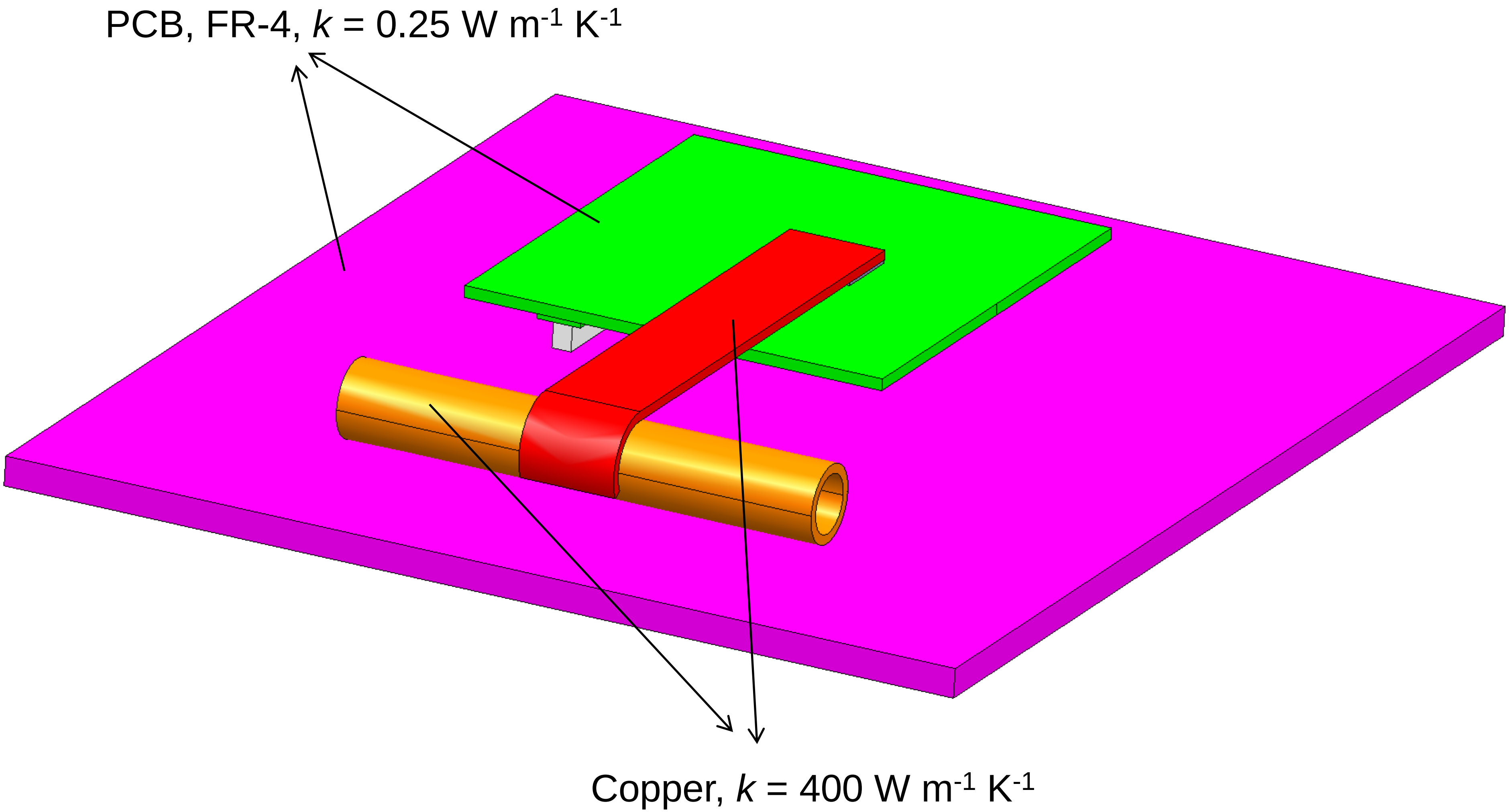
Cooling of GEM detector

CFD-2012-03_GEM

2012/03/13

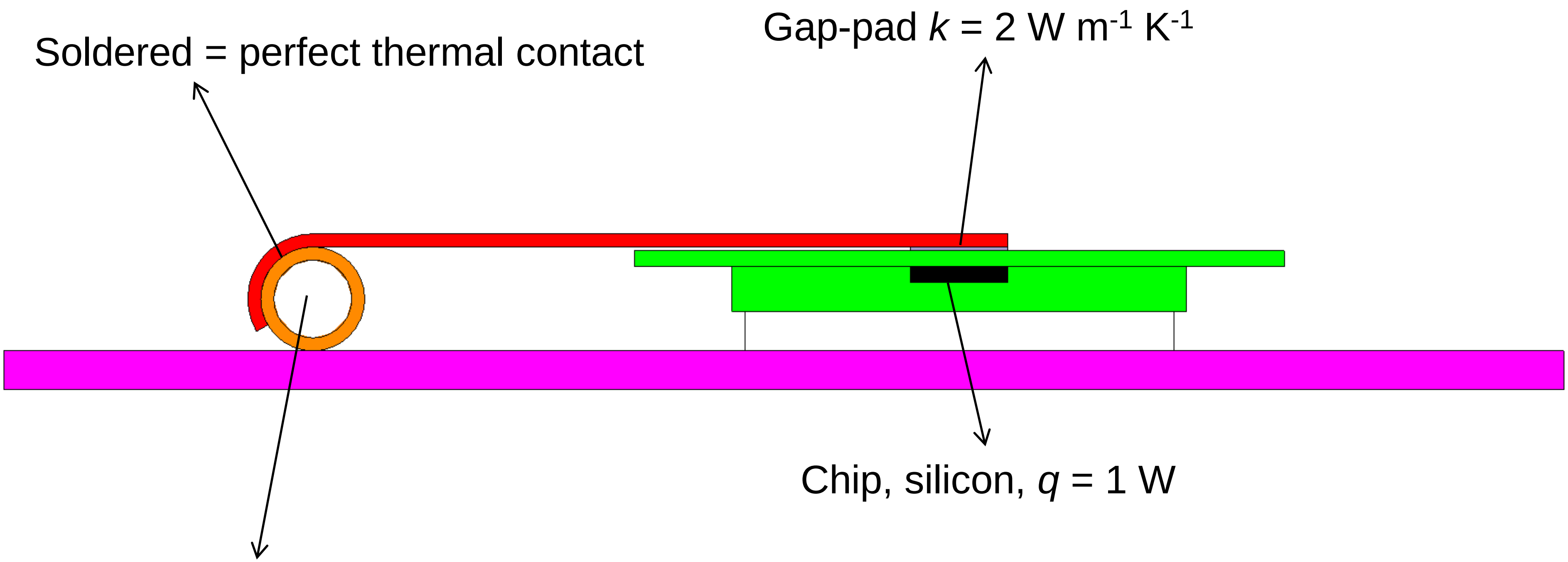
1. Geometry
and
material properties

Geometry and material properties



A single chip is considered in the CFD simulations

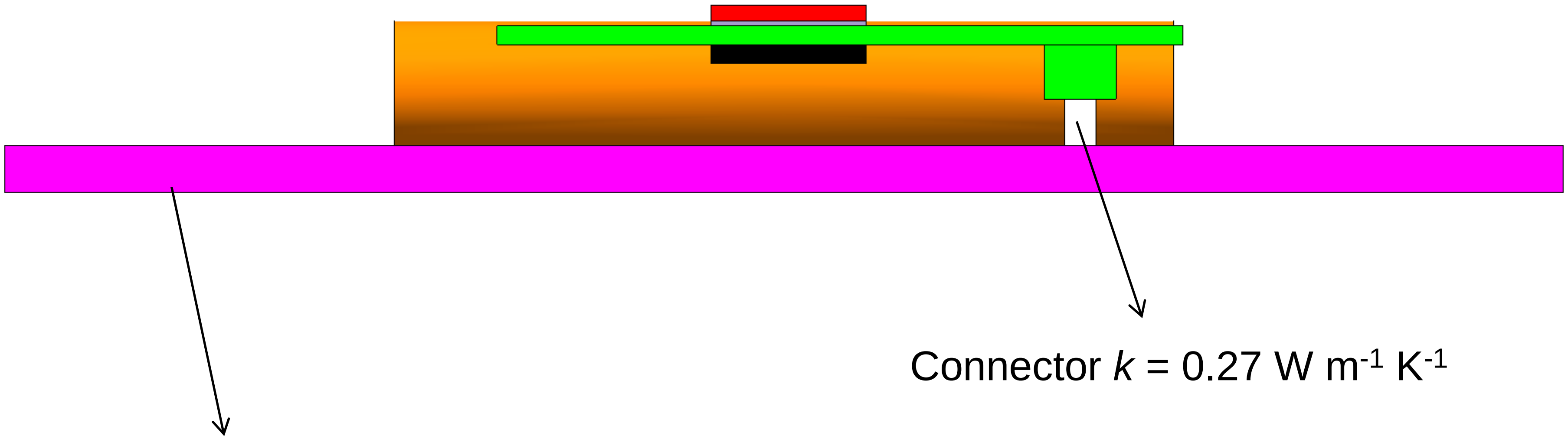
Geometry and material properties



Water, $T = 18°C$

