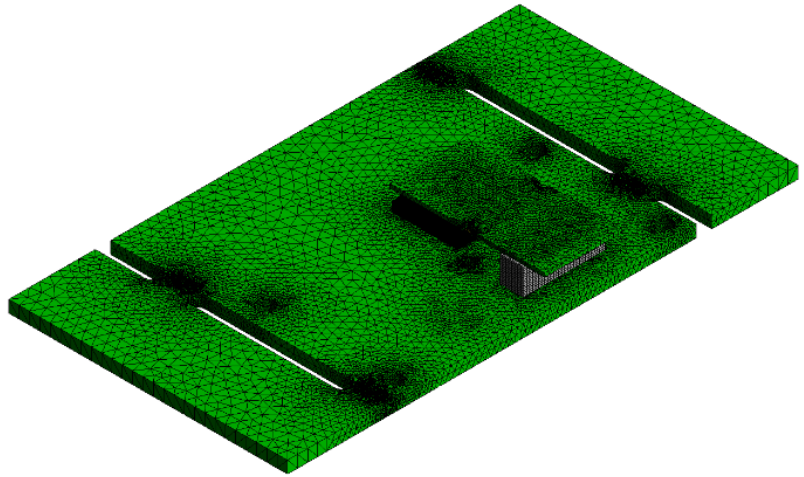
Thermal Simulation





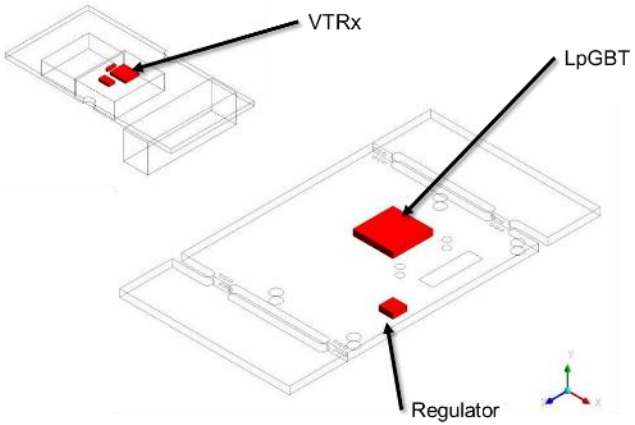


Mesh and heat transfer models



Heat Generation

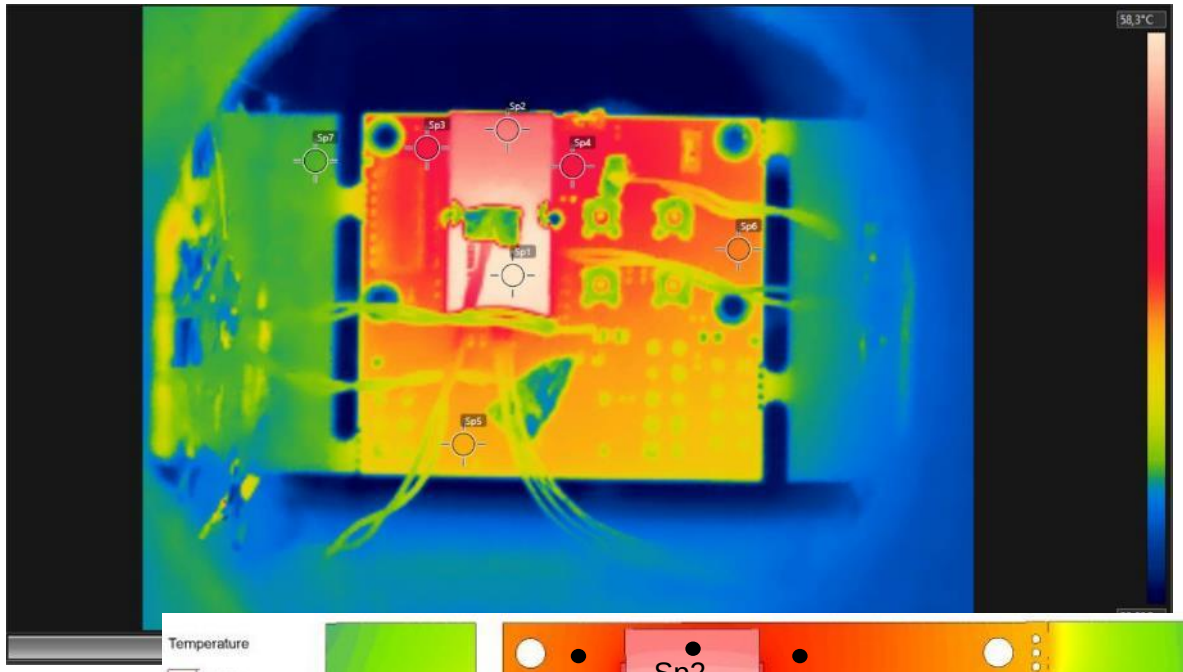
	V - mA	mW
LpGBT	1.2 – 147	176
VTRx	2.5 – 124	310
MAX 8528	1.3 – 147	191
Total	**2.5 – 271**	**677**

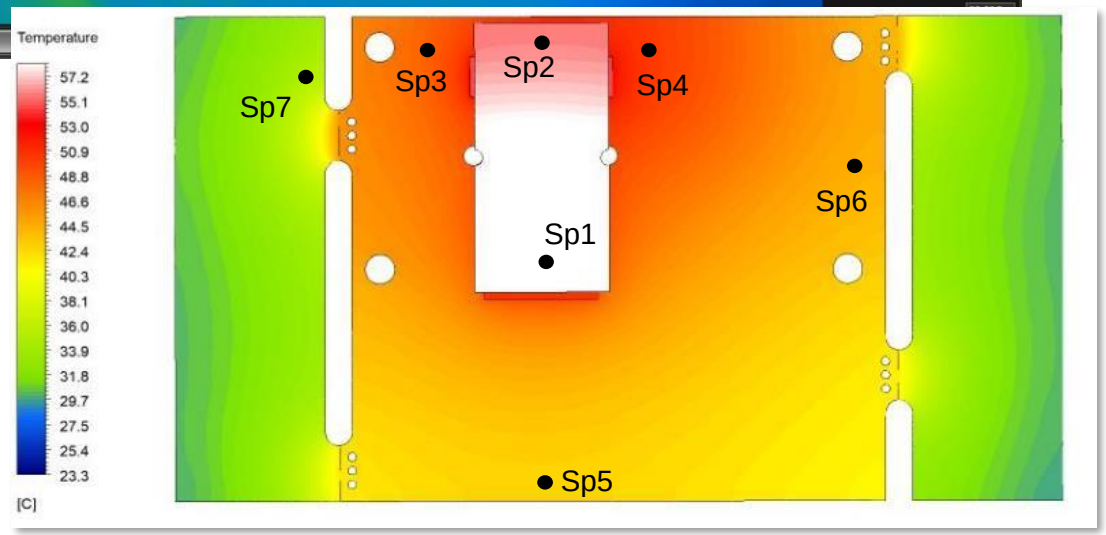


- More than 2 millions of cells.
- Laminar model
- Boussinesq approximation of the density dependence with the temperature of the air.
- Radiation model for the radiative power exchange between the surfaces.

