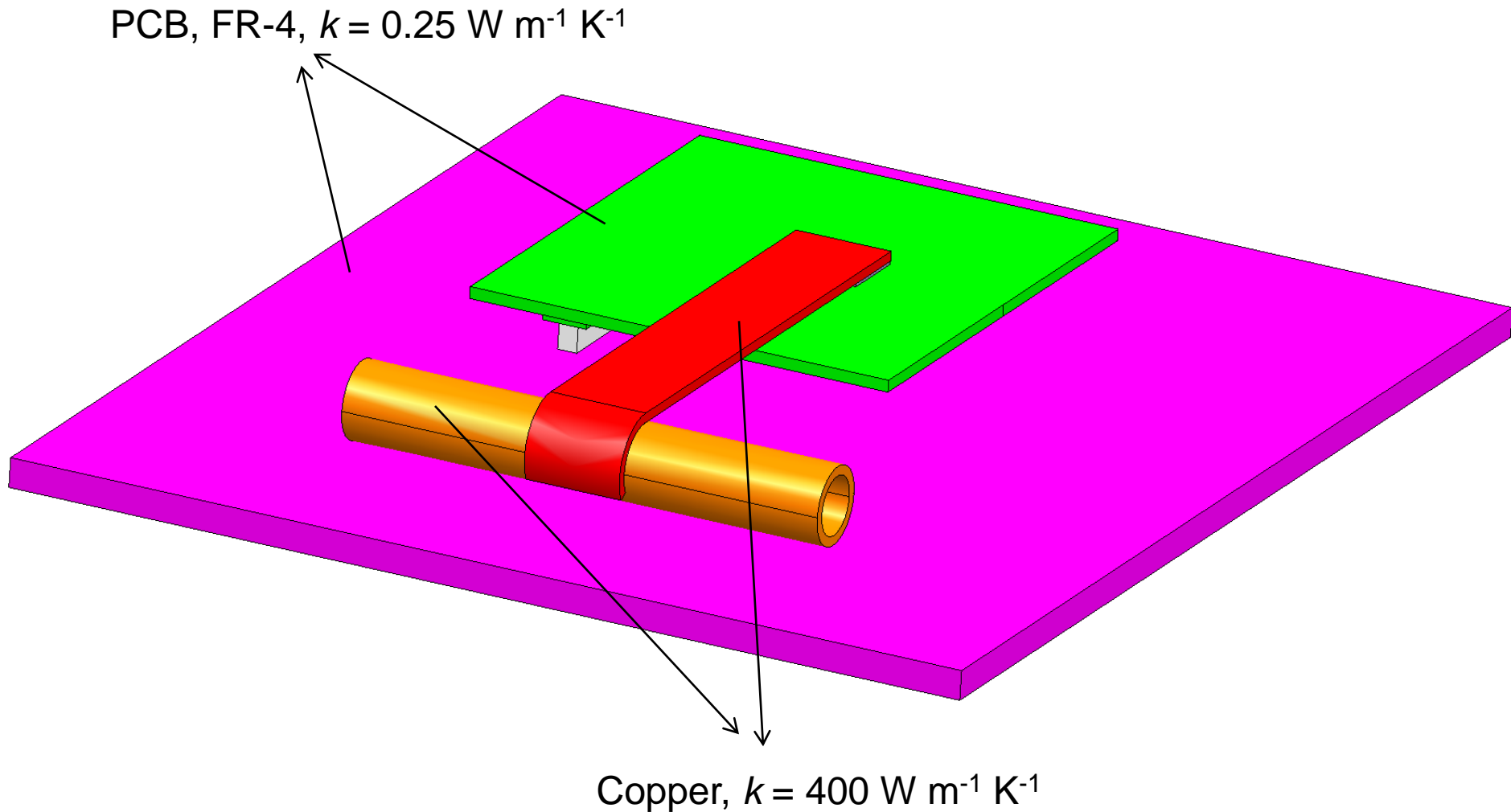


Cooling of GEM detector

CFD-2012-03_GEM
2012/03/13

1. Geometry and material properties



A single chip is considered in the CFD simulations

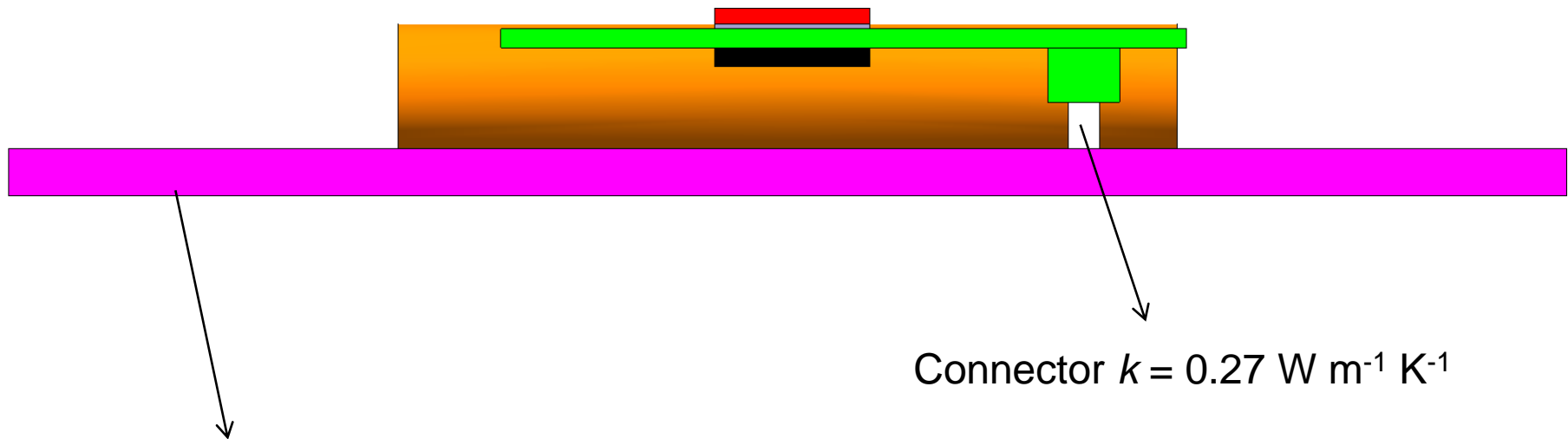
Soldered = perfect thermal contact

Gap-pad $k = 2 \text{ W m}^{-1} \text{ K}^{-1}$

