Usage of synthetic graphite in future tracking detectors

DPG Münster 29.03.17 – HK 36.9

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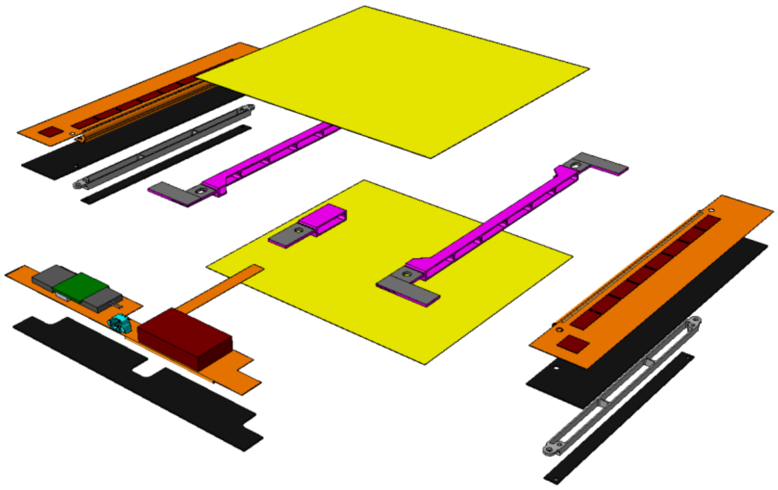
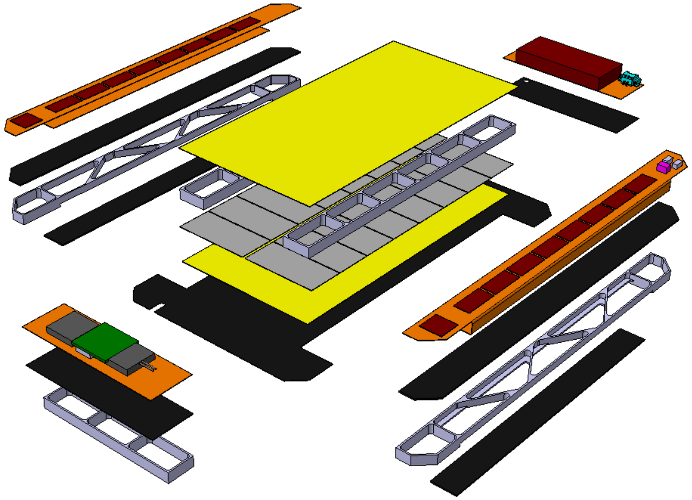
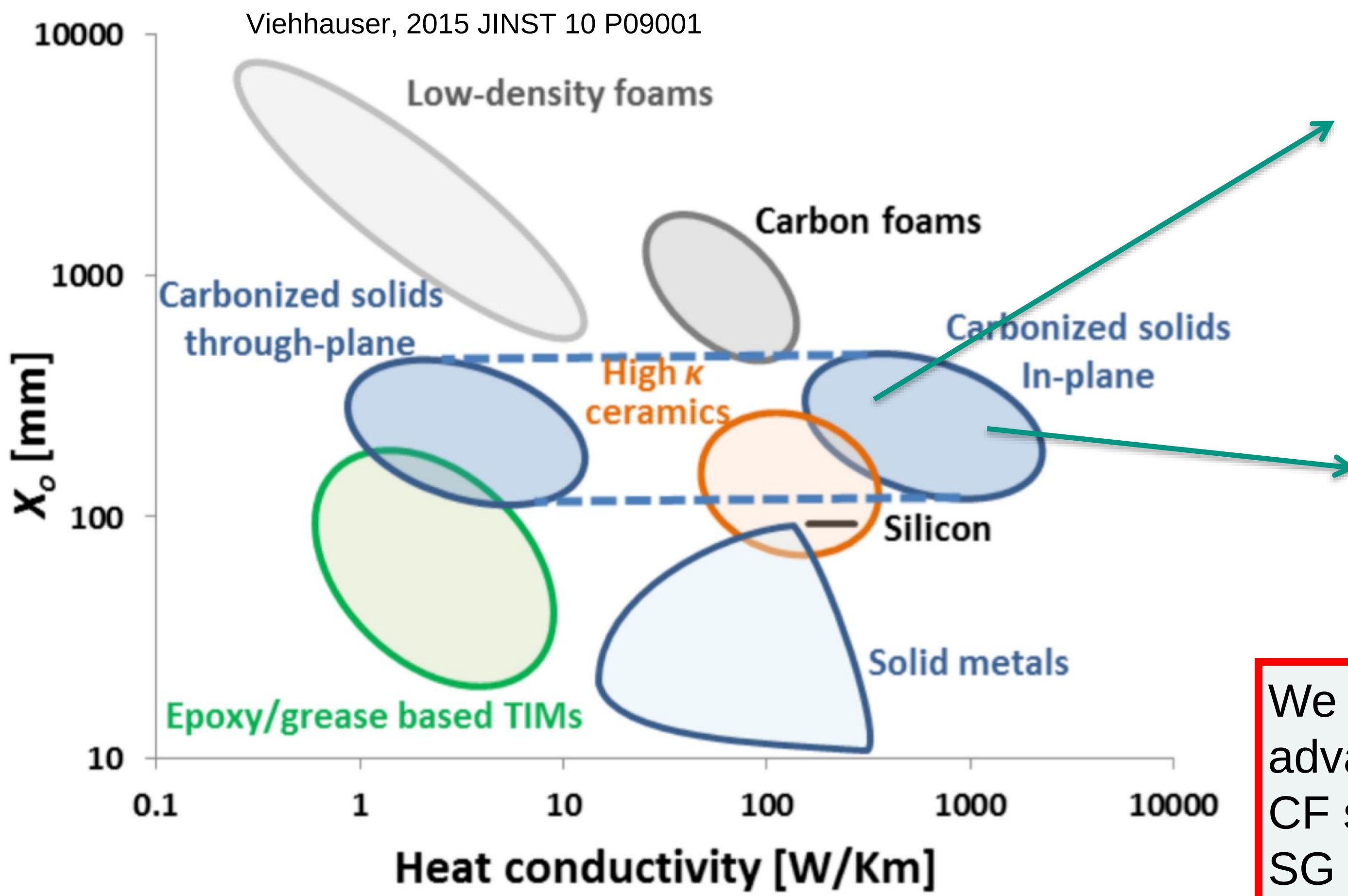




