Qualification of different materials for heat transfer in module construction

Tobias Barvich, Conny Beskidt, Wim de Boer, Alexander Dierlamm, Dirk Heil, ●Stefan Maier

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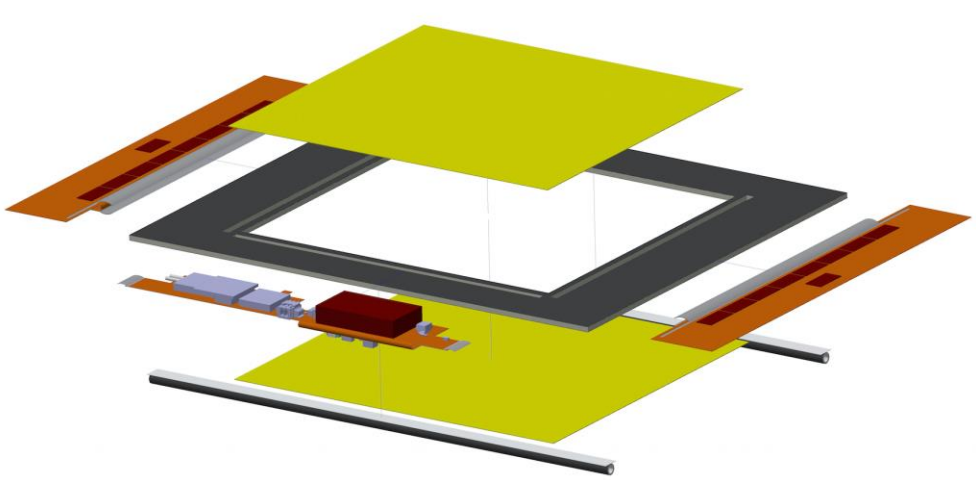
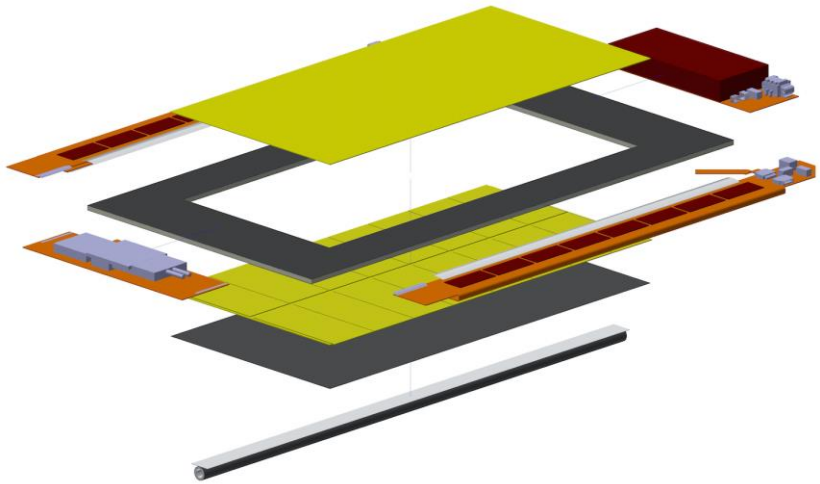
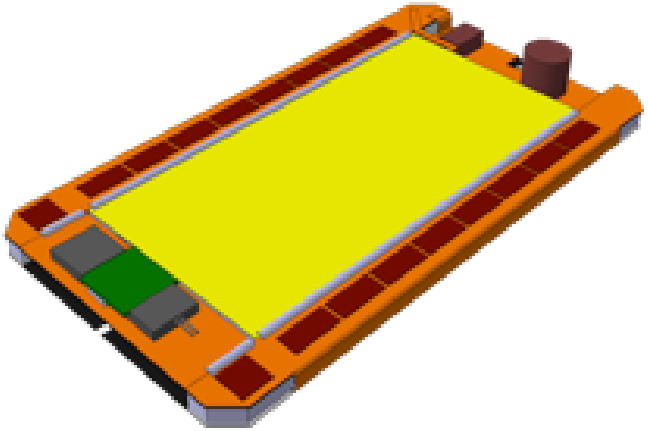
Institut für Experimentelle Kernphysik

