Update in the microchannel cooling simulations of DEPFET vertex detector for a future linear e+ e- collider

I. Garcia
M.A. Villarejo
M. Vos

INSTITUTO DE FÍSICA CORPUSCULAR

DEPFET
Active Pixel Detector

Summary

1. Test vs simulation
   - 1.1 Test
   - 1.2 Simulation
   - 1.3 Comparison

- 2. CO2 as an option?

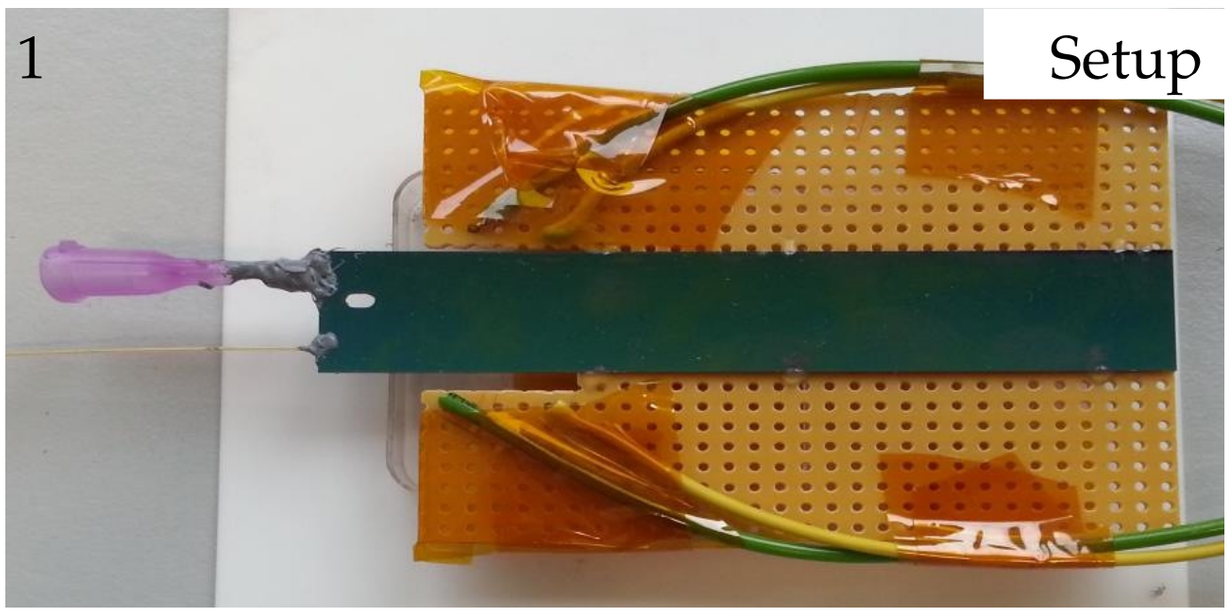
- 3. Results with other coolants
  - 3.1 Coolants properties
  - 3.2 Coolants comparison
  - 3.3 Simulation results