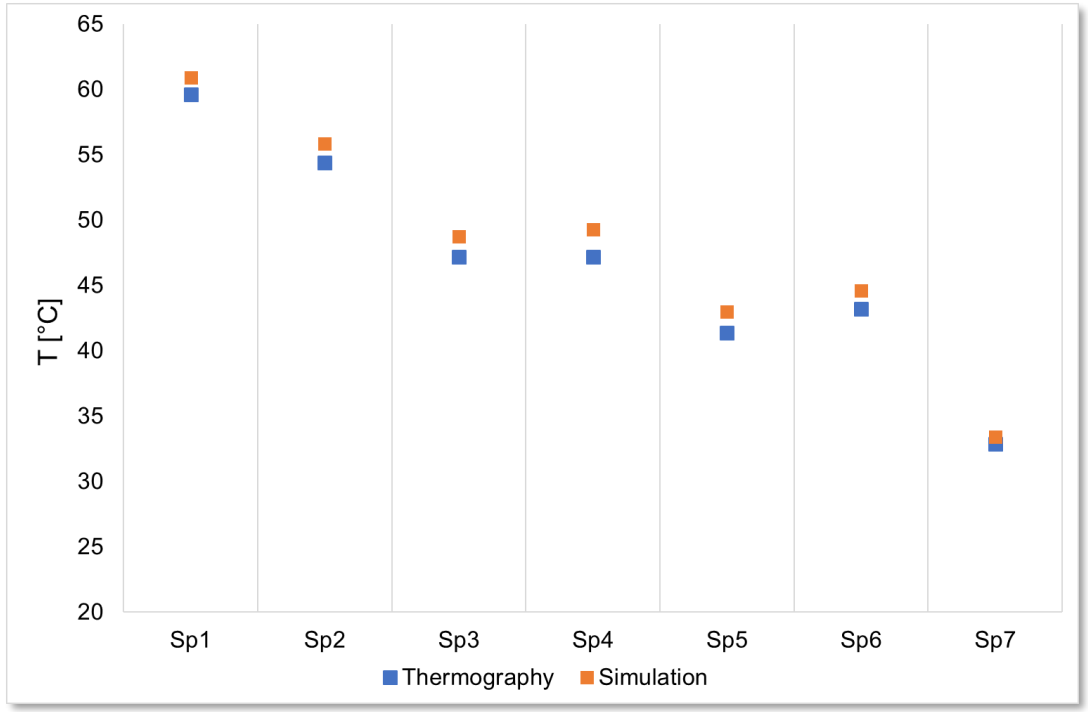
Validation Process

Results



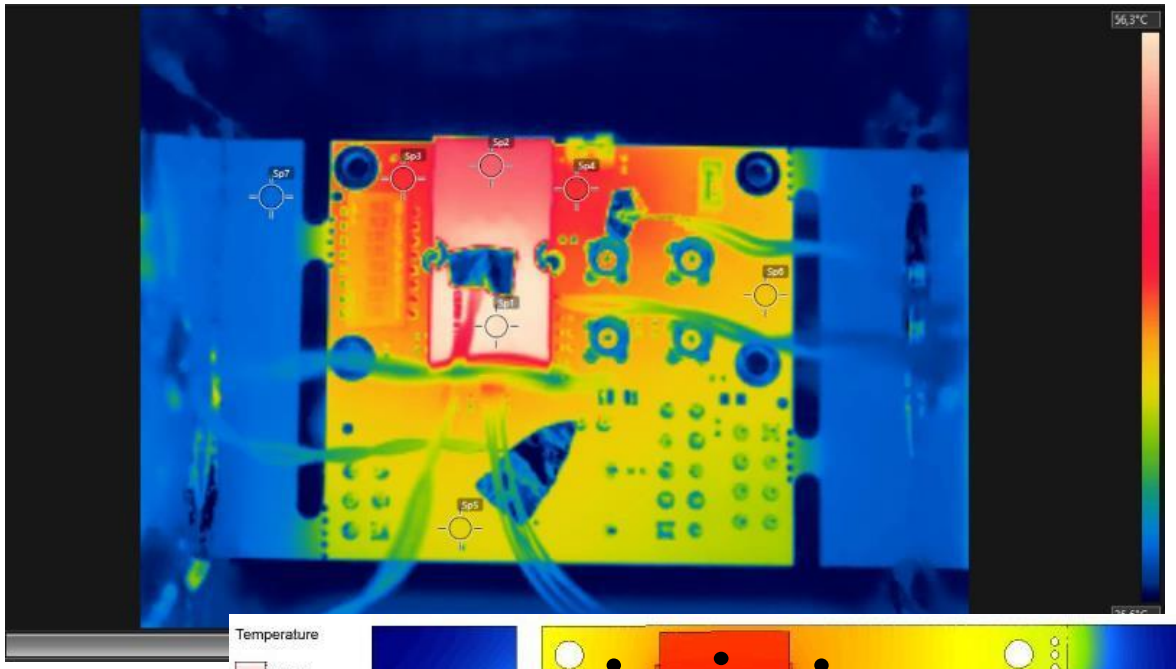


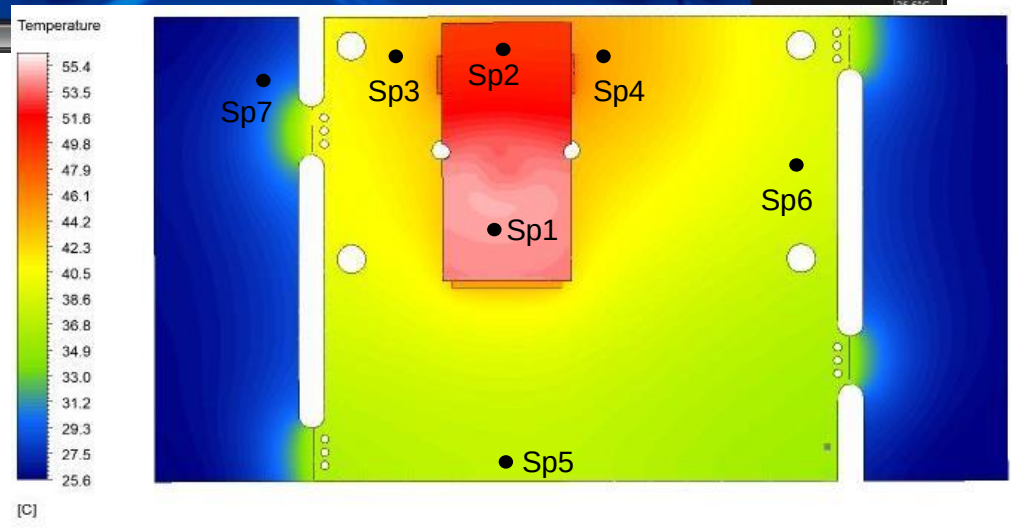
- DEMO portcard was studied with two different positions of the Peltier cell:
  - Peltier cell placed at the bottom wall of the box
    T ≅ 20°C
  - Peltier cell placed at the top wall of the box
    T ≅ 12°C (see next slide)



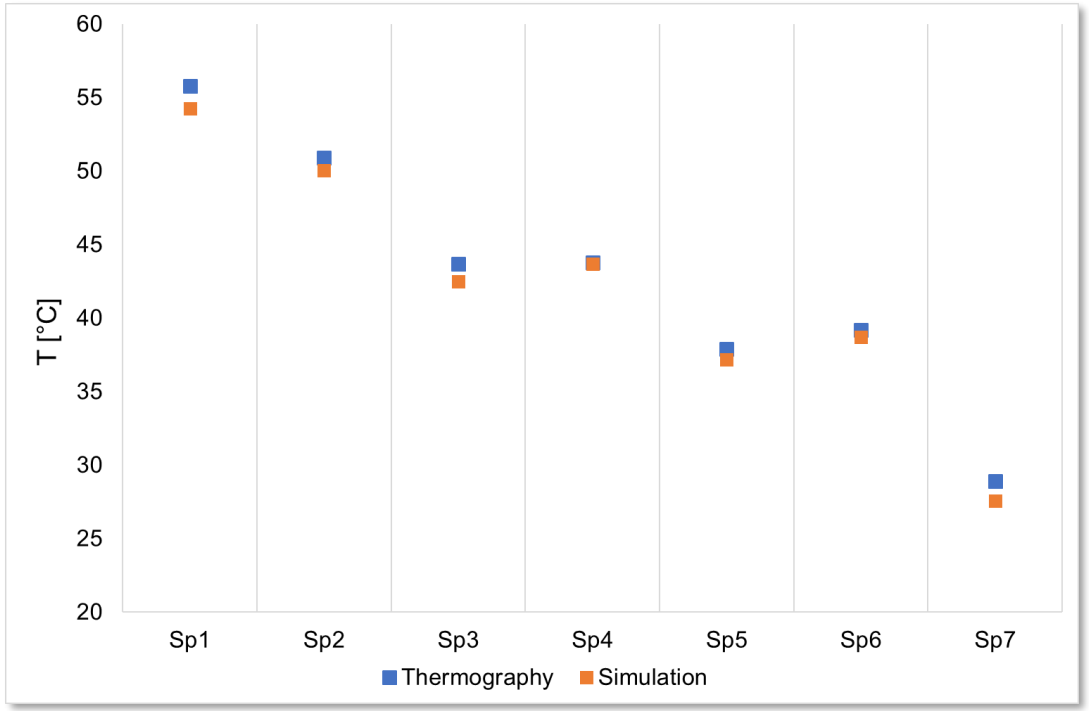
Validation Process

Results





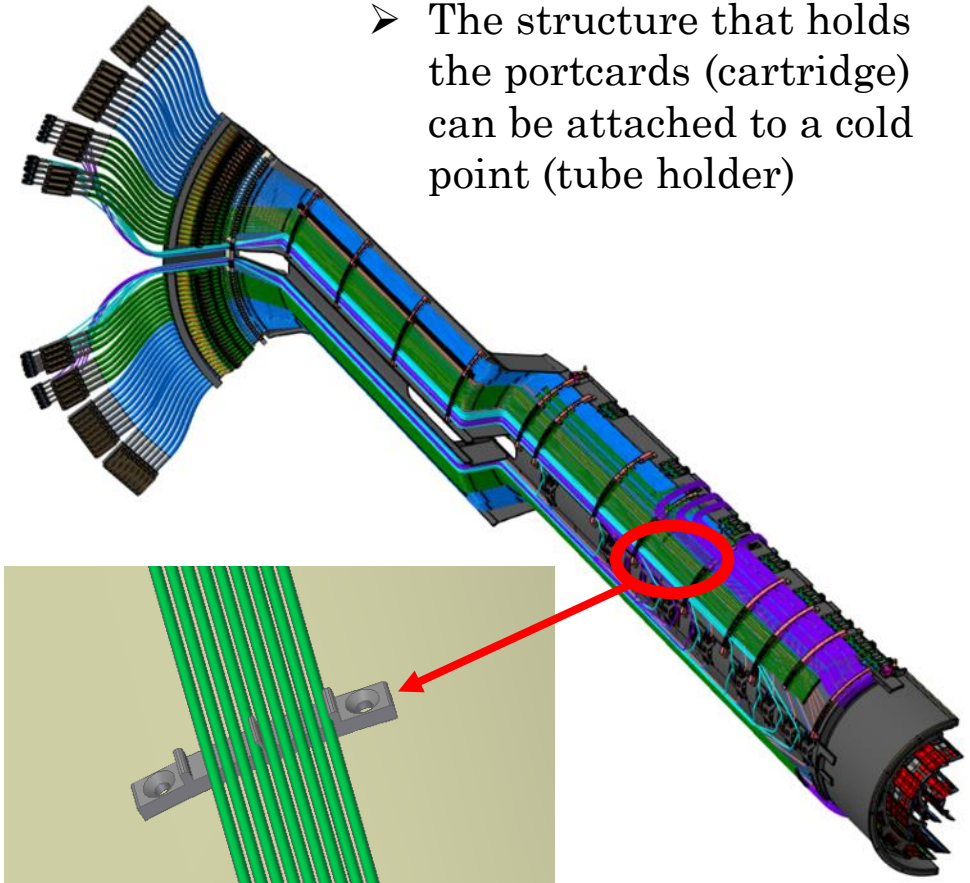
Peltier cell placed at the top wall of the box T ≅ 12°C