Chip, silicon, $q = 1 \text{ W}$

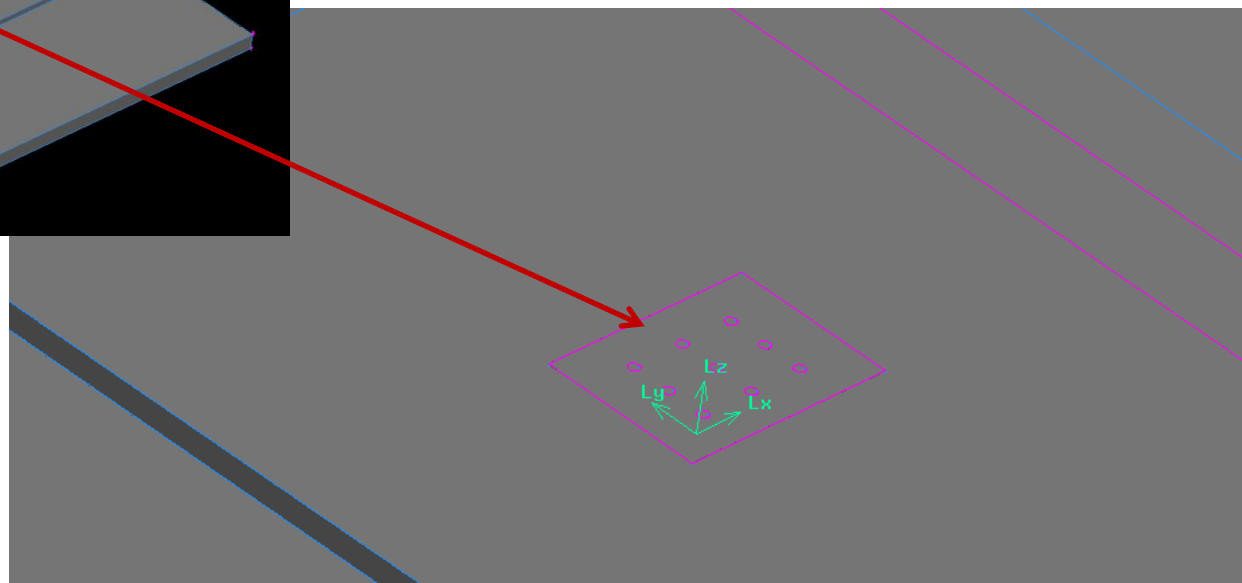
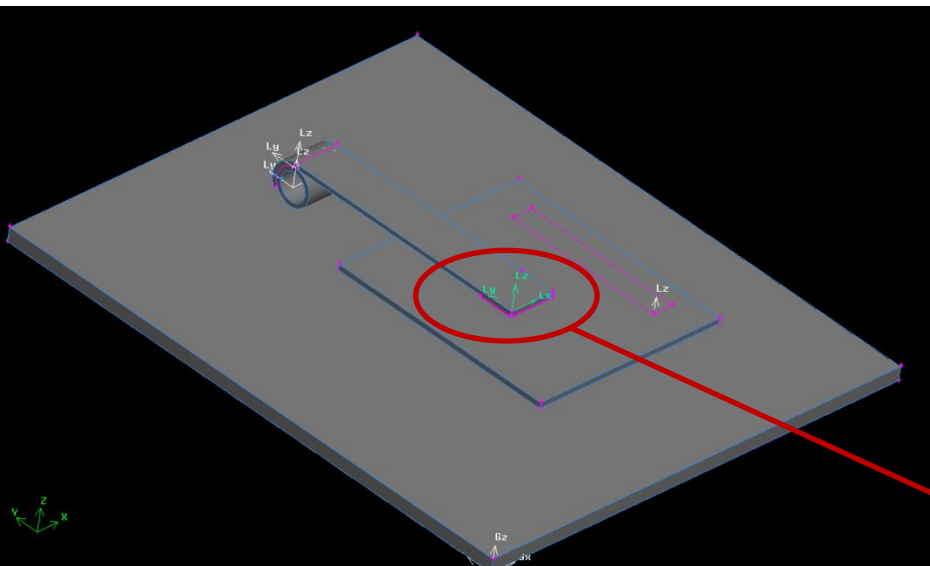
Water, $T = 18^\circ\text{C}$

All surfaces are adiabatic but the inner surface of the pipe



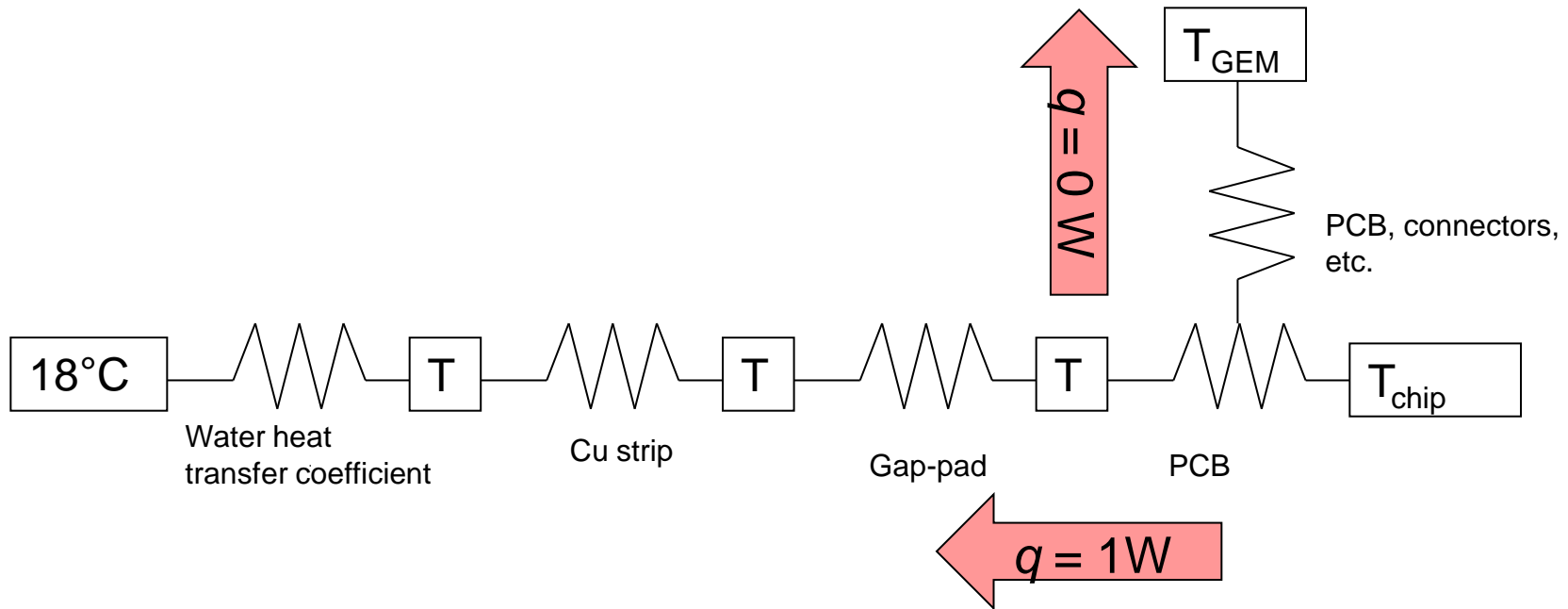
Connector $k = 0.27 \text{ W m}^{-1} \text{ K}^{-1}$

