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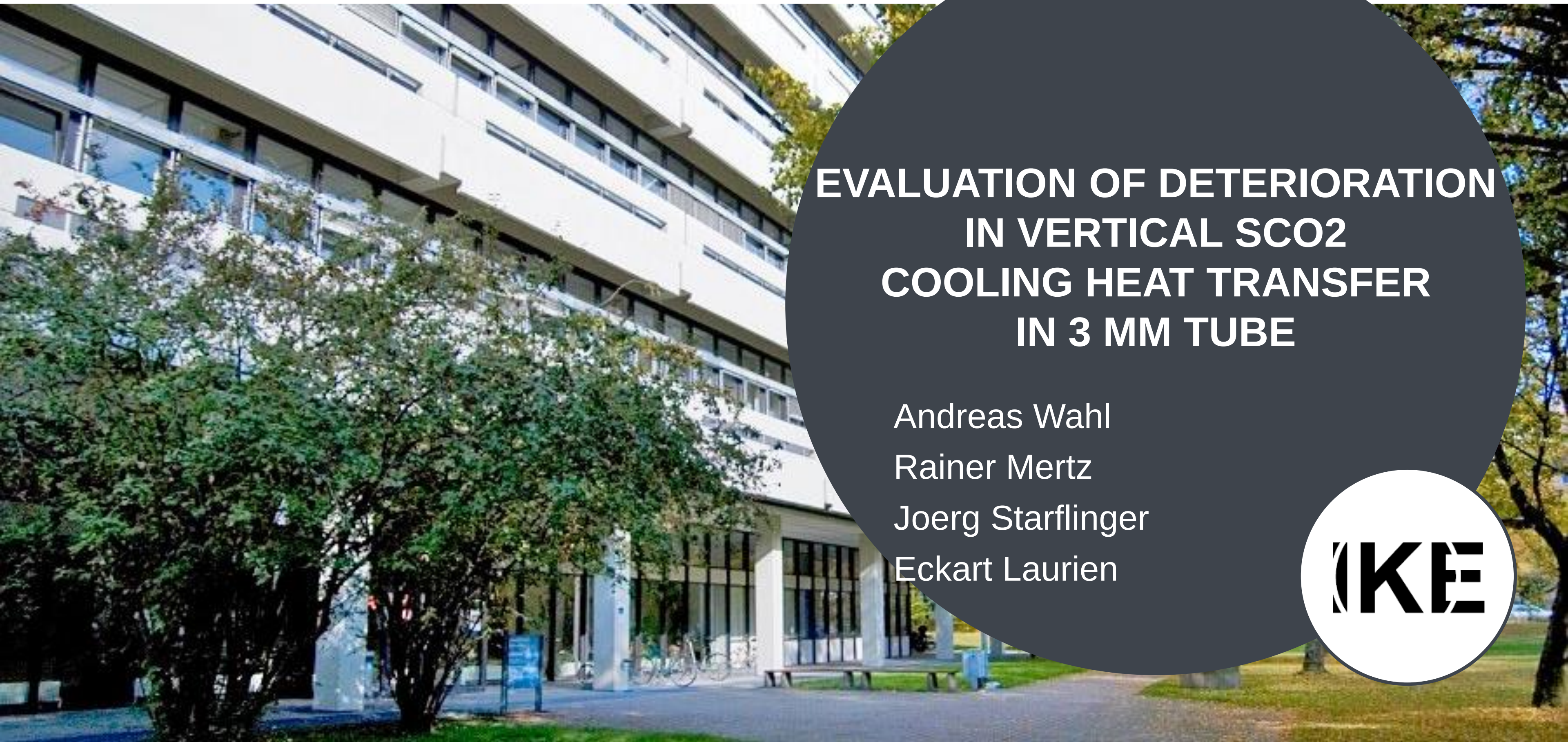
sCO2flex



