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FACULTY OF MECHANICAL
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Simulation of cooling system for PANDA electromagnetic calorimeter using CFD

PANDA Collaboration Meeting
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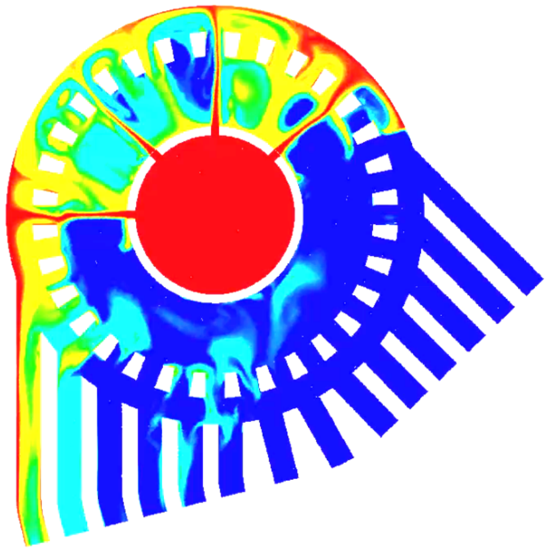
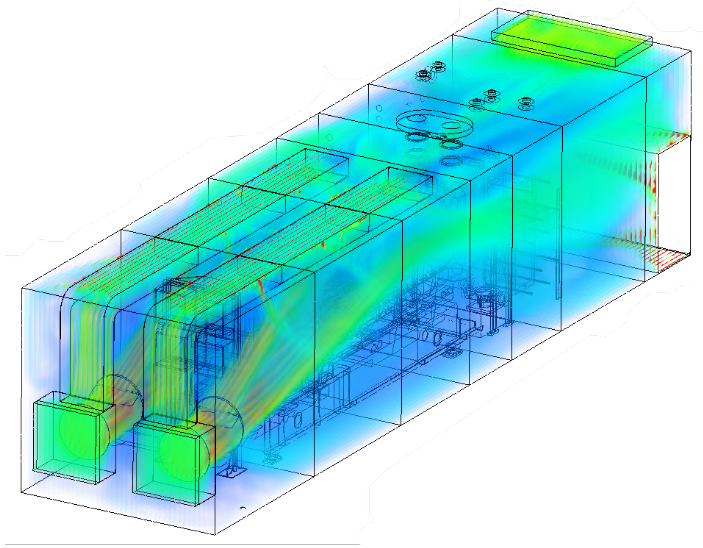
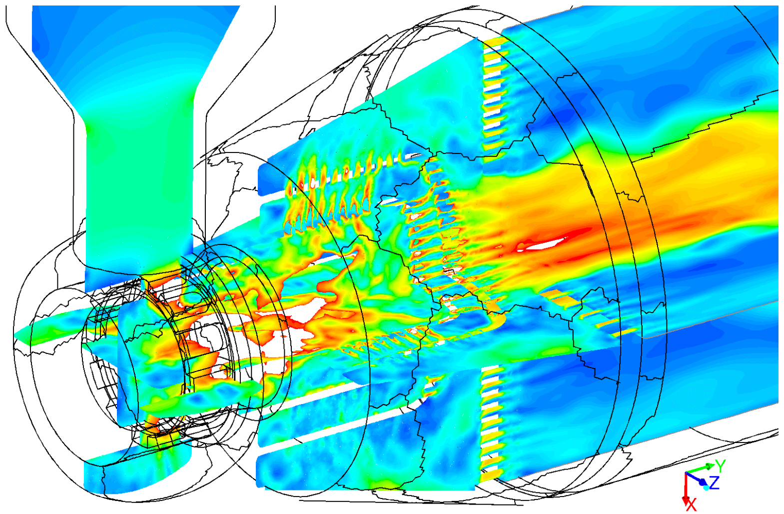
Ammonia-water solution-based heat exchangers



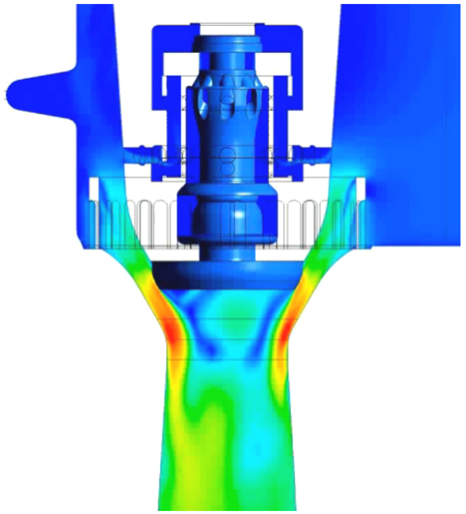
Cogeneration units



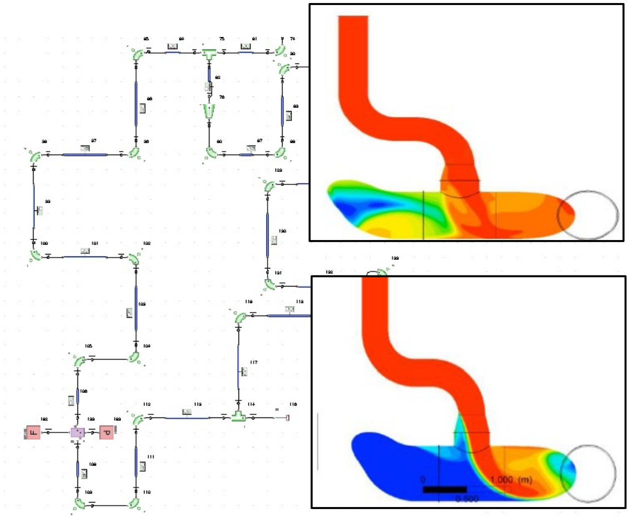
Complex geometries (reduction cages)



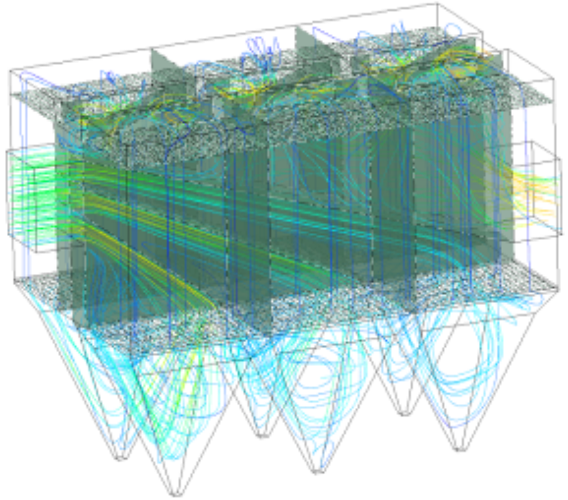
Complex geometries (valves)