Volume including the GEM sensors is not taken into account.
This surface is assumed as adiabatic.



9 copper cylinders (0.5 mm diameter) thermally connect the chip to the gap-pad through the PCB

2. Schematic and estimations



- ❑ The temperature of the GEM sensors will be the same as the PCB.
- ❑ In order to reduce the sensor temperature, the thermal resistances must be reduced:
 -) higher water flow rate -> higher heat transfer coefficient
 -) shorter Cu strip or larger “cross section”
 -) thinner gap-pad or higher thermal conductivity
 -) good thermal contact Cu strip/gap-pad and gap-pad/PCB
 -) bigger or higher number of copper thermal vias through the PCB

- Heat load per VFAT chip = 1 W
- # VFAT chips = 30
- Total heat load = 1 W * 30 + 4 W = 34W

Di [mm]	Vel. [ms ⁻¹]	Flow rate [kg s ⁻¹]	Temp. rise [K]	Re [-]	HTC [Wm ⁻² K ⁻¹]	Δp (2 m pipe) [bar]
6	1	0.028	0.29	5700	4700	0.06
6	1.8*	0.051	0.16	10200	8200	0.17
4	1	0.013	0.65	3800	4500	0.11
4	1.8*	0.023	0.36	6800	8400	0.28

* Erosion limit for copper pipe

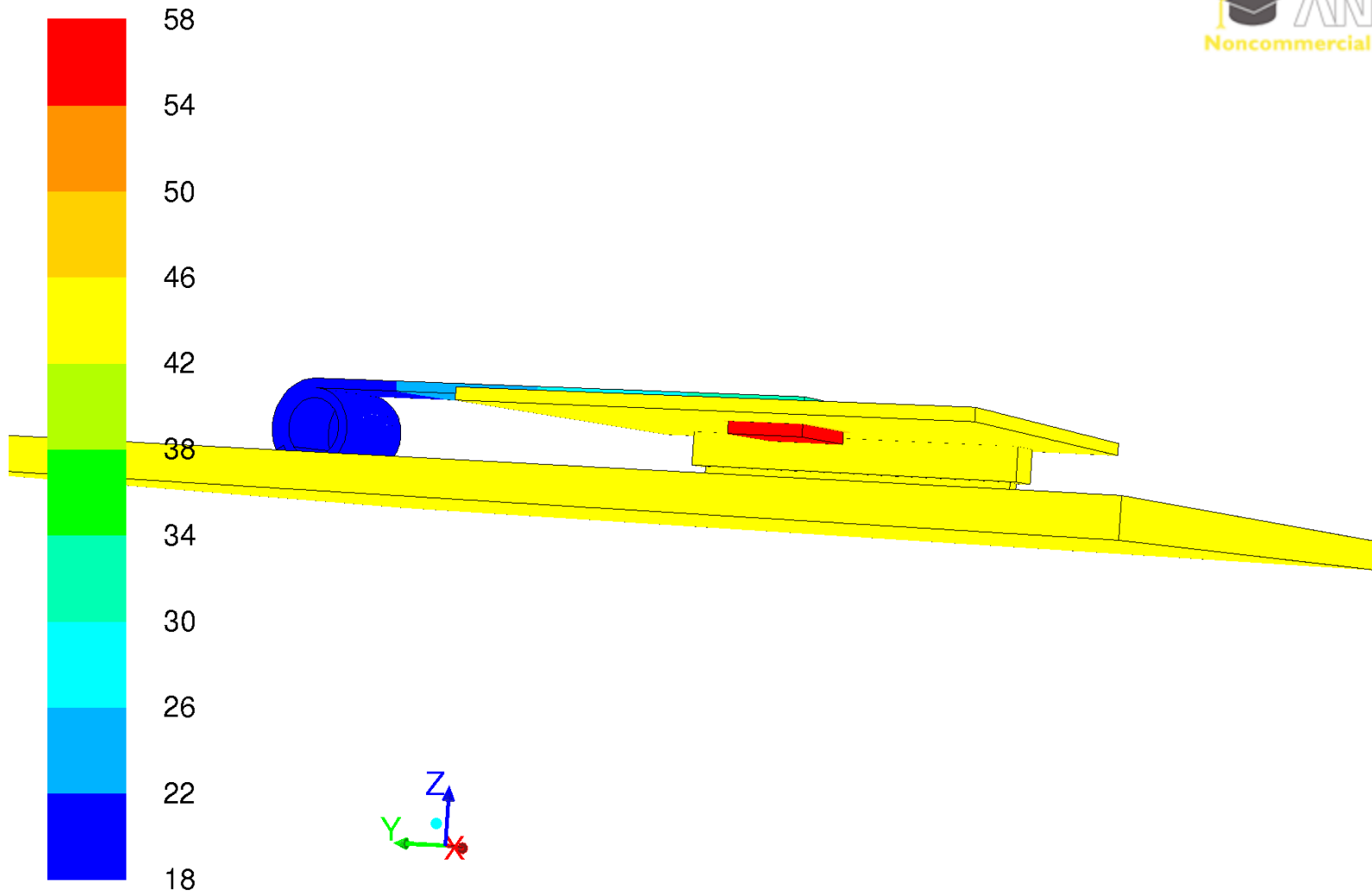
- Low water temperature rise is good to achieve a uniform sensor temperature.
- The diameter of the pipe may be reduced if needed because of geometrical constraints.