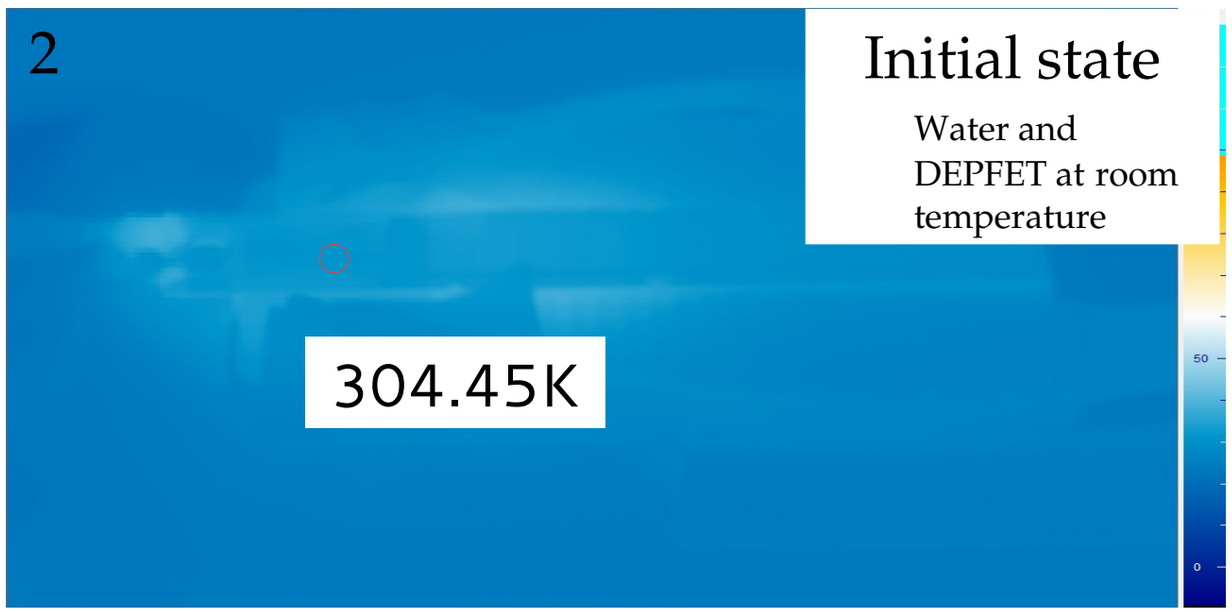
- 4. Future work

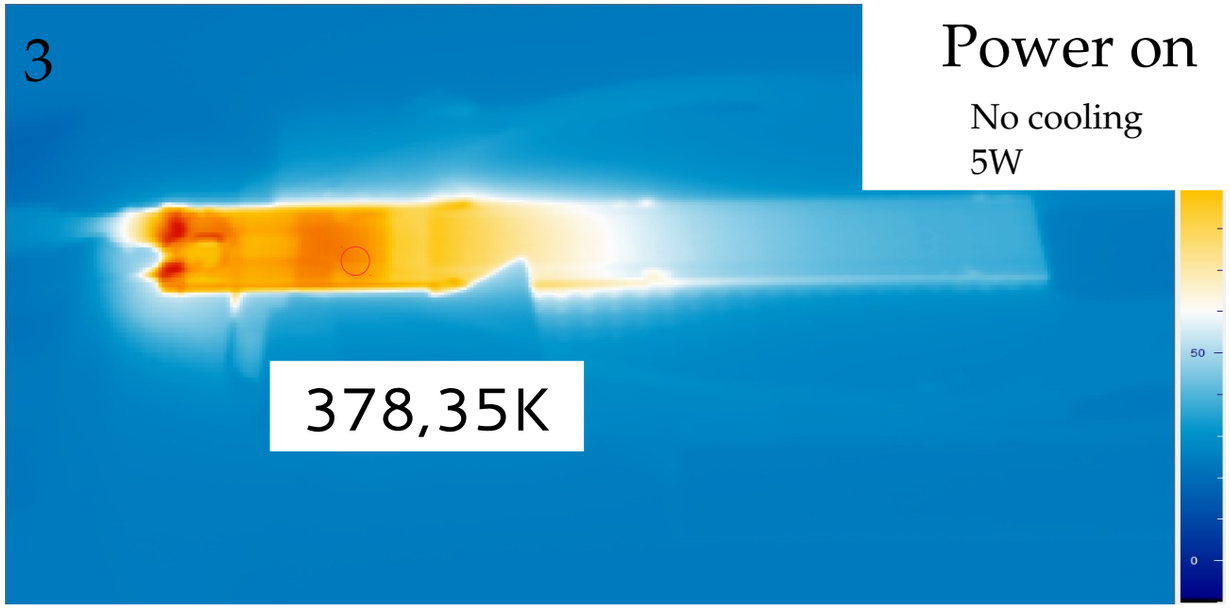
- 5. Conclusions

1.1 Test with 5W and water as coolant

Test 1: 5W

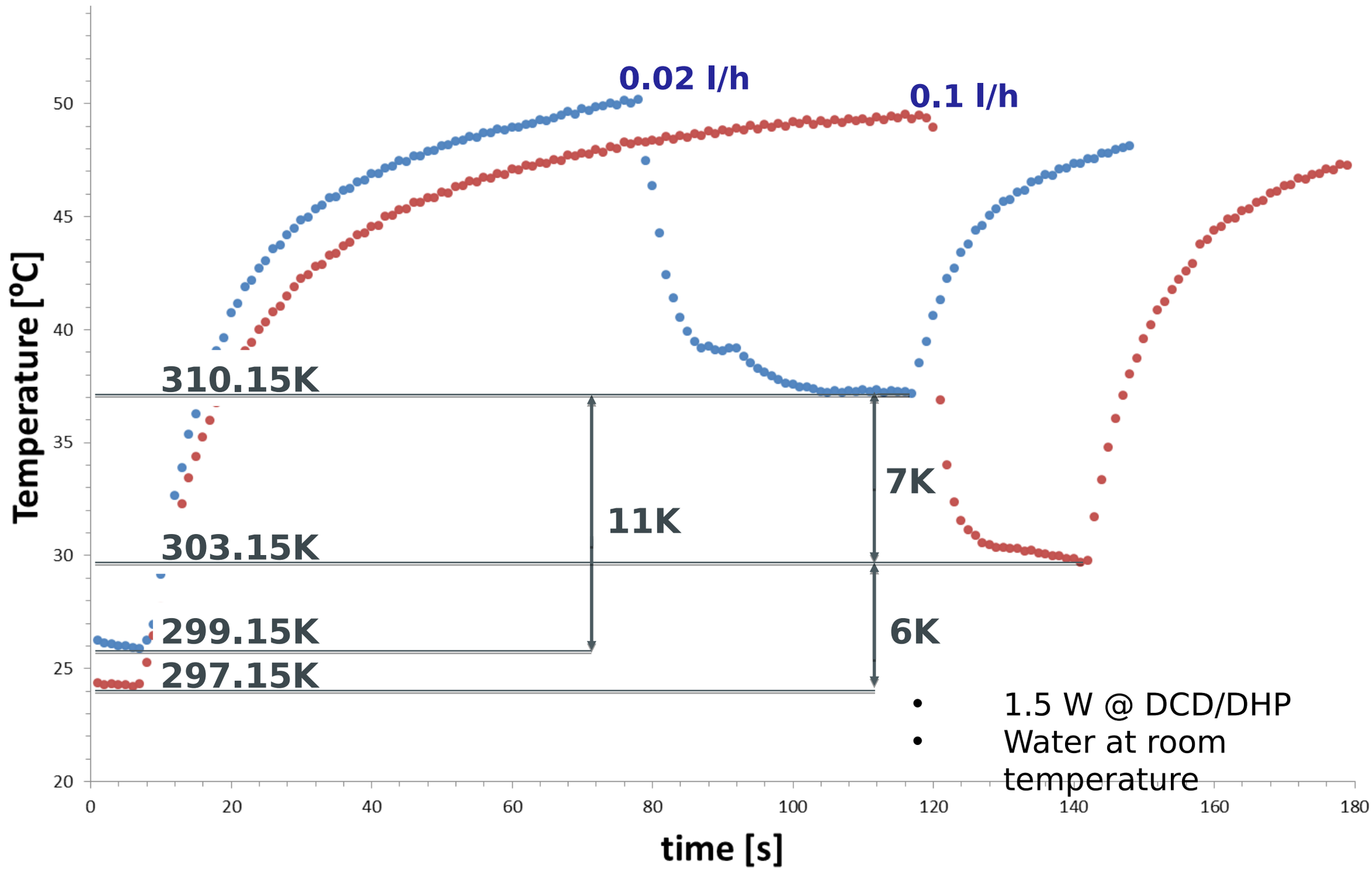






1.1 Test with 5W and water as coolant

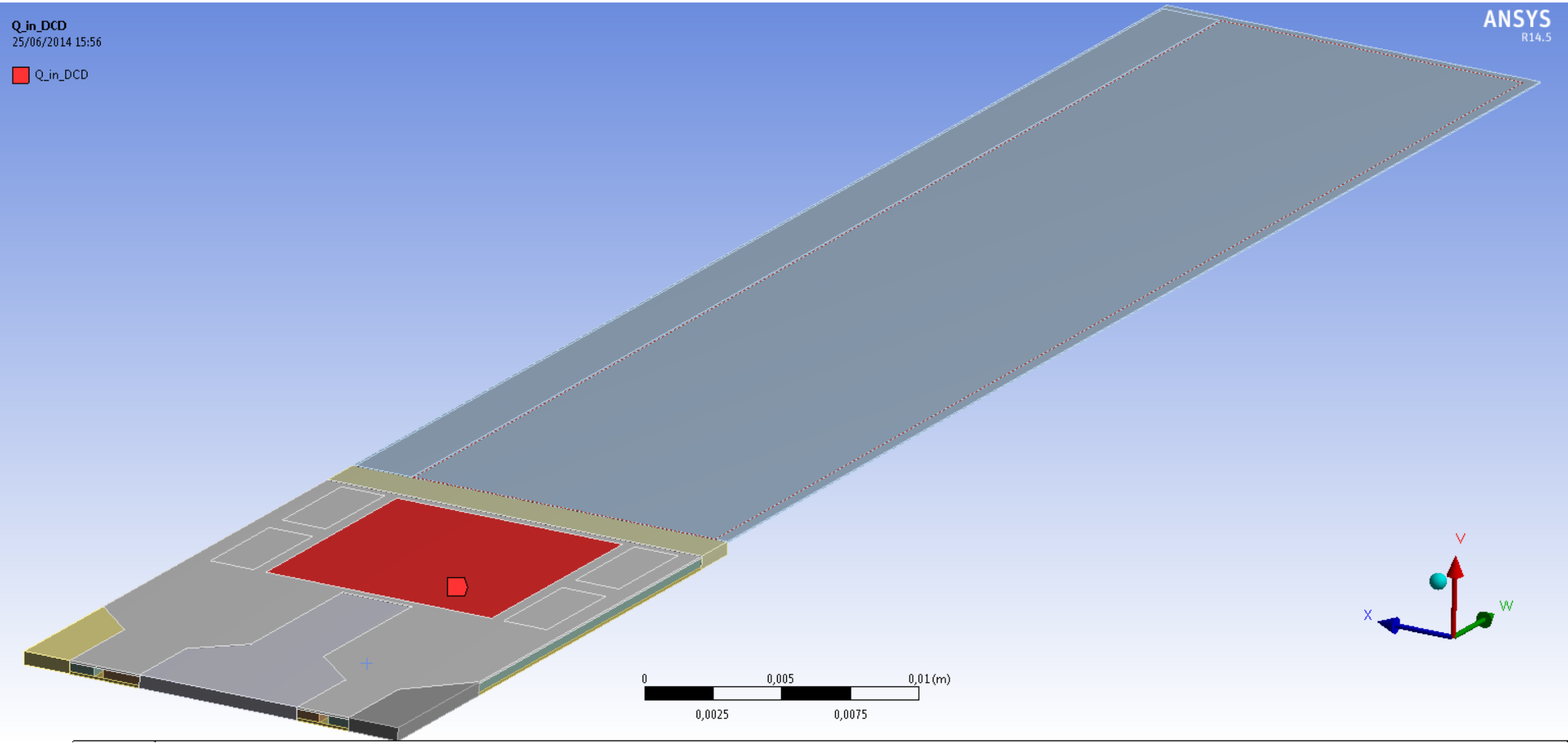
Test 2 and 3: 1.5W with different volumetric flow



- 1.5 W @ DCD/DHP
- Water at room temperature

1.2 Simulations with 5W and water as coolant

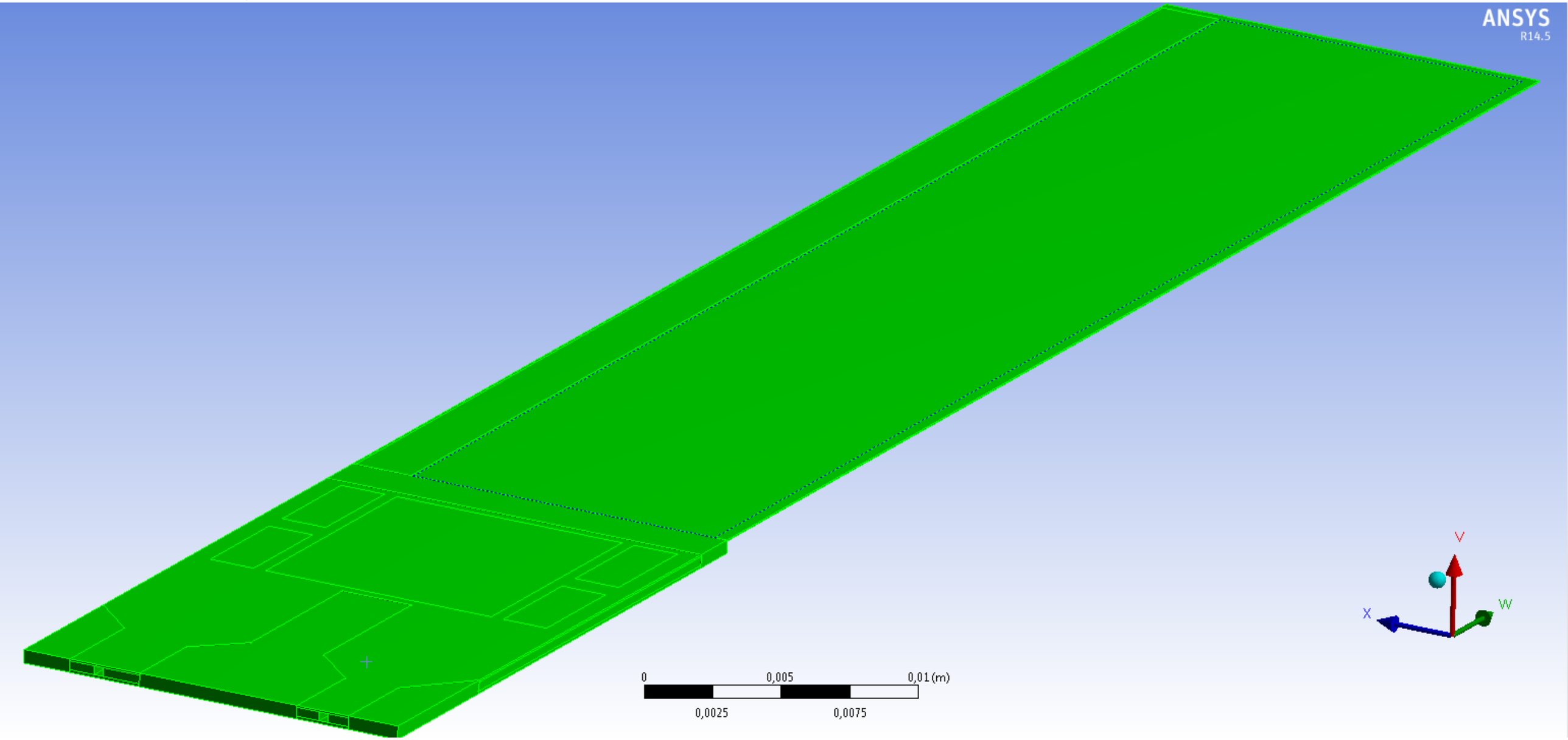
Boundary conditions: Q_in



Q_in_DCD=5W

1.2 Simulations with 5W and water as coolant

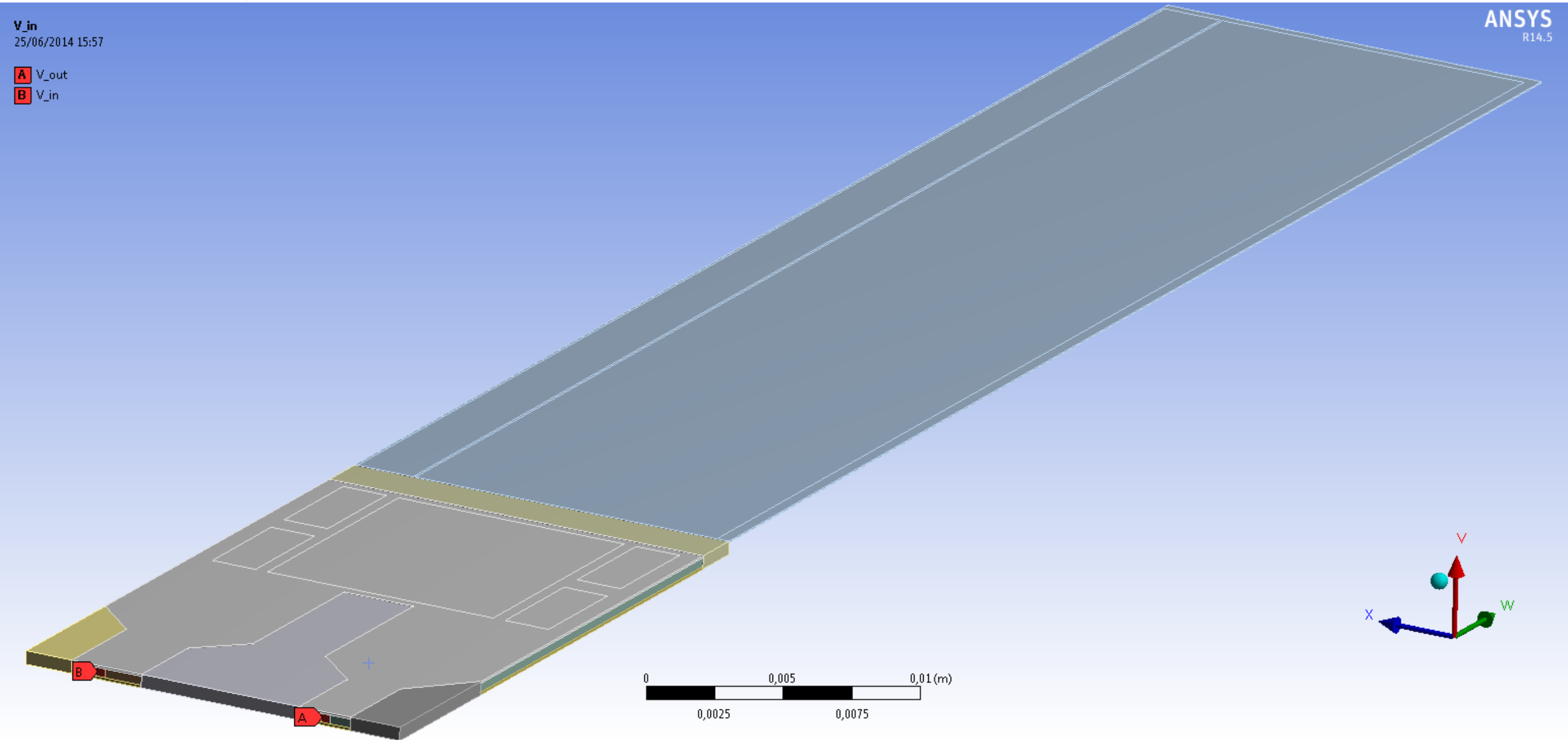
Boundary conditions: Q_out



T_out=at 297.15K, 299.15K and 304.45K
h=5 [W m^-2 K^-1]

1.2 Simulations with 5W and water as coolant

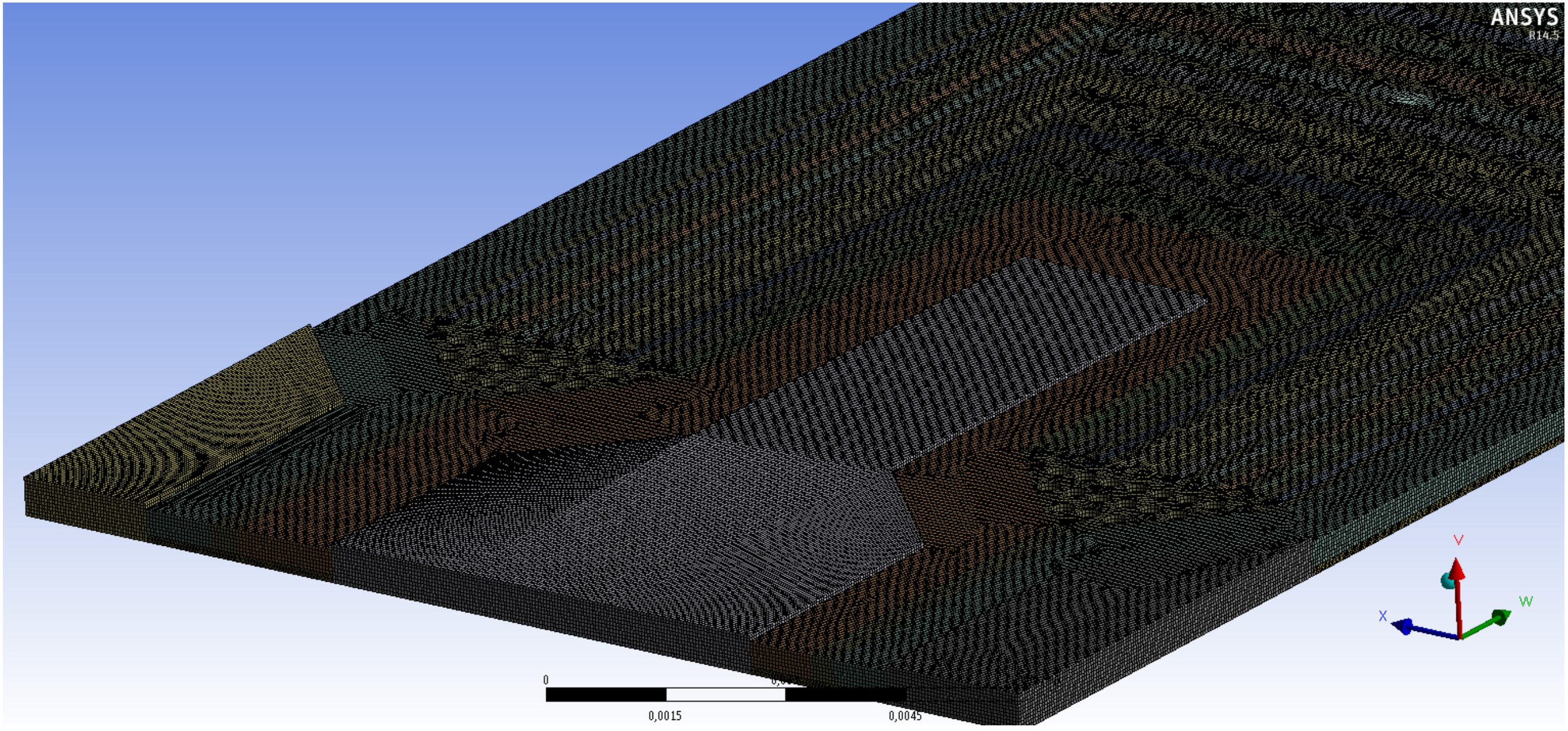
Boundary conditions: V_in&V_out



V_in=2.15m/s (0.1 l/h) and 0.43m/s (0.02 l/h)
Fluid: water at 297.15K, 299.15K and 304.45K in the entrance