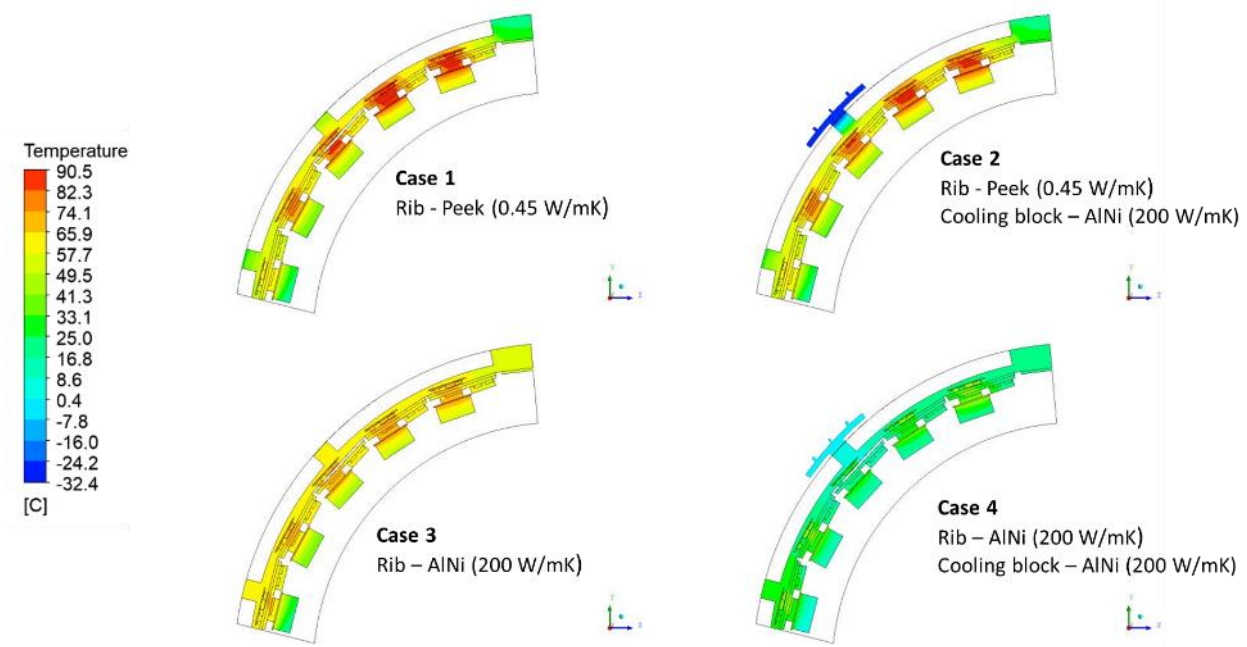
Active cooling solution

Concept

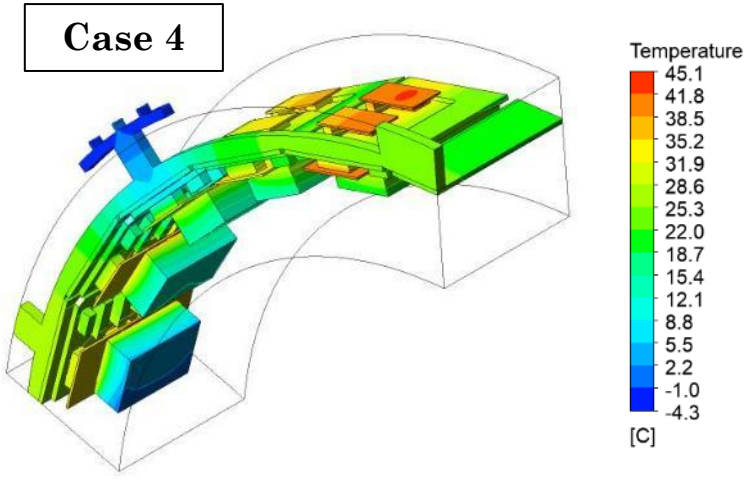
- The idea was to intercept the TPBX cooling pipe that runs on the service cylinder



- The structure that holds the portcards (cartridge) can be attached to a cold point (tube holder)

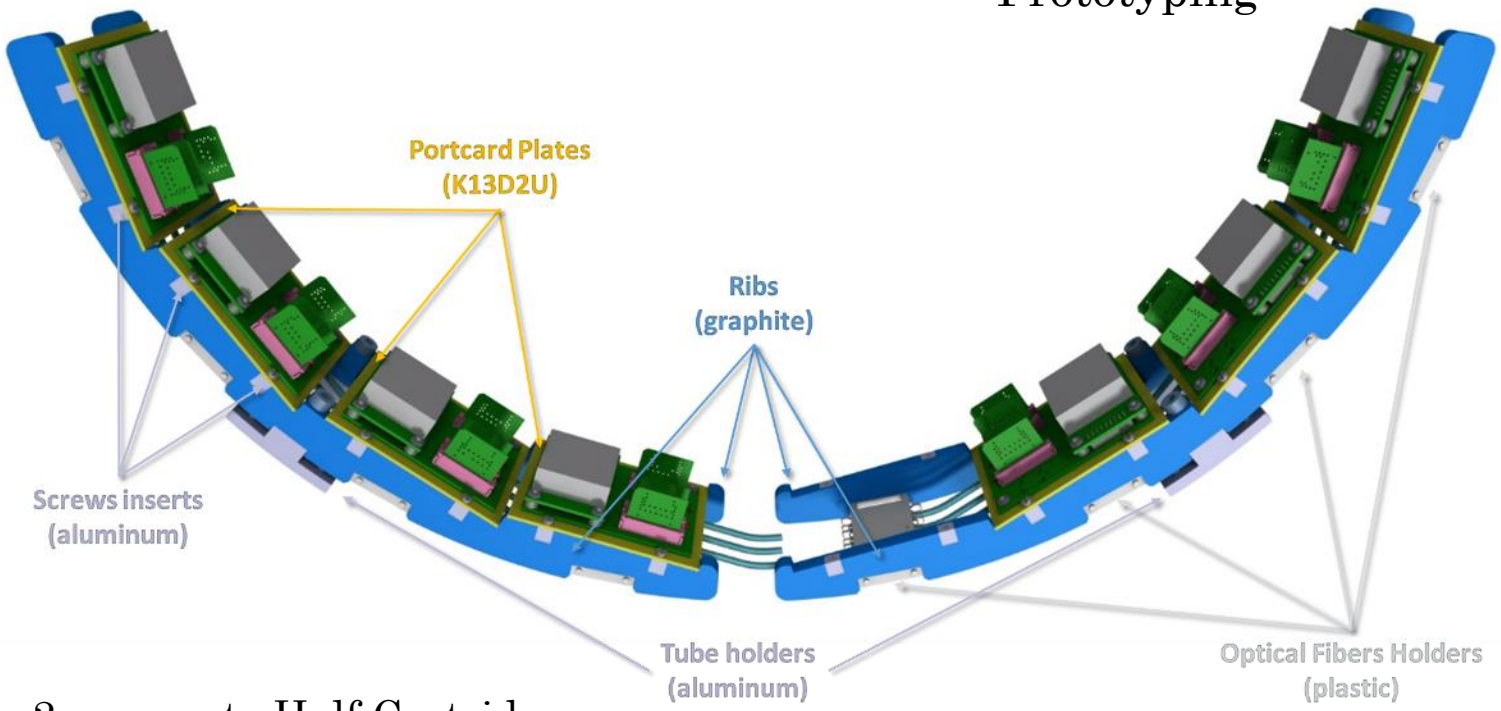


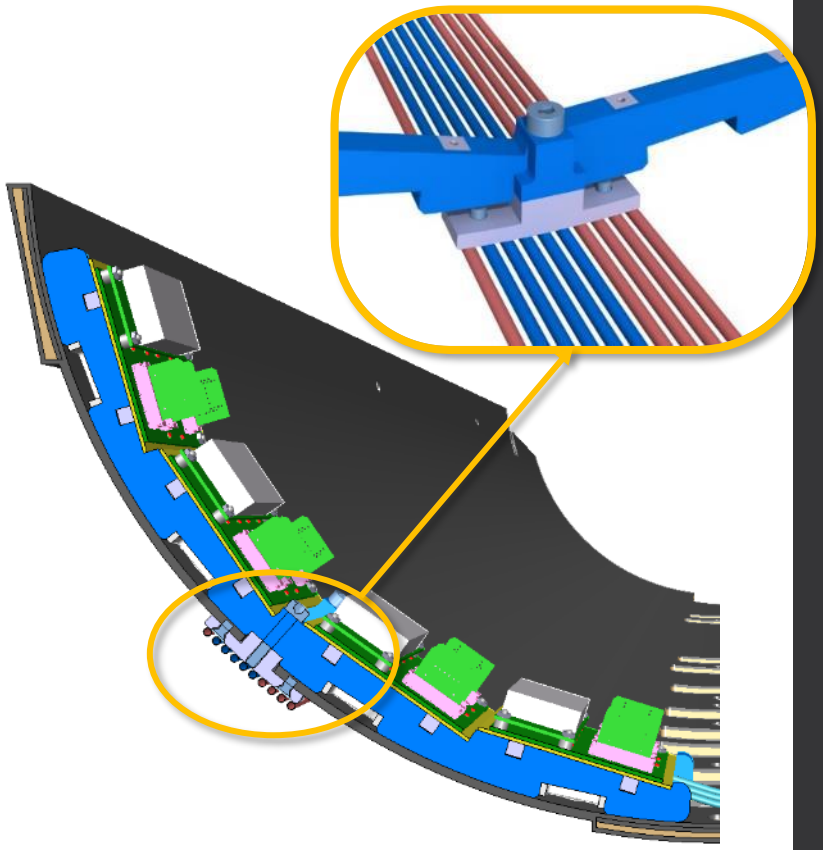
- Thermal simulations have been performed on the first concept to evaluate the cooling efficiency



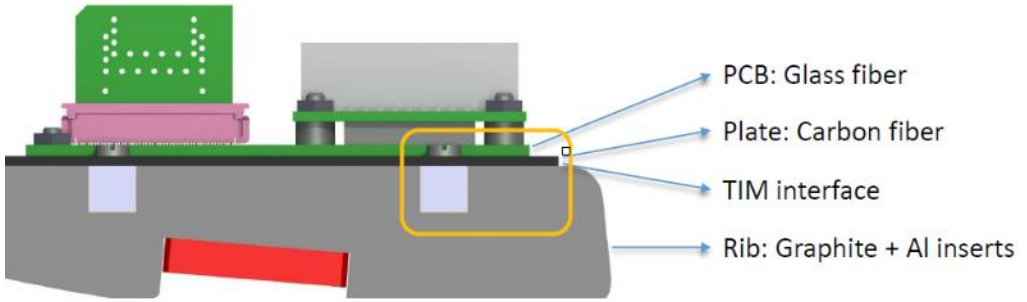
Active cooling solution

Prototyping





- 2x separate Half Cartridges
- Graphite ribs (blue parts) + Aluminum inserts
- Cold plates for portcards (yellow parts)
- MT-MT connector holders (ABS - 3Dprint)
- **5 cartridges of 7 portcards for each quarter of a Barrel**