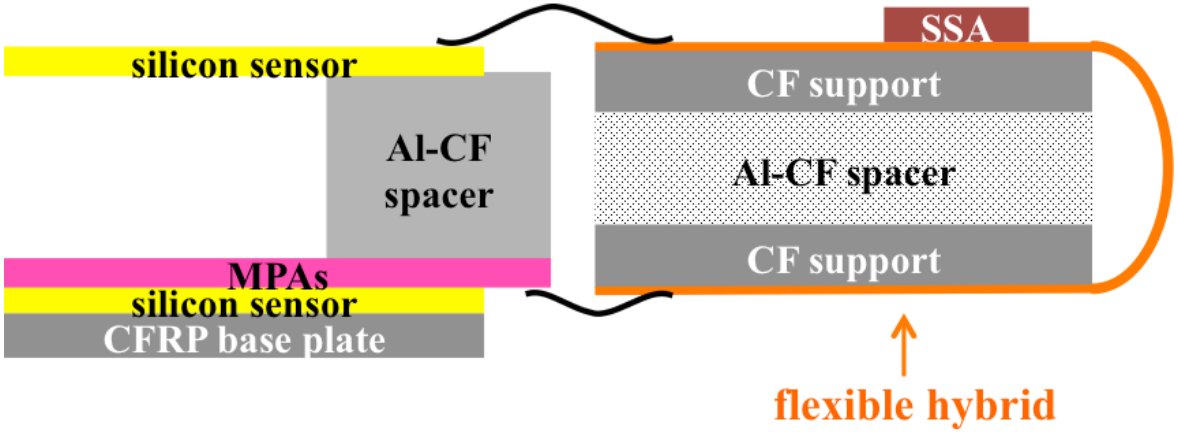




CMS Requirements for HL-LHC Tracker

- Trigger capability → Modules with two sensors sharing a common hybrid allows for signal correlations
- Higher granularity → pixel sensors in inner tracker, Pixel-Strip (PS) modules in inner tracker, Strip-Strip (2S) modules in outer tracker

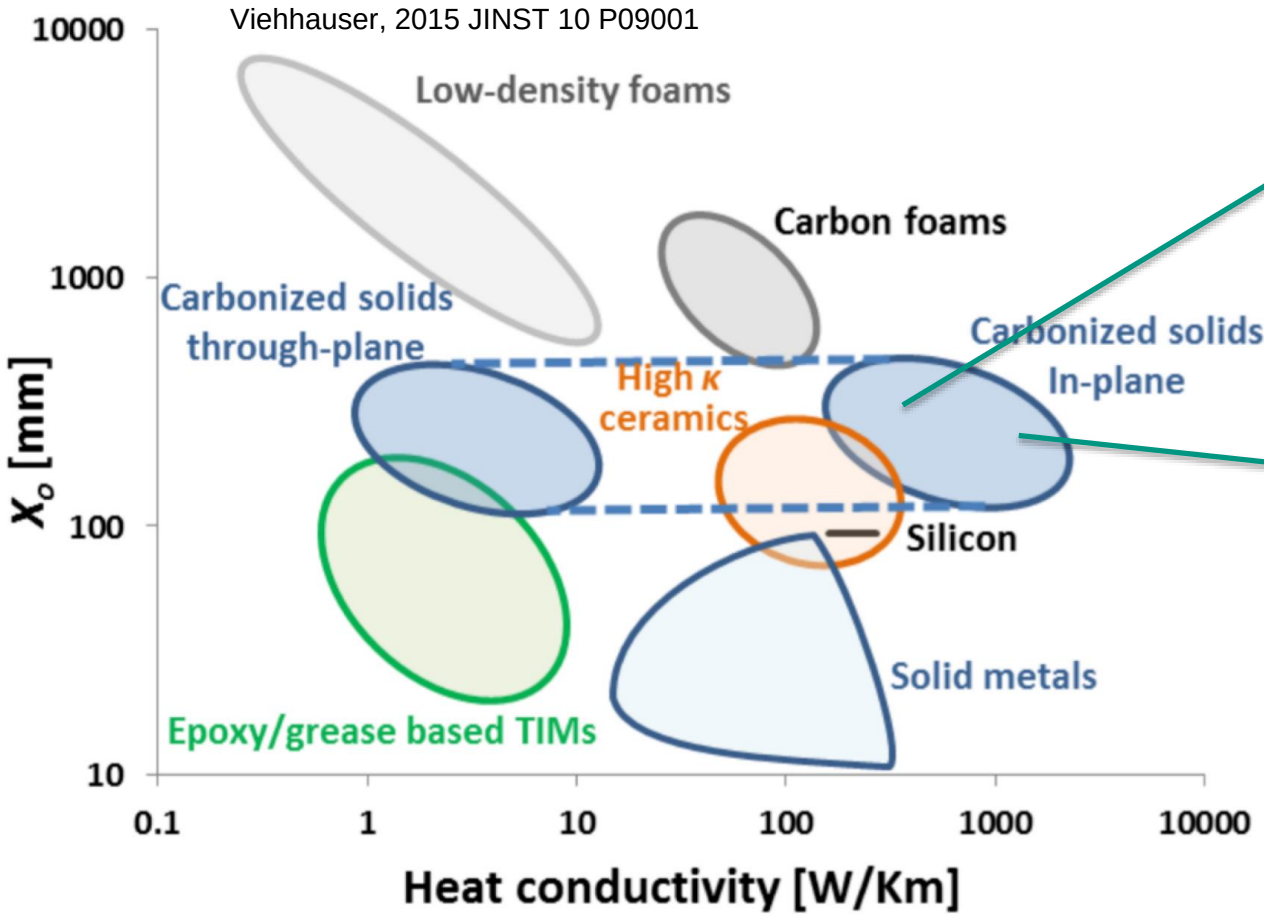




- ≈ 8400 2S and 7000 PS modules with a total power of 90-100 kW

- **How to transfer 90-100 kW from the modules to the CO_2 cooling (-30°C)?**

Heat conducting materials



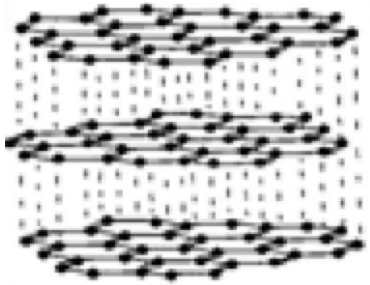
Carbon fiber (CF) in epoxy matrix (strong, medium heat conductivity