3. Simulation results

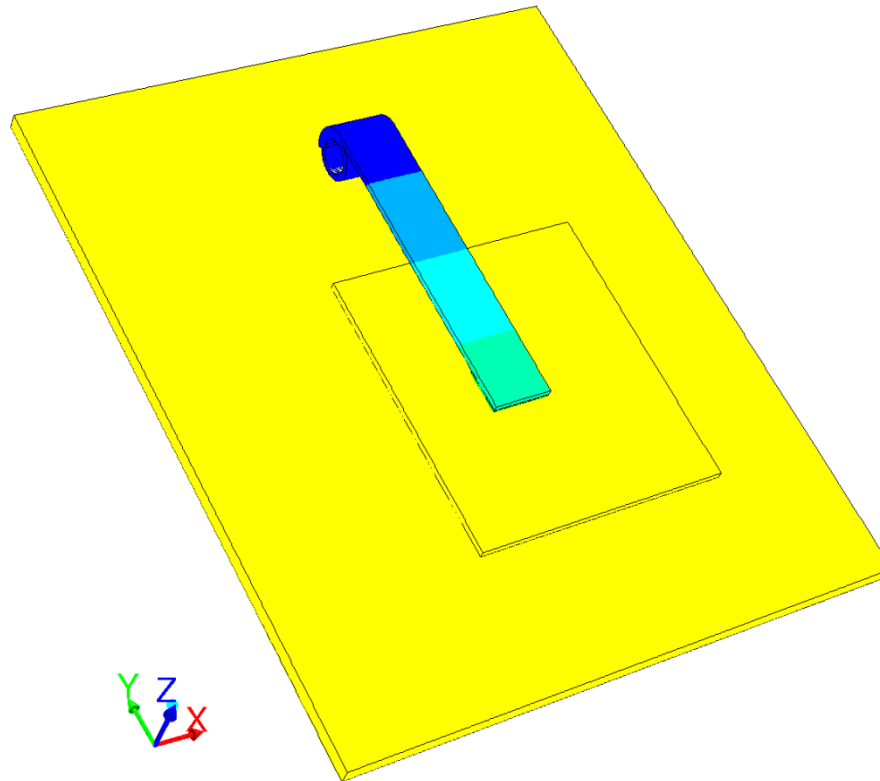
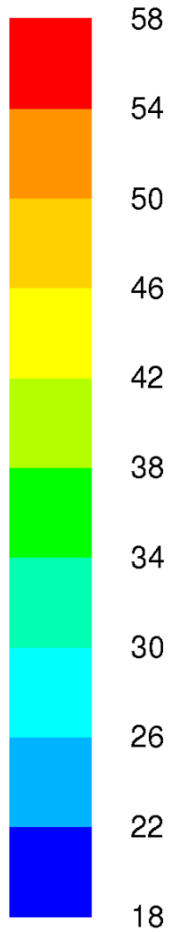
□ Different geometries have been studied and compared:

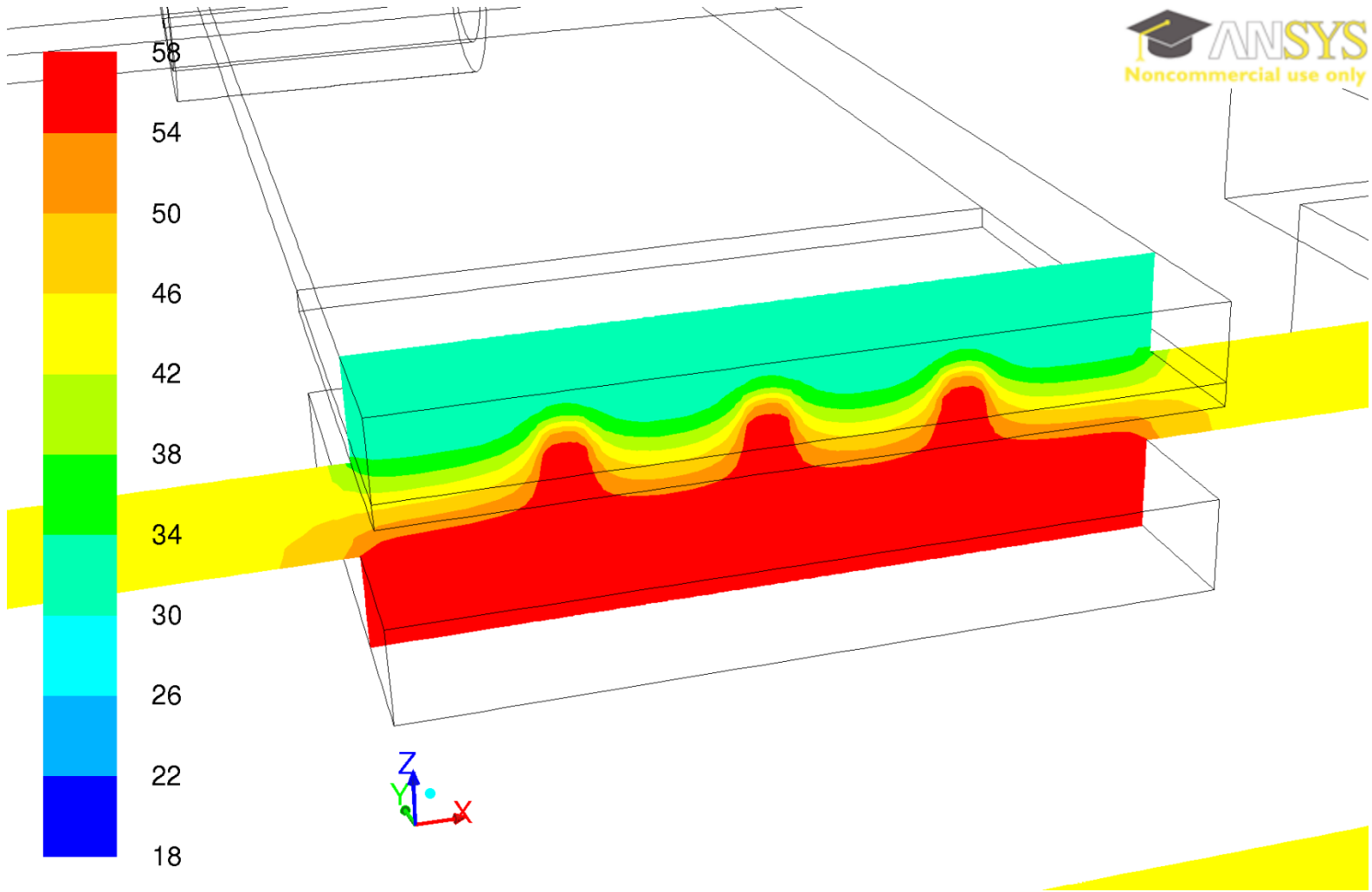
1. Reference geometry: 10 mm wide, 1 mm thick copper sheet
2. Reference geometry with lower contact area between copper sheet and water pipe
3. Y-shaped copper sheet (40 mm at pipe side, 10 mm at PCB side)
4. Wider copper sheet (40 mm) with 10 mm wide gap-pad
5. Wider copper sheet with wider gap-pad (40 mm)