EVALUATION OF DETERIORATION IN VERTICAL SCO2 COOLING HEAT TRANSFER IN 3 MM TUBE

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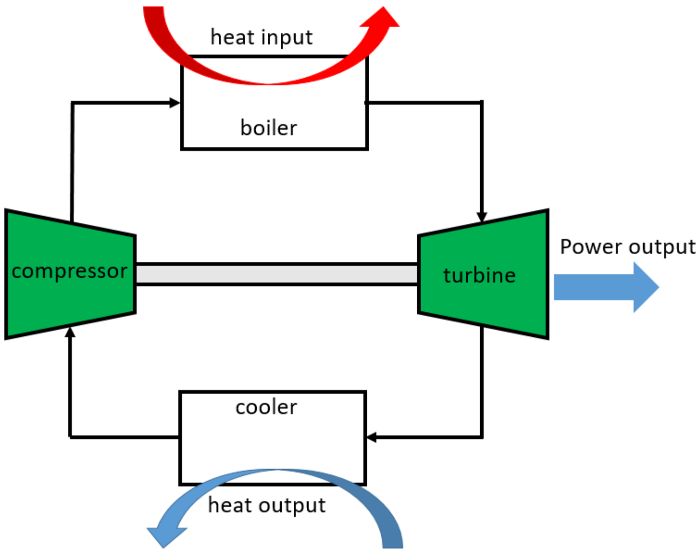
IKE

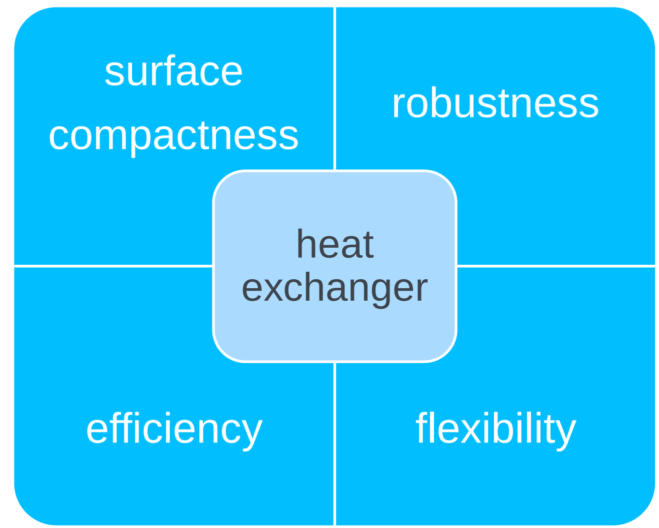
Outline

- Motivation and aims
- Experimental setup
- Data reduction
- Results
- Conclusion and next steps