1.2 Simulations with 5W and water as coolant

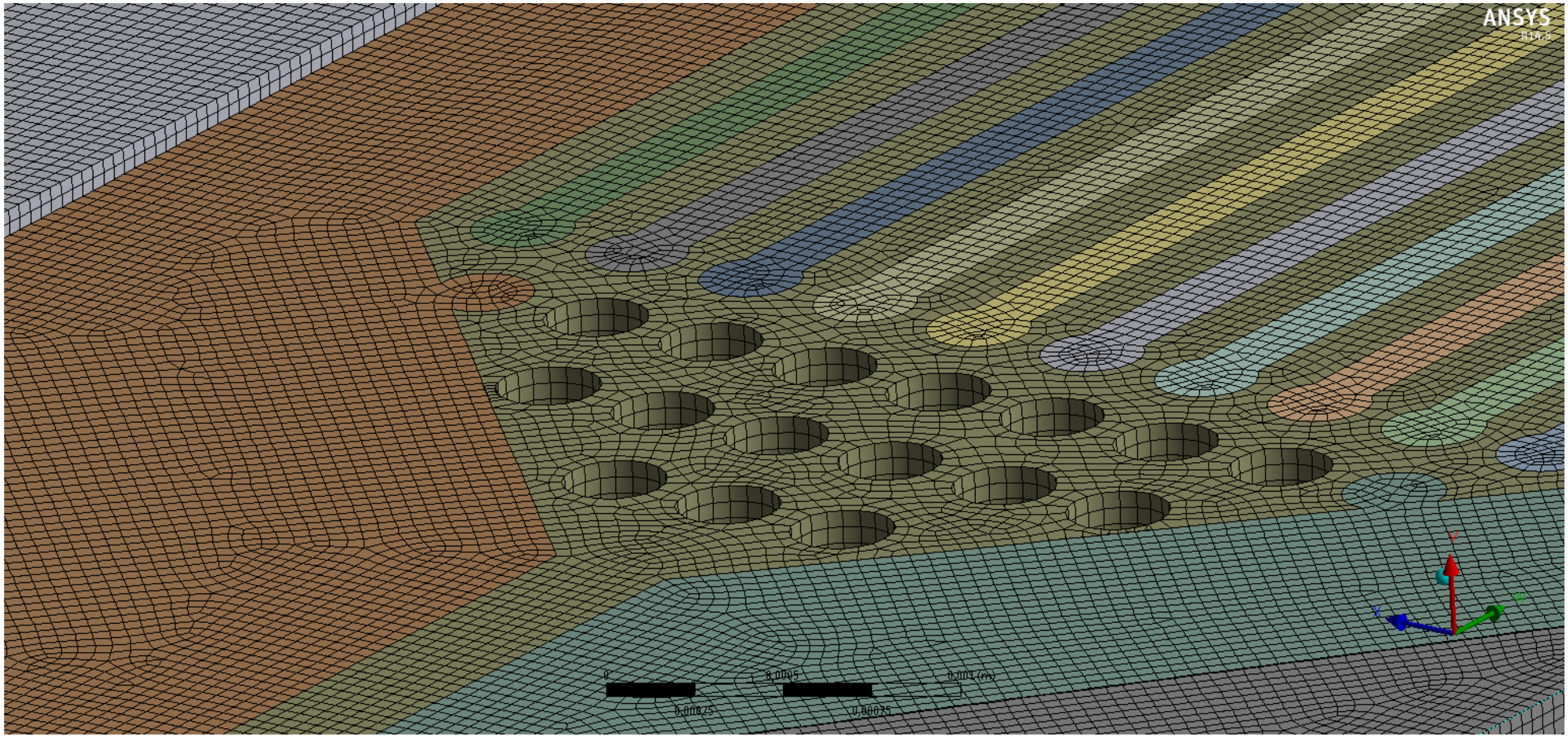
Mesh



5,15M elements divided mostly in 30% Hex8 and 70% Tet4

1.2 Simulations with 5W and water as coolant

Mesh: detail



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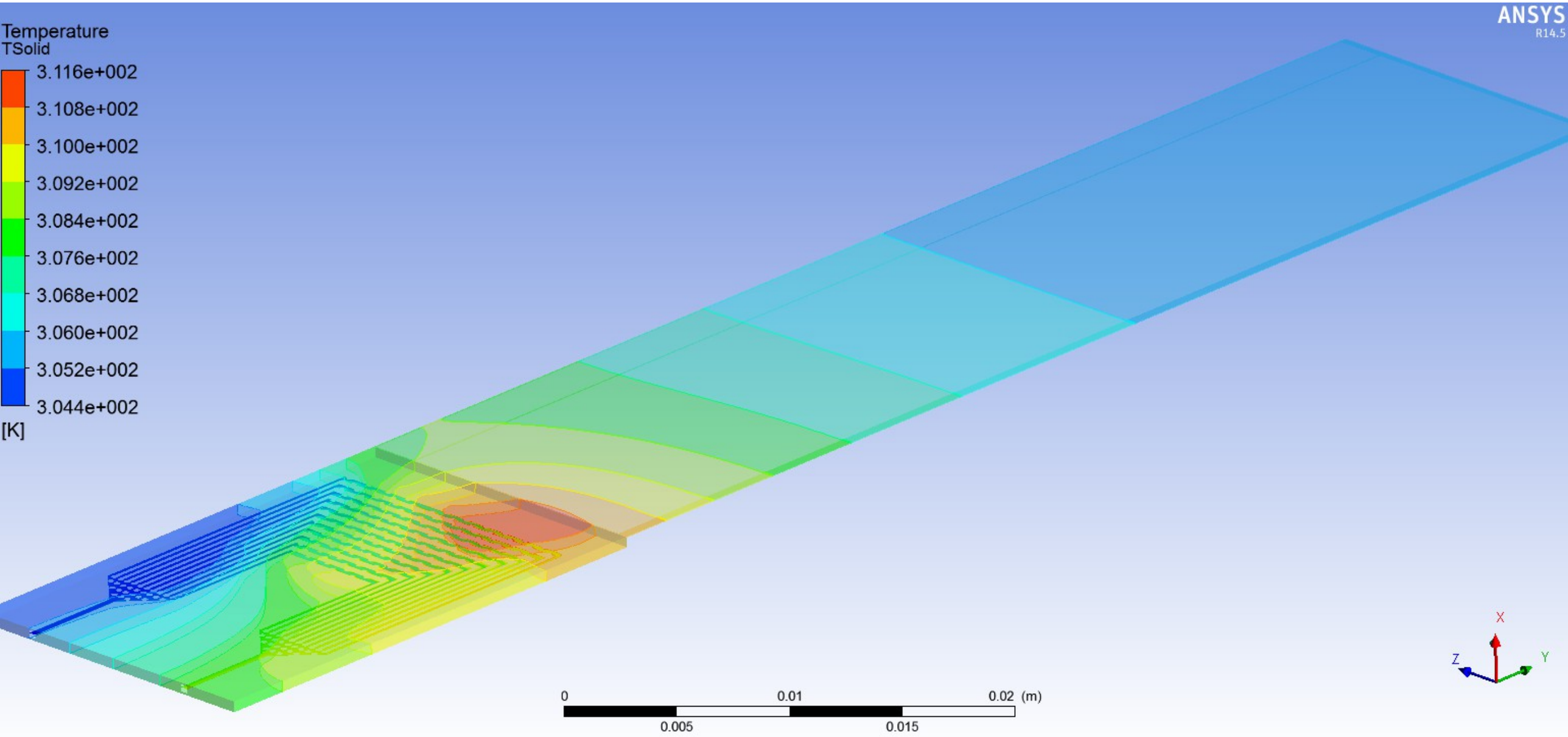
1.2 Simulations with 5W and water as coolant

Results: simulation of the test 1 (slide 3)



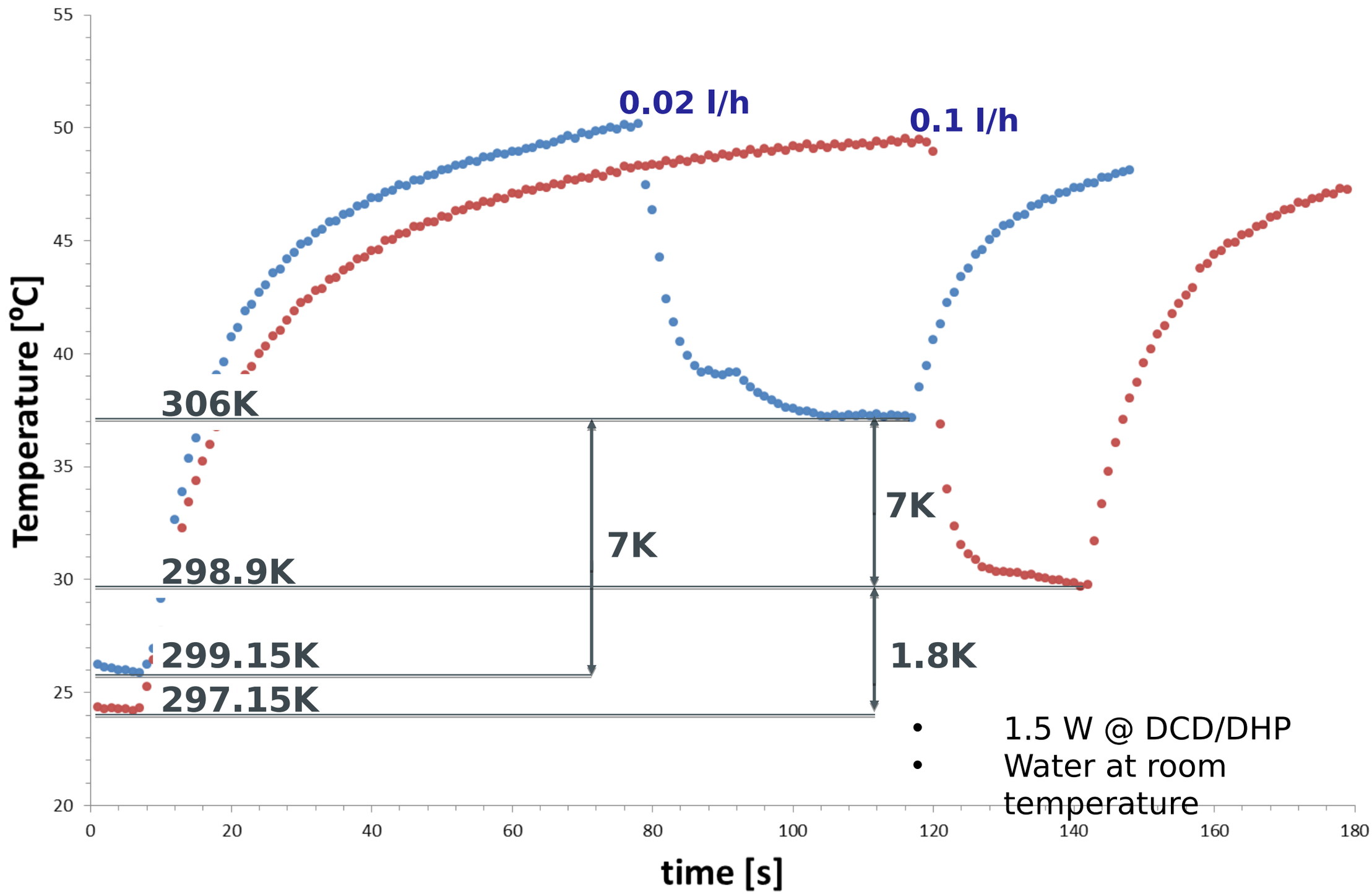
T_water_out=308.6K

Q_water=Cp*m*ΔT=4186*2.15*0.00038*0.00034*997*(308.6-304.4)= 4.87W

97% of the 5W is absorbed by the cooling flow

1.2 Simulations with 1.5W and water as coolant

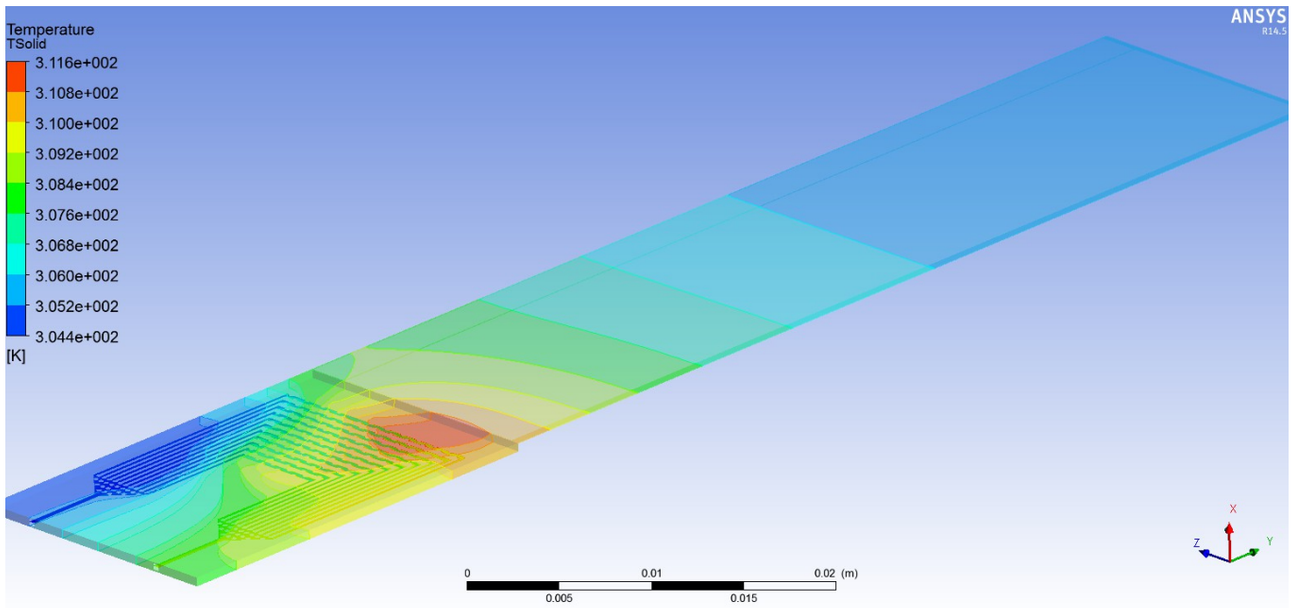
Results: simulation of the test 2 and 3 (slide 4)