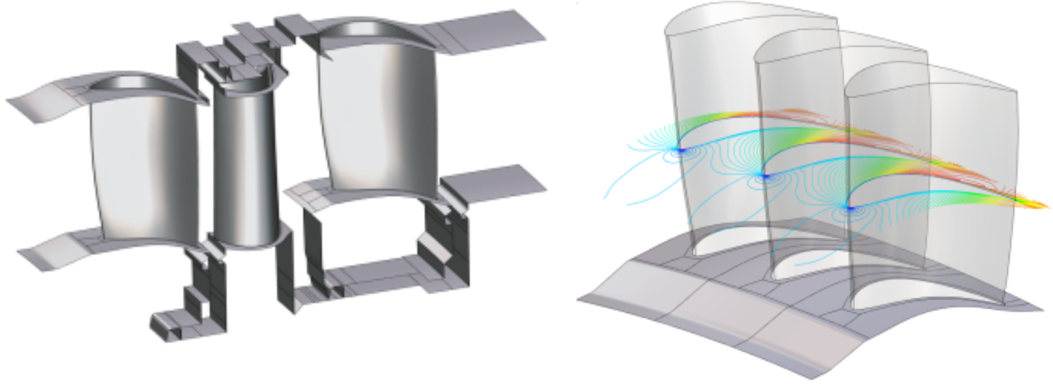
1D & 3D analysis (Nuclear Power Plant)



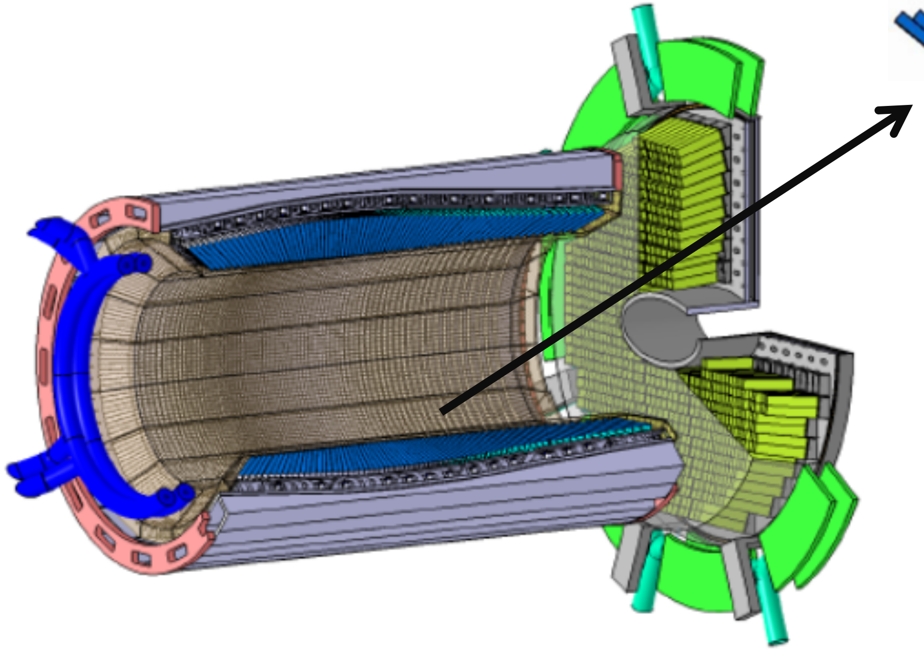
Electrostatic precipitators of flue dust

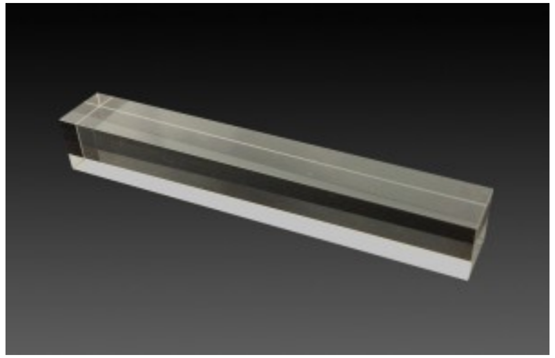


Turbomachinery



Introduction





$PbWO_4$ light yield ↑↓ temperature

lower temperature is better
temperature stability

among all crystals ≈ 1 K

within a single crystal ≈ 0.1 K

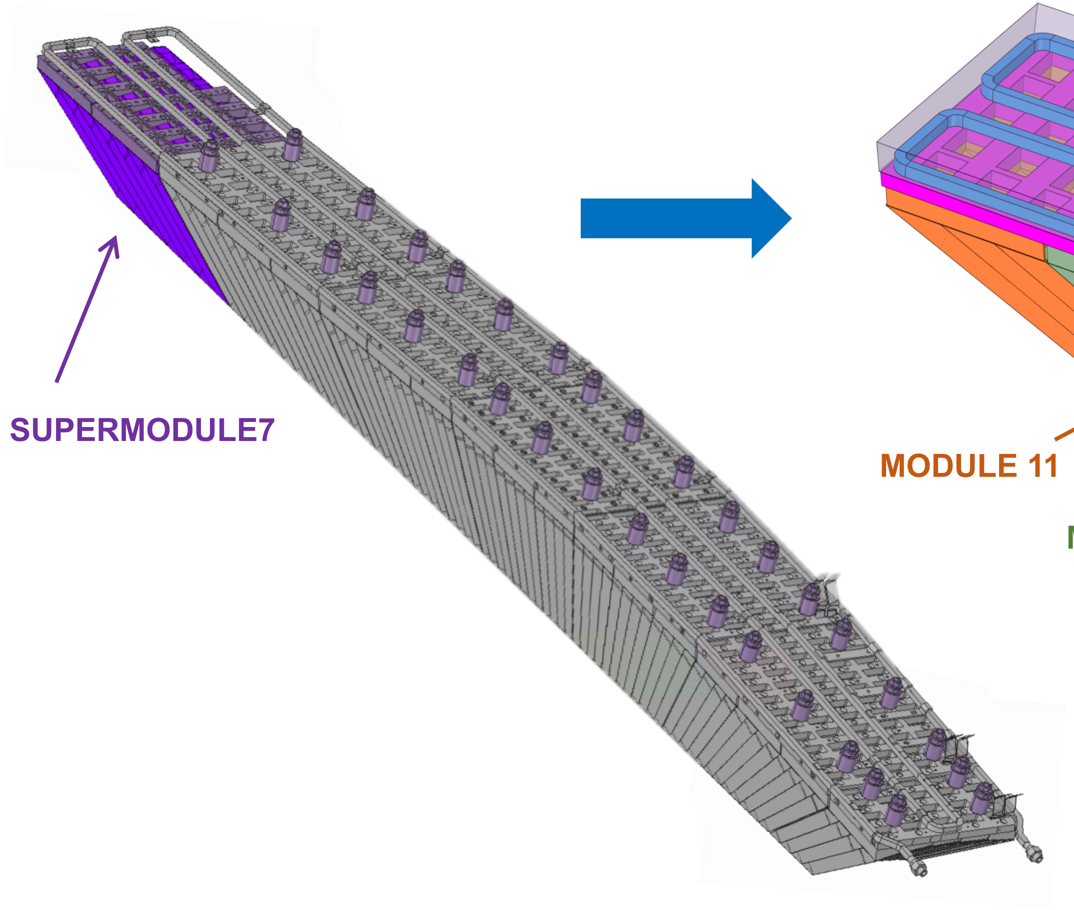
How can this be achieved?