Synthetic graphite (SG), double sided adhesive

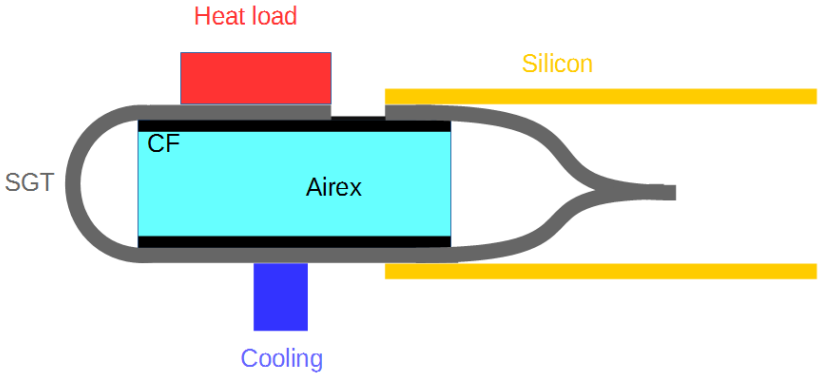
We tried combination: CF sandwich with SG tape to glue hybrids and sensors

Synthetic graphite (SG)

- Produced simply by sintering polyimide tape above 3000°C (plasma ovens) → carbon changes into liquid crystal phase and forms highly conductive graphene layers in x,y directions
- Graphite covered with adhesive layers on both sides, so components can be directly glued to cooling structure with SG tape

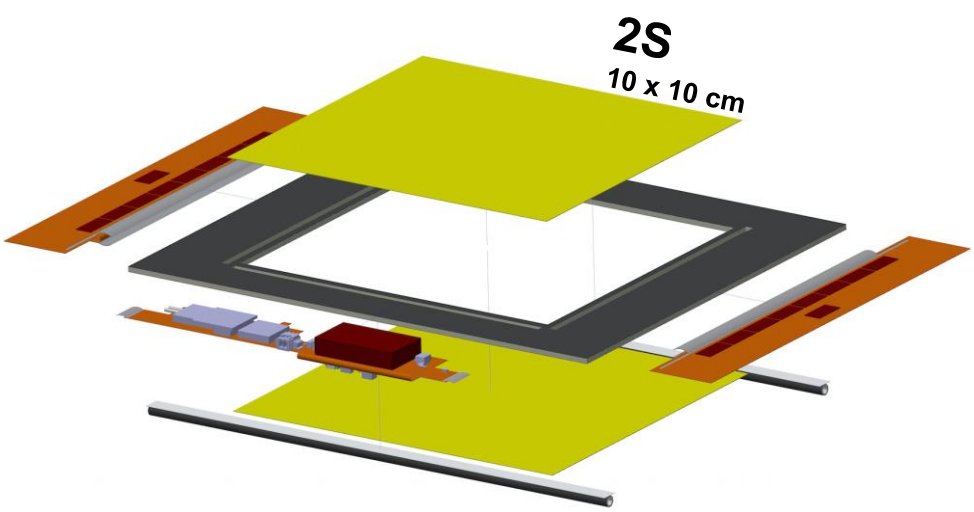


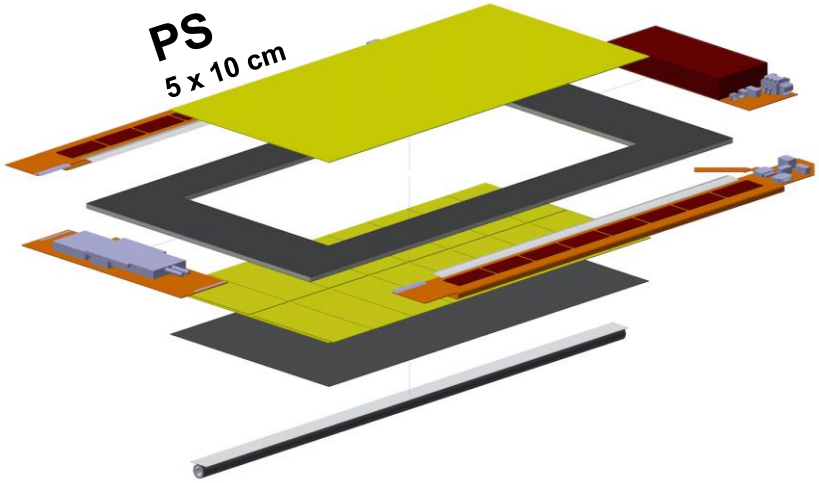
- Typical thickness 25 or 40 µm graphite with 12 µm adhesive layers
- Adhesive layers withstand HV of sensor



- Widely used for cooling in electronics (mobile phones,…) so cheap and many manufacturers (providing precut shapes)