Motivation

- flexible and efficient 25 MWe sCO_2 brayton cycle

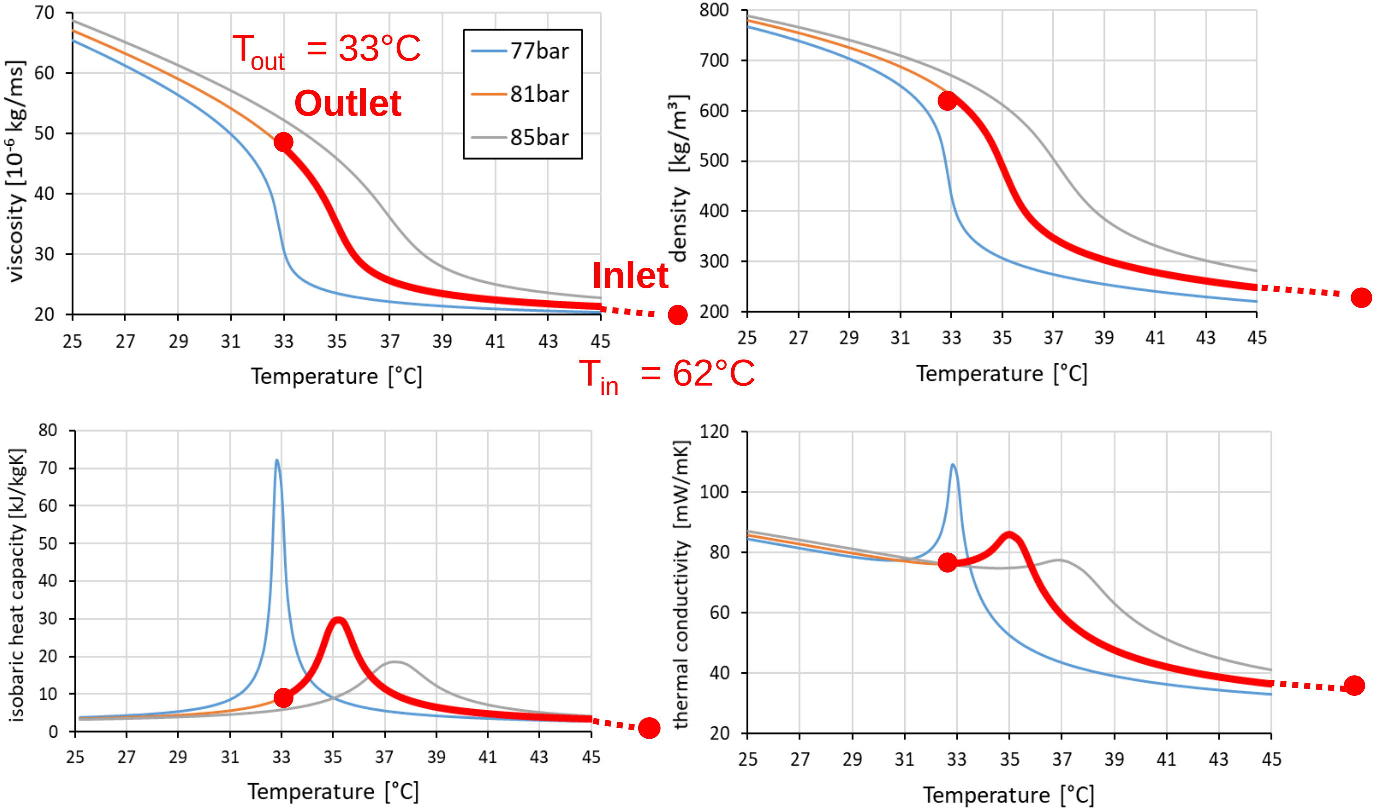




- Support of the development of compact heat exchanger
  - surface compactness
  - robustness

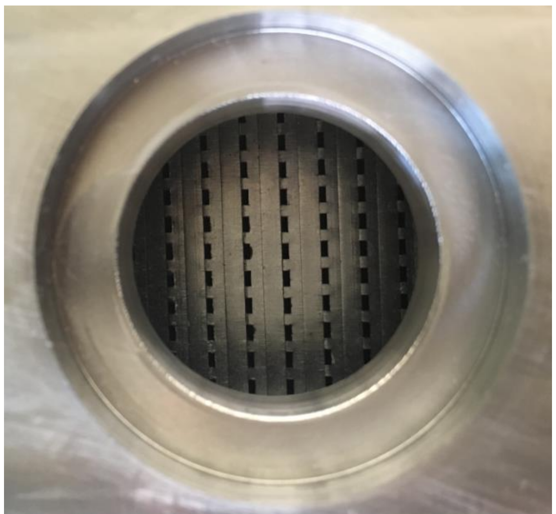
Variabel fluid properties near the critical point of CO_2

- Design point
  - p_{in} = 81 bar,
  - T_{in} = 62°C,
  - T_{out} = 33°C
- Variable fluid properties influence local heat transfer



Aim of work

- Experimental cooling heat transfer and pressure drop in 2 mm single channel flow
- recommendation of heat transfer correlation to be used for design of compact HX