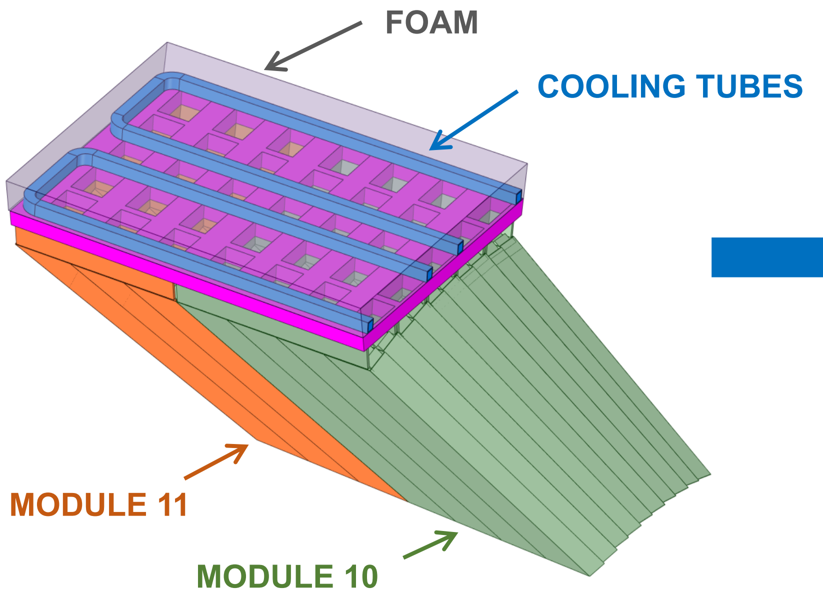
- ? number of cooling tubes
- ? shape of cooling tubes
- ? mass flow rate of cooling medium
- ? inlet temperature of cooling medium

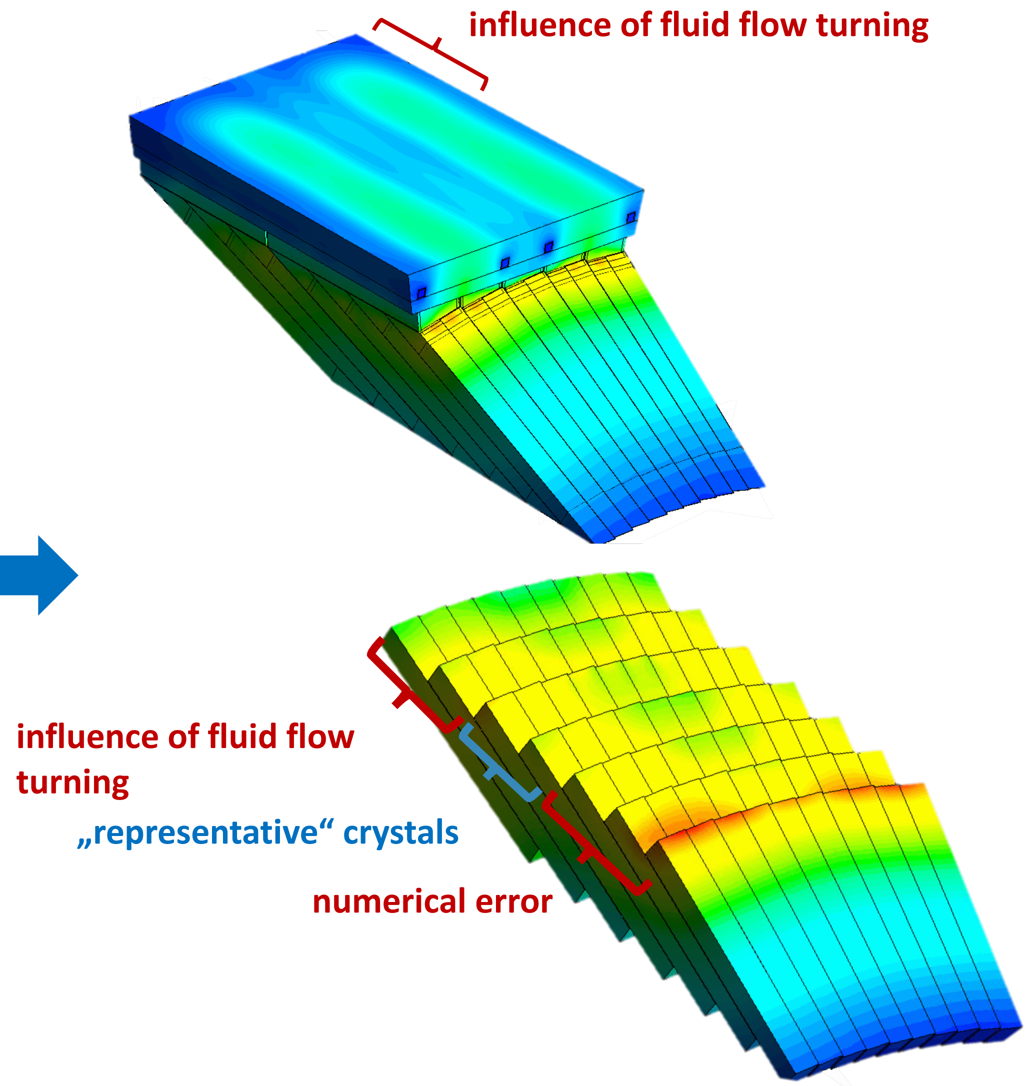
- ! limited space for cooling circuits
- ! crystals cannot be cooled down directly
- ! homogenous temperature field
- ! different pressure losses in each cooling circuit