All surfaces are adiabatic but the inner surface of the pipe

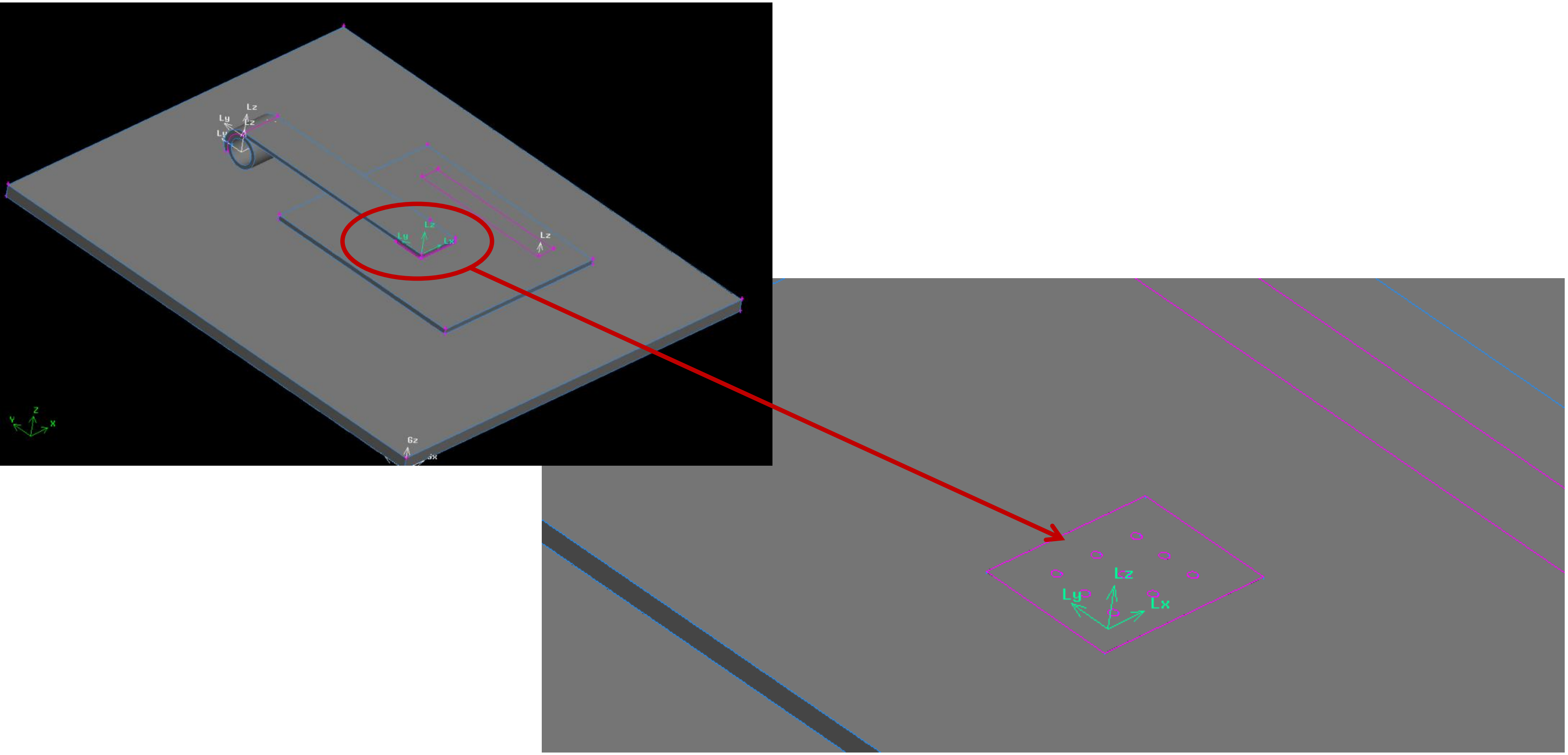
Geometry and material properties



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

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

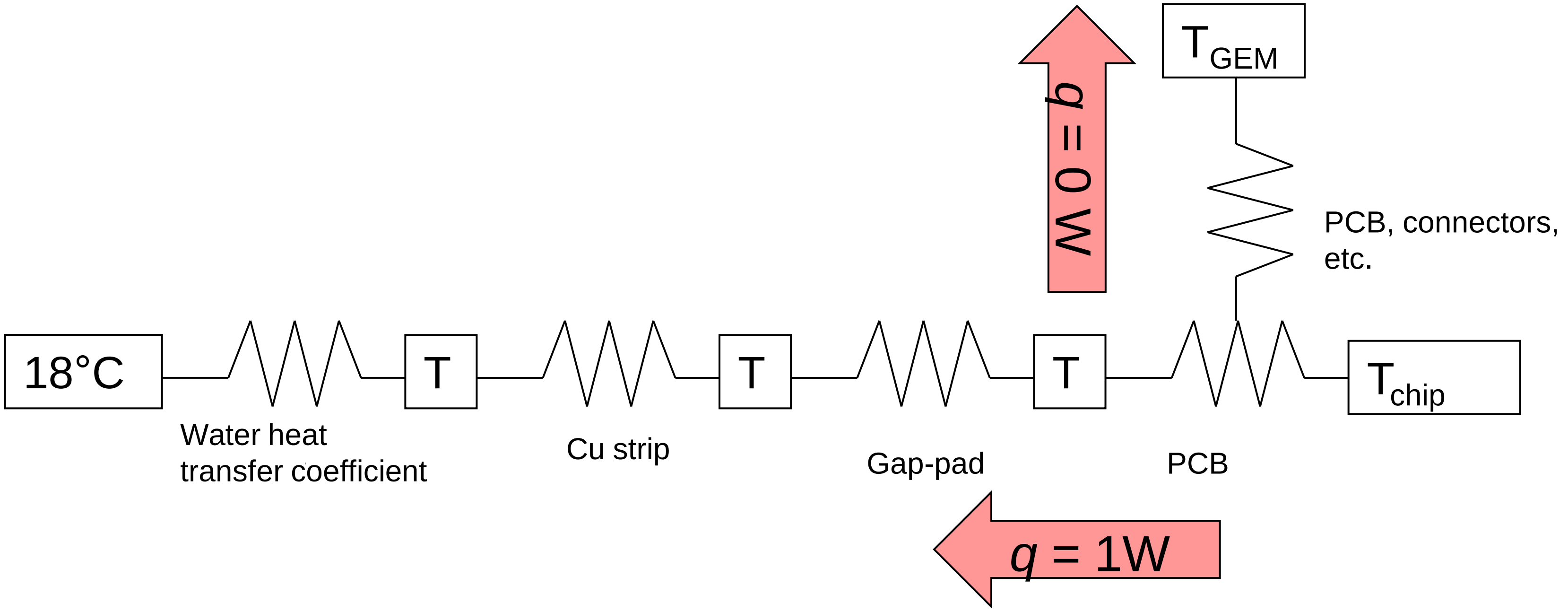
Geometry and material properties



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

2. Schematic and estimations