Compact HX, IKE, Stuttgart

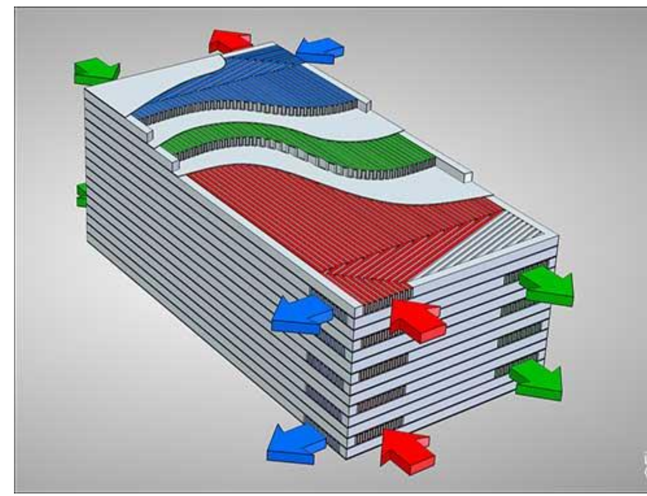
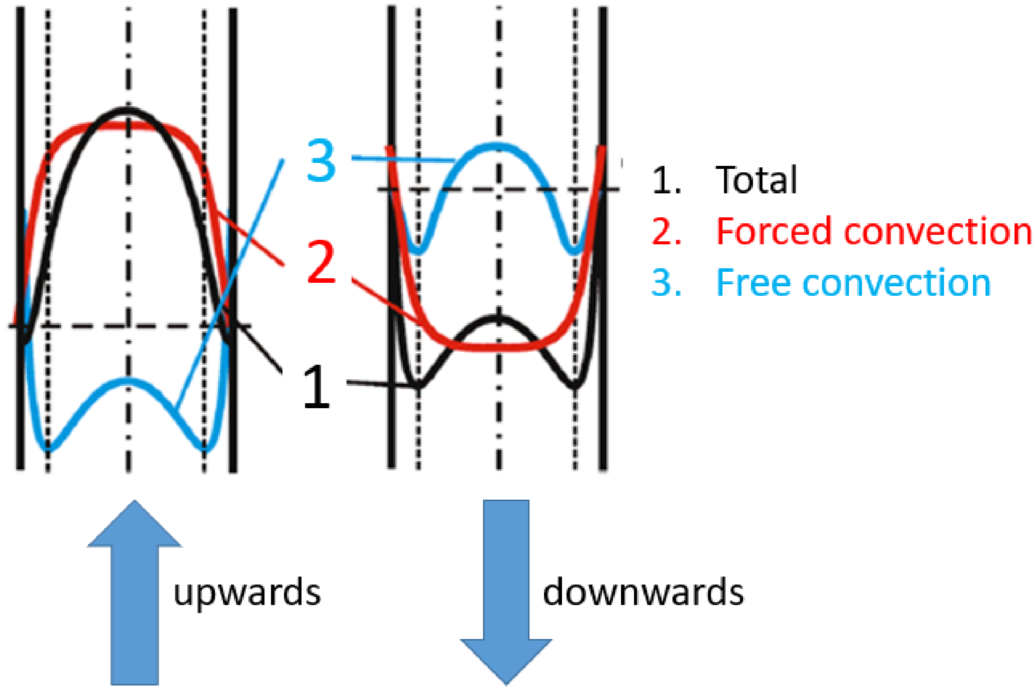