First approach

- **partial geometry is used for simulation in order to:**
  - decrease pre-processing time
  - decrease computational time





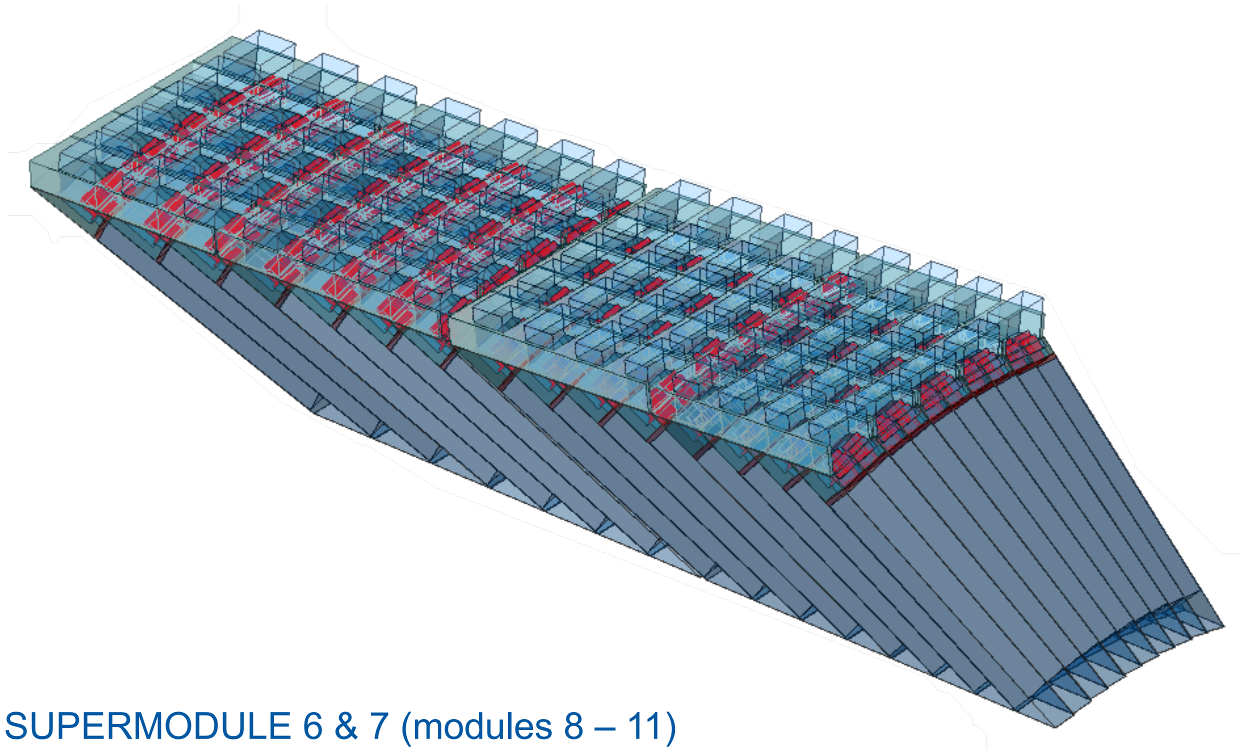


- **computational domain should be extended to increase the number of „representative“ crystals**

Computational domain

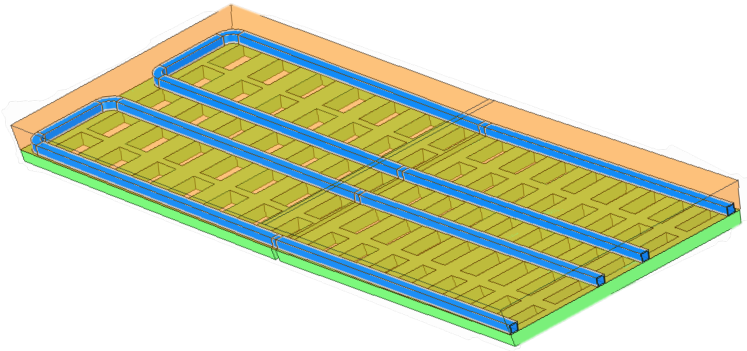
- **ccomputational domain has been divided to two parts: <u>base domain</u> (crystals etc.) and <u>cooling system</u>**
  - simplifies the procedure of testing multiple cooling systems
  - ensures the base domain is not influenced by changes in computational mesh

BASE DOMAIN

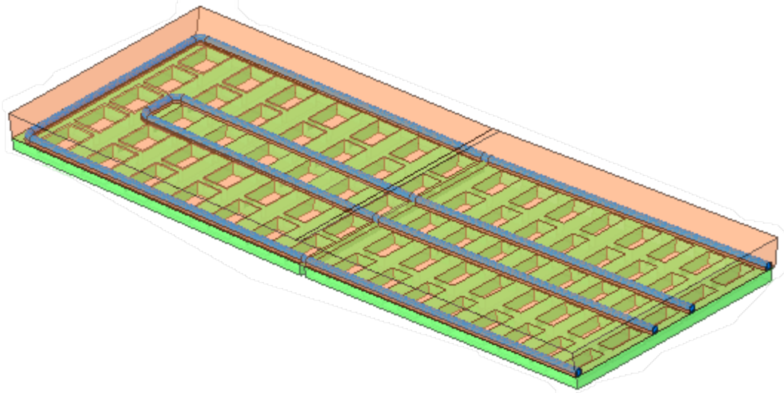


- SUPERMODULE 6 & 7 (modules 8 – 11)
  - domain consists of 150 crystals
  - 100 of them are considered as representative for the rest of SLICE