Schematic of the problem



- ❑ 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

Water in the pipe

- 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

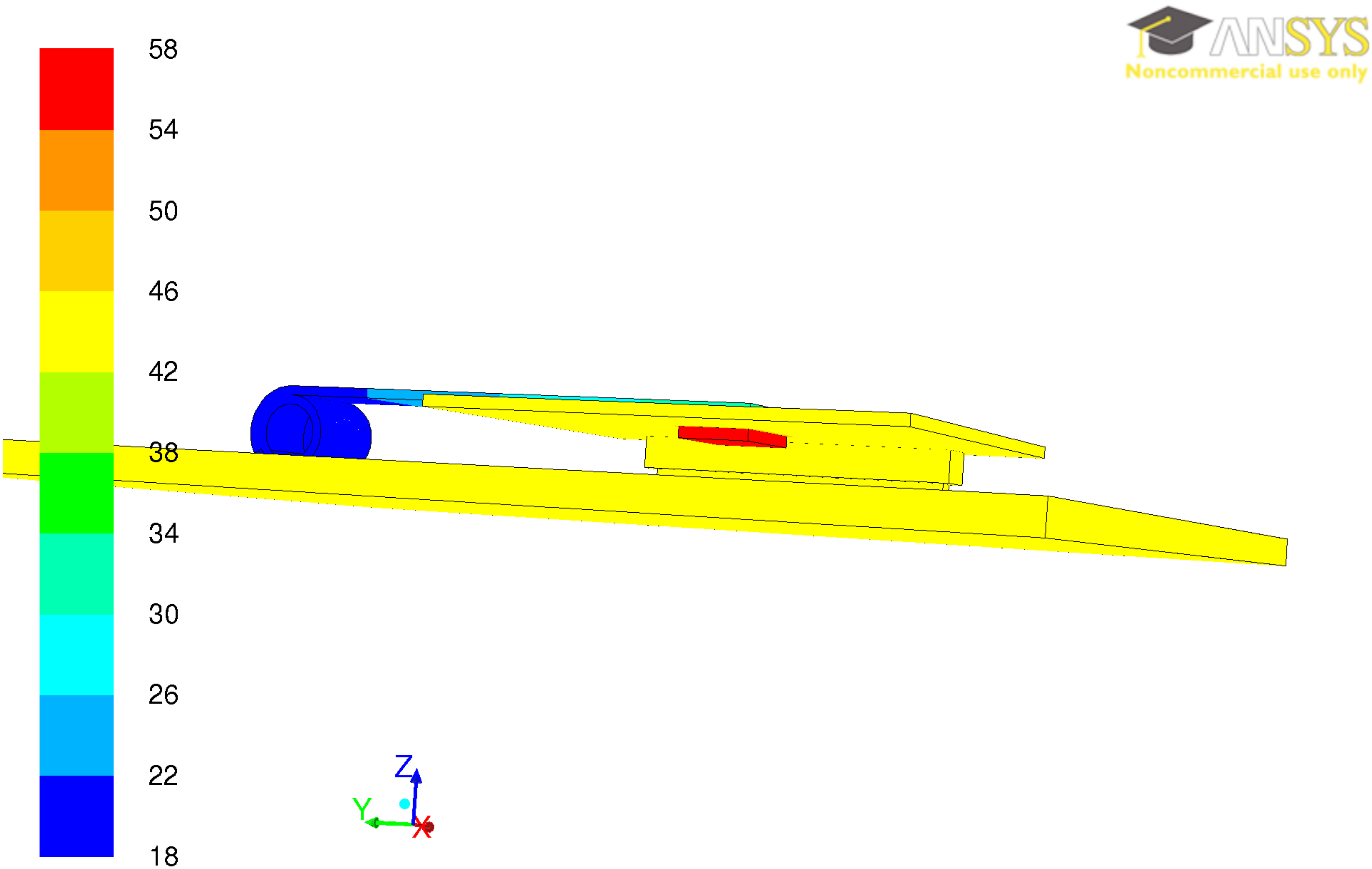
- ❑ Low water temperature rise is good to achieve a uniform sensor temperature.
- ❑ The diameter of the pipe may be reduced if needed because of geometrical constraints.