Plate and Fin HX, Fives Cryo, France

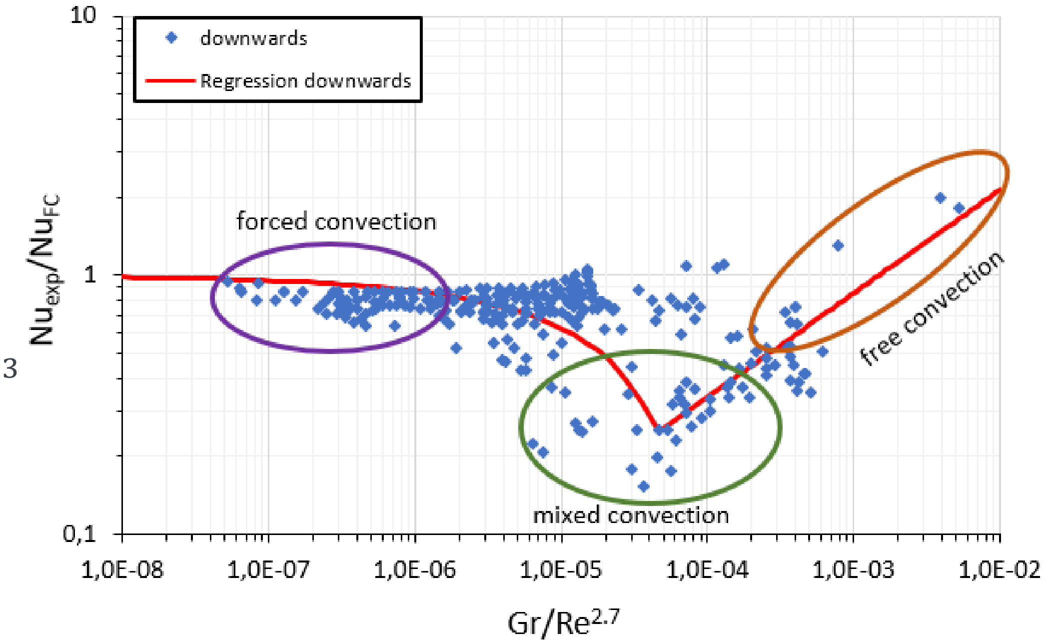
Deteriorated and enhanced heat transfer in vertical sCO2 cooling flow



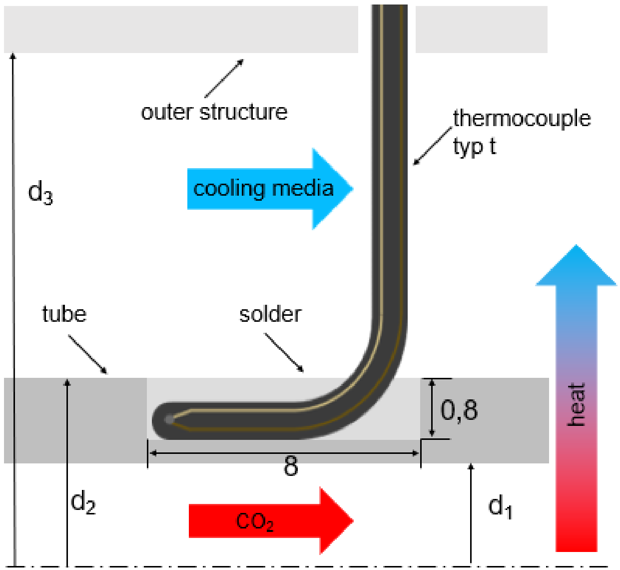
Literature Review

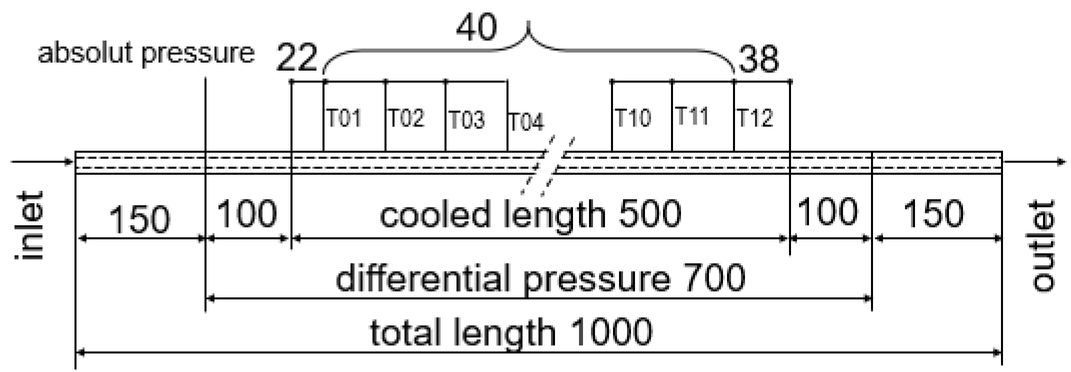
- Jackson (1979)
- $\frac{Gr}{Re^{2.7}} > 10^{-5}$
- $Gr = \frac{(\rho_b - \overline{\rho}) \cdot \rho_b \cdot g \cdot d^3}{\eta_b^2}$
- Evaluation of ratio: $\frac{Nu_{exp}}{Nu_{FC}}$
- $\mathrm{Nu_{FC}} = \ 0.0183 \ Re_b^{0.82} \overline{Pr}_b^{0.5} \left(\frac{\rho_b}{\rho_w}\right)^{-0.3}$