1) Reference geometry

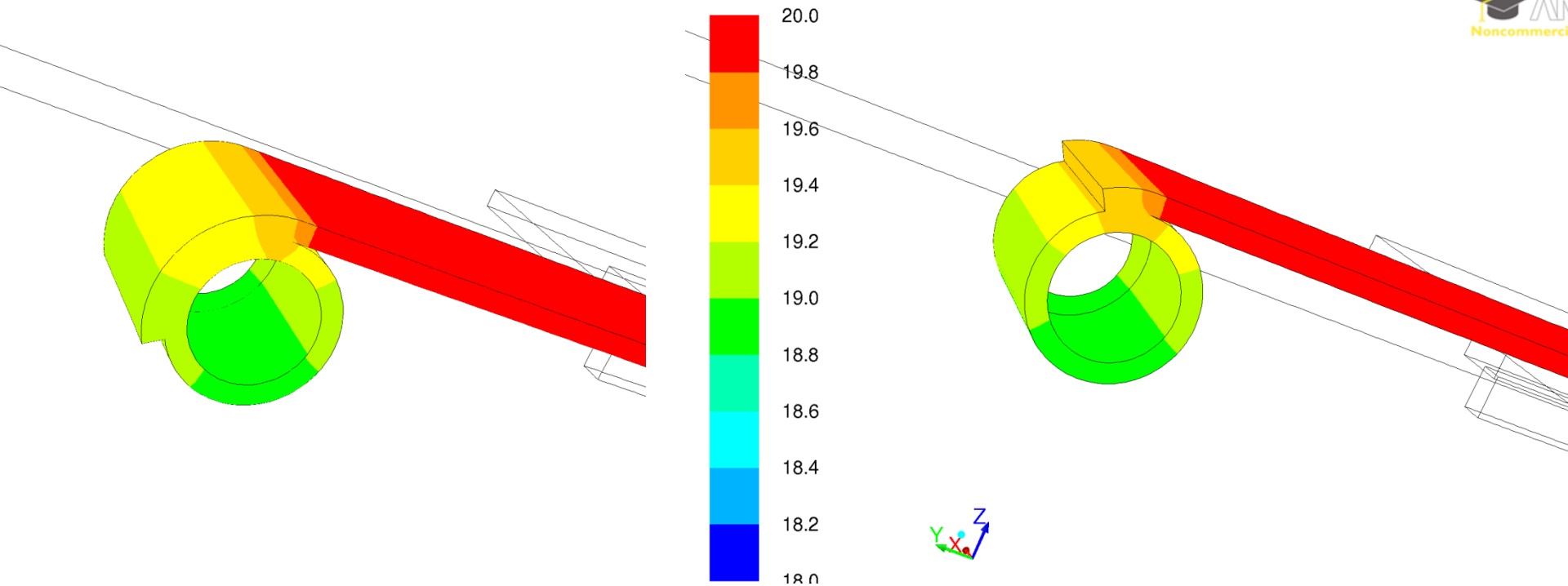


1) Reference geometry

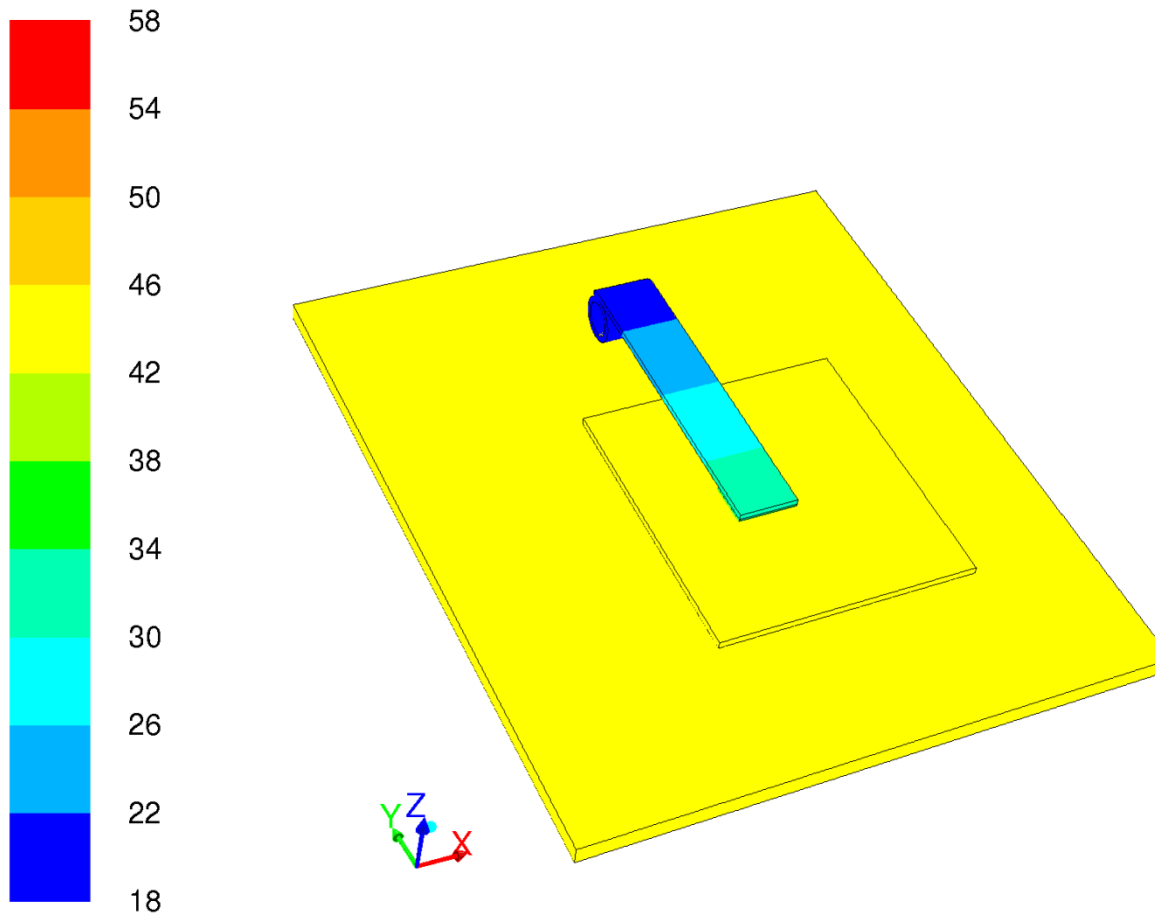