3. Simulation results

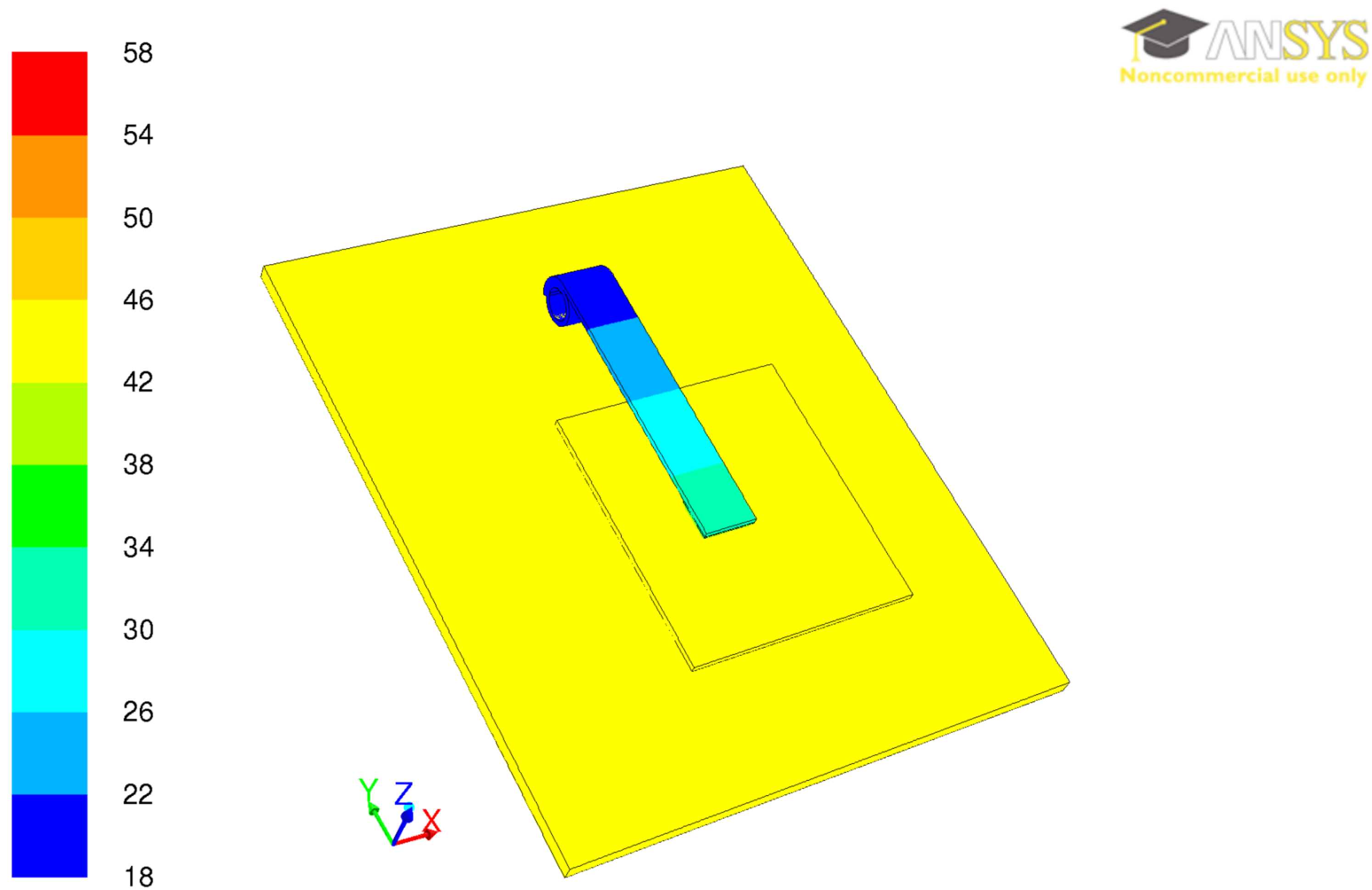
❑ Different geometries have been studied and compared:

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)