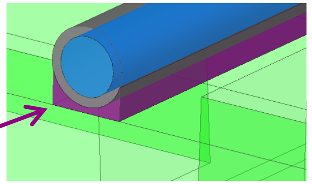
COOLING SYSTEMS



- rectangular tubes
- inner dim. 8 x 8 mm
- two separate circuits

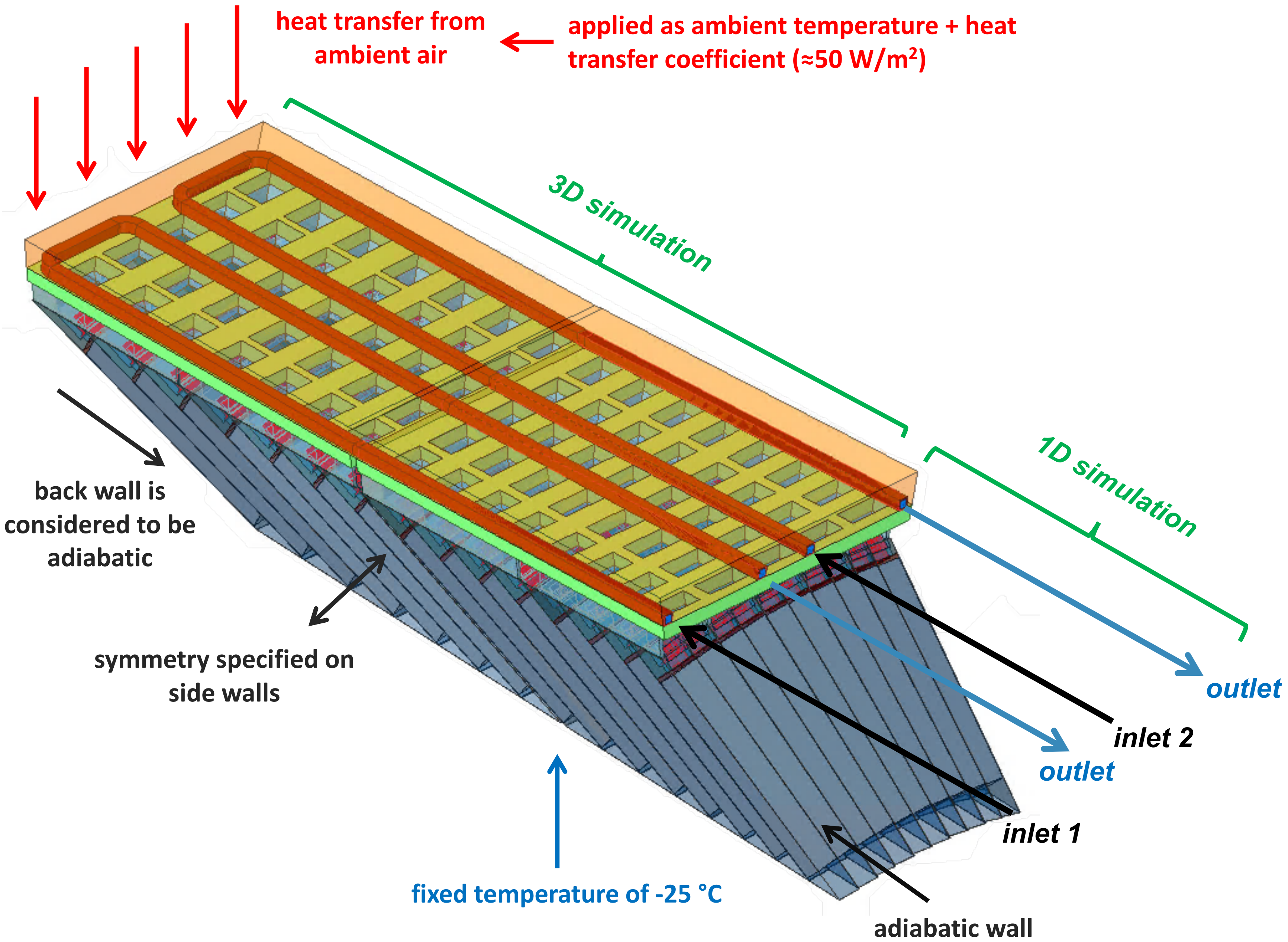


- round tubes
- inner diam. 8 mm
- two separate circuits



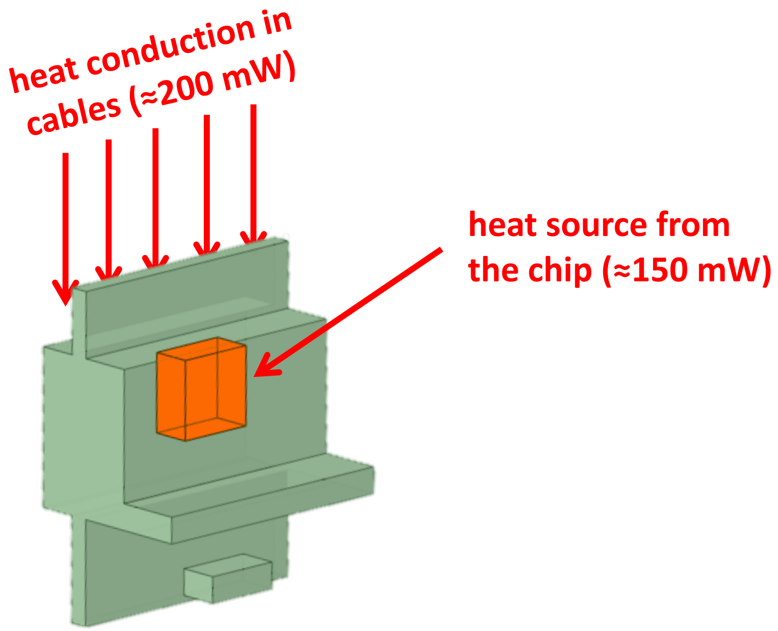
connection

Numerical simulation setup



Heat sources:
- ambient temperature 25 °C
- read-out electronics
- heat conduction in cables

Cooling fluid:
- -28 °C, 0.4 kg/s at inlet
- pressure of 1 atm at outlet
- mixture of water/methanol (40/60)