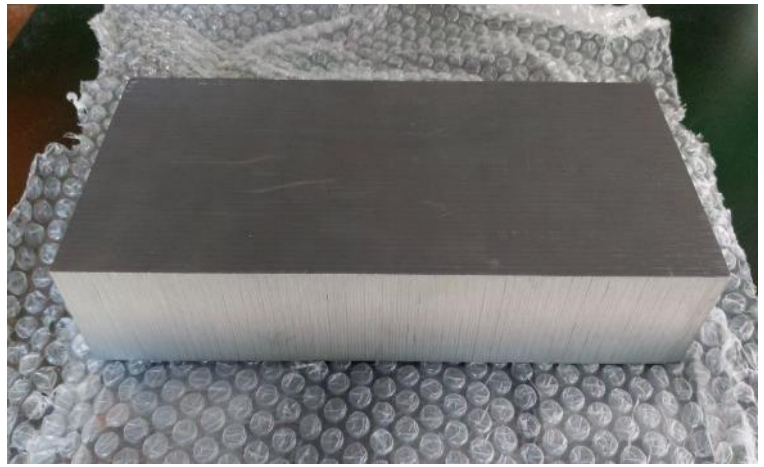


Heat Path

Portcards → CF plates → graphite ribs → tube holders → CO_2 pipes

Active cooling solution

Prototyping



Graphite Ribs

- Material: **Graphite IG-45** (250x50x100mm block)

GRADE	Bulk Density	Hardness	Flexural Strength	Compressive Strength	Tensile Strength	Young's Modulus	Coeff. Of Thermal Expansion	Thermal Conductivity
	g/cm^3	HSD	MPa	MPa	MPa	GPa	10^{-6}/K	W/(m·K)
IG-45	1.88	55	60	110	40	12.0	4.9	140

- Produced at the **INFN-TO internal workshop**
- **Machined by wire-EDM**
- Finished with milling and drilling operations

RESULTS:

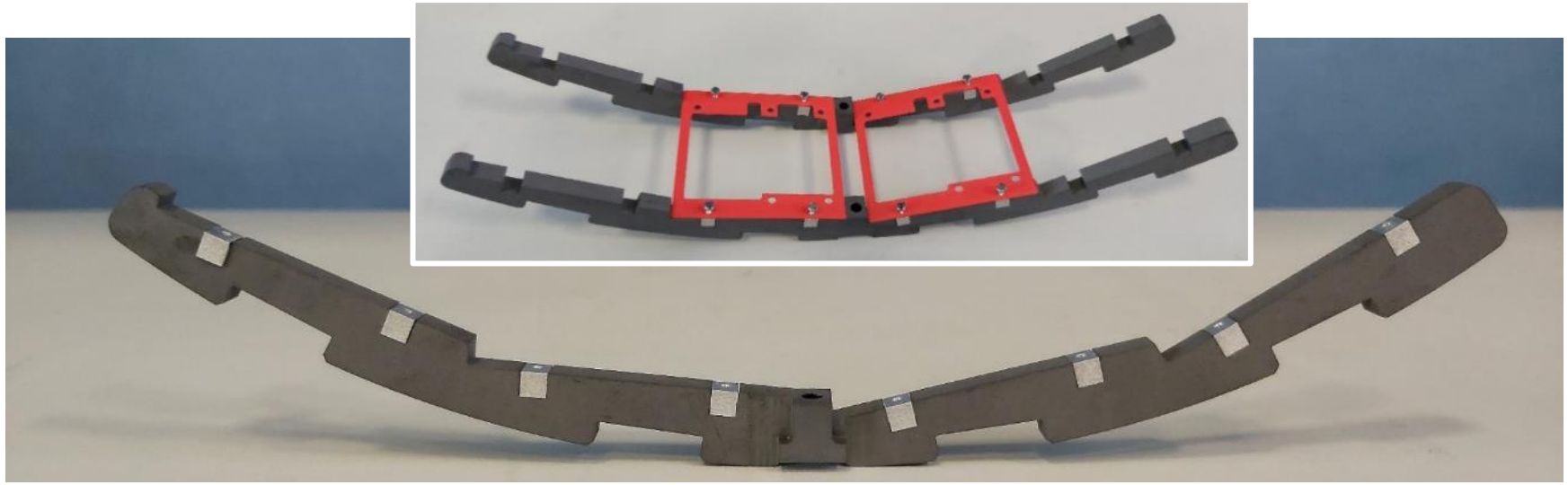
- Feasible processing (no criticality)
- Non-fragile component (safe handling)

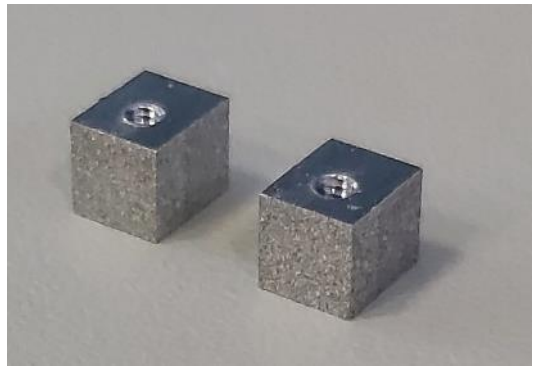
NOTE: coating required to avoid graphite powder during handling

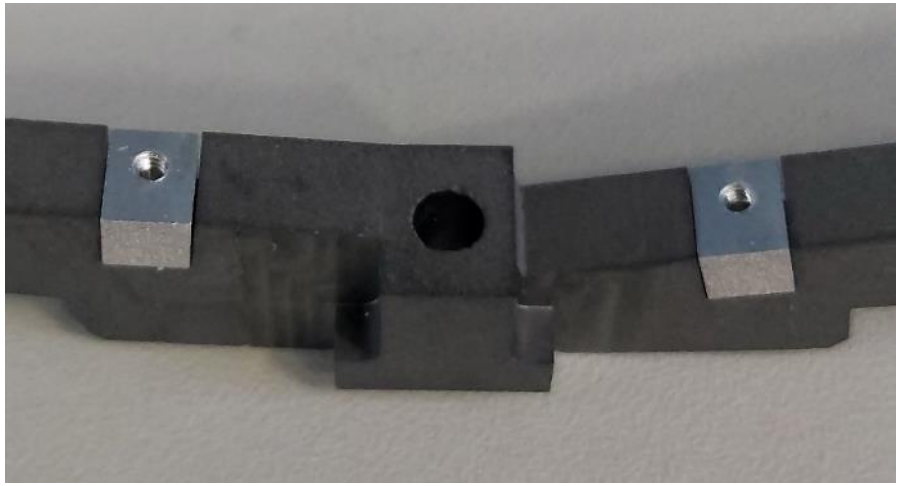
- Rib brushed with diluted Araldite-2011
- No coating on heat exchange surfaces

Active cooling solution

Prototyping





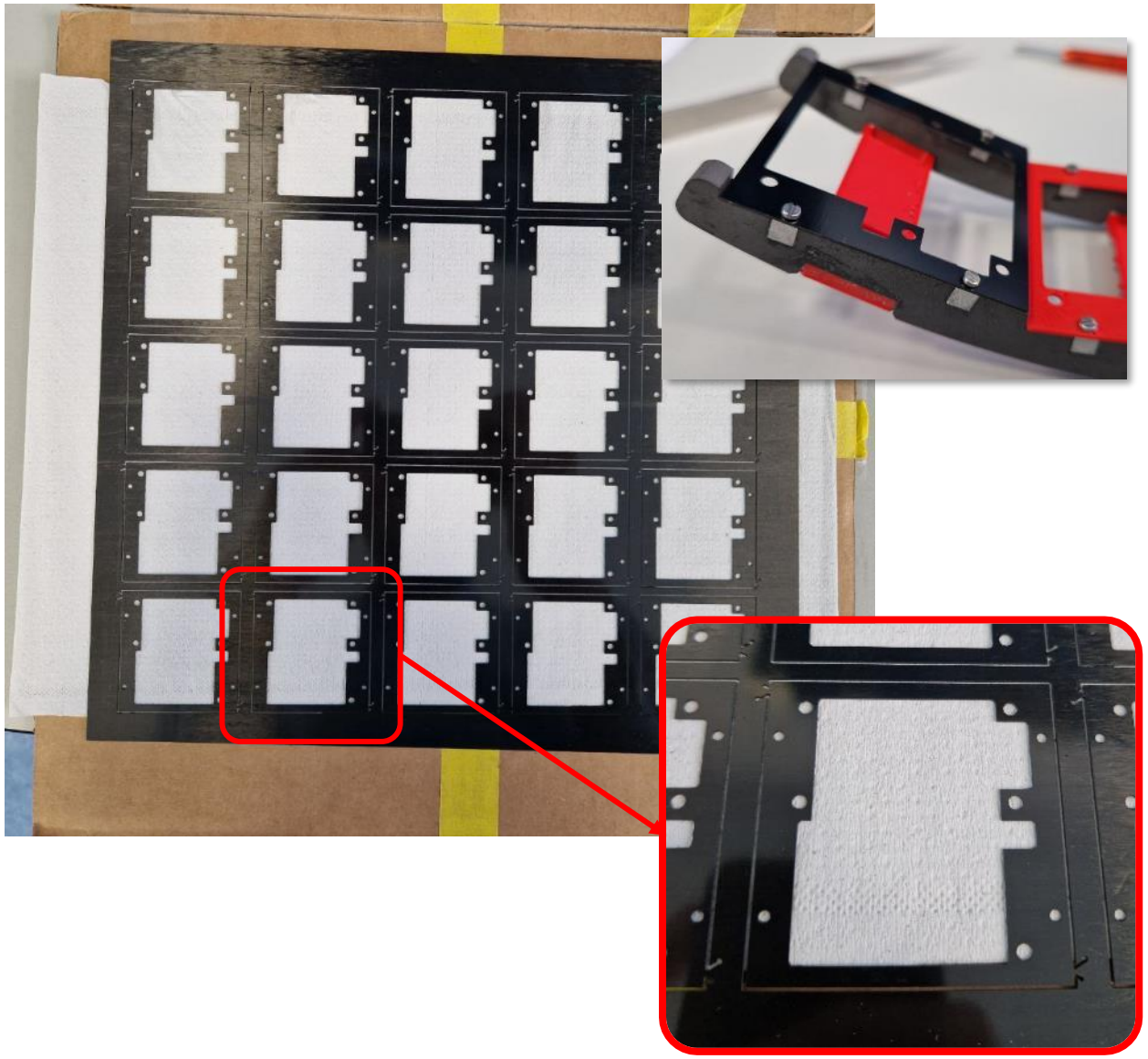


Aluminum Inserts

- Material: **ANTICORODAL**
- Produced in the **INFN-TO internal workshop**
- **Machined by wire-EDM**
- M1.6 threaded hole
- Glued to the rib using Araldite 2011