- Bruch (2008)
- D = 6 mm

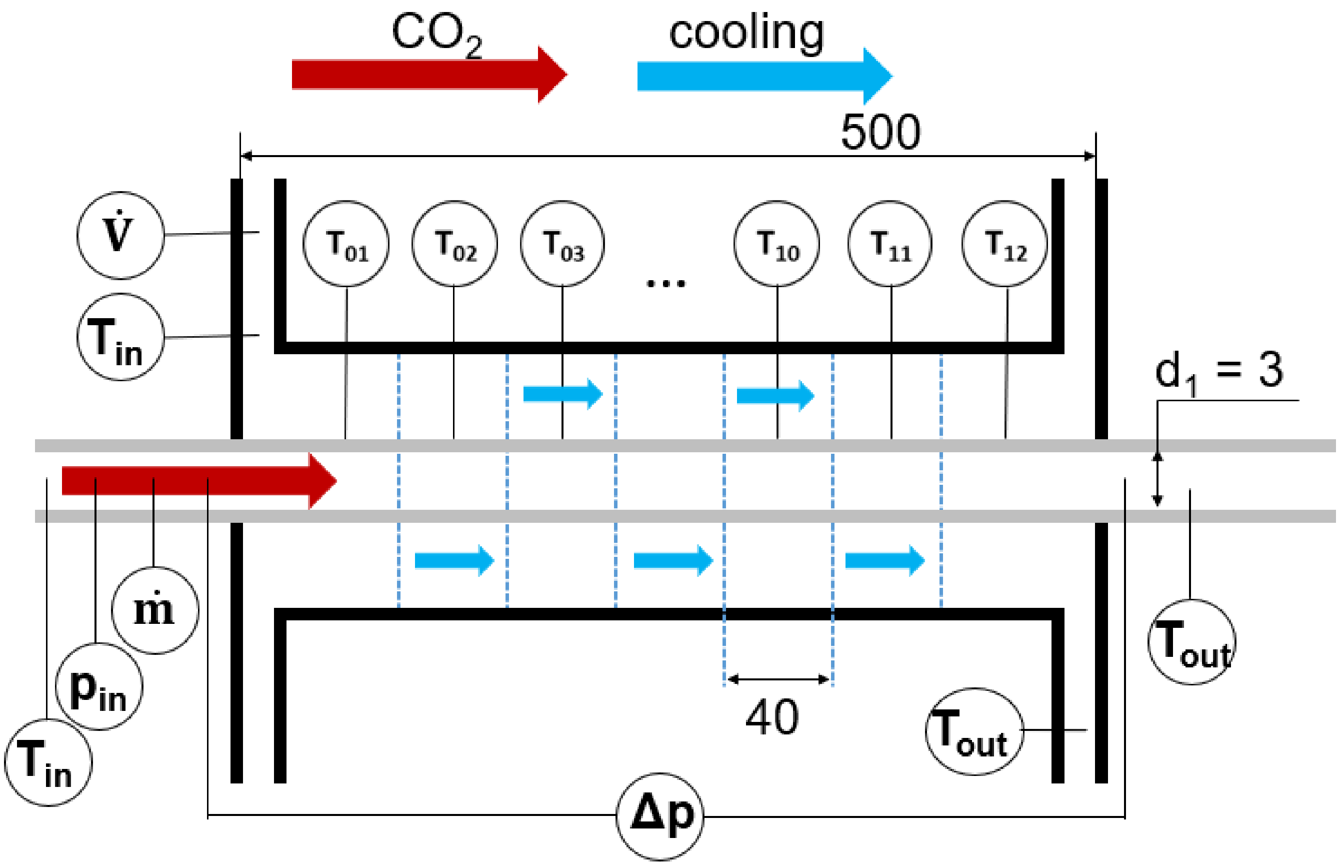


Experimental setup for cooling heat transfer (I)