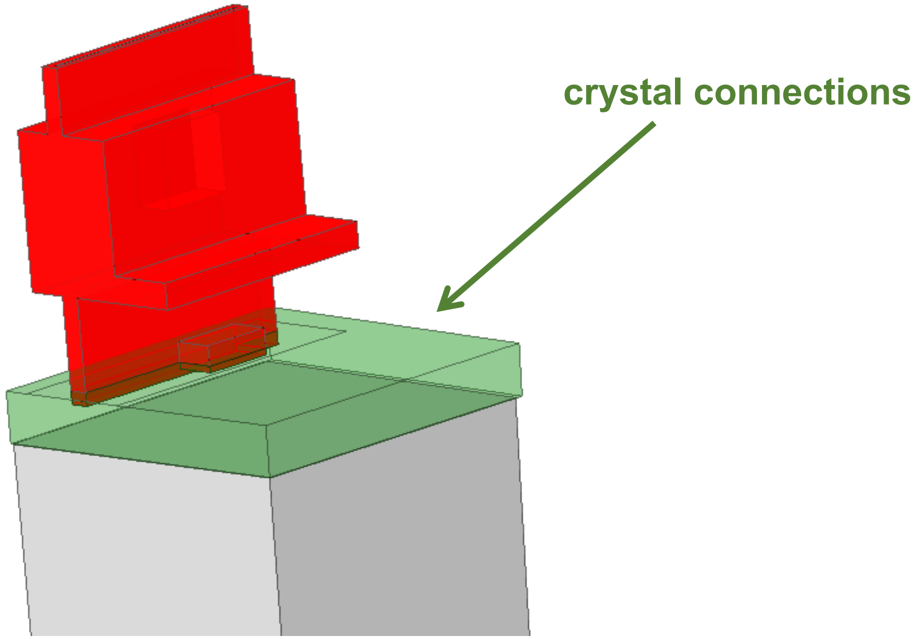
Material properties

Component	Material	Specific heat capacity [J kg-1 K^{-1}]	Thermal conductivity [W m^{-1} K^{-1}]	Density [kg m^{-3}]	Other
Crystals	$PbWO_4$	262	3.22	8280	Ref. temp. 30 °C
Crystal casings	Carbon fibres	1100	78.8	NaN	Ref. temp. 120 °C
Crystal connections	Duralum	920	147	2900	Ref. temp. 25 °C
APFEL asics	Aluminium	903	237	2702	Ref. temp. 25 °C
Electronic board holders	Duralum	920	147	2900	Ref. temp. 25 °C
Intermediate plates	Duralum	920	147	2900	Ref. temp. 25 °C
Supermodule plate	Duralum	920	147	2900	Ref. temp. 25 °C
Foam	HOCOTOL	880	154	2830	Ref. temp. 25 °C
Cooling tubes	Copper	385	401	8933	Ref. temp. 25 °C
Cooling medium	Water/methanol (40/60)	3151	0.341	930	Ref. temp. 25 °C Ref. pressure 1 atm
Ambient medium	Ideal gas	-	-	-	-

- **Material properties are NOT defined for operating temperature**
- **General values are taken since we do not have specific material sheets available**