Heat conduction materials



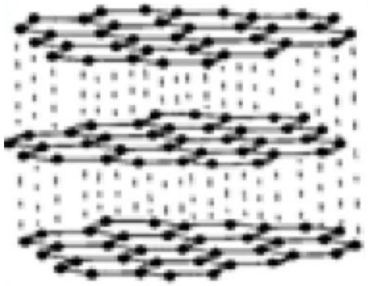
Carbon fiber (CF) in epoxy matrix (strong, medium heat conductivity

Synthetic graphite (SG), double sided adhesive

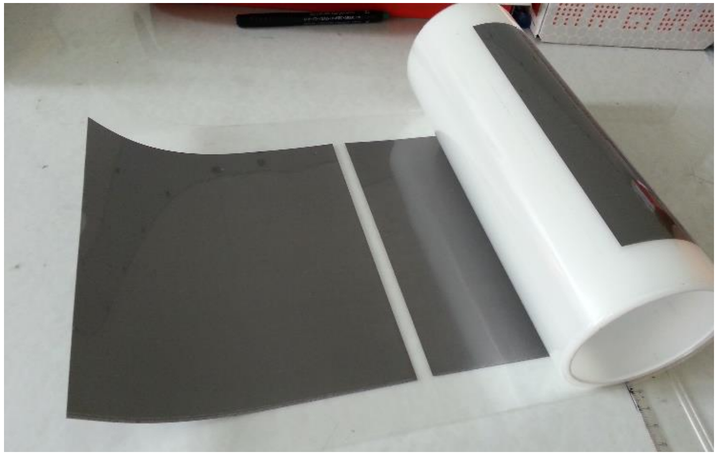
We combined the advantages:
CF sandwich with SG tape to glue components of sensor modules