Cross section with copper thermal vias

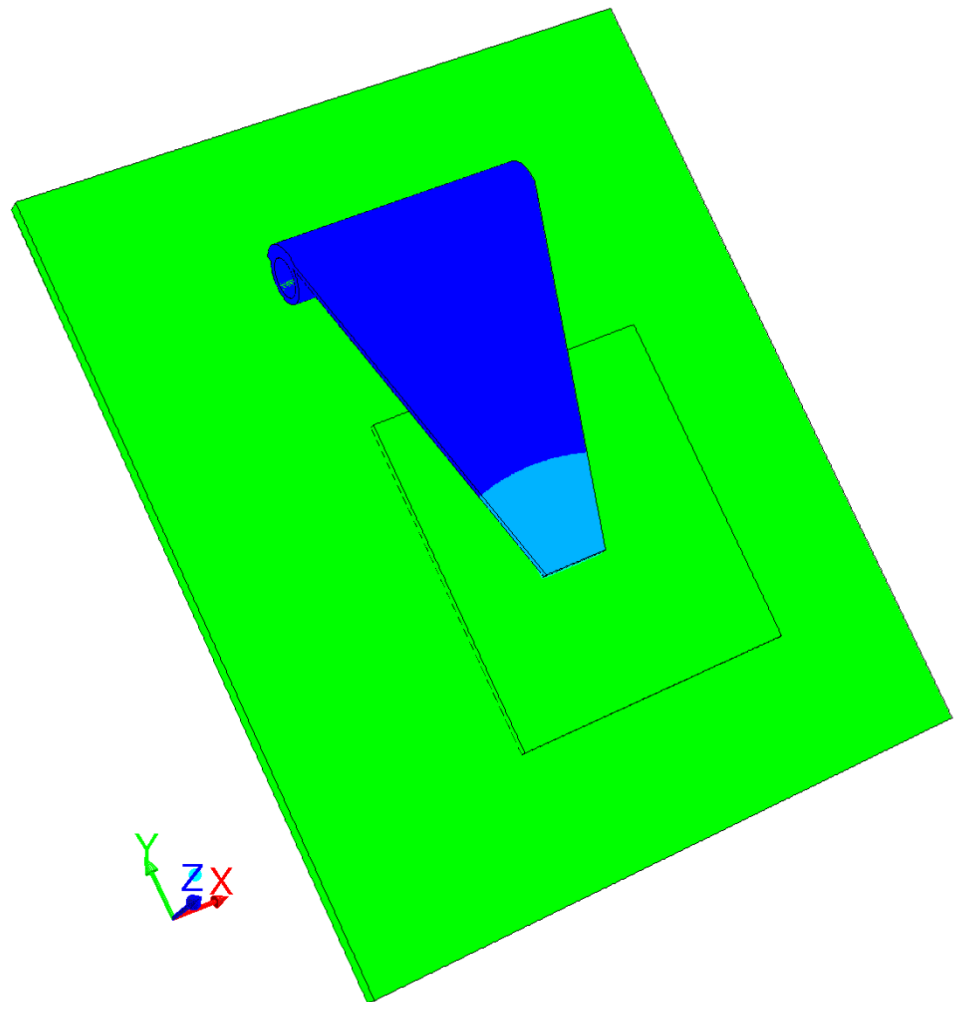
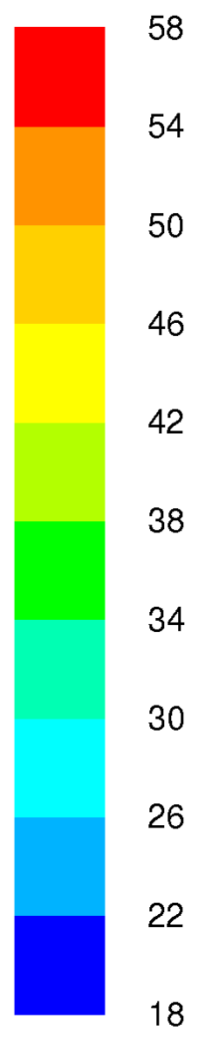