Active cooling solution

Prototyping



Carbon Fibers Plate

- Material: **Carbon Fiber K13C2U – 5 ply (90-0-90-0-90)**
- Machined by **water cut**
- Company: **WatAJet S.r.l.**
- Screwed to the rib using M1.6 aluminum screws

  (not yet produced)

NOTE: the plates were made thinking of having 3 of 5 plies perpendicular to the ribs, in order to improve the heat exchange with the ribs.

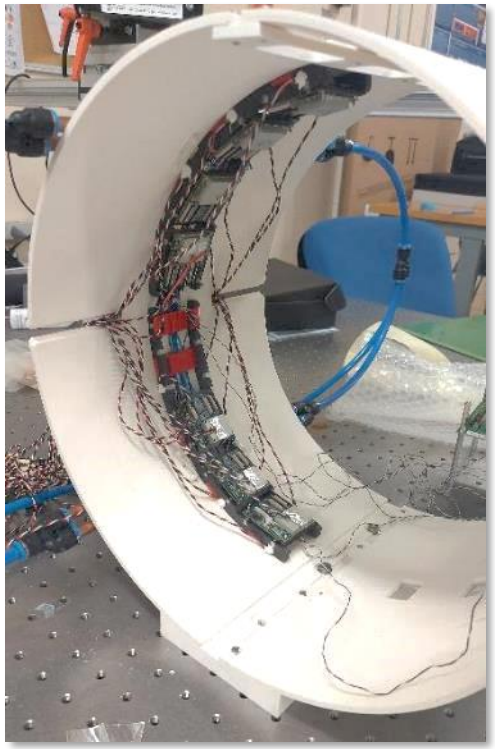
Plates realized in strong collaboration with TFPX team and Purdue Lab.

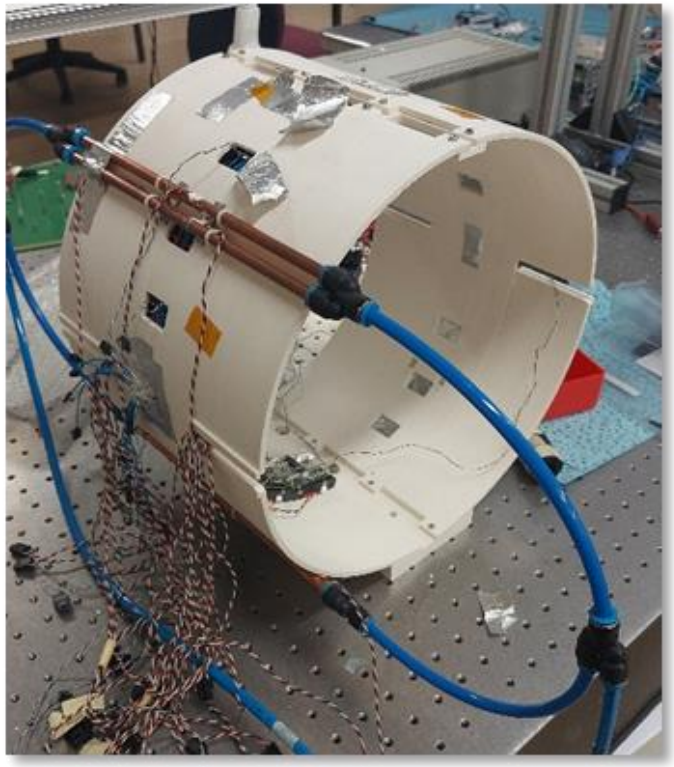
Thermal Test

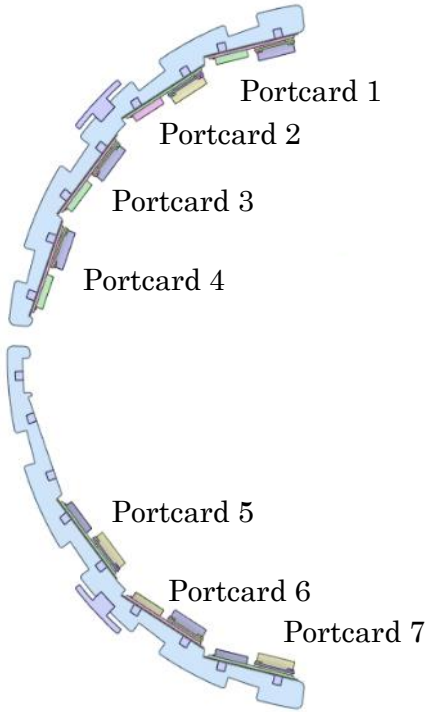
Scope of measurements:

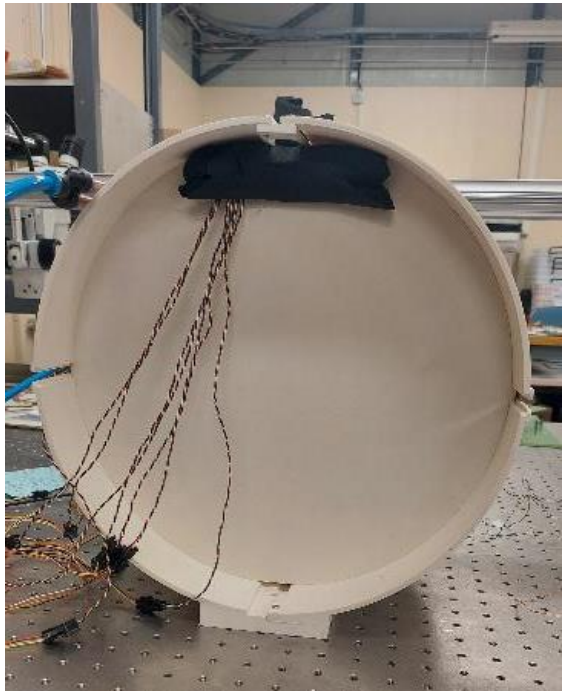
- Test the capability of cooling concept to intercept the pipe and remove heat from portcards.

- The setup has been designed to obtain a controlled boundary conditions around the cartridge to be robust in the input parameters for thermal simulations.









- 2 cartridges with 7 portcards have been tested

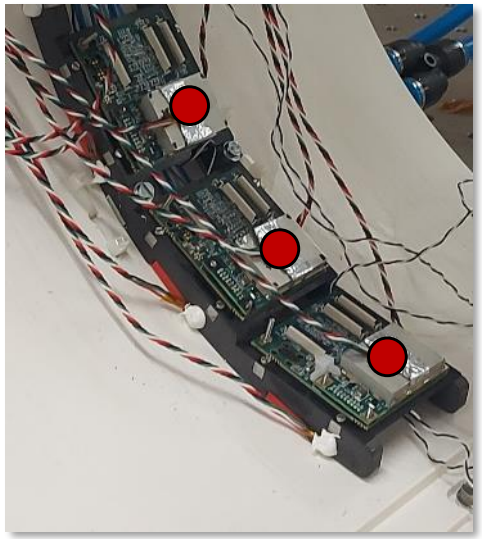
- The cooling was provided by a chiller set to 10°C

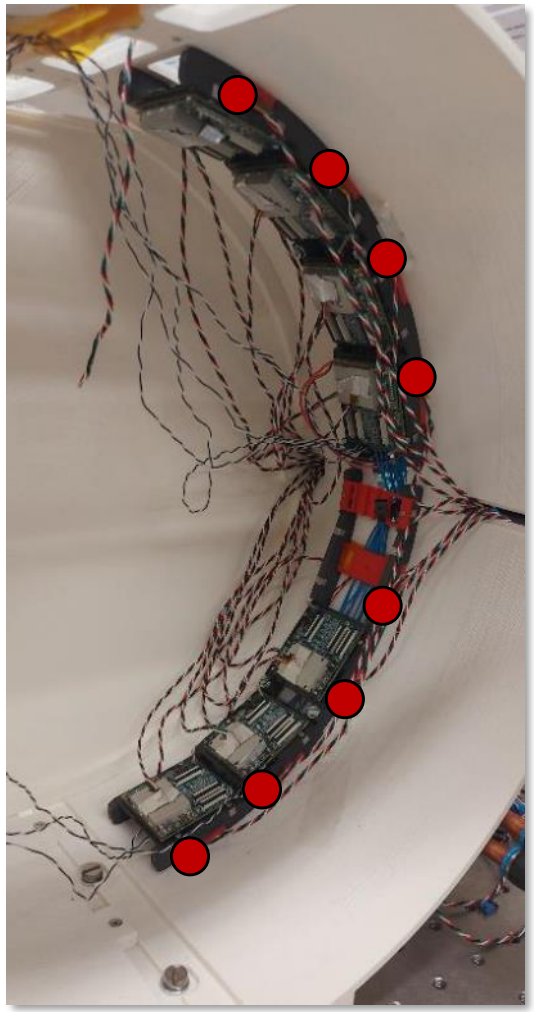
- The cartridges have been tested in an enclosure of 10 cm to decrease the movement of the air