A module study



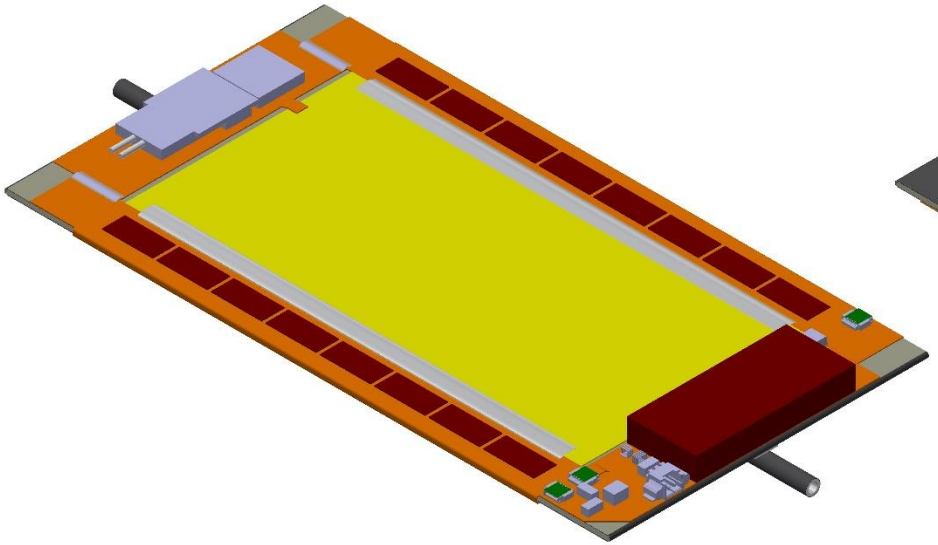


- Support from CF foam sandwich: unidirectional (UD) carbon fiber (0°/90°-layers each side) with Airex R82.60 foam in between
- Synthetic graphite tape (SGT) folded around support

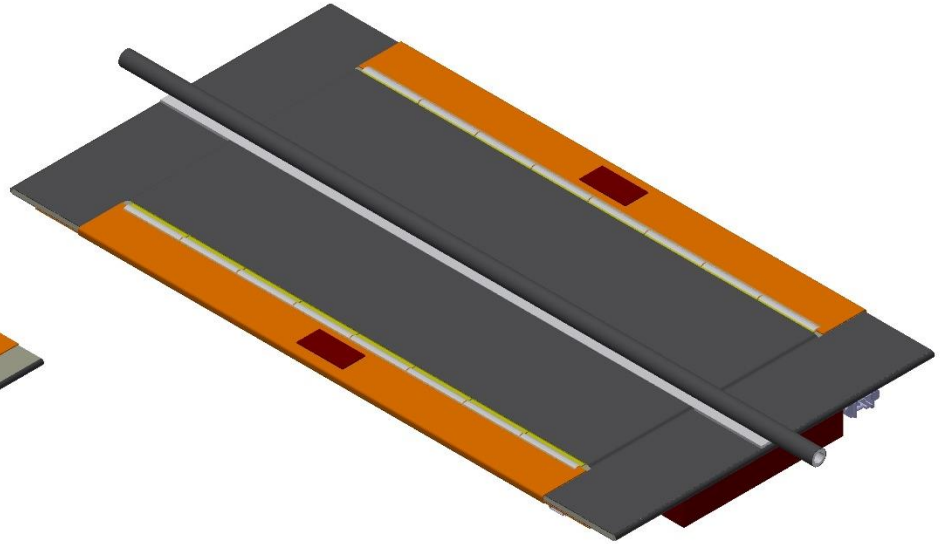
Module construction by simply pressing the parts on the adhesive glue layer (automatization possible)