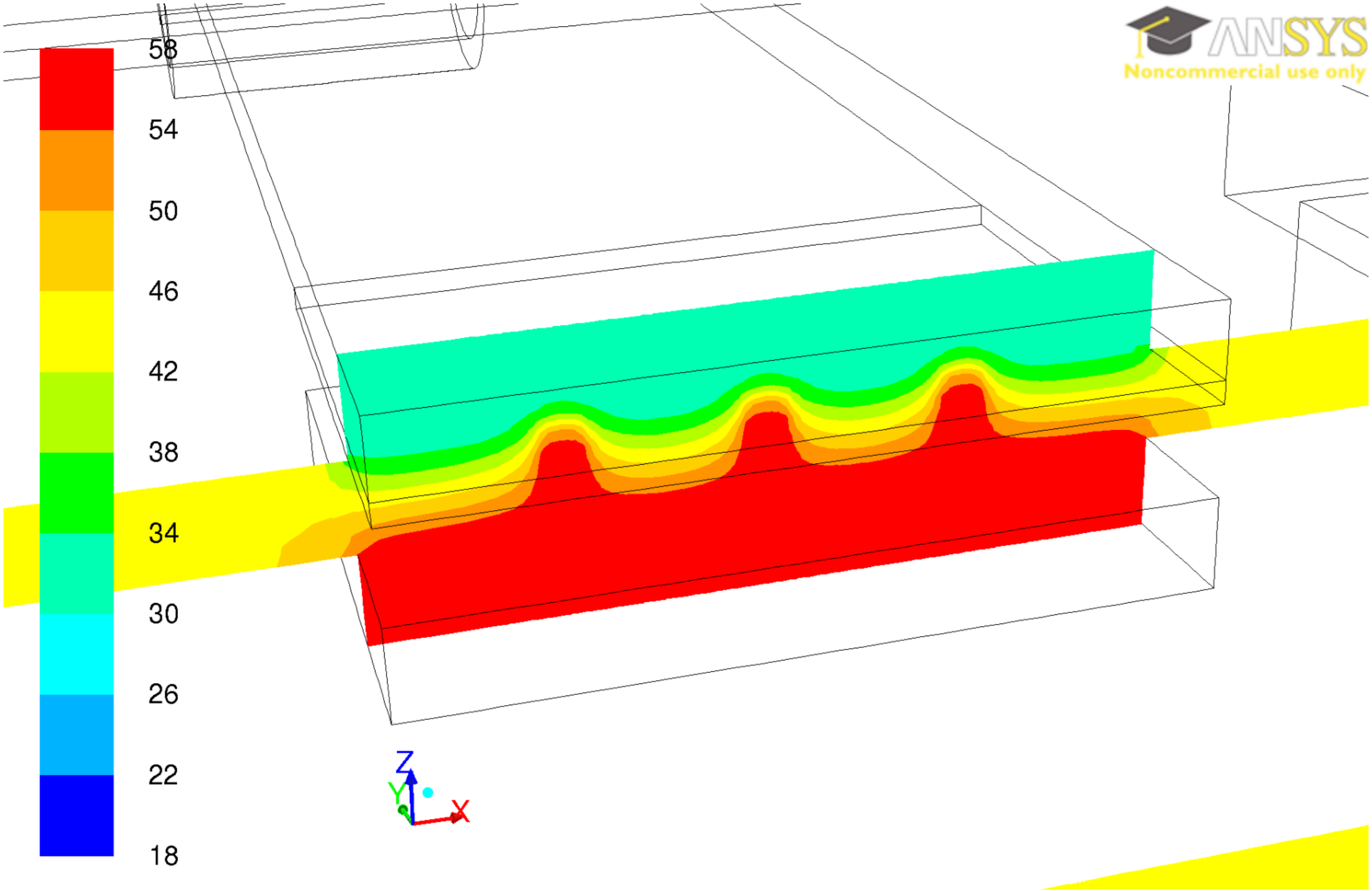
1) Reference geometry



1) Reference geometry

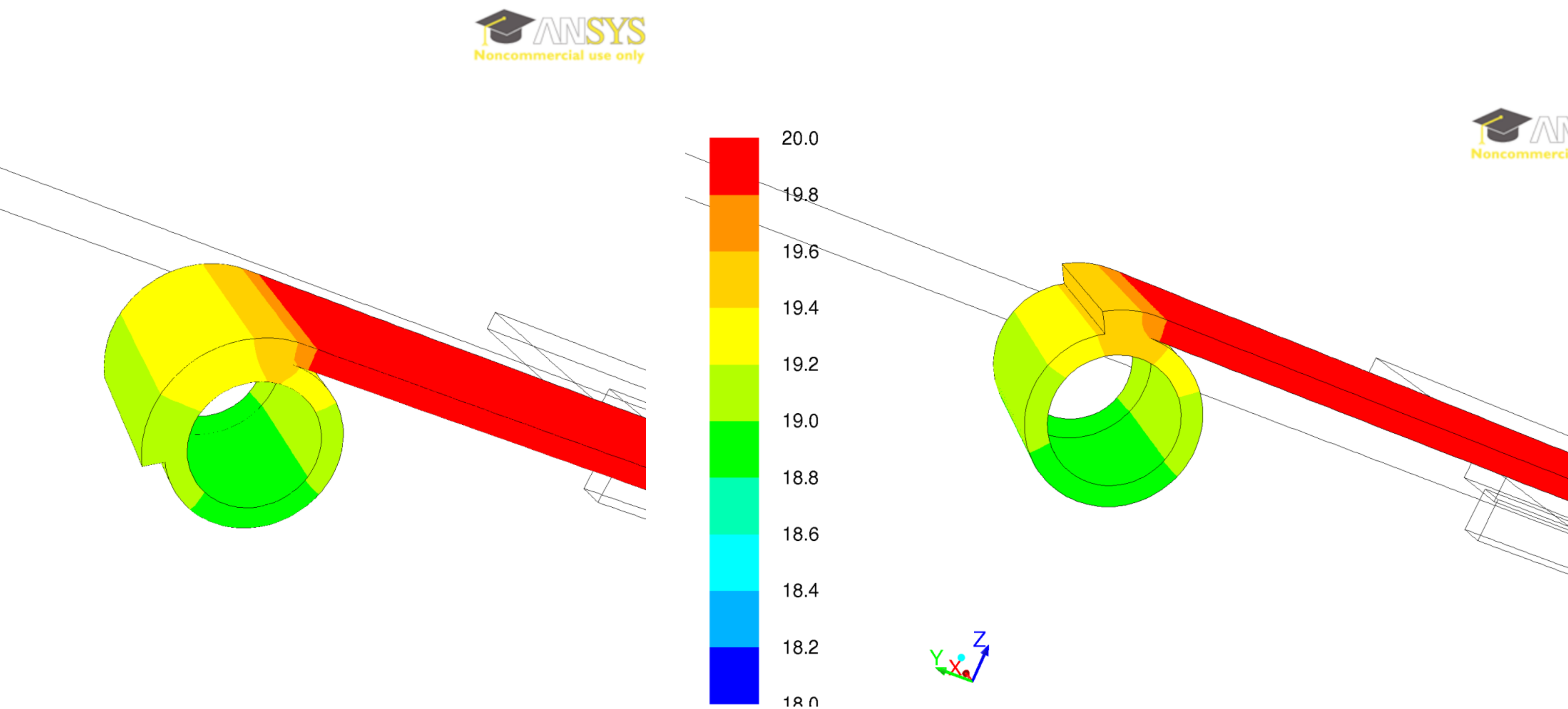


1) Reference geometry



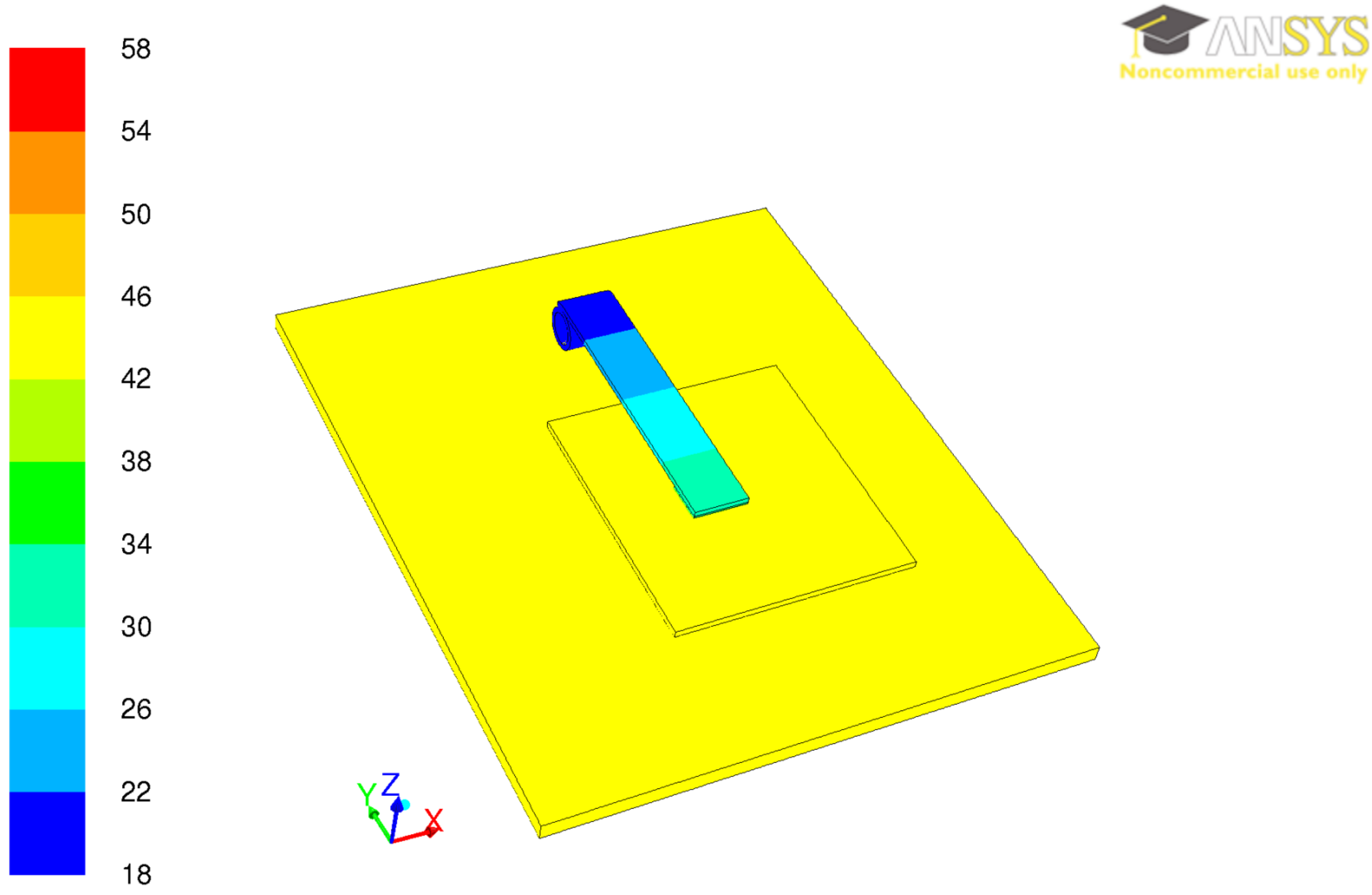
Cross section with copper thermal vias