Thermal Test

Temperature probes:
30 temperature probes are placed on the system

- 7 on the DC-DC converter of each portcard
- 16 on the grafite cartridges
- 2 on the cooling pipes
- 4 on the tube holders
- 1 on the air



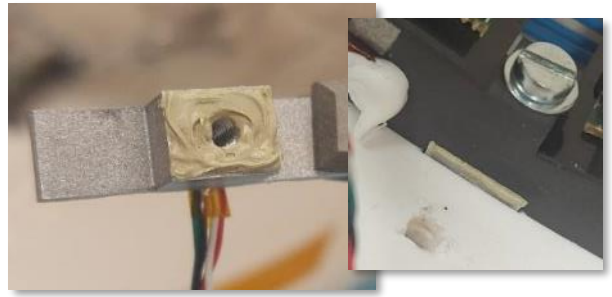


The 7 portcards have been tested in an enclosure with three different cases of thermal interfaces/connections:

Case 1: tube holders not shaped

Case 2: tube holders shaped to increase the contact surface with the pipes

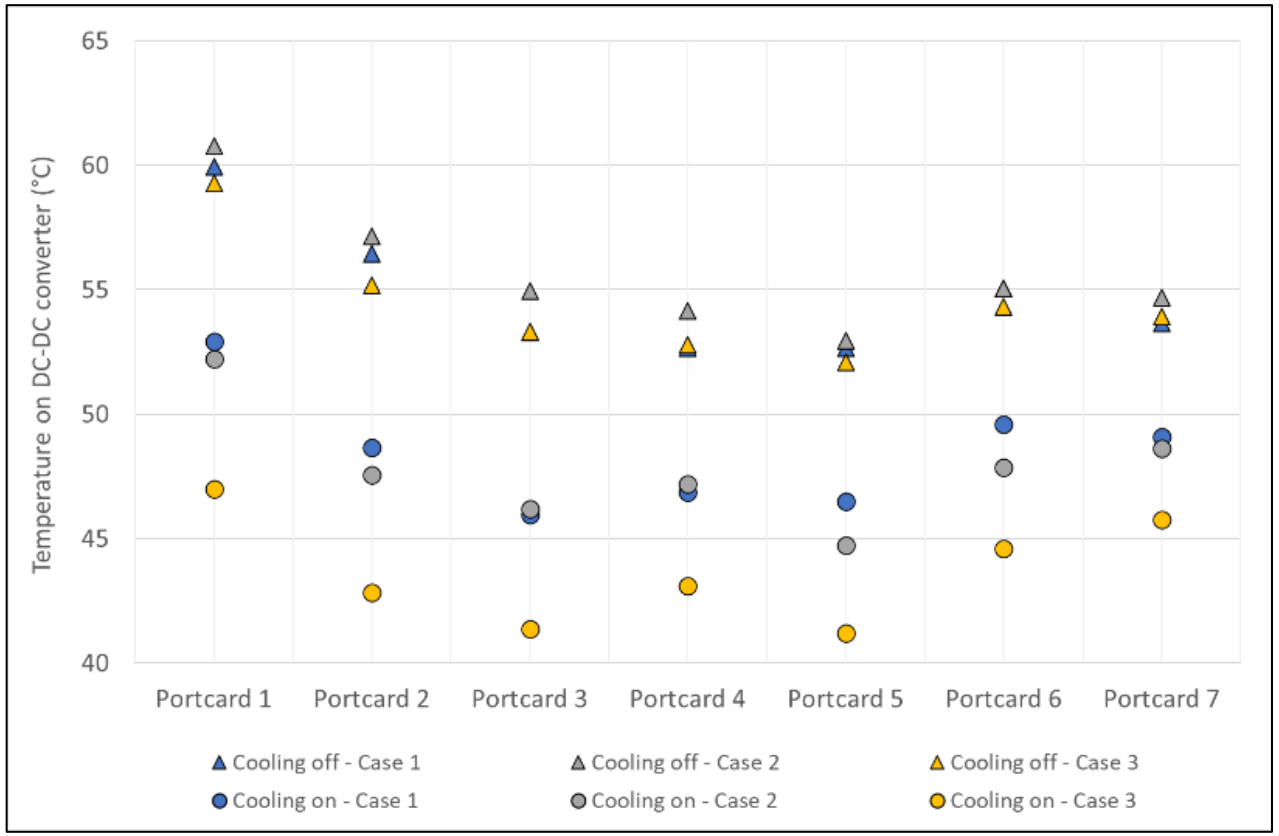
Case 3: tube holders shaped and thermal grease (moresco + diamond) applied between pipe and tube holder and between tube holder and cartridge.

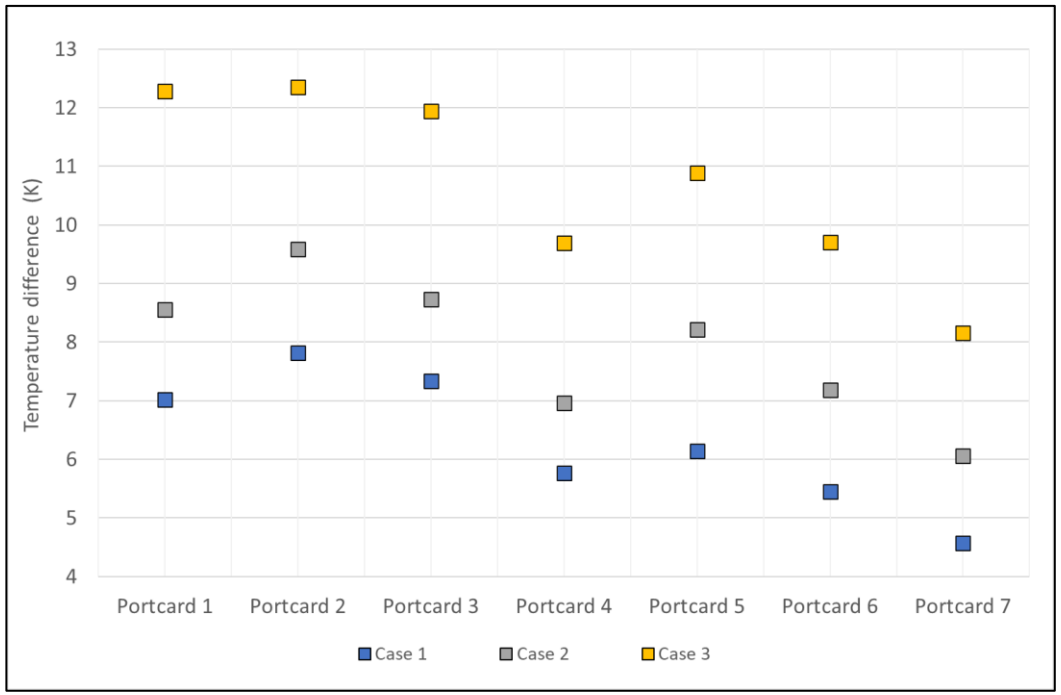


Thermal Test

- The plots summarise the cooling efficiency of the three cases
- As expected, the thermal grease makes the system more efficient for the cooling
- A reduction of around 10-12 °C between w/wo cooling conditions

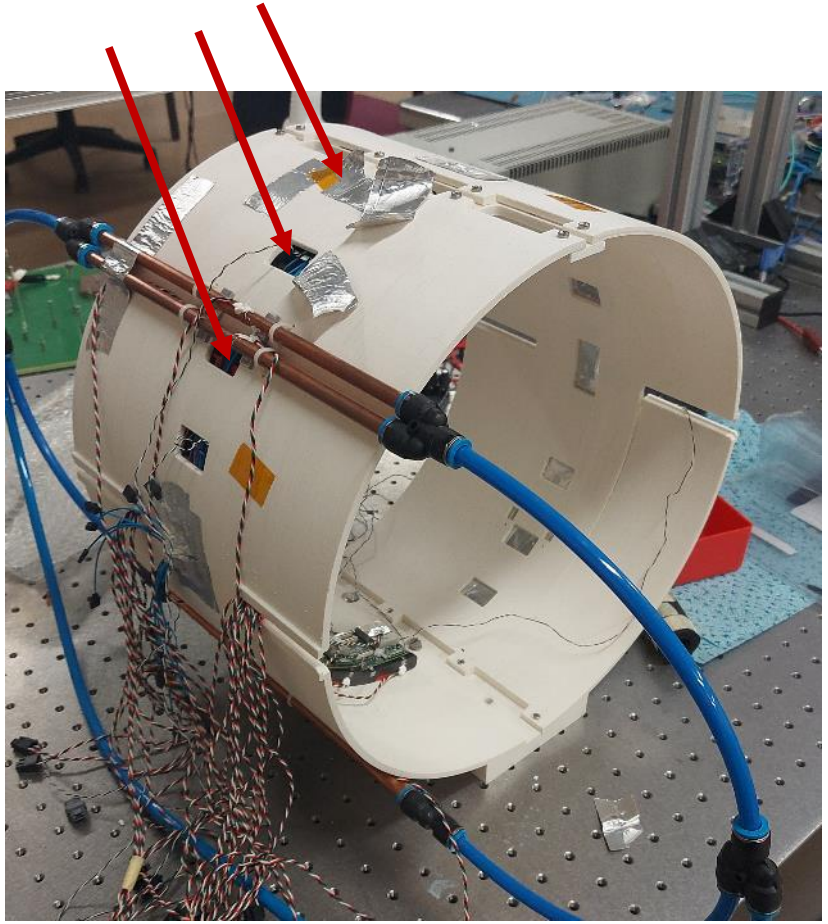
Powers	Watt
Portcard 1	2.0
Portcard 2	1.7
Portcard 3	1.7
Portcard 4	1.8
Portcard 5	2.4
Portcard 6	1.8
Portcard 7	1.9