PS module

Top



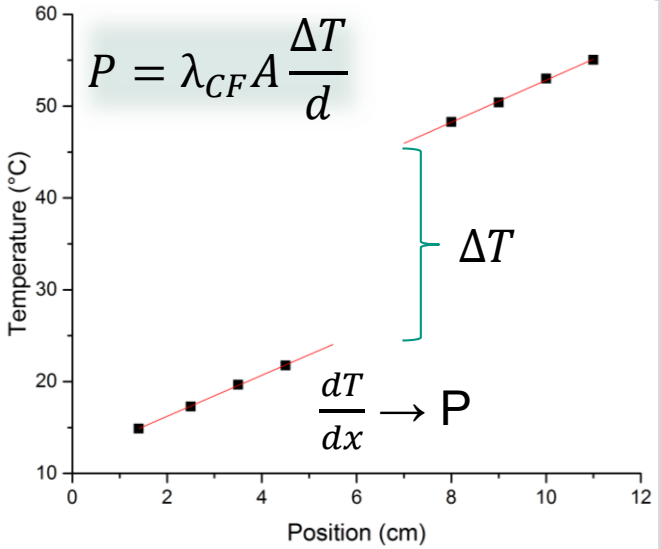
Bottom

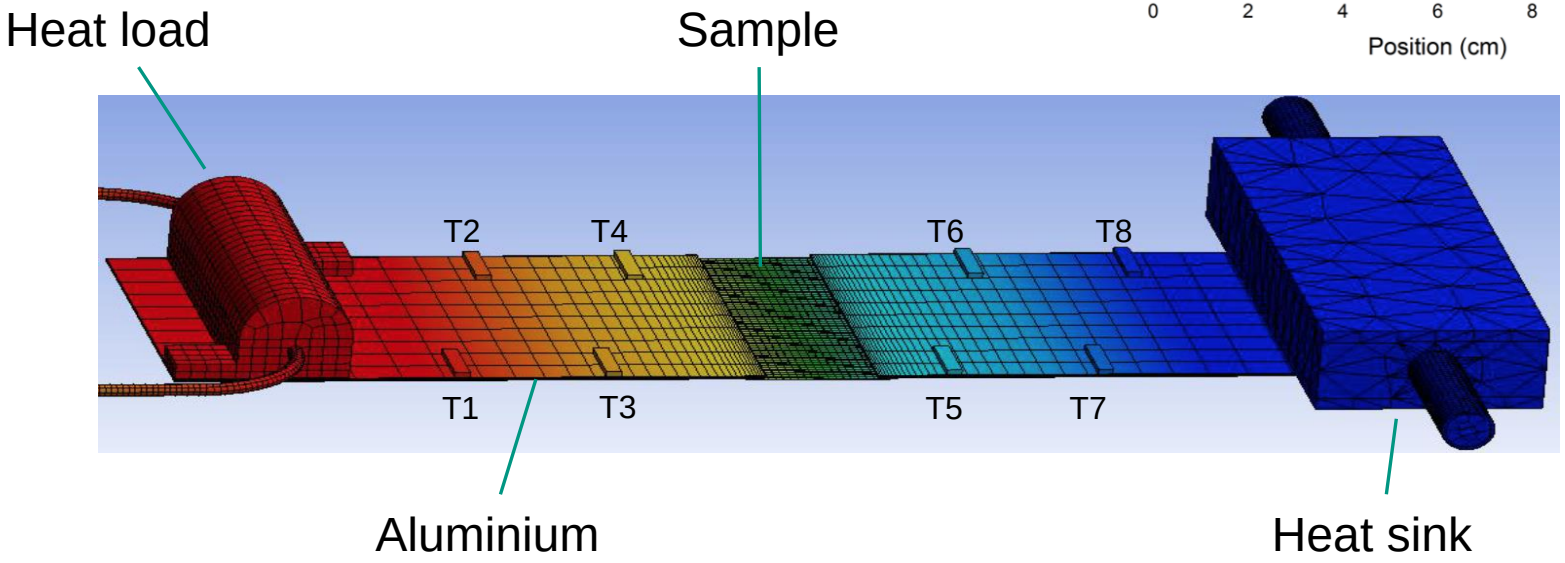


- Baseplate from synthetic graphite with cooling pipe glued to it
- Pixel sensor and MPAs at bottom generates 3W, so needs to be directly glued to cooling tube

Thermal conductivity measurement

- Problem to measure heat conductivity in thin layer: how much heat goes through the layer?
- Basic idea: conduct heat via known conductor between heat source, sample and heat sink and determine heat flow from temperature drop in the known conductor.





Results

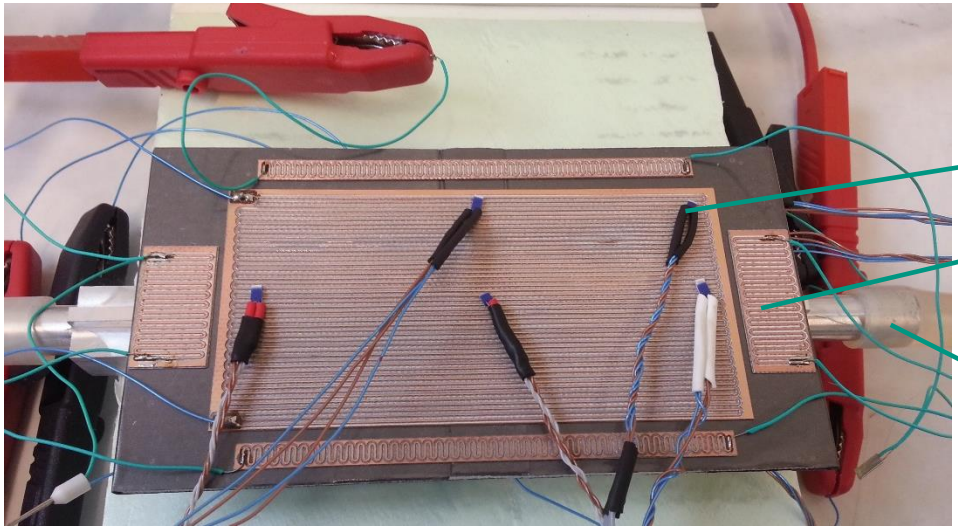
	CF			SGT
	Mitsubishi* 0°	**Mits. 0°/90°/0°**	**Granoc** 0°**	**DSN5040**
λ_x (W/mK)	270	143	220	600
λ_y (W/mK)	~1.6	80	1.6	600
λ_z (W/mK)	~1.6	~1.6	1.6	20
d (µm)	78	~200	50	40
ρ (g/cm³)	2.38	2.38	2.38	1.36

The heat conductivity of SG is in both longitudinal directions more than twice and in transversal direction more than ten times as good as CF