Synthetic graphite

- Produced by sintering polyimide tape above 3000°C (plasma ovens) so carbon changes into liquid crystal phase and forms highly conductive graphene layers in x,y directions

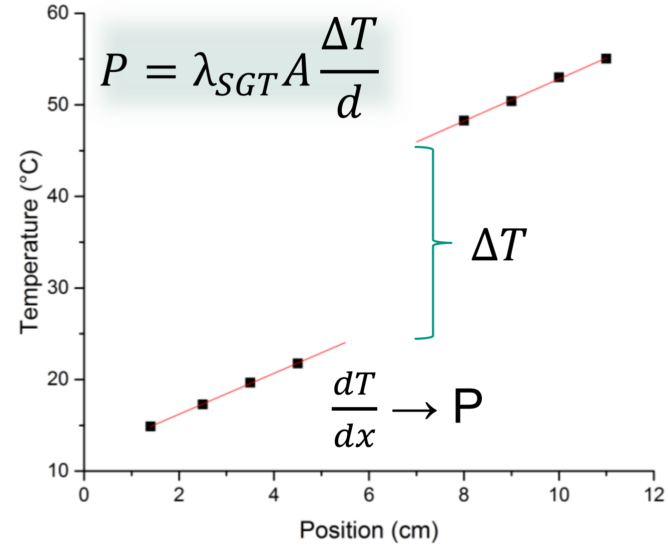


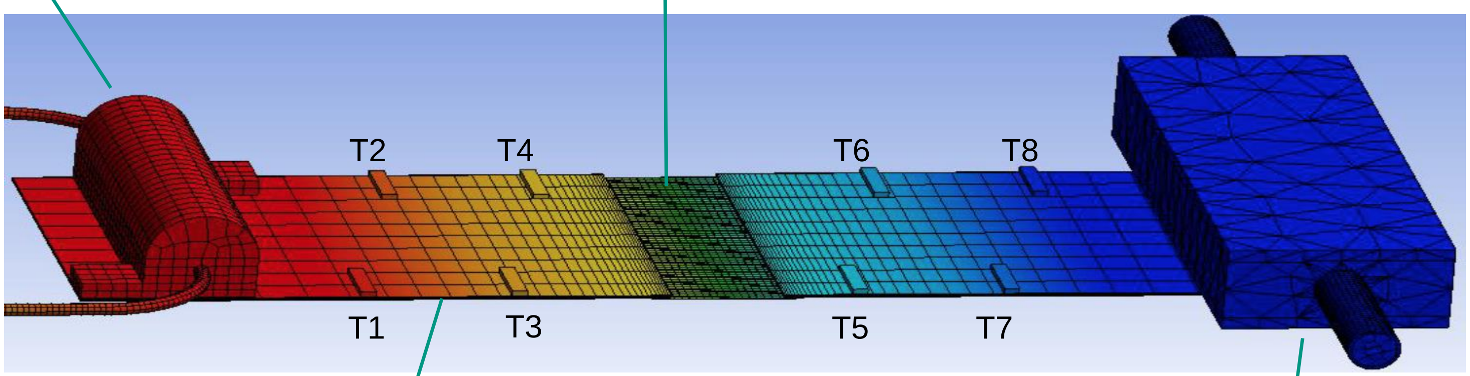
- Graphite covered with adhesive layers on both sides, so it can be directly glued to components
- Thermal link between components and cooling structure
- Adhesive PET layers withstand HV
- Widely used for cooling in electronics (mobile phones,…) so cheap and many manufacturers (providing precut shapes)



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.