2) Smaller copper sheet/pipe contact area



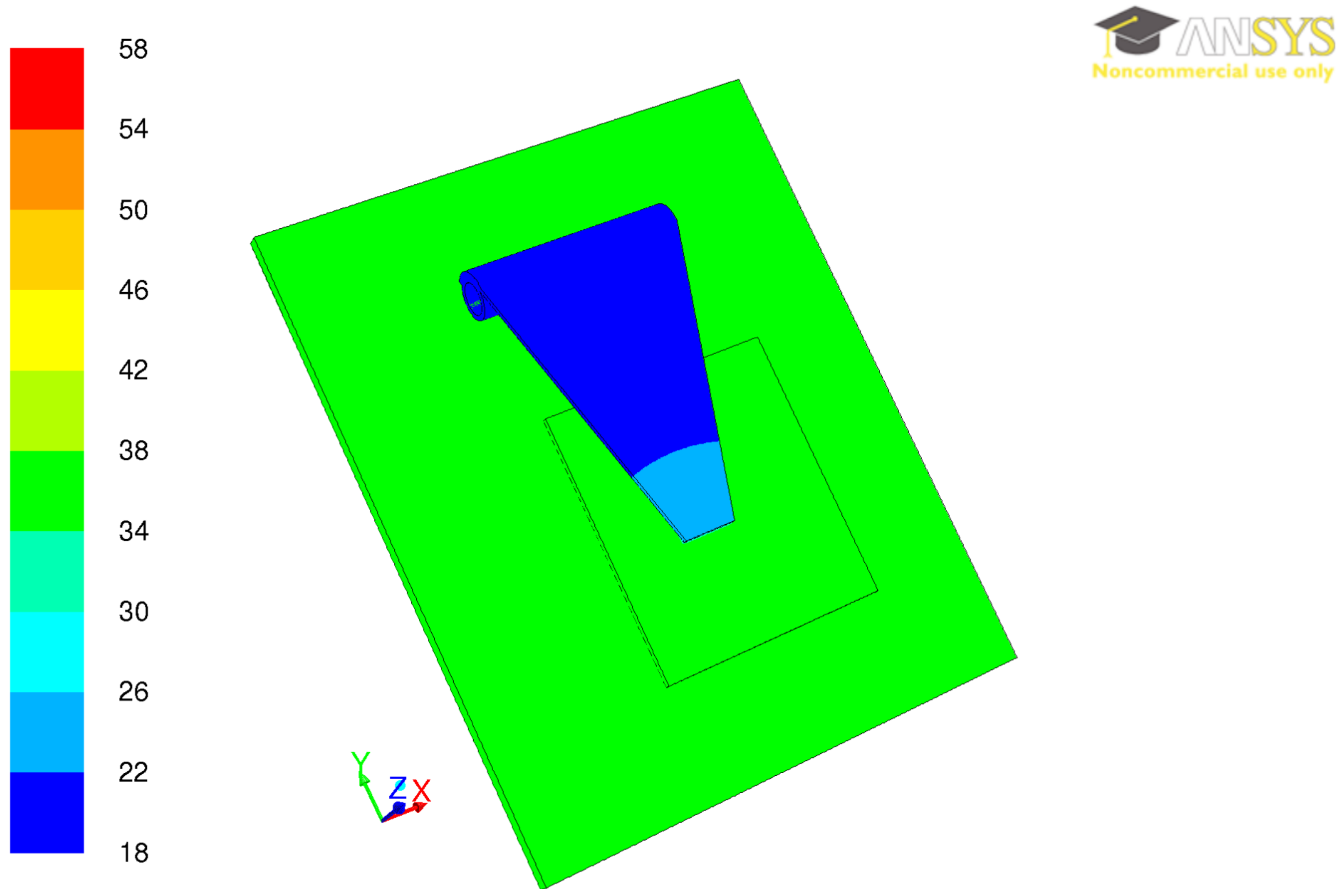
- Negligible influence of the reduced soldering area
- Around 1~2 K temperature drop due to the water heat transfer coefficient