- 1.5 W @ DCD/DHP
- Water at room temperature

1.3 Comparison between tests and simulations

Test 1: 5W (0.1l/h)



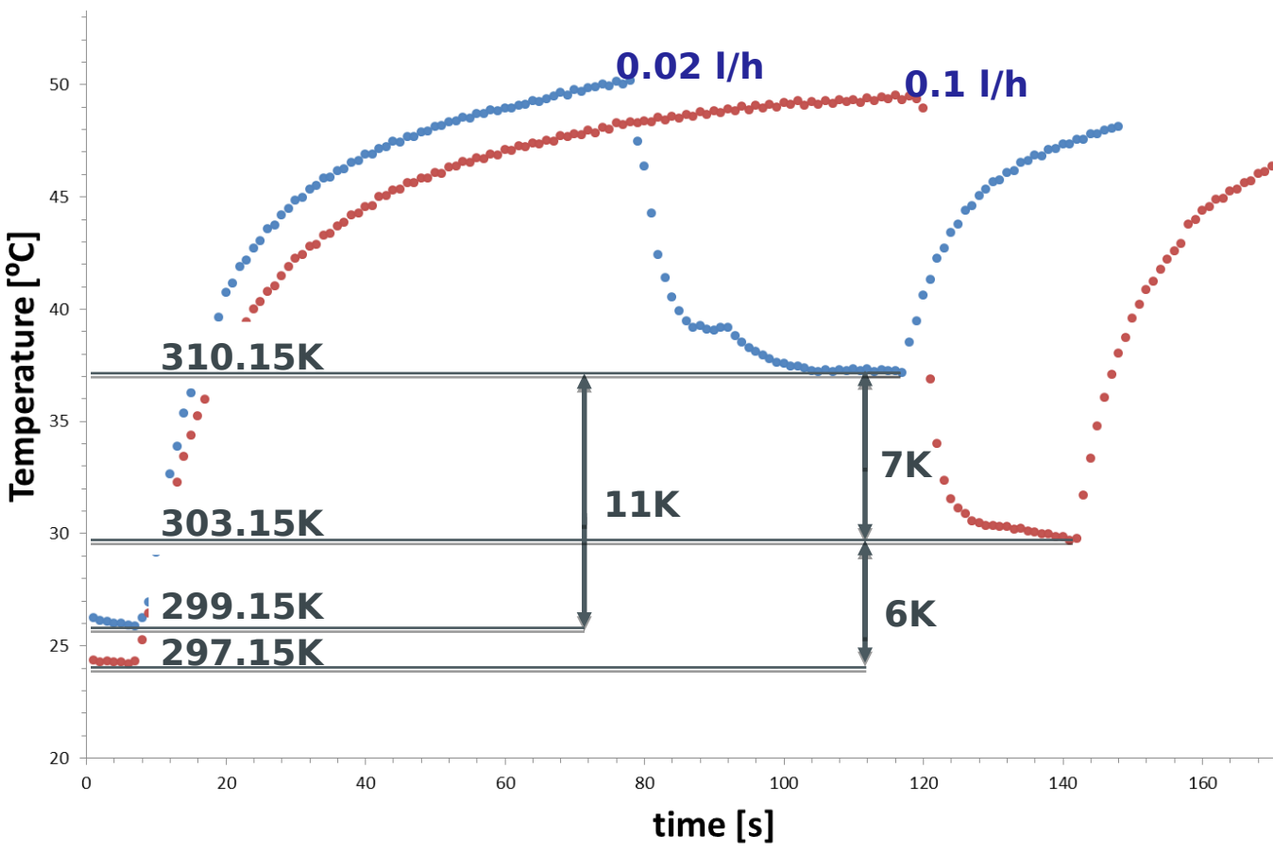
Simulation: ΔT=7.15K

Test: ΔT=8.4K

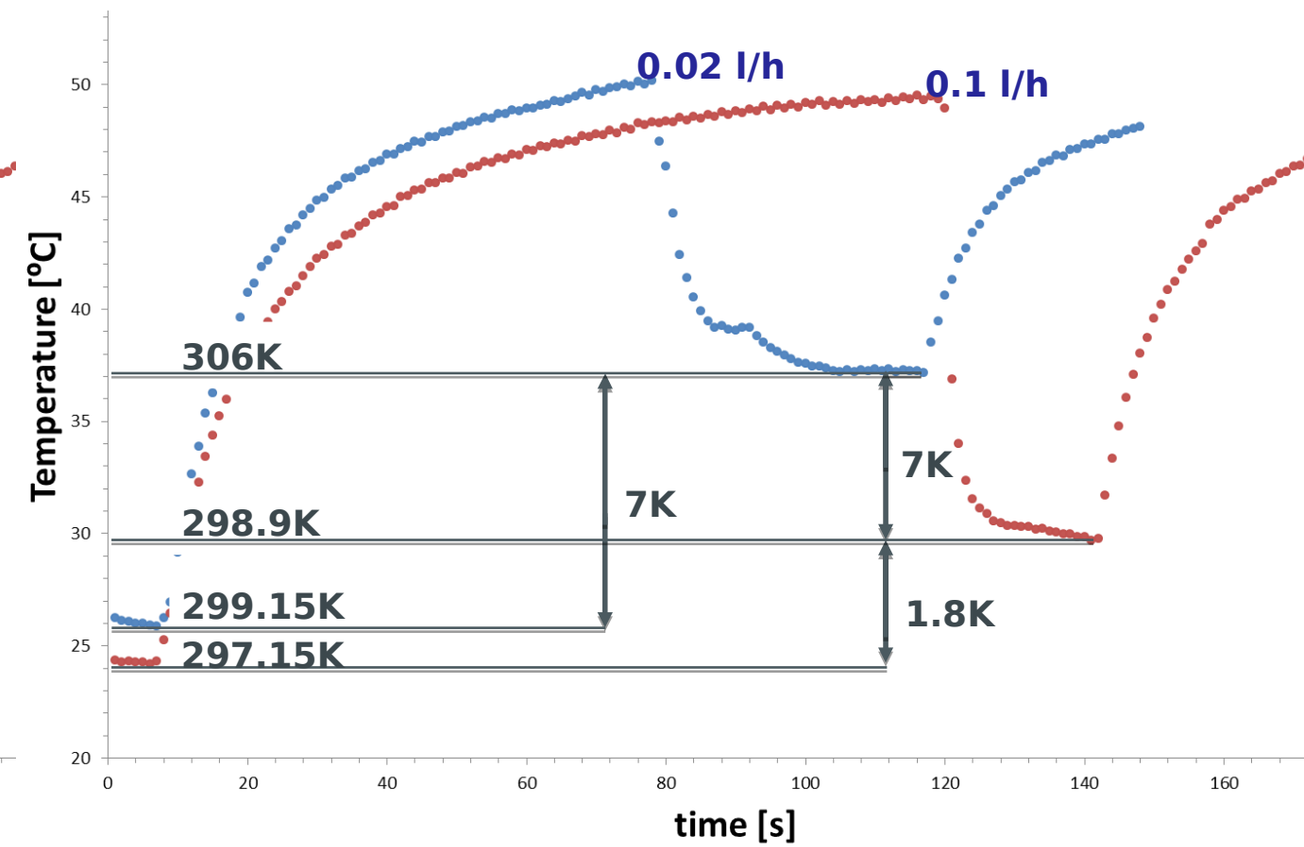
1.3 Comparison between tests and simulations

Test 2 and 3: 1.5W with different volumetric flow

Tests



Simulations



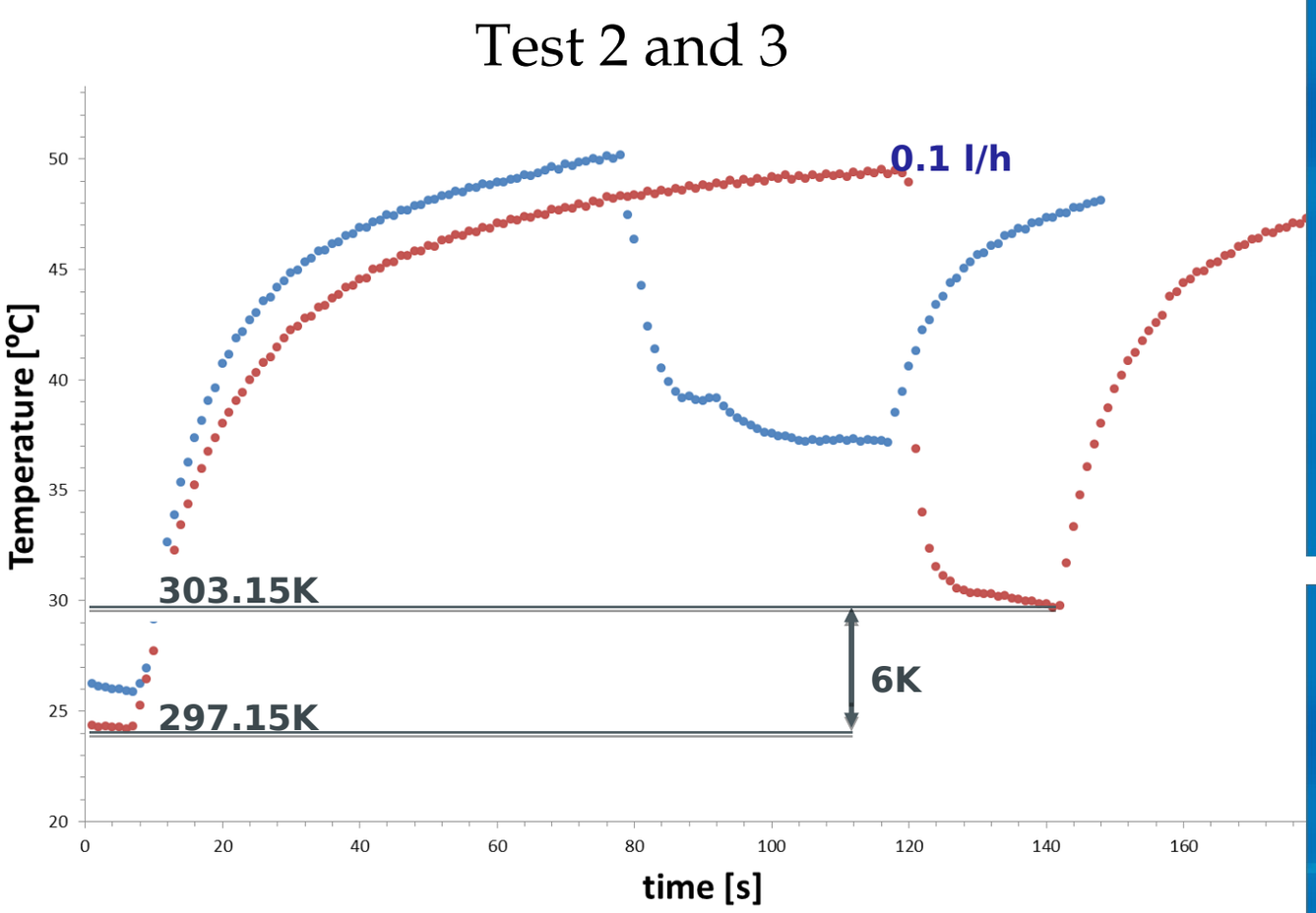
- Initial conditions: the same (297.15K and 299.15K)