*K13D2U
**YS-90: E9026A-05S

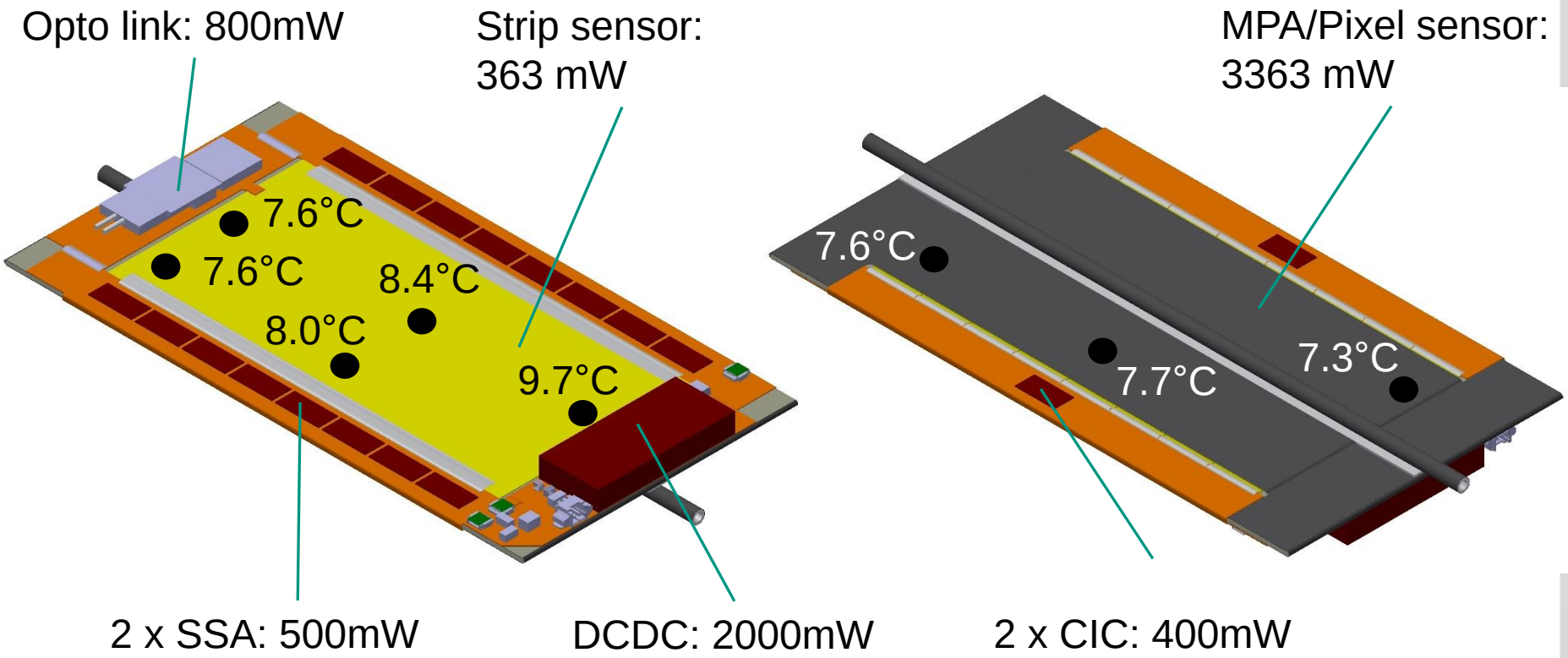
Thermal dummy PS module

- Support
  - Hot press process (4bar, 120°C, 2h)
  - 0°/90°/ Airex /90°/0°

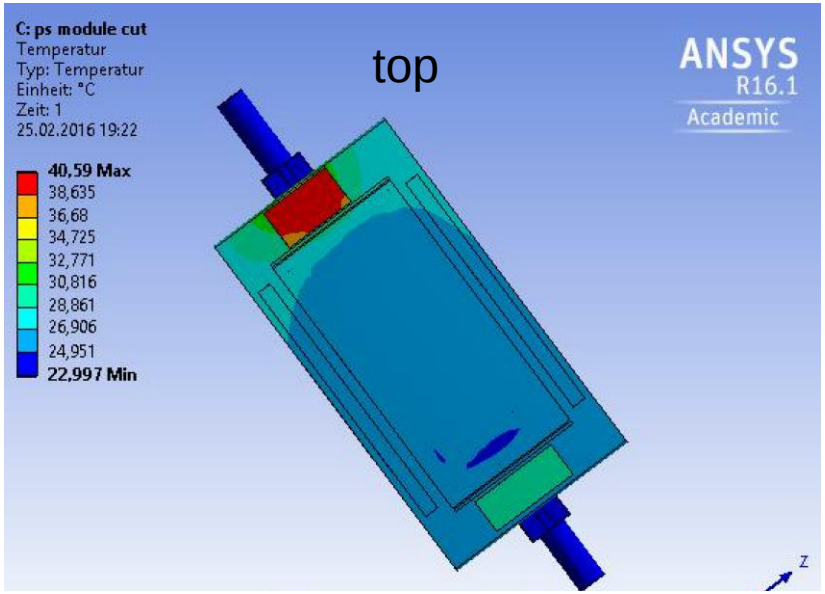


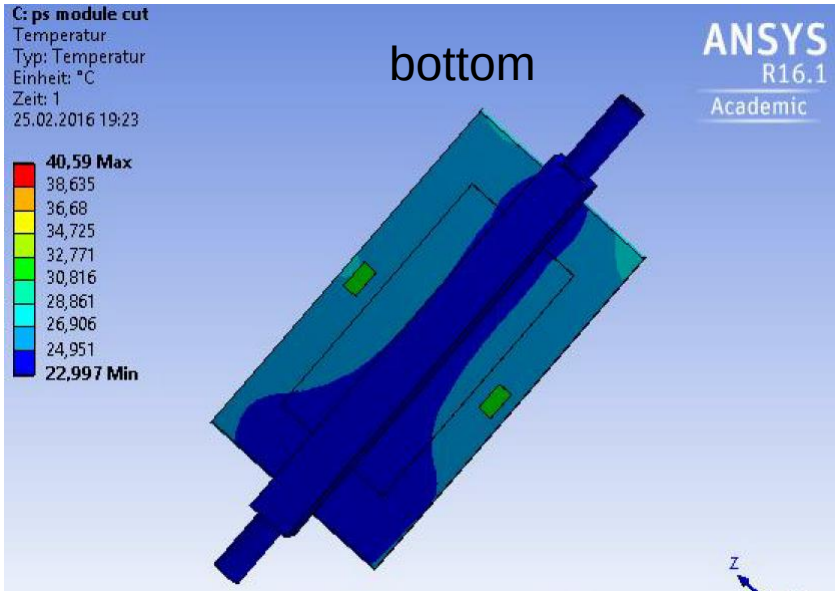
- Dummy module
  - temperature sensors
  - heating resistors (thin PCB with copper on both sides and top shaped as resistor)
  - water cooling (23°C)

Dummy PS module – ΔT measurements

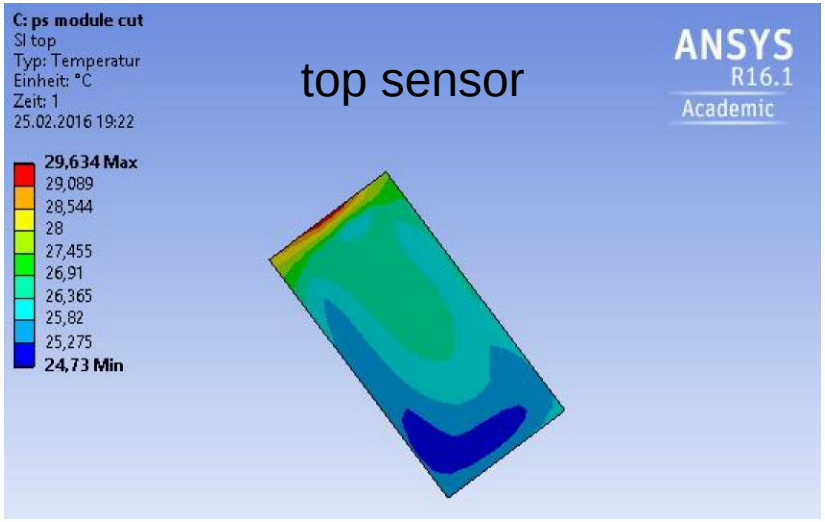