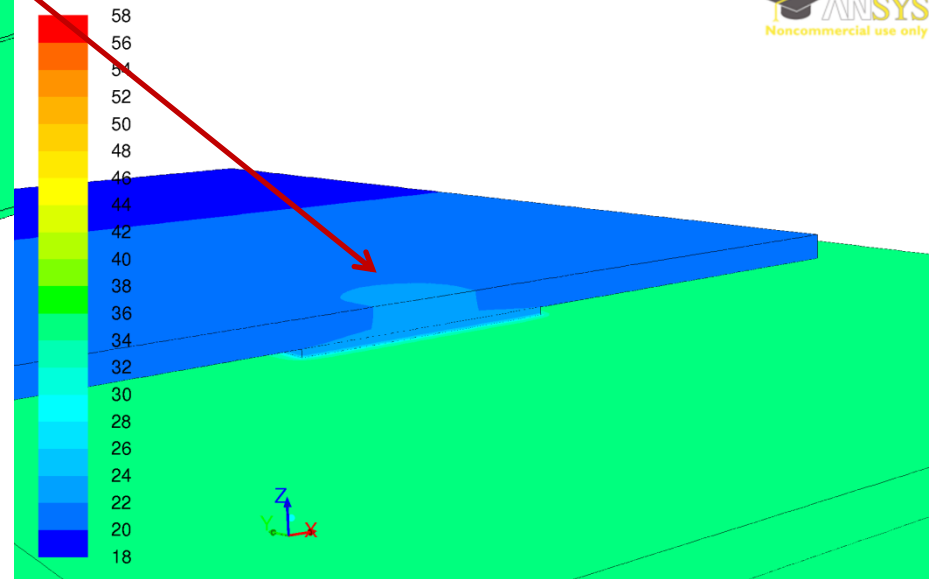
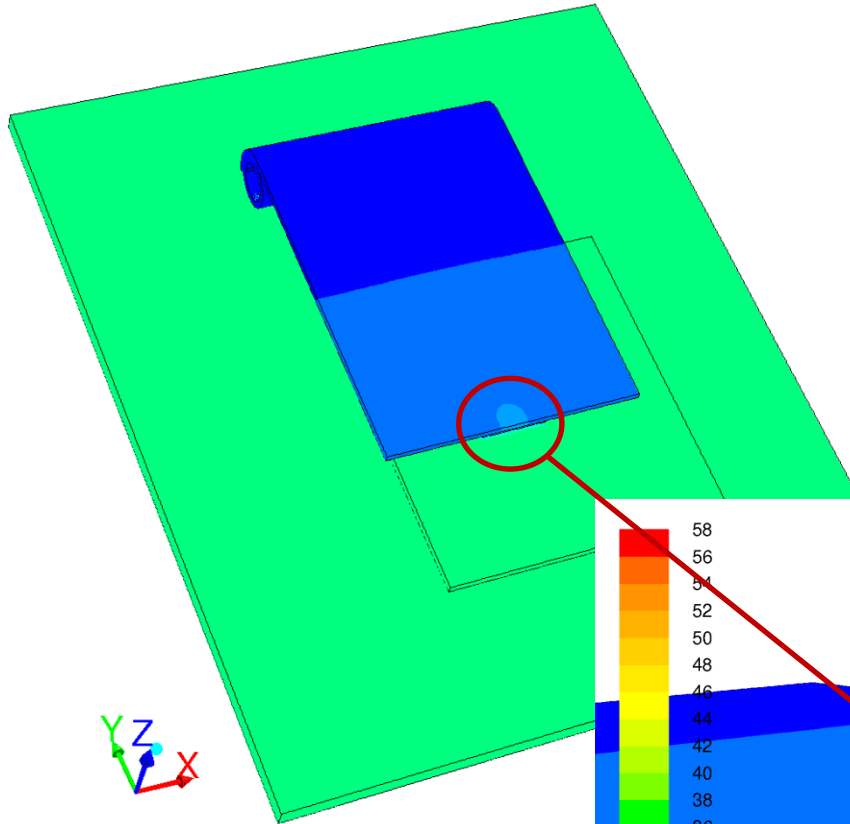
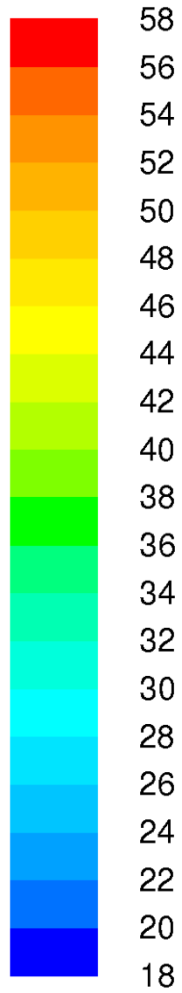
- Negligible influence of the reduced soldering area
- Around 1~2 K temperature drop due to the water heat transfer coefficient

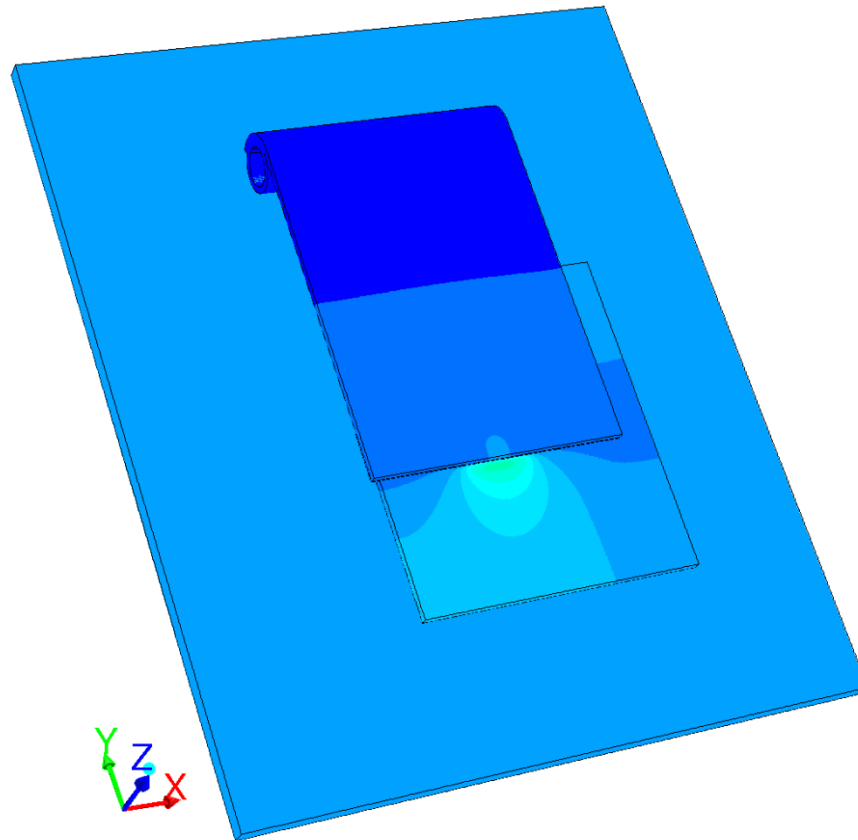
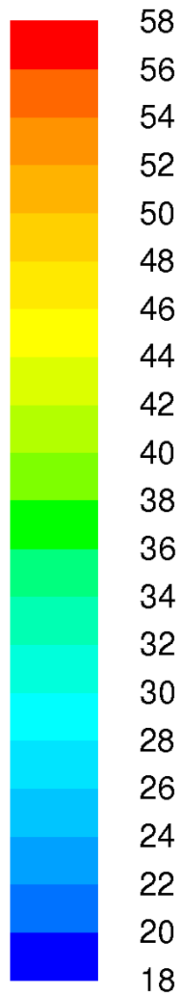