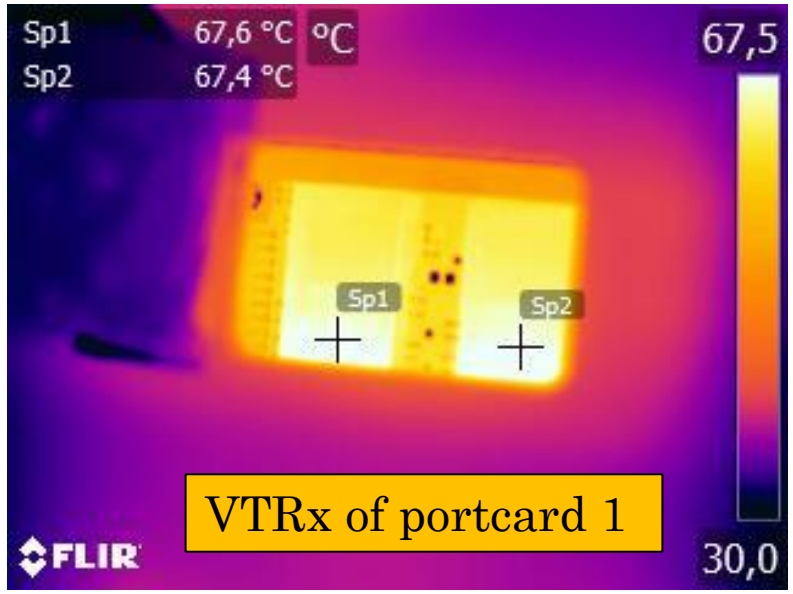


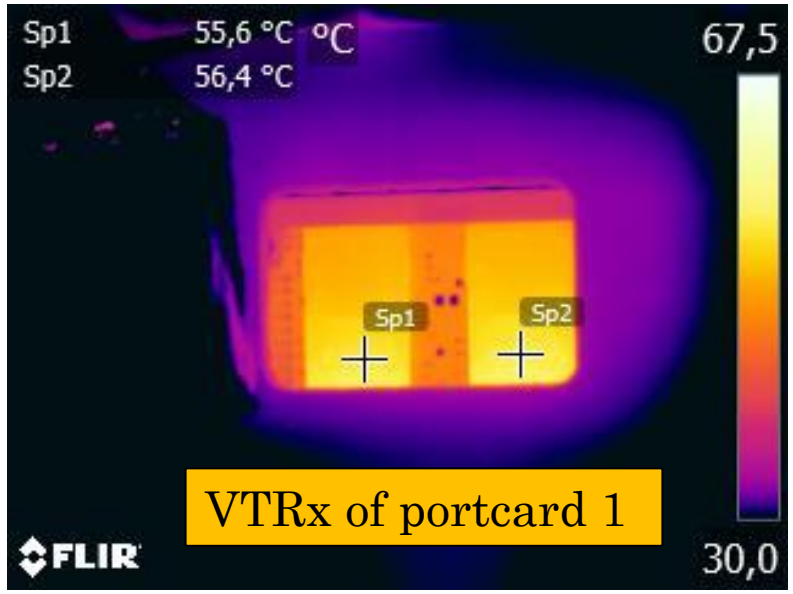


Thermal Test

Windows for the thermographic survey of VTRx







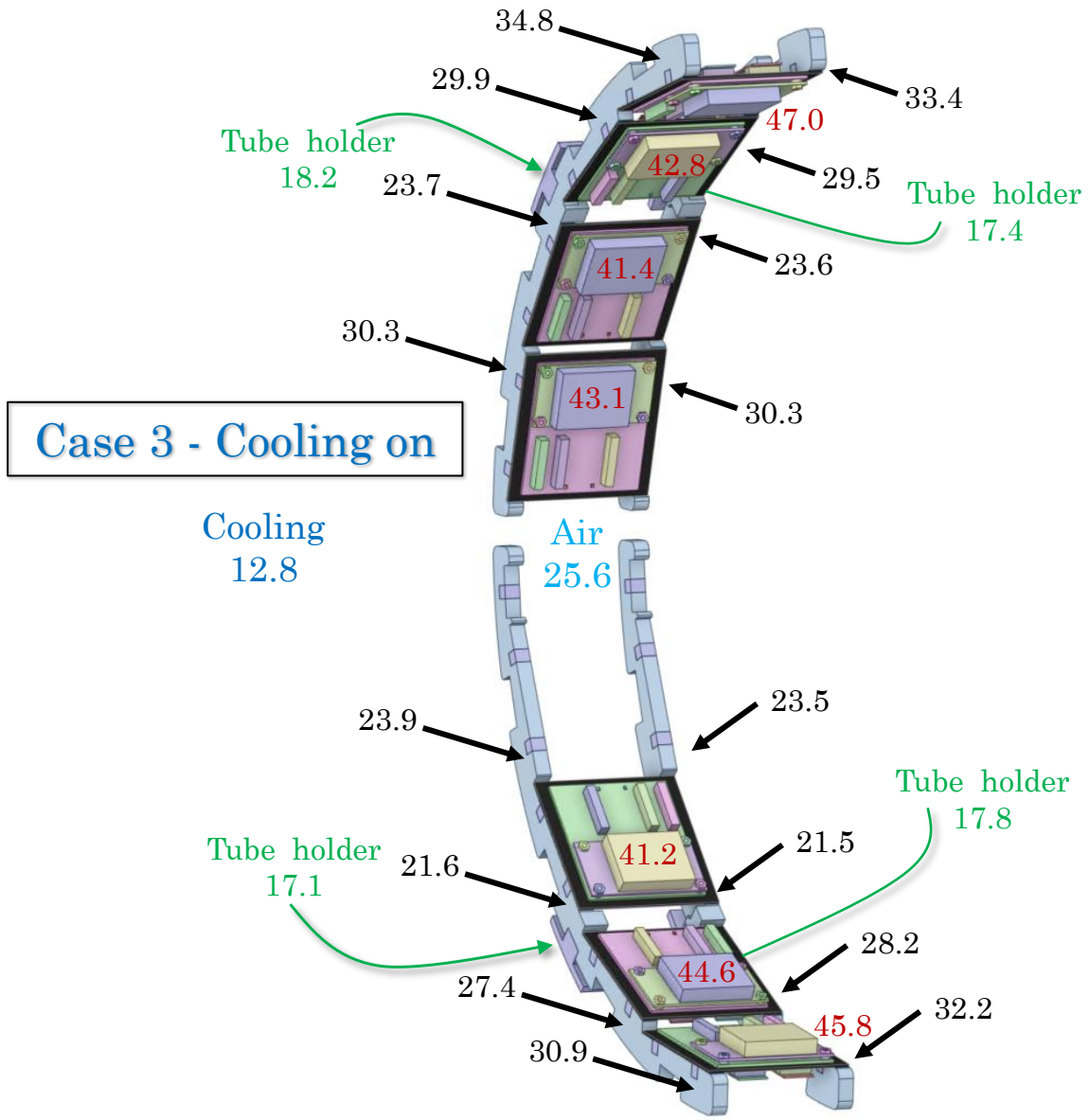
- Thermographic survey can help to measure the temperature of the other components of the portcard
- The reduction of 12 K between w/wo cooling conditions is confirmed also for the VTRx

Thermal Test

A rough calculation can be done with the measurements to predict what we can have in the operating condition of the portcard

- Considering Case 3, from the temperature difference between cooling pipe and DC-DC converter it is possible to scale temperatures when the cooling is in cold condition (CO_2 @-35°C)

	DC-DC converter temperature (°C)
Portcard 1	-0.9
Portcard 2	-5.1
Portcard 3	-6.6
Portcard 4	-4.8
Portcard 5	-6.6
Portcard 6	-3.2
Portcard 7	-2.1