} **needs to be reviewed**

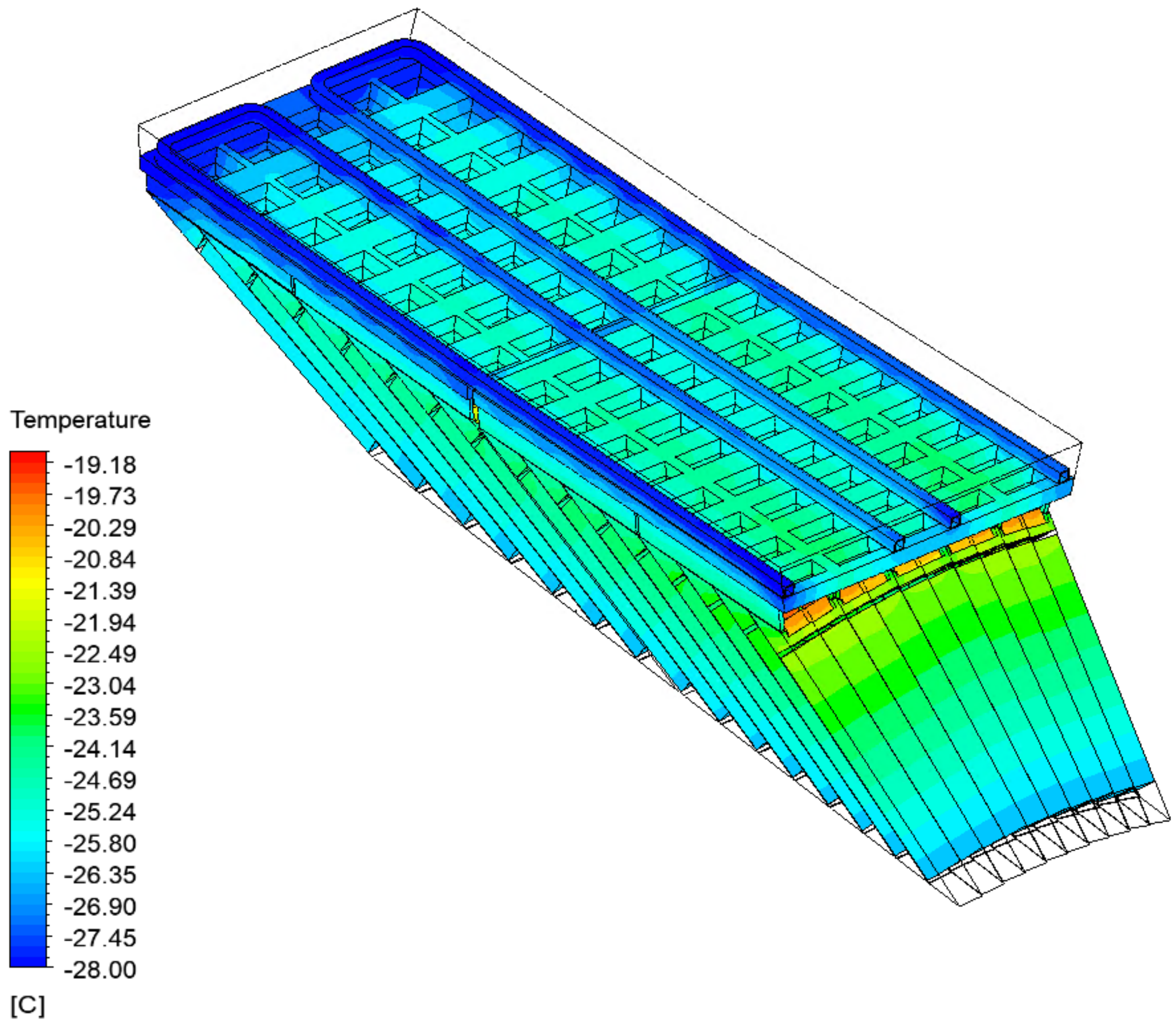
Material properties



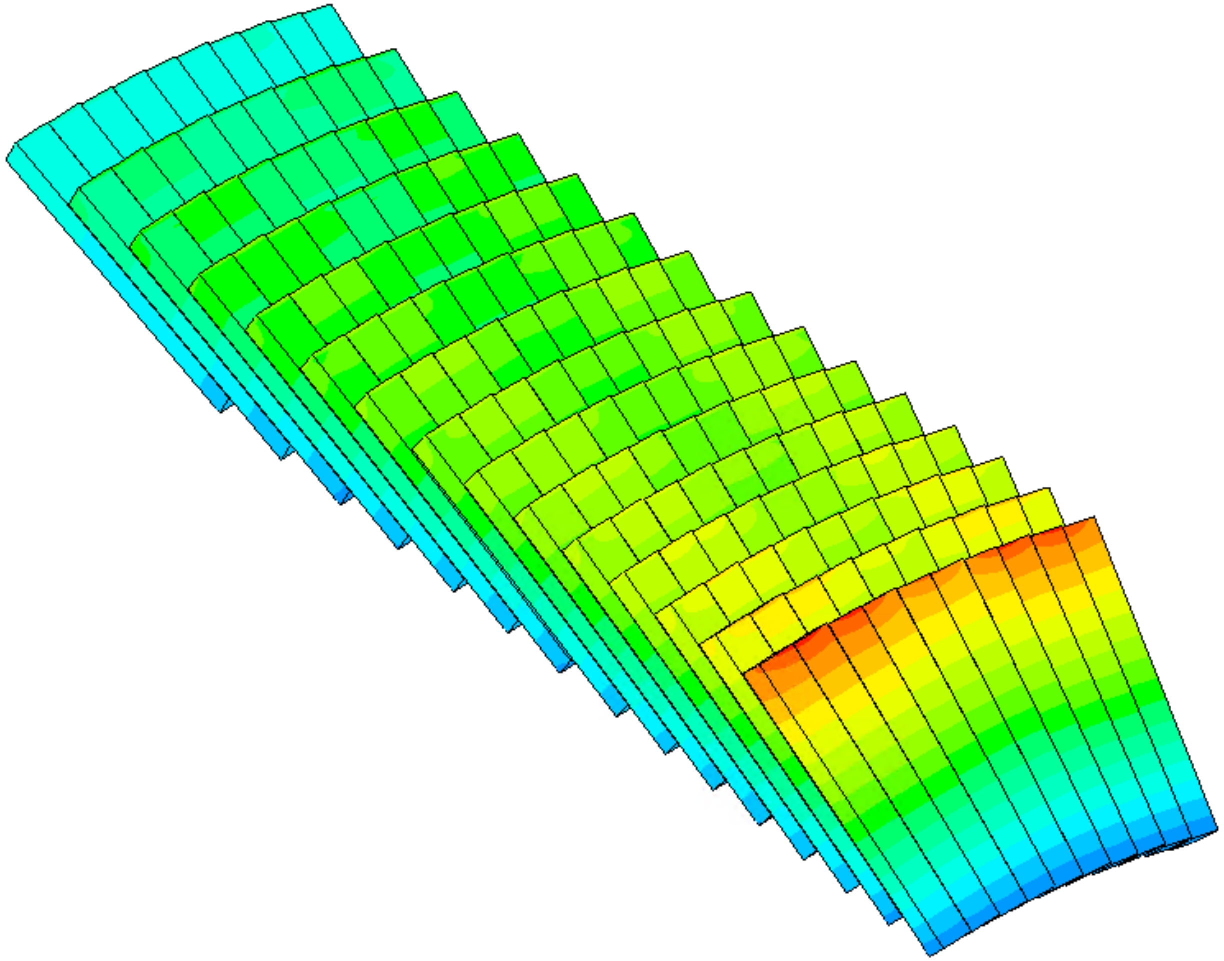
- **the connection was modeled since there was no direct connection in the default geometry**

Preliminary results

Temperature field – surface of the domain (without foam)