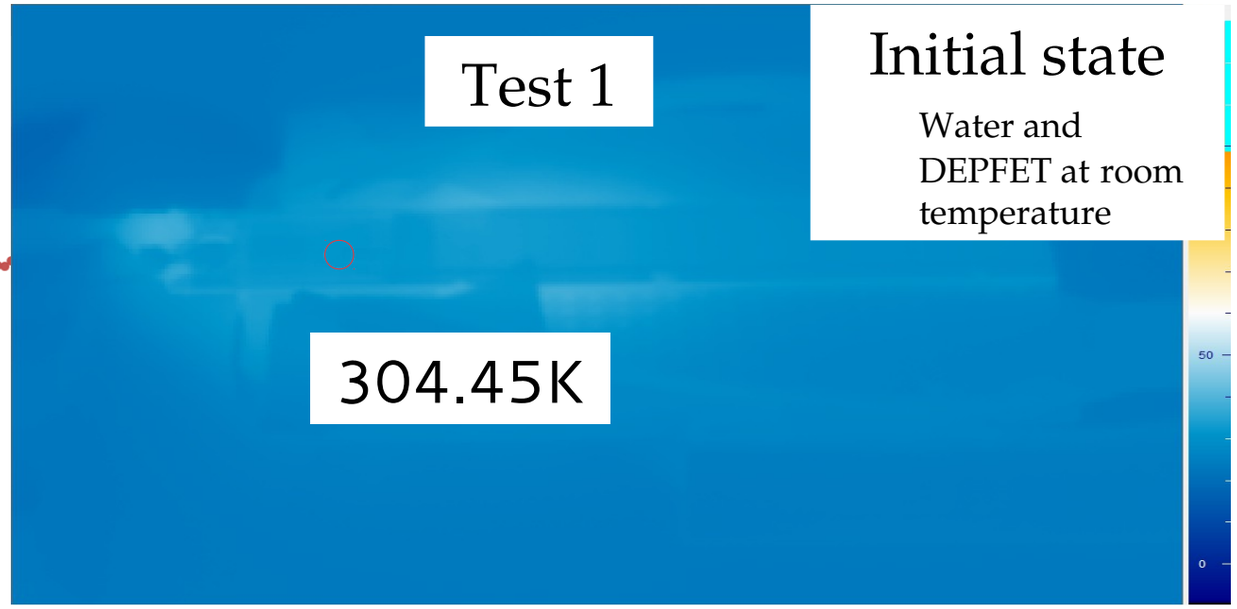
- Final temperature: Δ of 4K between tests and simulation (310.15K-306K and 303.15K - 298.9K)

- ΔT=7K with different flows in tests and simulations

1.3 Comparison between tests and simulations

Test 1, 2 and 3: 5W vs 1.5W





Test 1 (5W) : ΔT=8.4K

Test 2 (1.5W): ΔT=6K

V_in=2.15m/s

2. CO2 cooling

LHCb detectors op. Temperature ~ -40ºC

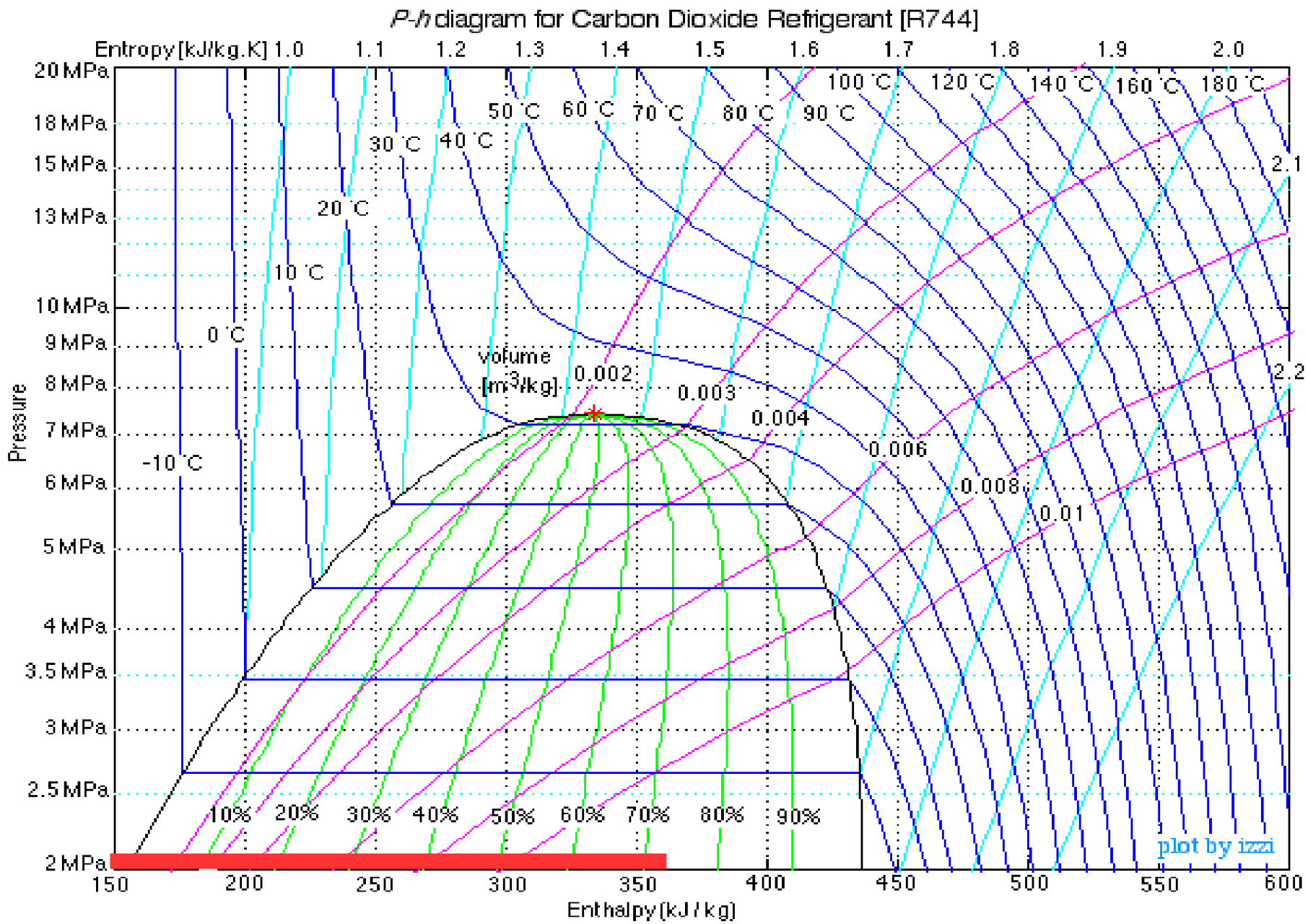
ATLAS IBL detectors op. Temperature ~ -20ºC

WHY CO2?

Low T →Low μ → Low ΔP

Low frozen T

Compared mainly with fluorocarbon fluids at -40-20ºC



2. CO2 cooling

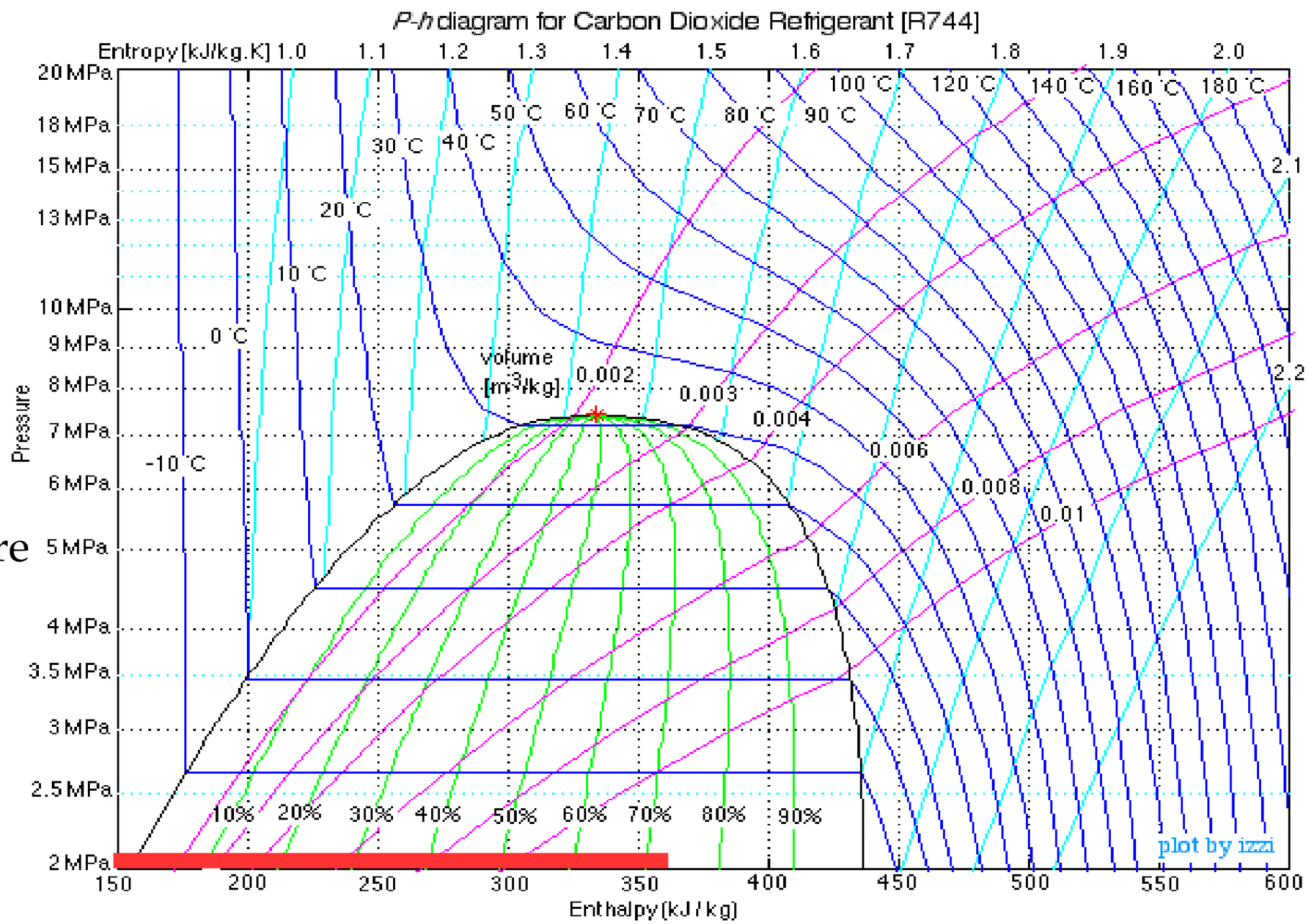
DEPFET detectors op. Temperature ~ +25ºC

If P=20 bar (2MPa)

- Biphase fluid

- High ΔT though the sensor (250-293K)

- Op. Fluid Temperature very different from the Op. DEPFET Temperature



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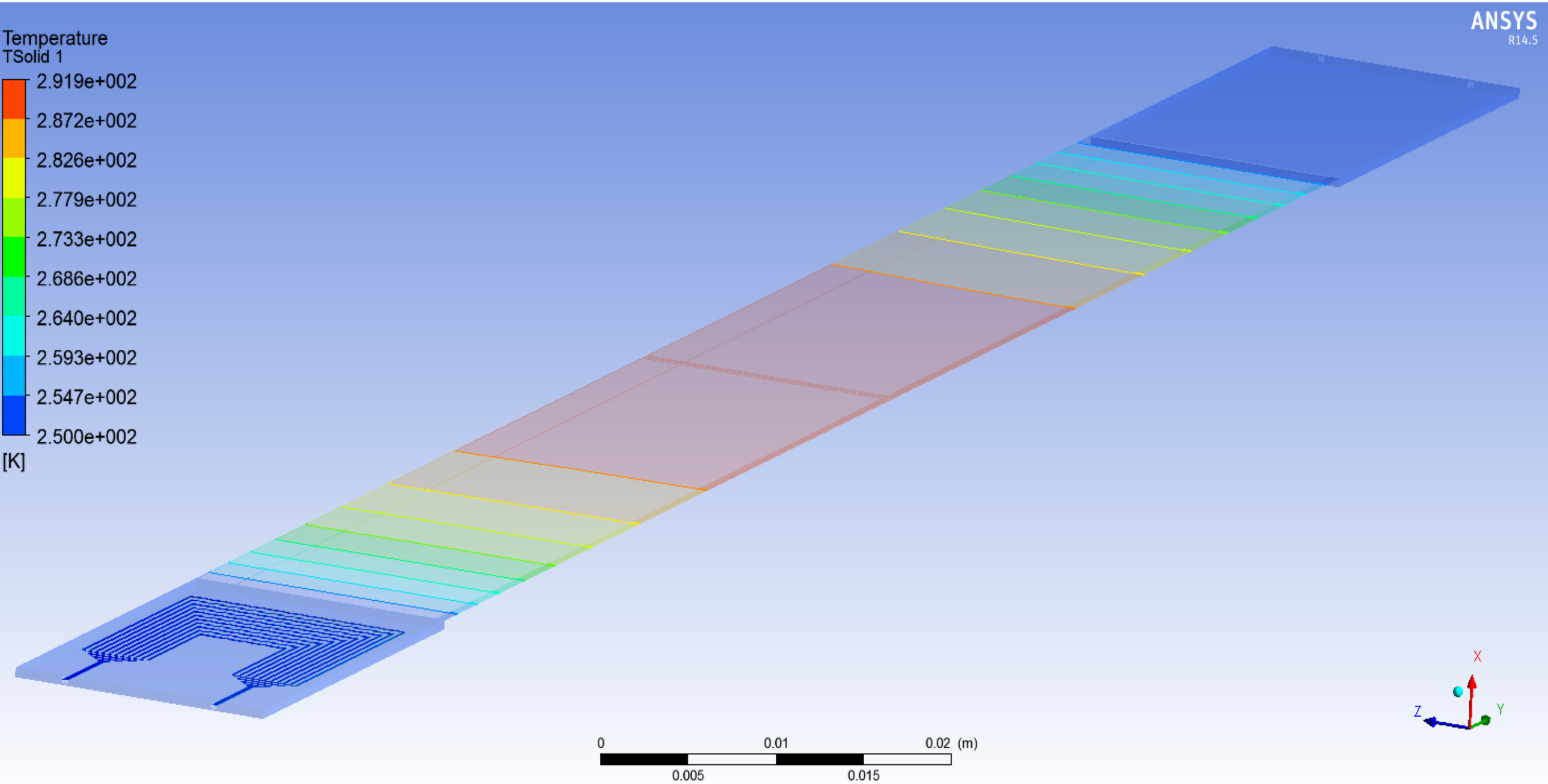