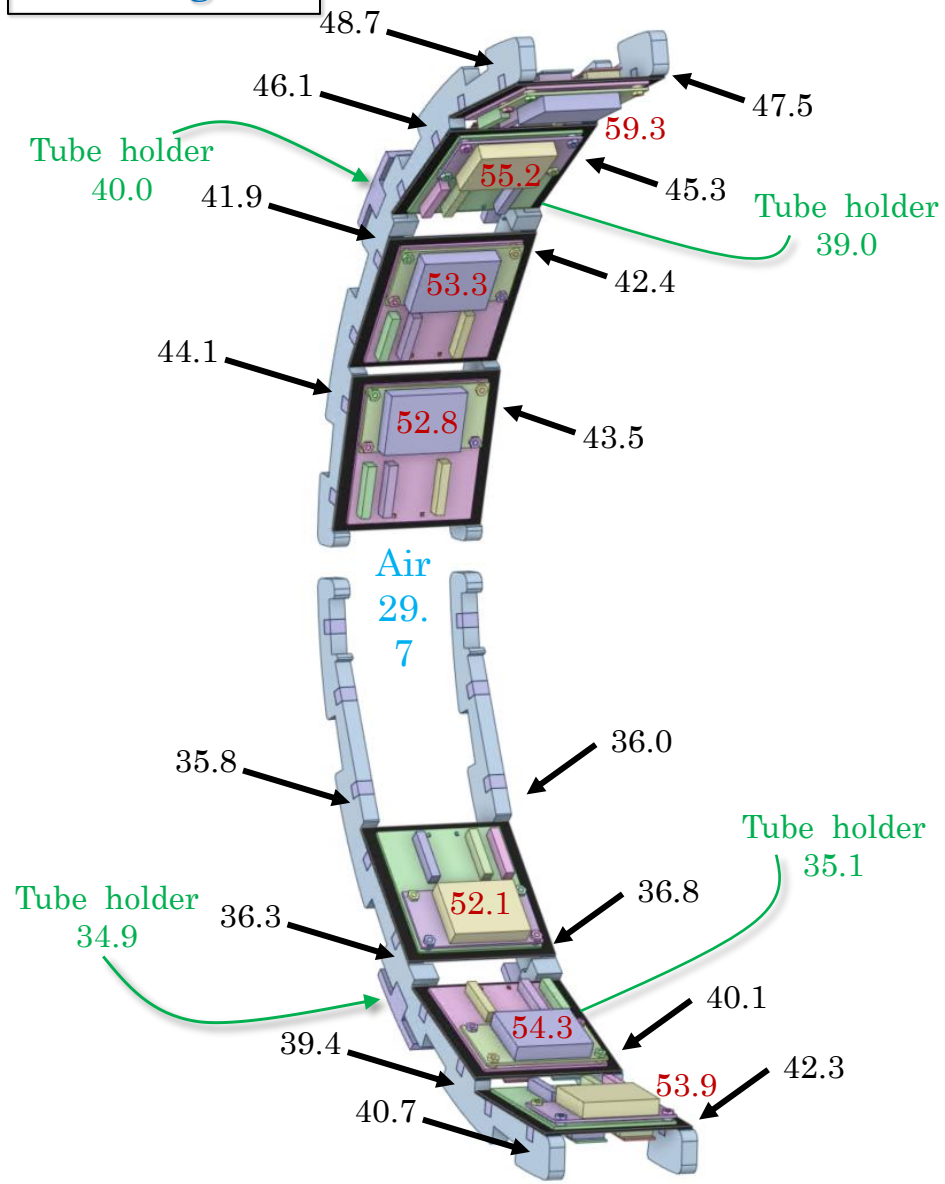
Conclusions

- The cooling of electronics components in CMS upgrade Phase 2 is crucial for the life of the detector over the years.
- Modules of the Inner Tracker TBPX and TFPX need to be connected to electrical-optical interfaces (portcard) that need to be cooled.
- A validation process have been performed on a DEMO portcard in order to assess the robustness of thermal simulation outputs.
- Thanks to preliminary thermal simulations, the idea of cooling solution has been developed and then prototyped. The active cooling does not foresee a dedicated cooling line for the portcards, but it intercepts cooling pipe running near to them.
- Thermal test has been performed on the first prototype in ambient conditions (20°C) with two scopes:
  - Evaluate the cooling efficiency.
  - Validate future thermal simulations that can give information when the portcard will operate in cold conditions.

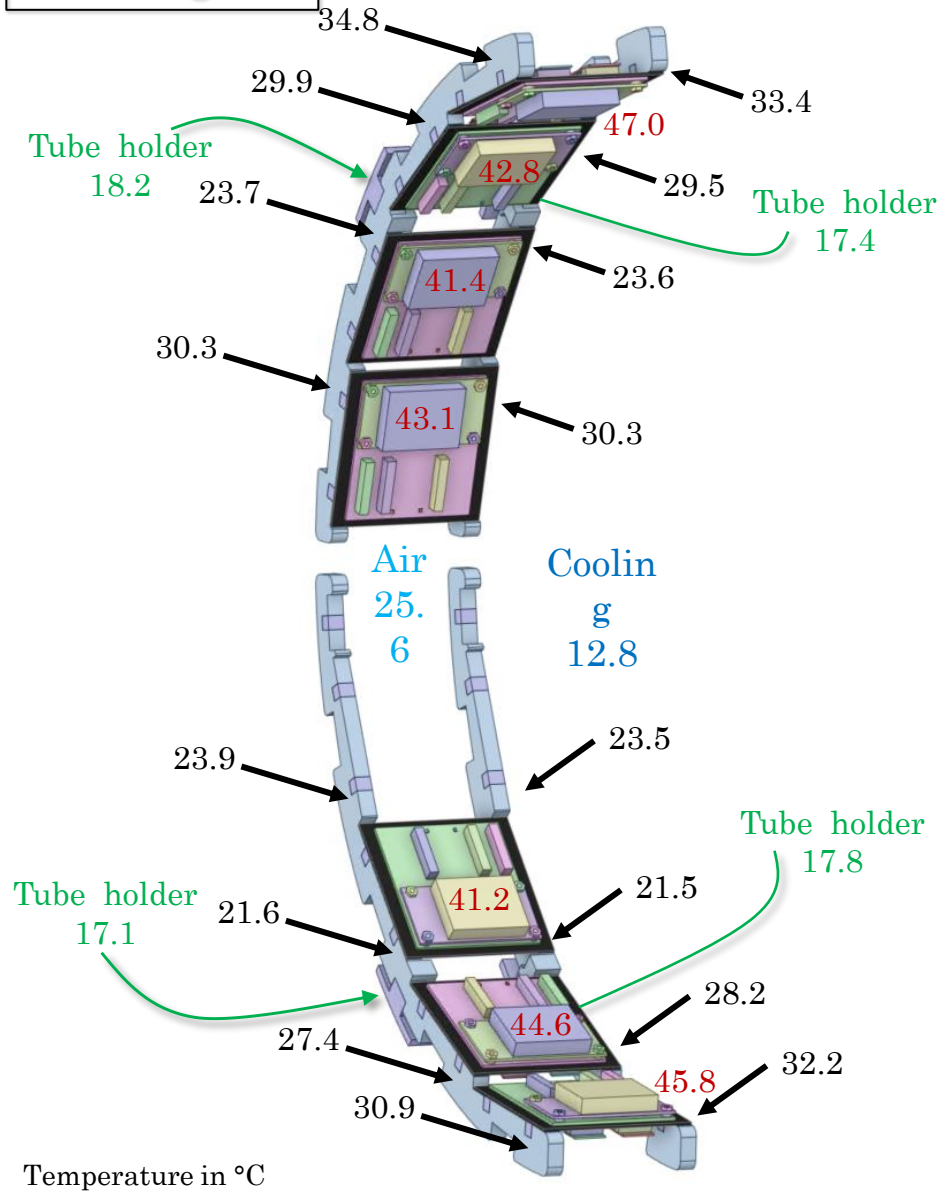
Backup

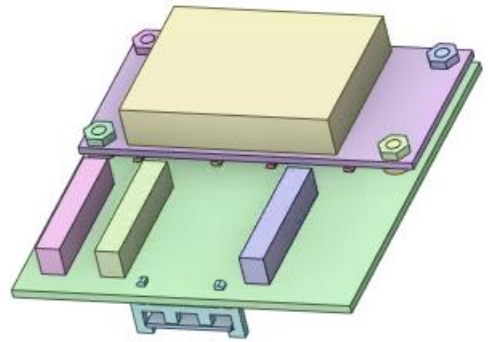
Case 3 – Detailed results

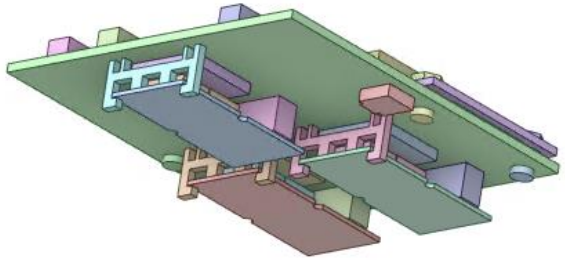
Cooling off



Cooling on

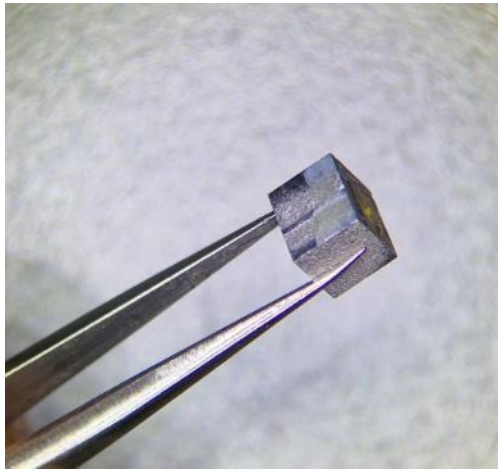


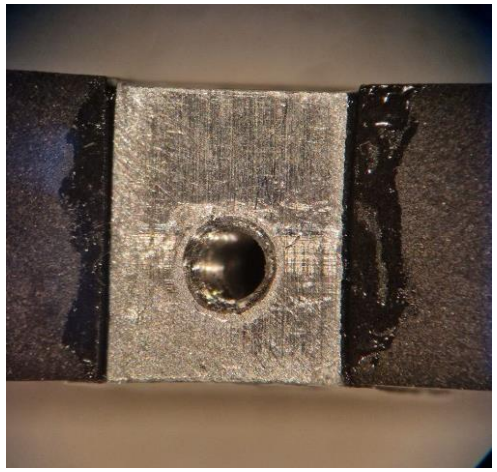




Temperature in °C

Assembly procedure





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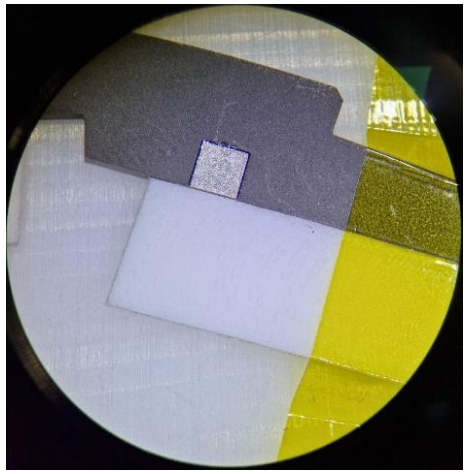
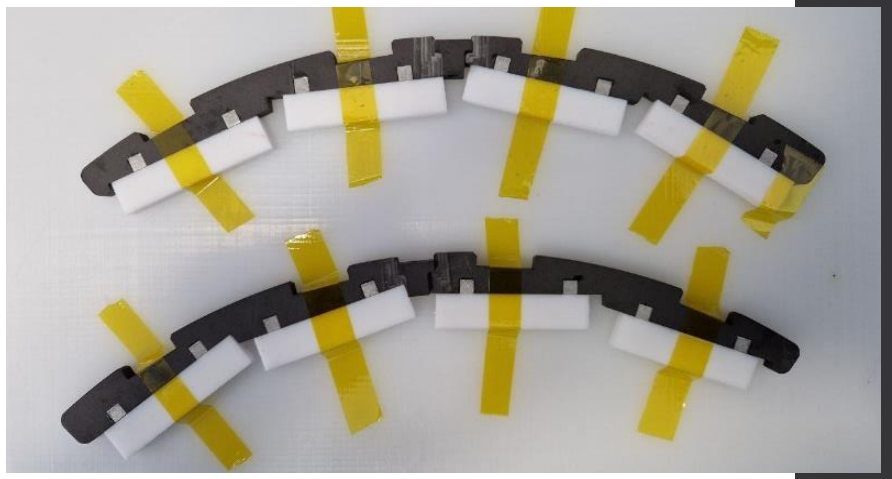


Gluing result verified by microscope



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