2) Smaller copper sheet/pipe contact area

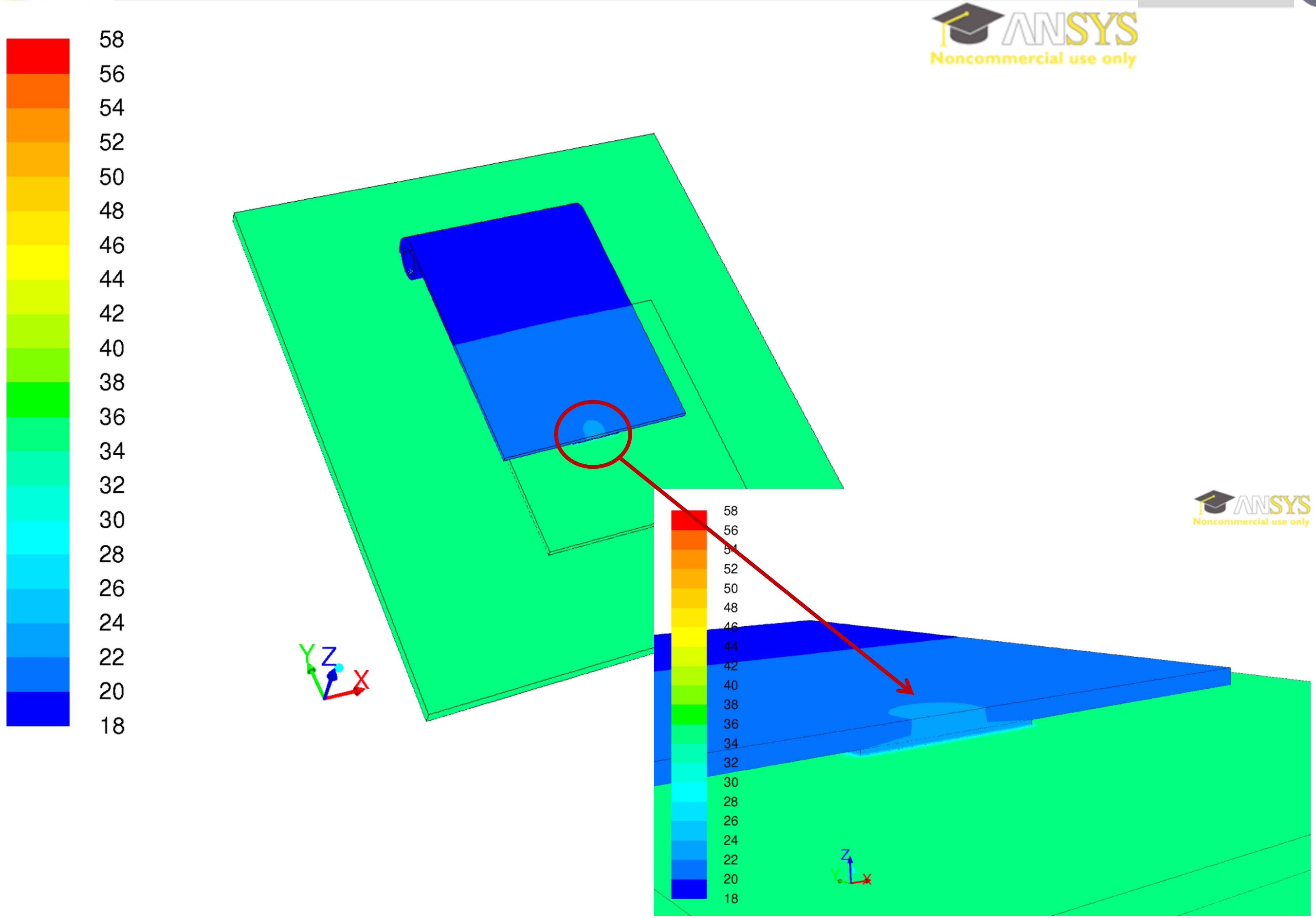


Same thermal performance as the reference geometry

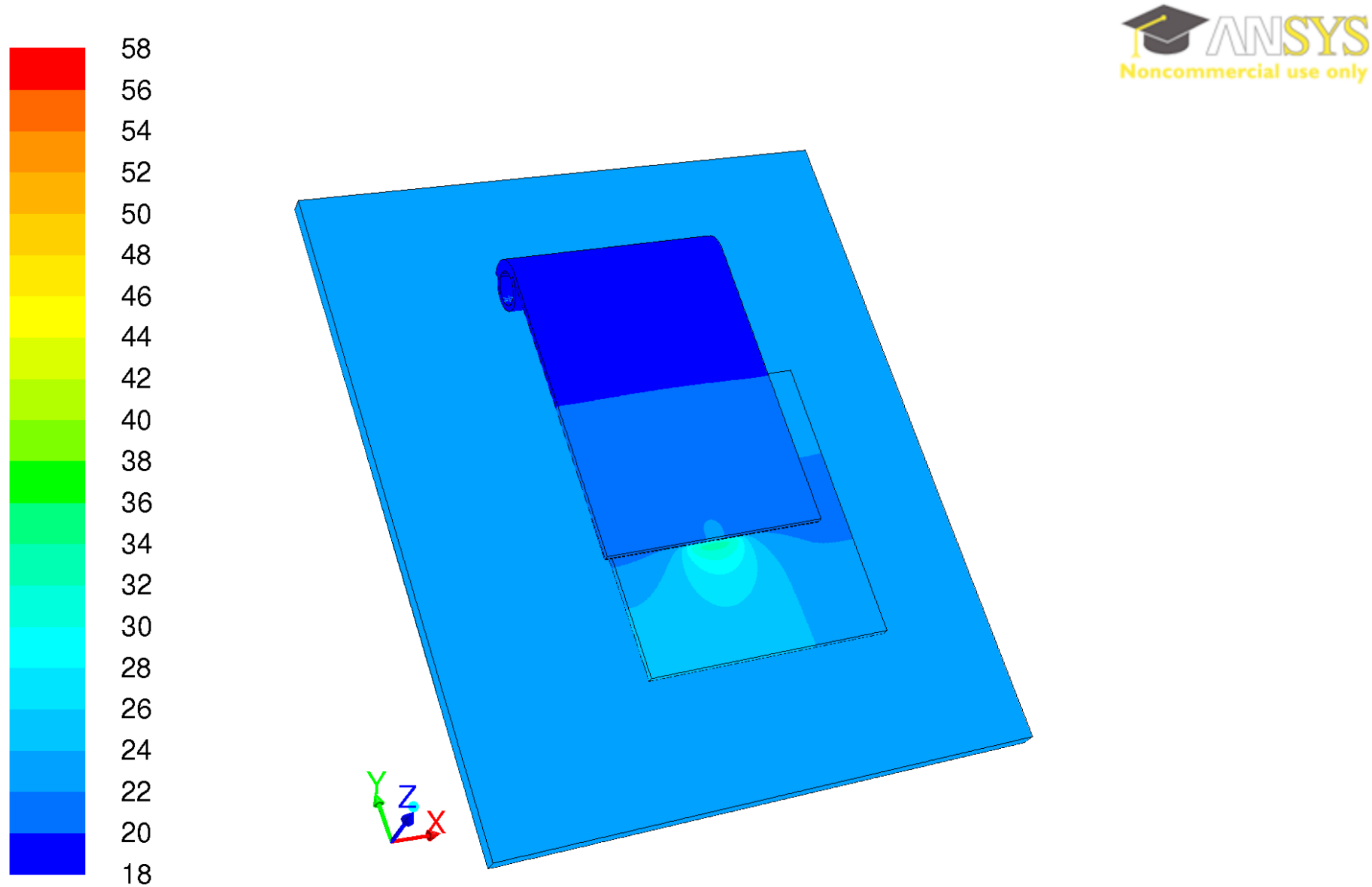
3) Y-shape copper sheet



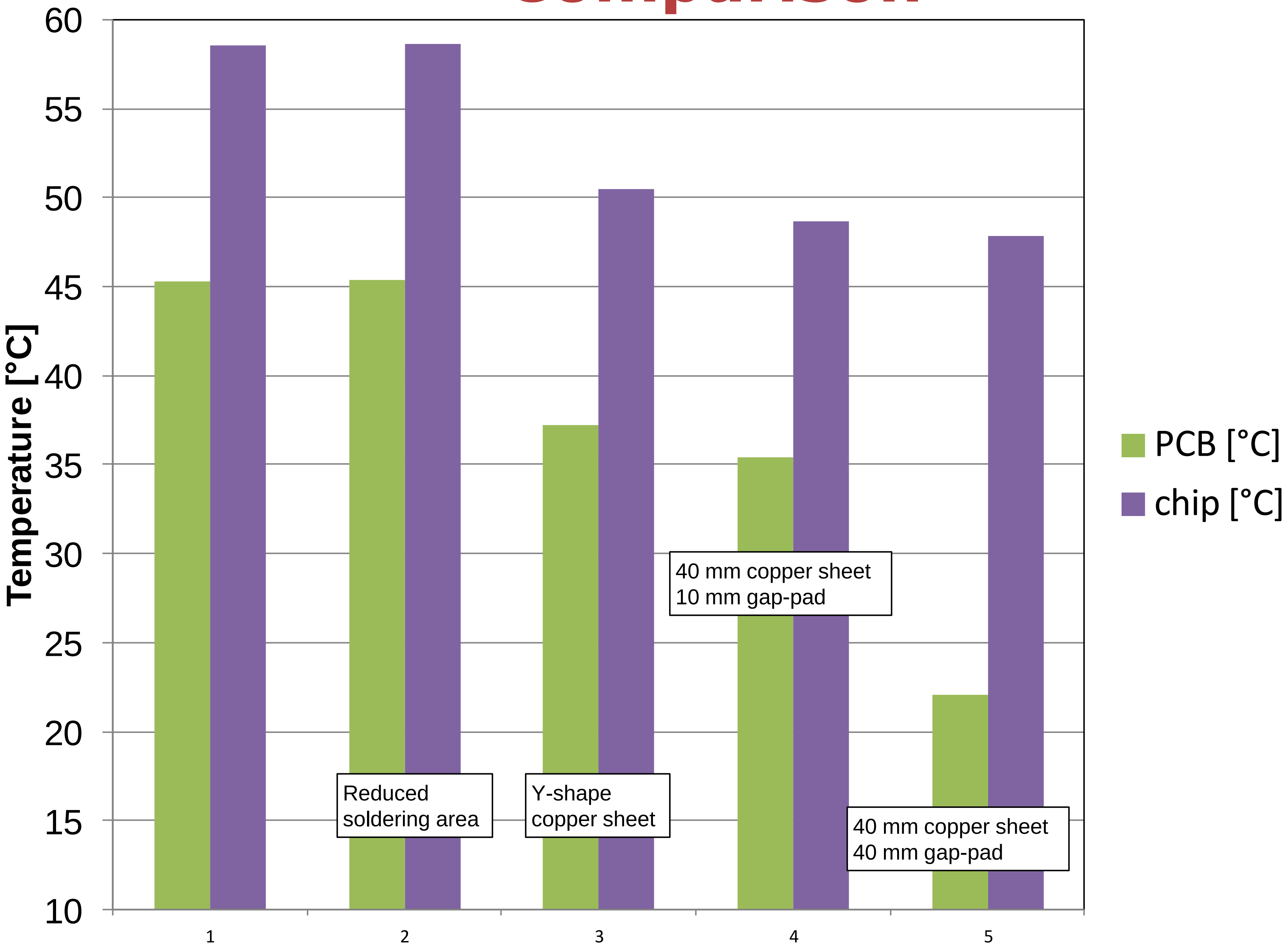
4) 40 mm wide copper sheet + 10 mm wide gap-pad



5) 40 mm wide copper sheet & gap-pad



Comparison



60
55
50
45
40
35
30
25
20
15
10
Temperature [°C]
1
2
3
4
5
PCB [°C]
chip [°C]
Reduced soldering area
Y-shape copper sheet
40 mm copper sheet 10 mm gap-pad
40 mm copper sheet 40 mm gap-pad

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.