2. CO2 cooling

DEPFET detectors op. Temperature ~ +25ºC

If P=65 bar (6.5MPa)

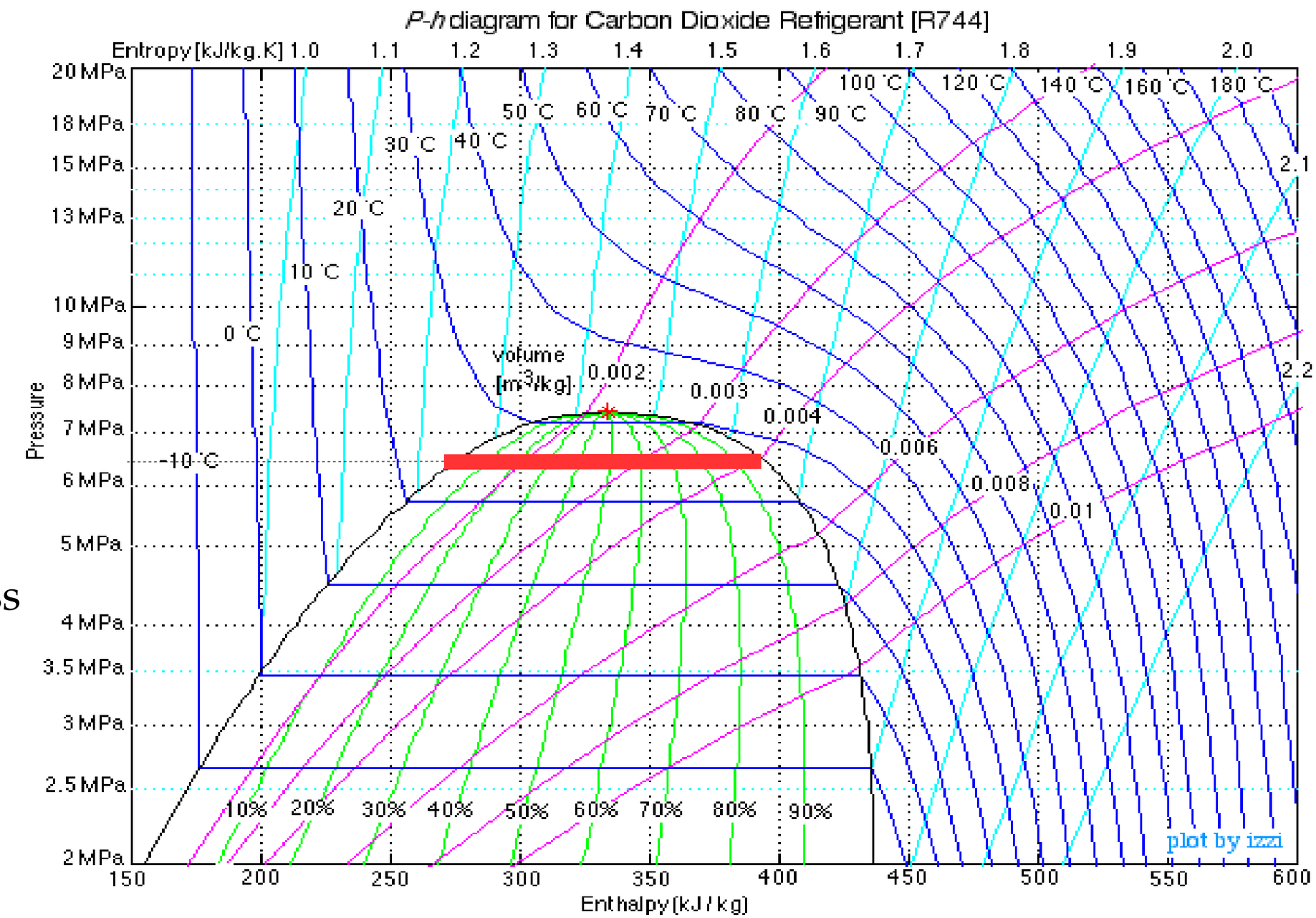
- Expensive

- Dangerous

- Pure water is better option in heat transfer (Cp, λ).

- Extra mechanical stress in the microchannels

- Biphase fluid



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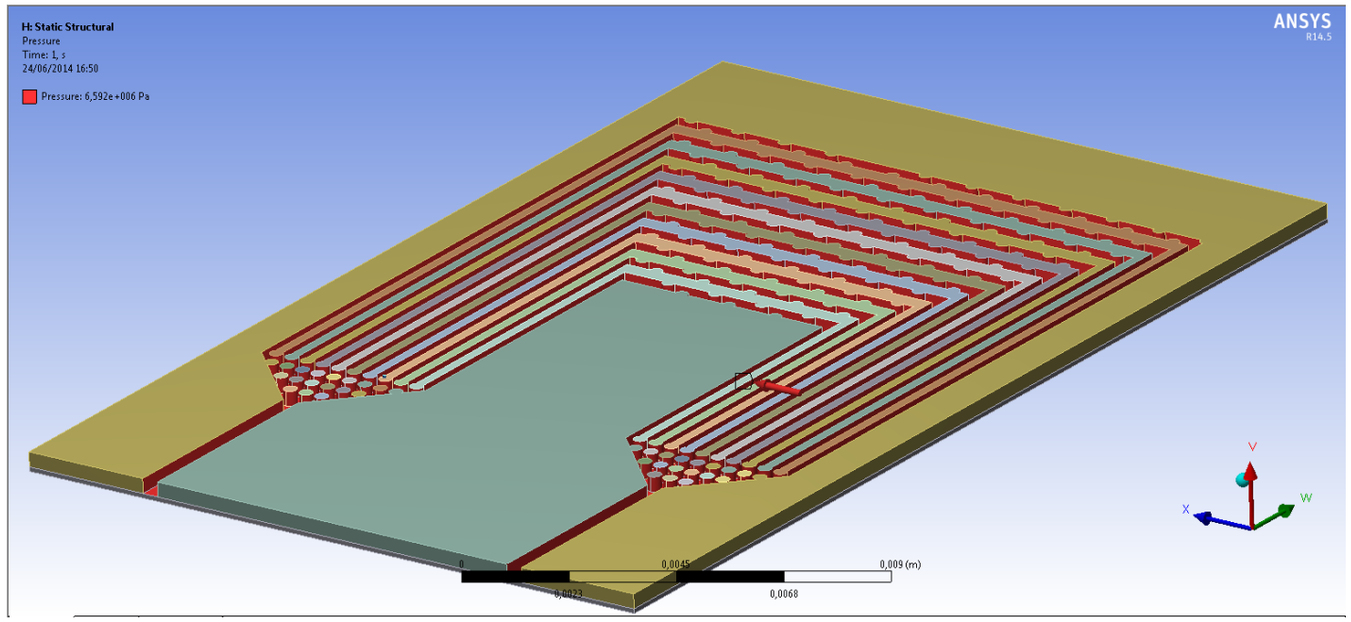
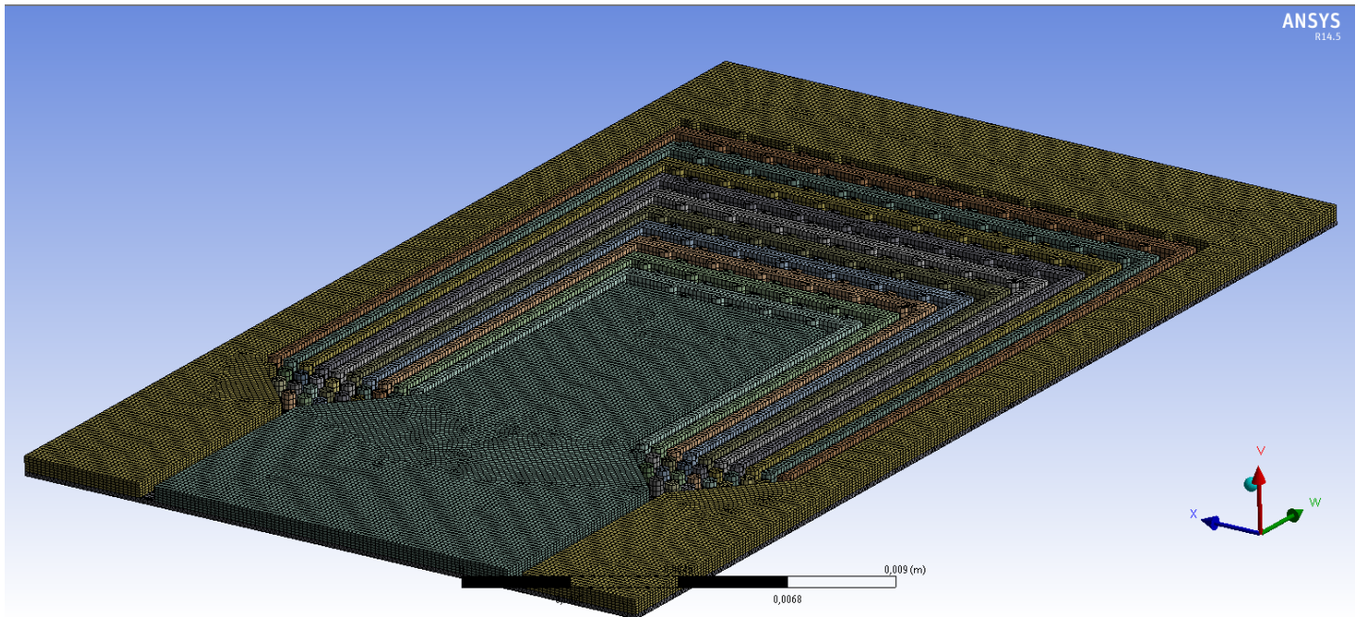


About 600K elements
75% Tet10
25% Hex20



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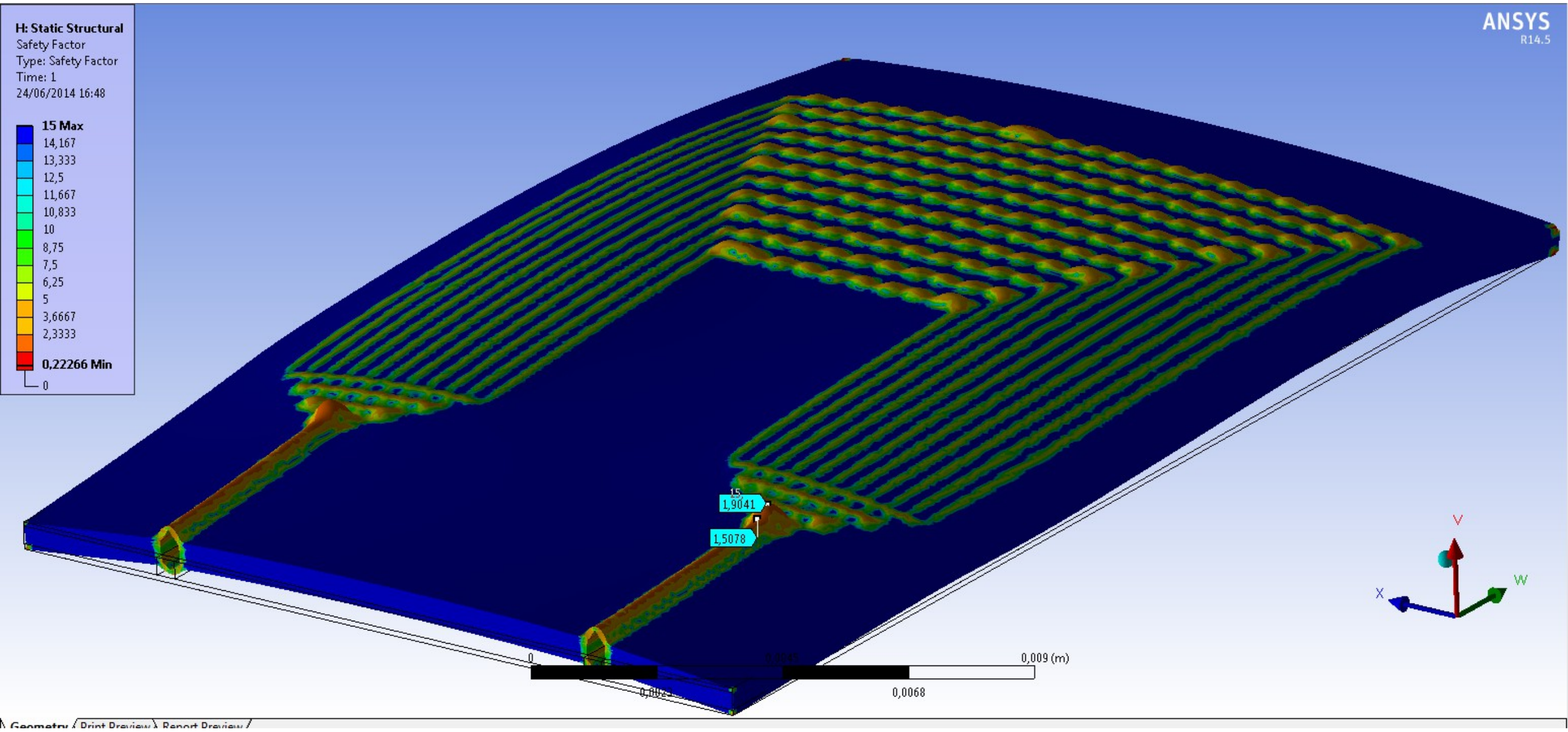