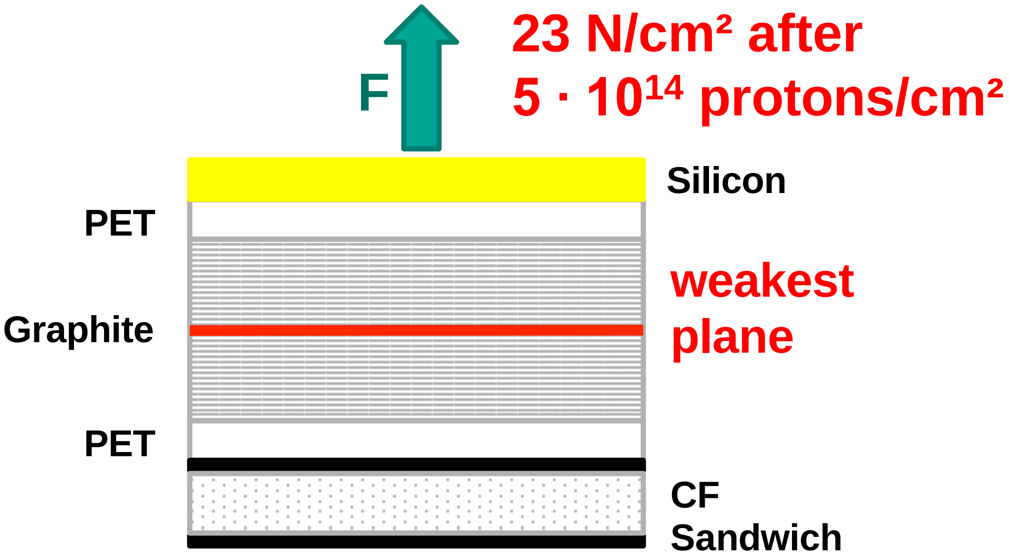
Thermal conductivity of various SGTs

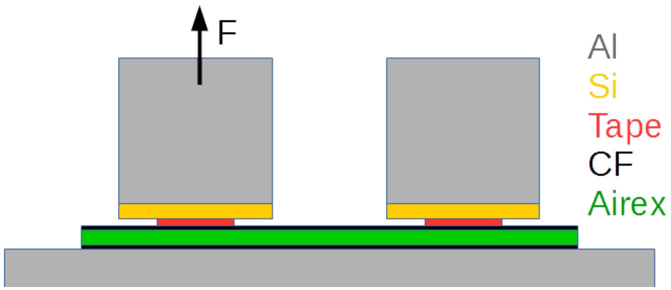
SGT	Graphite (µm)	Total (µm)	$\lambda_{Gr.,man.}$ $(\frac{W}{mK})$	R $(\frac{K}{W})$	$\lambda_{Gr.}$ $(\frac{W}{mK})$	$\lambda_{eff.}$ $(\frac{W}{mK})$
FGS-020[1]	200		600	6.9 (±0.3)	216 (±9)	
FGS-0125[1]	125		700	11.8 (±0.5)	203 (±9)	
BM1000[2]	150		600	21.2 (±0.6)	95 (±3)	
BM1000[2]	70		600	22.9 (±0.9)	187 (±7)	
GS2000[2]	45		1200	14.6 (±0.8)	455 (±25)	
TSM-1500D[3]	25	49	1500	13.9 (±1.3)	864 (±78)	442 (±40)
DSN5025-05C05C[4]	25	35	1500	14.5 (±1.3)	824 (±74)	593 (±53)
DSN5025-12C12C[4]	25	49	1500	14.3 (±1.3)	834 (±74)	427 (±38)
DSN5040-12C12C[4]	40	64	1200	12.4 (±0.8)	602 (±37)	379 (±23)

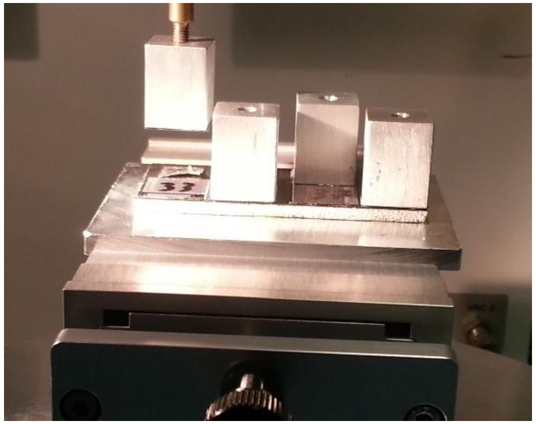
[1] Amec Thermasol
[2] Shenzhen JRFT Electronic Technology Co., Ltd.
[3] Shenzhen Laimeisi Silicon Industry Co., Ltd
[4] Suzhou Dasen Electronics Material Co, Ltd.