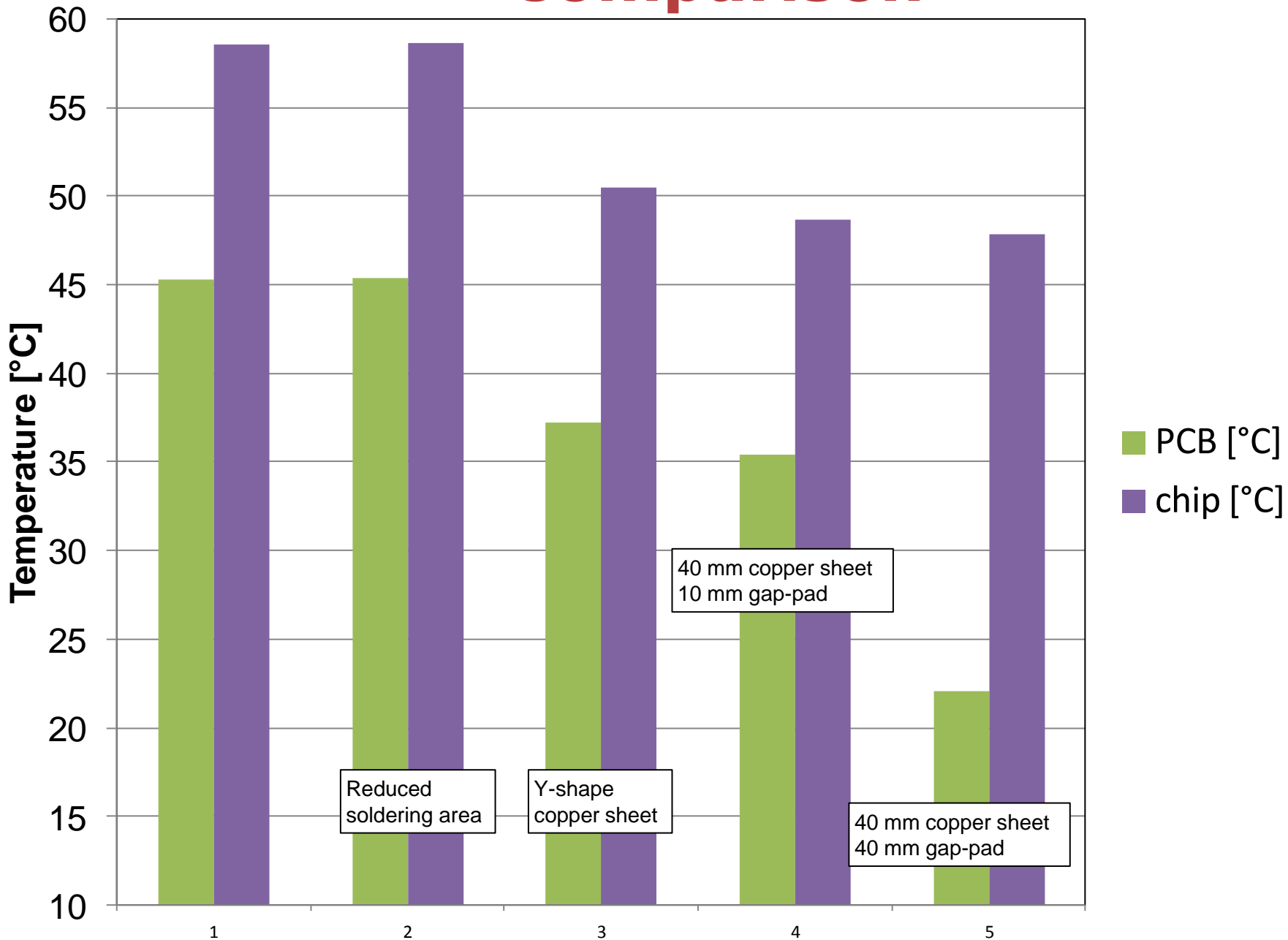
Same thermal performance as the reference geometry

3) Y-shape copper sheet









Conclusions

- 6 mm i.d. pipe, with 1 ms⁻¹ water velocity is enough to keep the water temperature rise below 0.3 K and achieve a good enough heat transfer coefficient with low pressure drop.
- Soldering area between copper sheet and pipe does not have a major influence.
- PCB temperature strongly depends on the width of the copper sheet and contact area among copper sheet, gap-pad and PCB.
- With 40 mm wide, 1 mm thick copper sheet + 40 mm X 10 mm gap-pad (0.3 mm thick) the PCB temperature is expected to be below 25 °C.
- Cooling of “dividers” is still an open issue.
- The gas flow around the GEM sensors (not taken into account in the present simulation) helps cooling the sensors and keeping the temperature uniform.
- If possible, increasing the copper sheet thickness is a another “cheap & easy” way to improve the thermal performance.