SF=Max. Stress allowed by the material / Simulated stress

3.1 Simulations with other coolants: main properties

Fluid (21-25ºC) 1 atm	Pure Water	Air	PGW2080	PGW6040	EGW2080	EGW6040
Cp [J kg^-1 K^-1][1]	4181.7	1004.4	4077.164	3537.17	3809.26	3047.408
λ [W m^-1 K^-1][1]	0.6069	2.61E-02	0.49305	0.32524	0.49824	0.34946
ρ [kg m^-3][1]	997.0	1.185	1018.56	1047.52	1034.88	1098.56
μ [kg m^-1 s^-1][1]	8.899E-04	1.831E-05	1.95E-03	9.51E-03	1.61E-03	5.17E-03
Relative permittivity[2]	80.2	1.00059	PG pure: 32		EG pure: 37.7	
X_0 [mm][3]	360.7	309367.09	364.4	371.8	357.7	351.6

PGW2080: 20% Propylene Glycol, 80% Pure Water

PGW6040: 60% Propylene Glycol, 40% Pure Water

EGW2080: 20% Ethylene Glycol, 80% Pure Water

EGW2080: 60% Ethylene Glycol, 40% Pure Water

[1]Manufacturer technical data sheet

[2]www.matweb.com

[3]own calculation

3.2 Coolants Comparison: PGW vs EGW

Advantages PGW

- Less dense
- High Cp
- No toxic
- Radiation length
- Low relative electric permittivity
- Environmenta friendly

Advantages EGW

- Less viscous
- High thermal transfer coefficient λ
- More stable with temperature differences
- Better understood (more history)

3.2 Coolants comparison: Water vs PGW&EGW

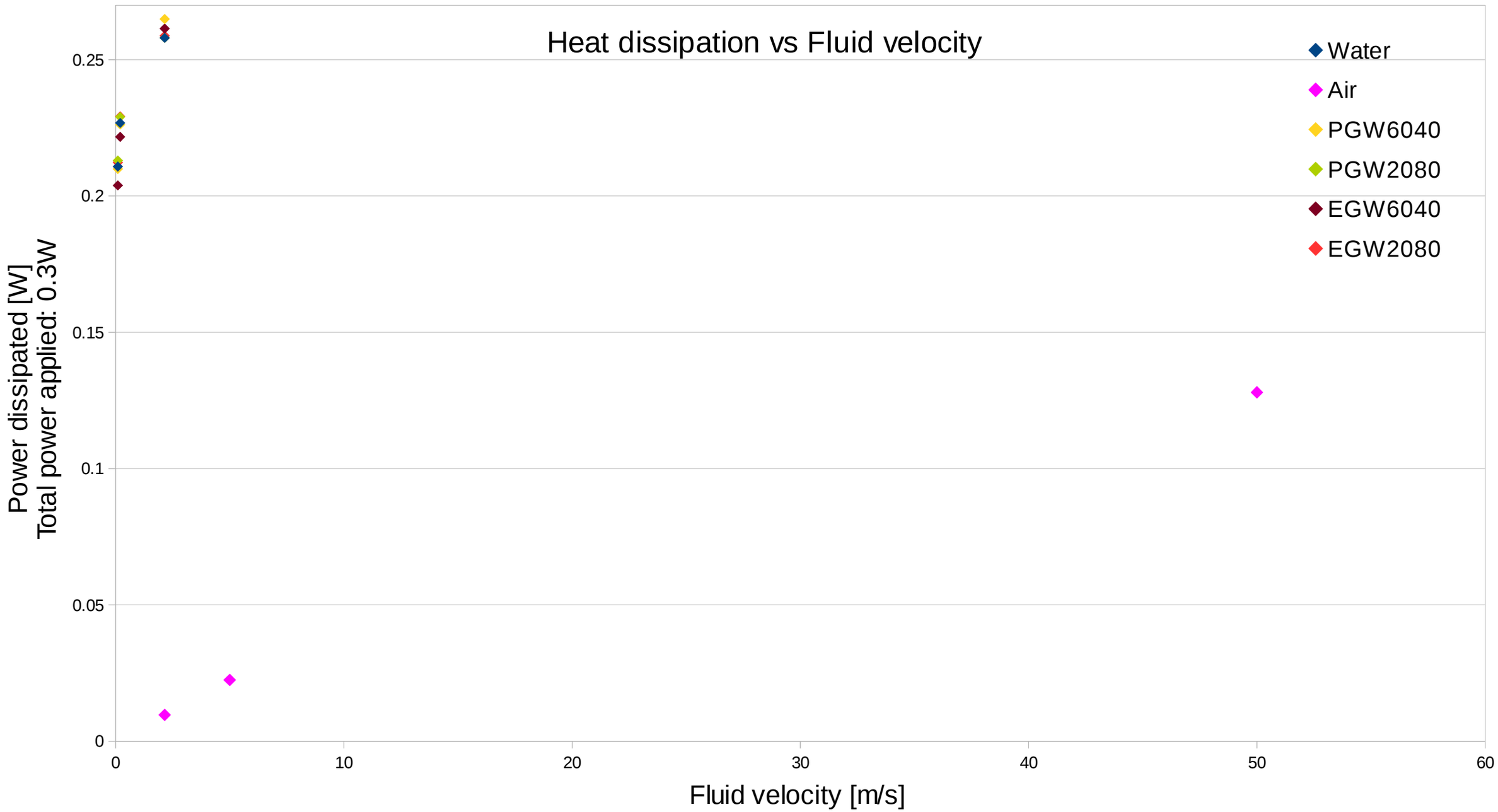
Advantages Desionized Water

- Cheaper
- Higher Cp
- Higher thermal transfer coefficient λ
- Less viscuous μ

Advantages PGW&EGW

- Less corrosive
- Low relative electric permittivity
- Higher boiling point and lower freezing point
- Higher Vapor Pressure (easier to evaporate)
- Less Denser

3.3 Coolants simulation result



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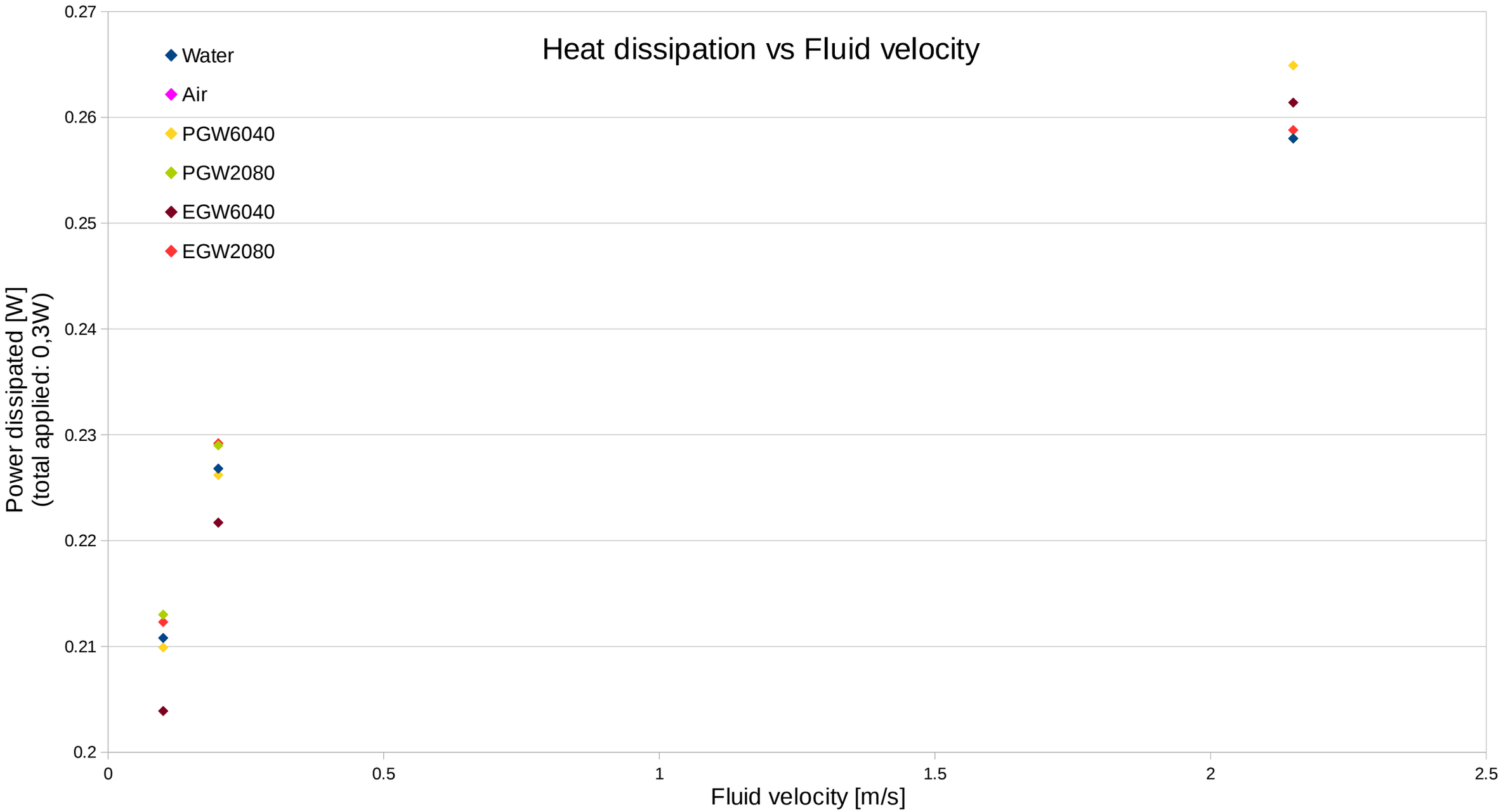
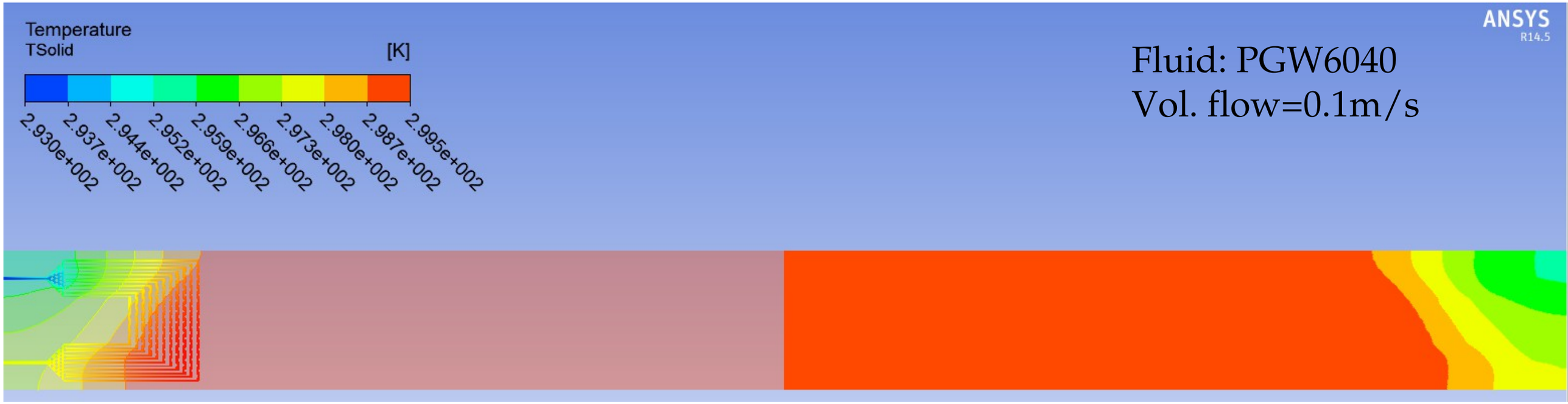