Irradiation tests of SGT – Pull forces

- Maximal force allowed on SGT, measured by pull test machine, was about 40 N/cm². Break at weakest point: graphene layers.



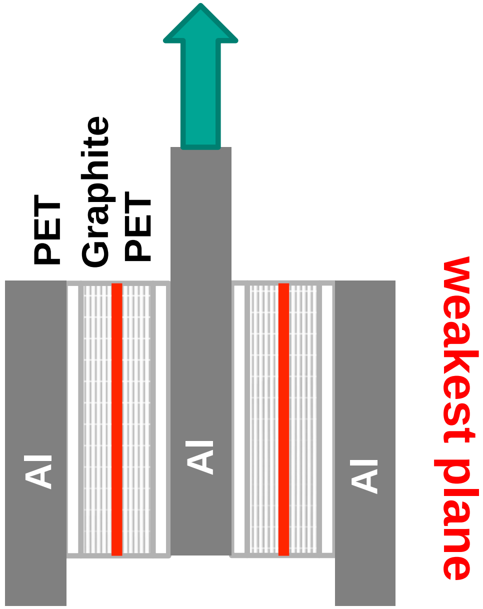


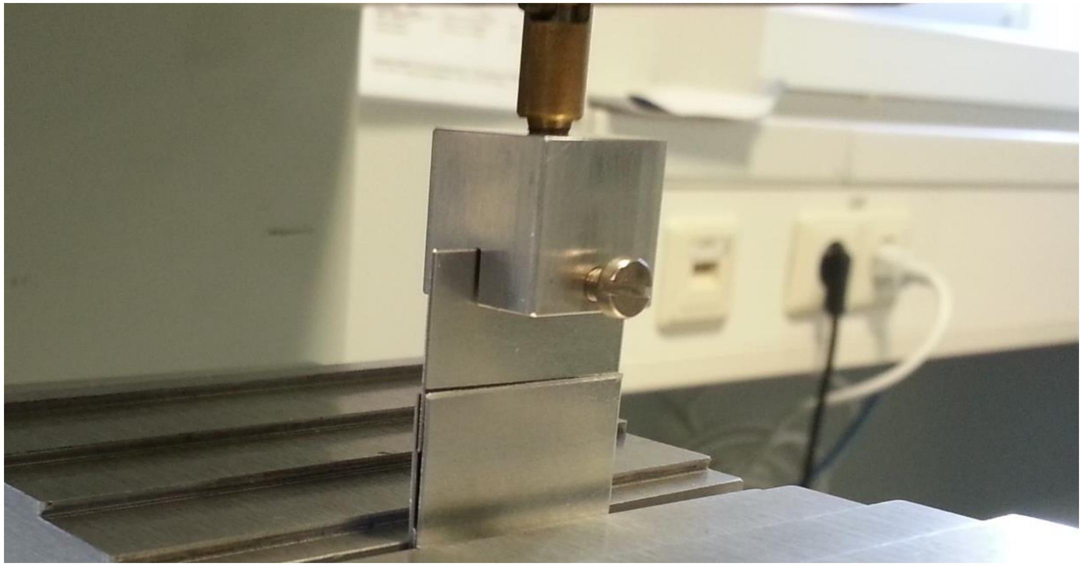


- Irradiation of 5·10^{14} protons/cm² reduces strength by about 40% (23 N/cm²)

Shear forces

- The graphene layers in the SGT are only weakly connected by Van-der-Waals forces, so they easily slide over each other