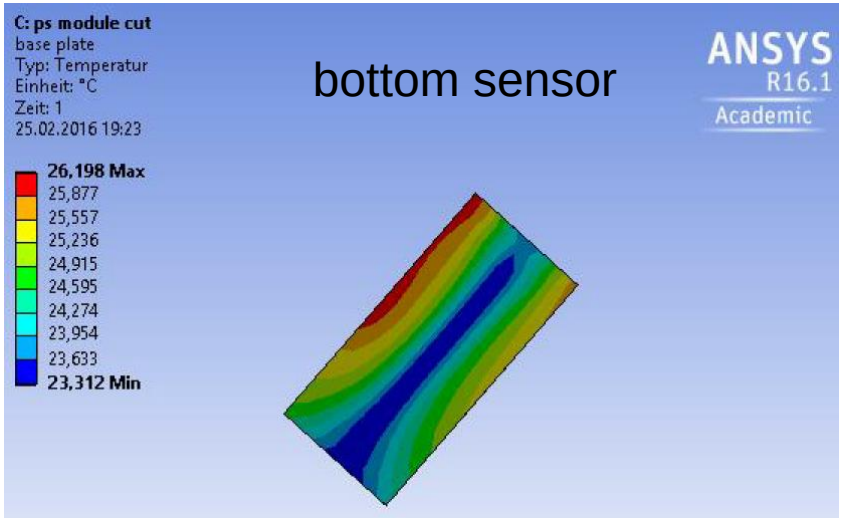
Dummy PS module – ΔT simulation





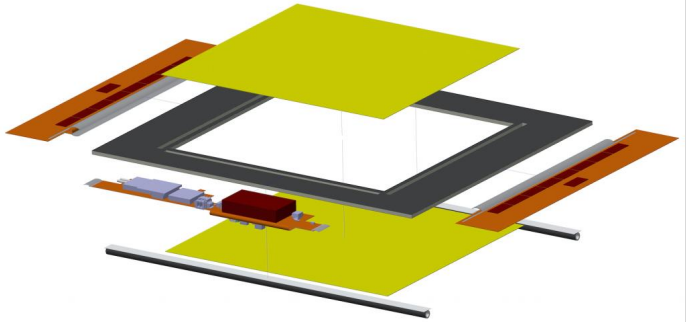
Coolant: 23°C

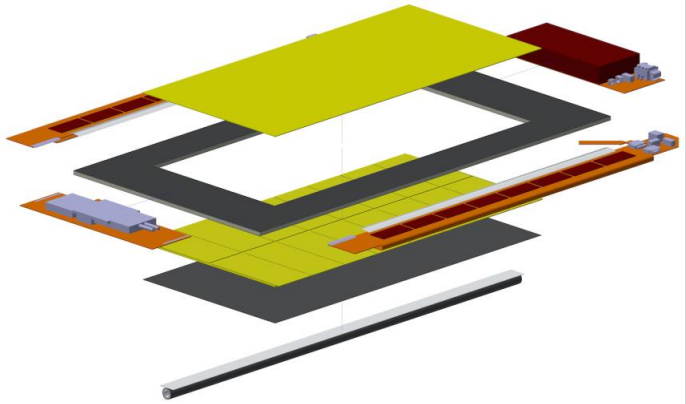




Conclusion

- SG tape interesting material for future module construction
- Sticks well to metal and CF by pressure sensitive adhesives
- SG tape allows for easy module construction (no curing time) and excellent thermal performance
- Proven to work for dummy prototypes