3.3 Coolants simulation result with current geometry

High vol. flow (2.15m/s)	Low vol. flow (0.1-0.2m/s)
- More heat dissipated	- Less heat dissipated
- High ΔT through the sensor	- Homogeneous T through the sensor
- High cross section	- Posibility to reduce cross section increassing the mass flow
- High material budget	- Less cross section less material



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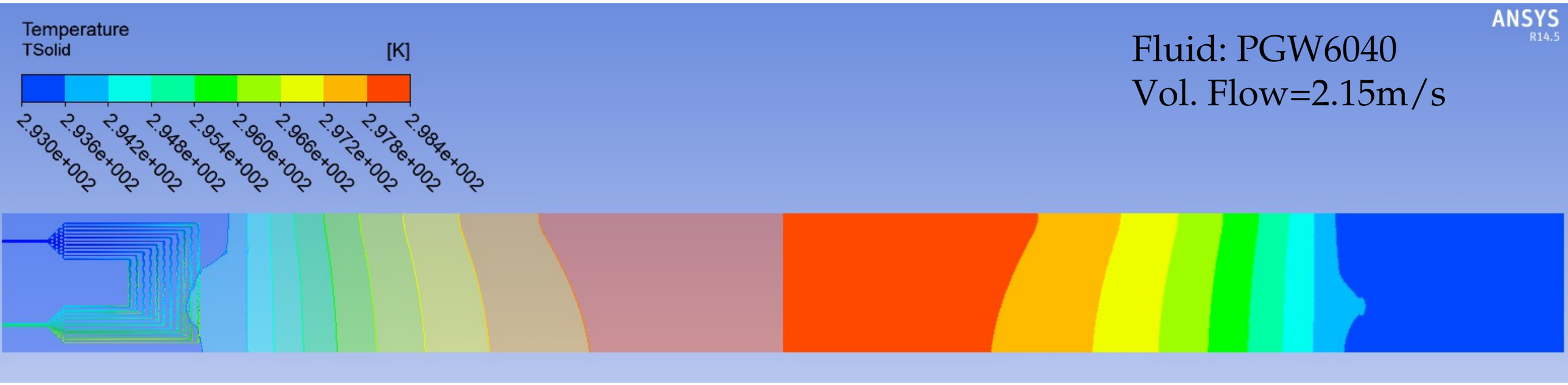

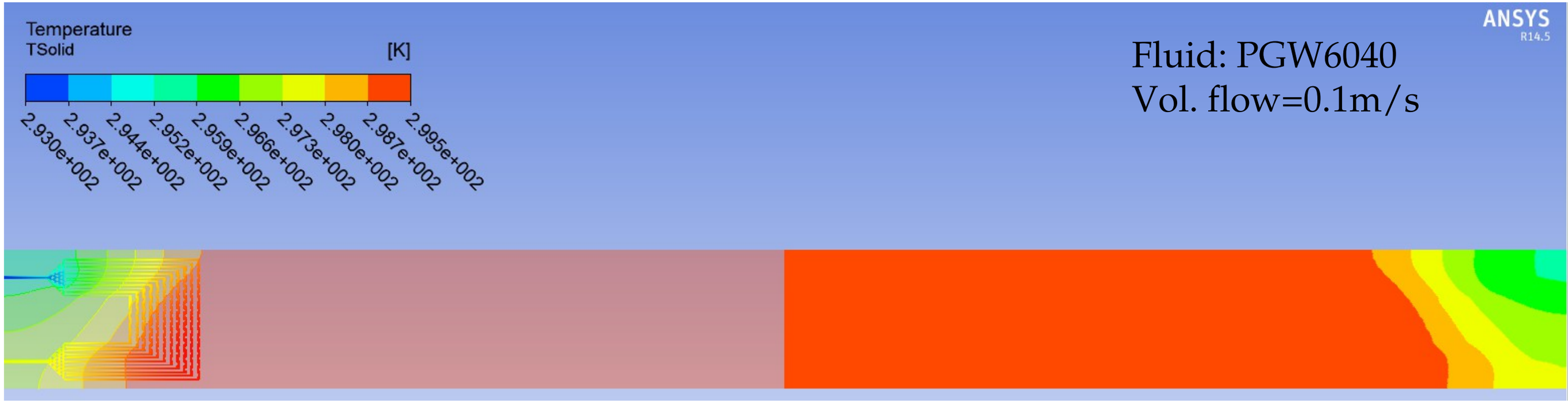

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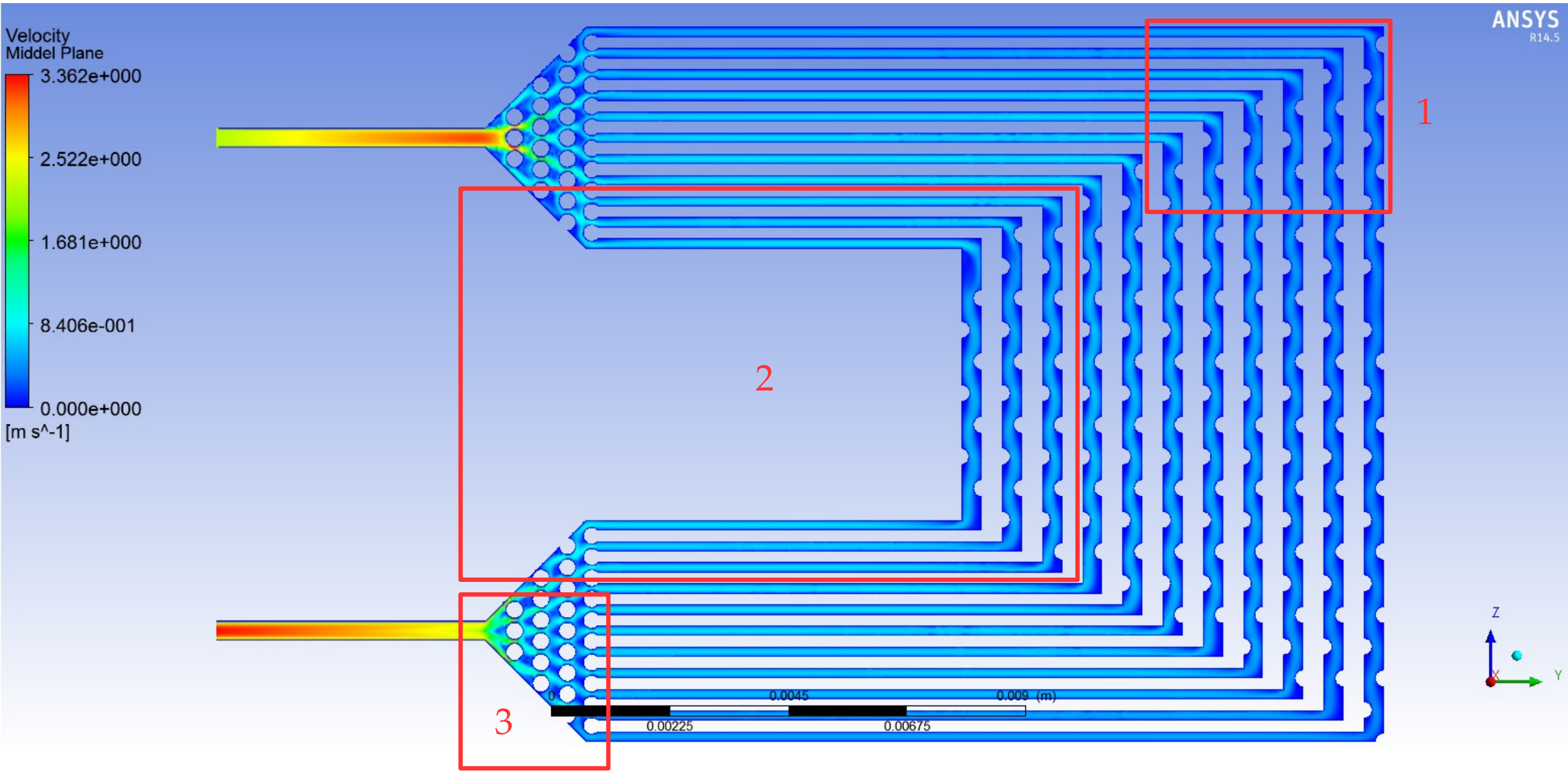
- High ΔT through the sensor	- Homogeneous T through the sensor
- High cross section	- Posibility to reduce cross section increassing the mass flow
- High material budget	- Less cross section less material

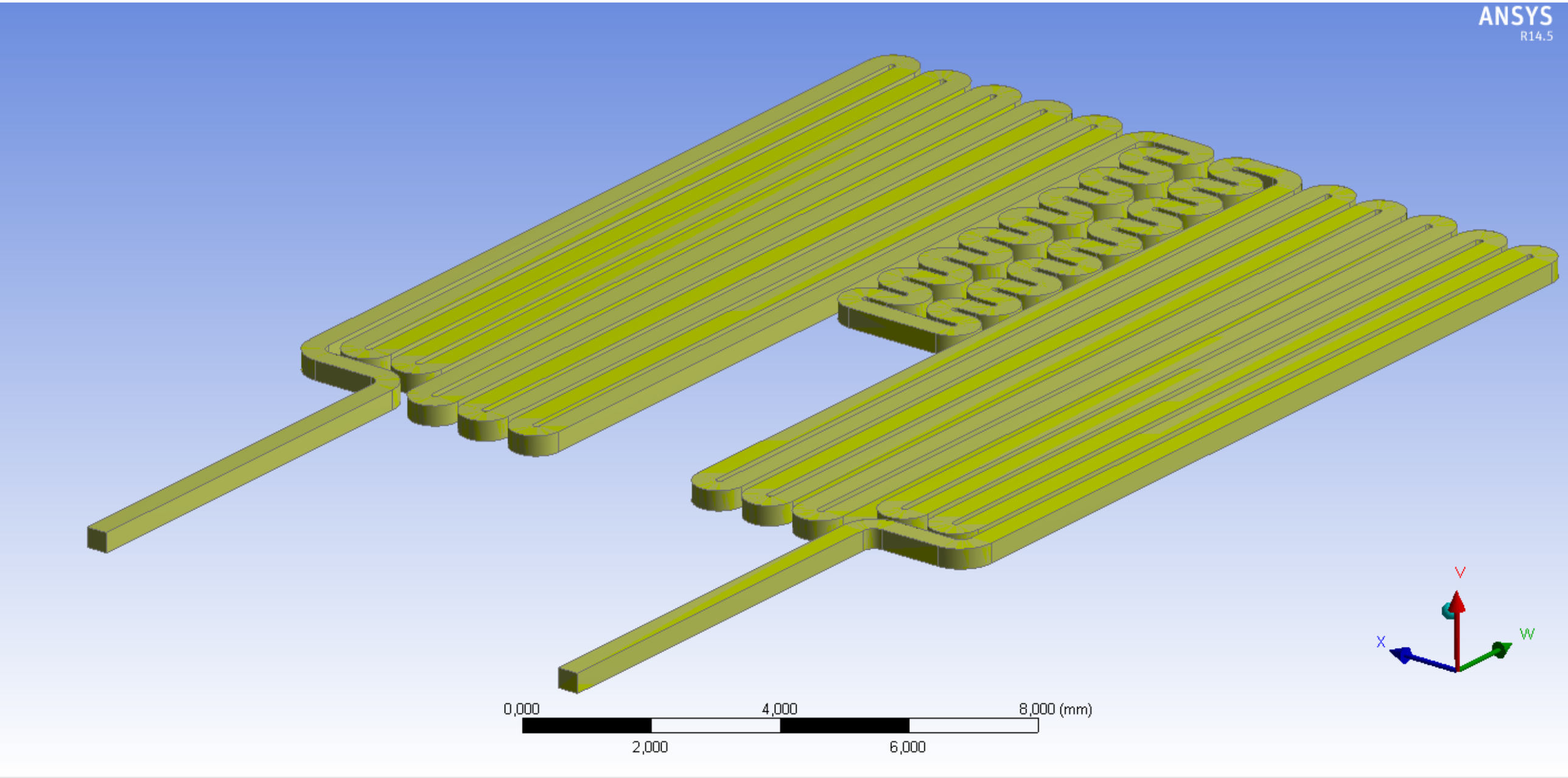
Proposed solution:

V: 0.15m/s ΔT near to 0 → we can save material (Si and fluid if we decrease the cross section) but to achieve the DT through the sensor near to 0 → rise up the volumetric flow to 2,15m/s then usage of PGW6040 which has better thermal performance

4 Microchannel alternative geometry



4 Microchannel alternative geometry



5. Future work

- Try to proximate (even more) simulations with test
- Material properties dependence with temperature (Si, water,...)
- Refine mesh
- Thermal stress and deformations
- Multiphase simulations (if needed)
- Simulations with more detailed elements (volume in switches, interface layer between chips and detector, ...)
- Optimize the microchannels geometry

6. Conclusions

- Simulations match with tests
- CO2 and gas (air) is not an option
- Different liquids proposed as options with its advantages and disadvantages
- At 297-298K temperature homogeneity on the sensor
- PGW6040 proposed as solution for 2,15 m/s reducing the material budget and obtaining a homogeneous T along the sensor