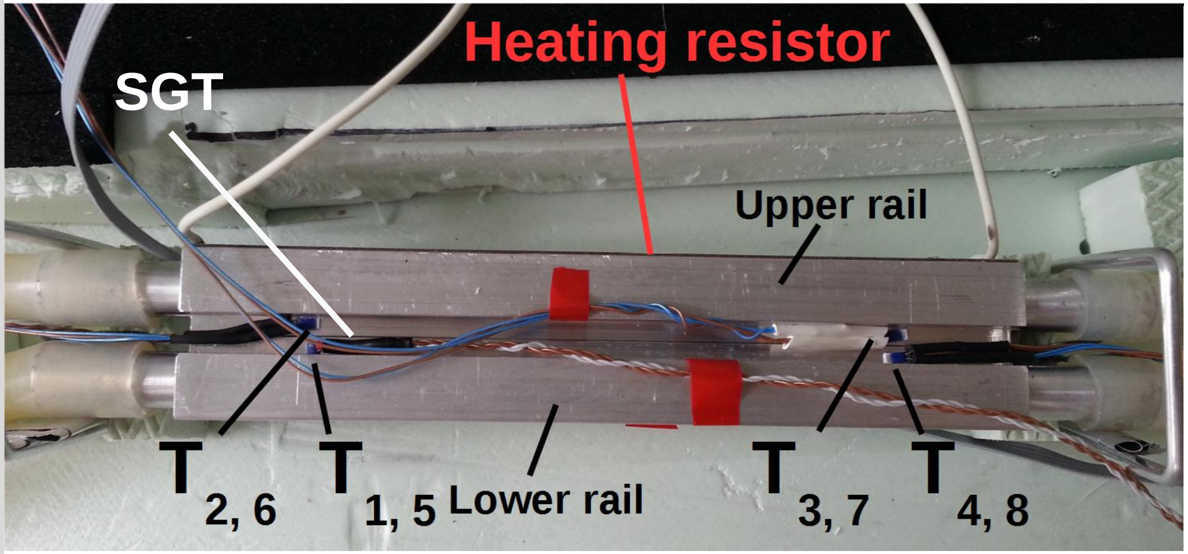


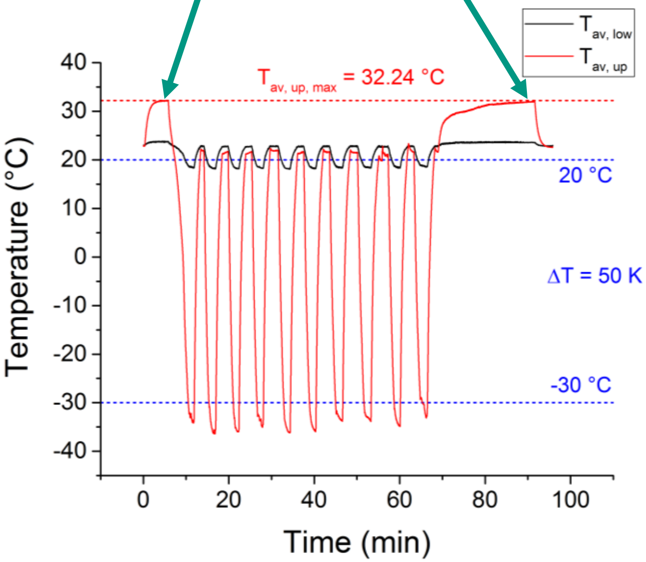


- 29 N/cm² enough to withstand thermal stress due to different CTE of glued components