Backup

Calculation λ

- $P = \frac{\Delta T}{R} = \frac{\Delta T}{R_b + R_c}$
- $P = \lambda_{Al} A_{Al} \frac{dT}{dx}$
- $R_b = \frac{1}{\frac{1}{R_R} + \frac{1}{R_{CF}}}$

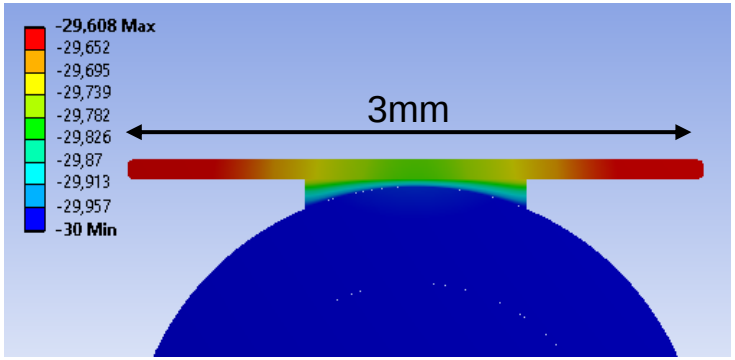
Rohacell

- $R_R = 1500\ K/W$
- $\lambda_{CF} = \frac{d}{R_{CF} \cdot A} = \frac{d}{R_{CF} \cdot b \cdot h}$
- R_c was determined with an aluminium-measurement as 3,3 K/W

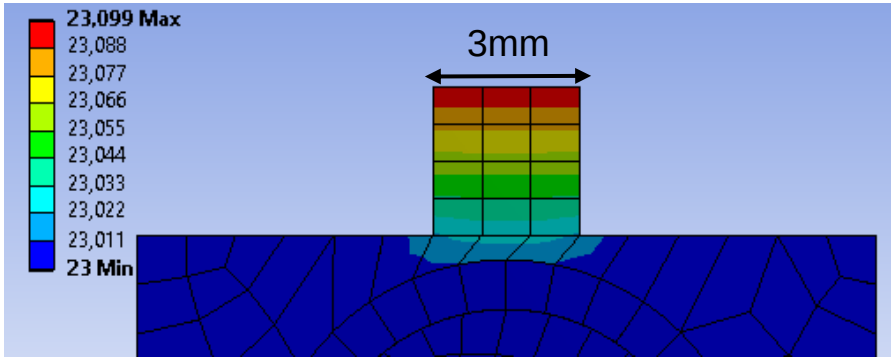
- Problems
  - Heat transfer trough the isolation → unable to measure big thermal resistances
  - No ideal setup, a vacuum tank instead of styrodur would be better

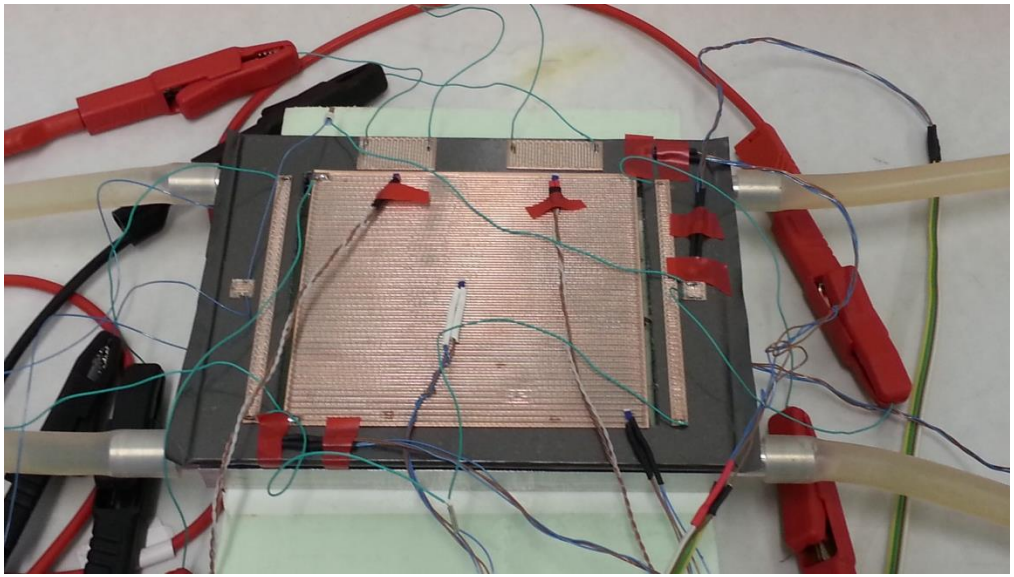
Thermal dummy module – cooling setup / 2S

Planned (CO_2)



Substitute





Thermal 2S dummy module - ΔT measurement