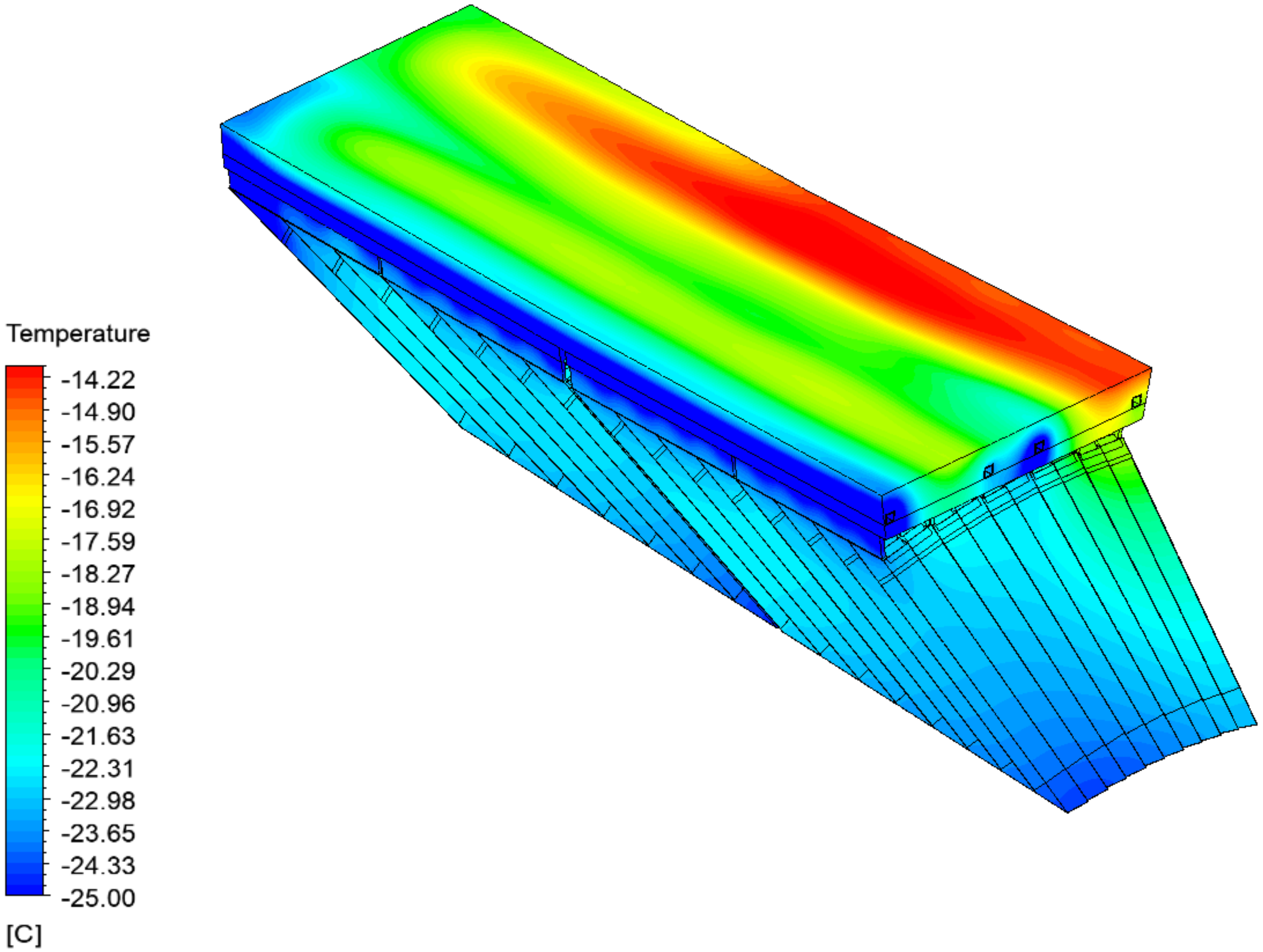
Temperature field – surface of the crystals



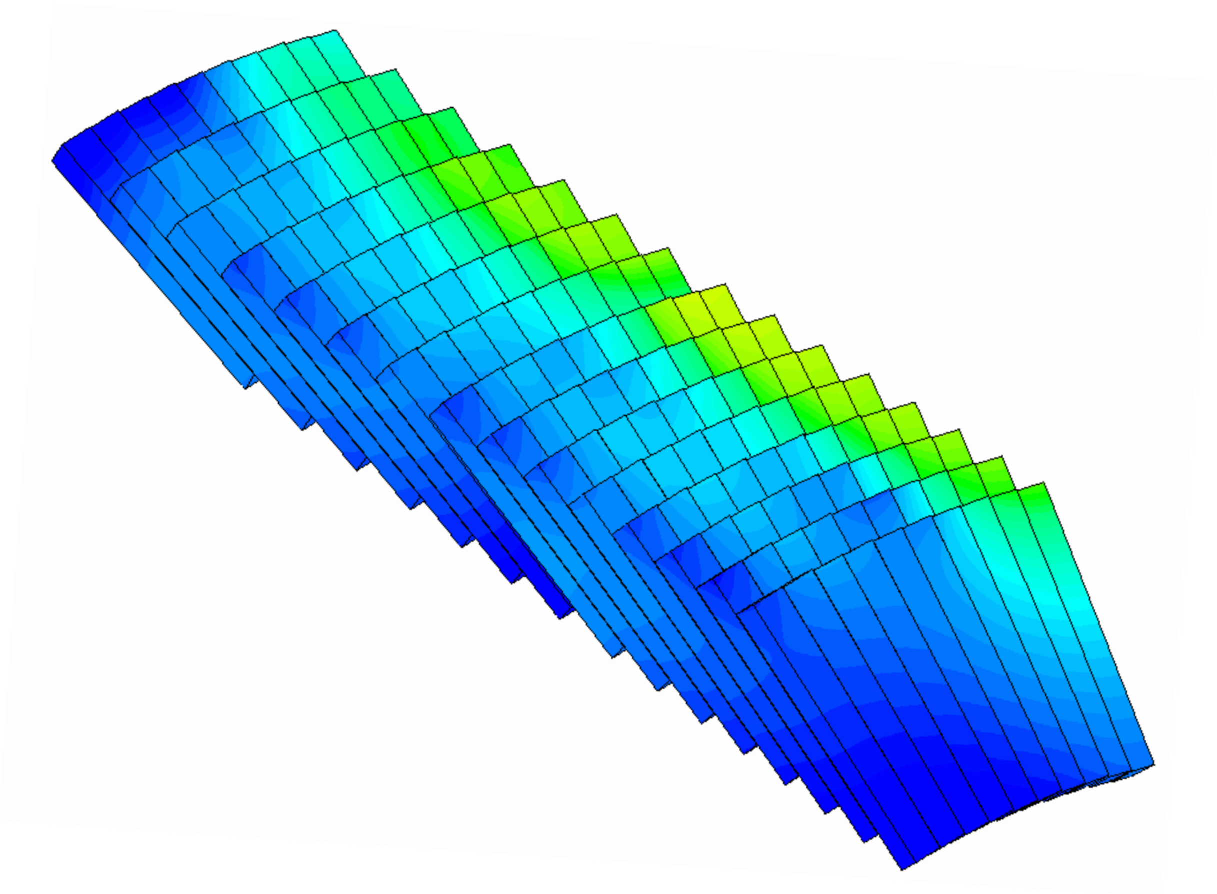
Preliminary results – cooling system failures

- **it is assumed that mass flow rate in the second circuits is only 5% of the mass flow rate in the first one**

Temperature field – surface of the whole domain



Temperature field – surface of the crystals



Conclusion

Goal: cool down crystals to approx. - 25 °C

ensure stability of temperature & homogenous temperature field

Difficulties: complex geometry with lots of connections between components that are simulated as ideal ones

lack of free space for proper cooling system

1D simplification of supermodules

high accuracy of simulations

sensitivity to boundary conditions

difficulties with material properties at working temperature

Follow-up research: result comparison between various cooling system designs

propose cooling design modifications

simulate cooling system failures

VALIDATION OF PARTIAL RESULTS

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Thank you

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