Shear forces due to CTE mismatches

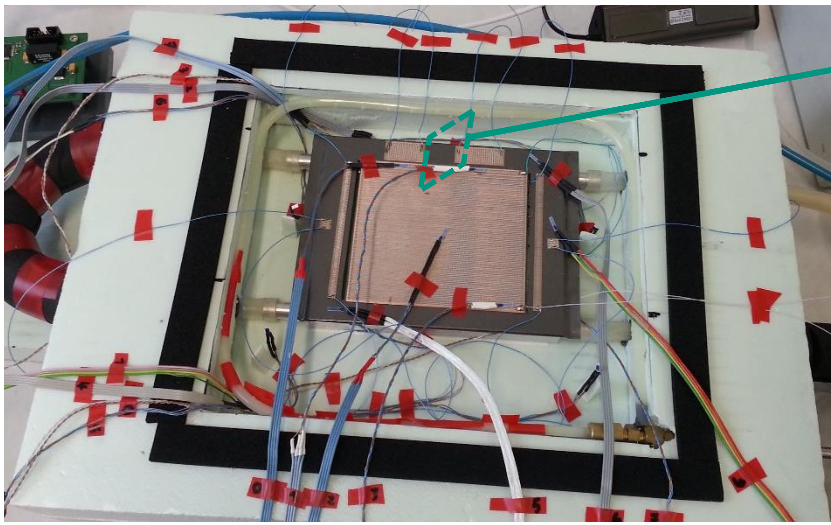
- Two aluminum rails connected by SGT
- Shear force on SGT generated by cooling down one rail (CTE Al: $22 \cdot 10^{-6}$)
- Thermal connection of the SGT was not affected by many thermal cycles between 20ºC and -30ºC

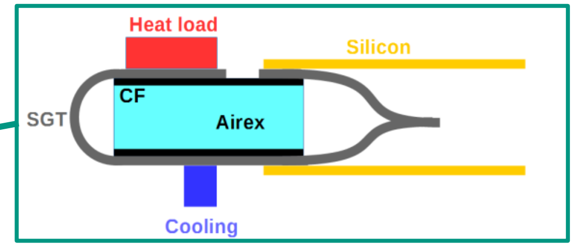


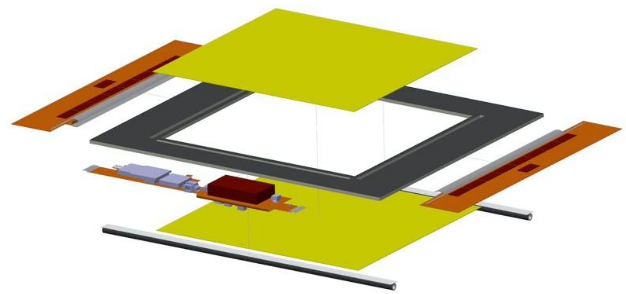


Example of application – CMS like modules

- The CMS tracker of the Phase II Upgrade consists of ~ 14000 modules with different granularities





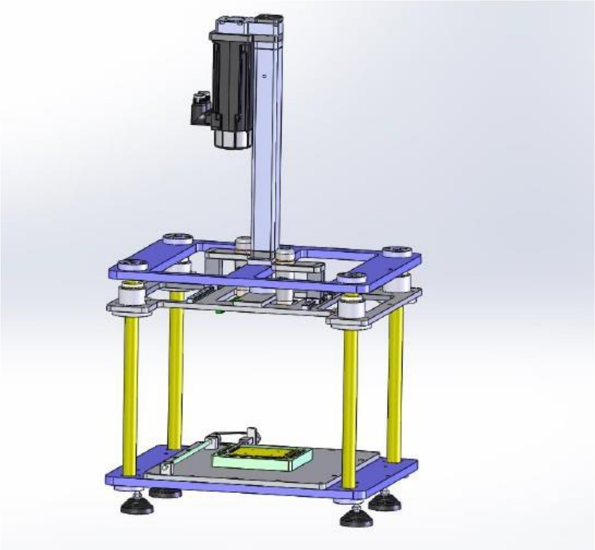


- With SGT complex cooling structures can be realized very easily due to its flexibility

Advantages of taped concepts

- By using taped components fast production procedures are possible

→ Semi-automated module production with gantries by pressing few parts together



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 with CMS-like dummy prototypes yielding **mechanically robust and radiation hard modules with excellent thermal performance with standard materials**