Experimental setup for cooling heat transfer (II)



Experimental matrix

CO_2			
temperature	pressure	mass flux	
[°C]	[bar]	[kg/m²s]	[g/s]
51-20	80	141	1
		177	1,25
		212	1,5
		283	2,0
		354	2,5

flow orientation	number of experiments
upwards	45
downwards	159

= 204

Data reduction

1. transfered heat

$$\dot{Q}_{CO2} = \dot{m}_{CO2} * [h_{in}(T_{in}, p_{in}) - h_{out}(T_{out}, p_{out})]$$

$$\dot{Q}_{cool} = \dot{V} * \rho * \ c_p * (T_{out} - T_{in})$$

2. heat flux

$$\dot{q}_{CO2} = \frac{\dot{Q}_{CO2}}{\pi d L}$$

3. fluid- and tube temperatures

$$T_{CO2,b} = \frac{T_{CO2,in} + T_{CO2,out}}{2}$$

$$T_t = \frac{\sum_{i=1}^{12} T_{t,i}}{12}, T_{CO2,w} = T_t + \ \dot{q}_{CO2} \cdot \frac{\ln(\frac{4\ mm}{3\ mm})}{2\pi L \lambda}$$

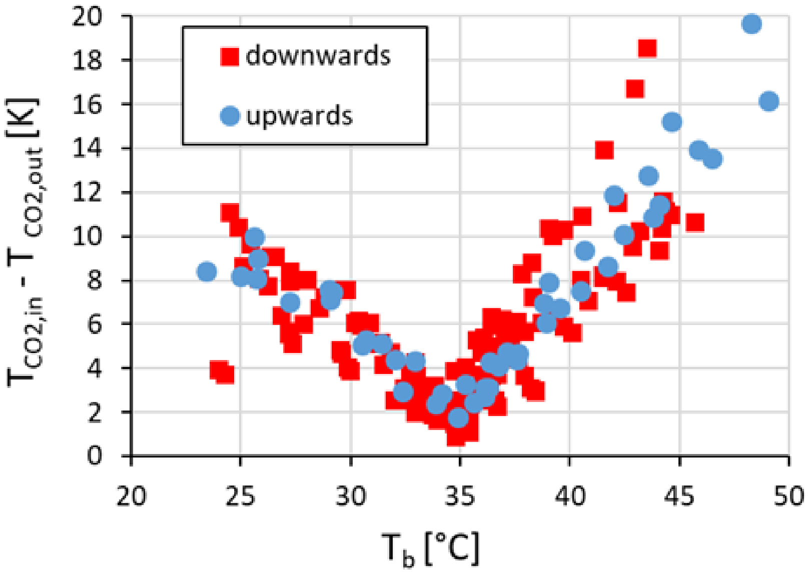
4. heat transfer coefficient

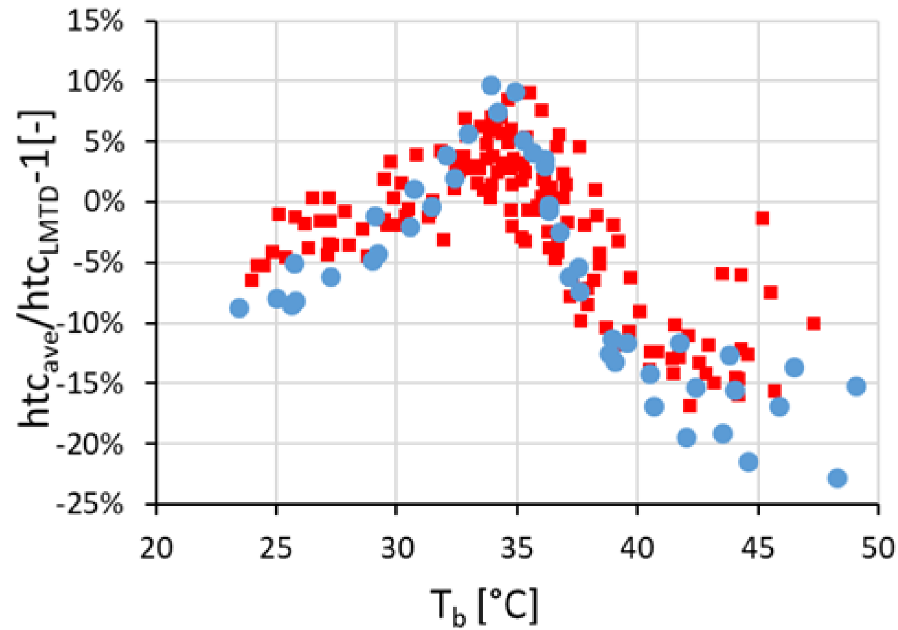
$$htc_{CO2} = \frac{\dot{q}_{CO2}}{\Delta T}$$

$$\Delta T_{ave} = T_{CO2,b} - \ T_{CO2,w}$$

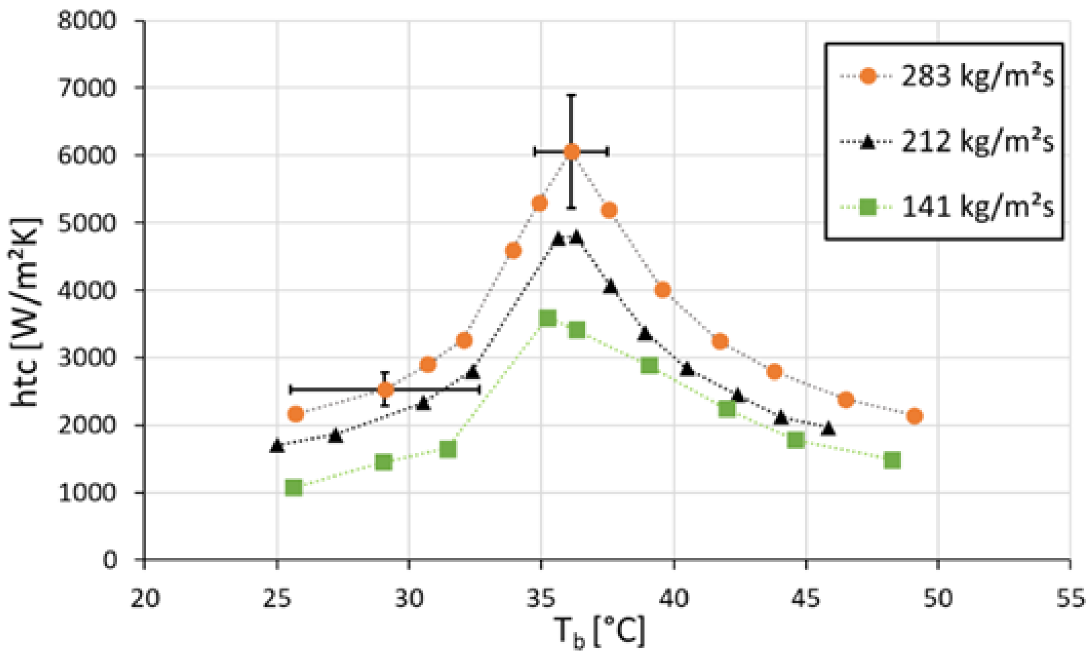
$$\Delta T_{LMTD} = \frac{(T_{in} - \ T_{CO2,w,1}) - (T_{out} - \ T_{CO2,w,12})}{\ln(\frac{T_{in} - \ T_{CO2,w,1}}{T_{out} - \ T_{CO2,w,12}})}$$

Experimental system validation

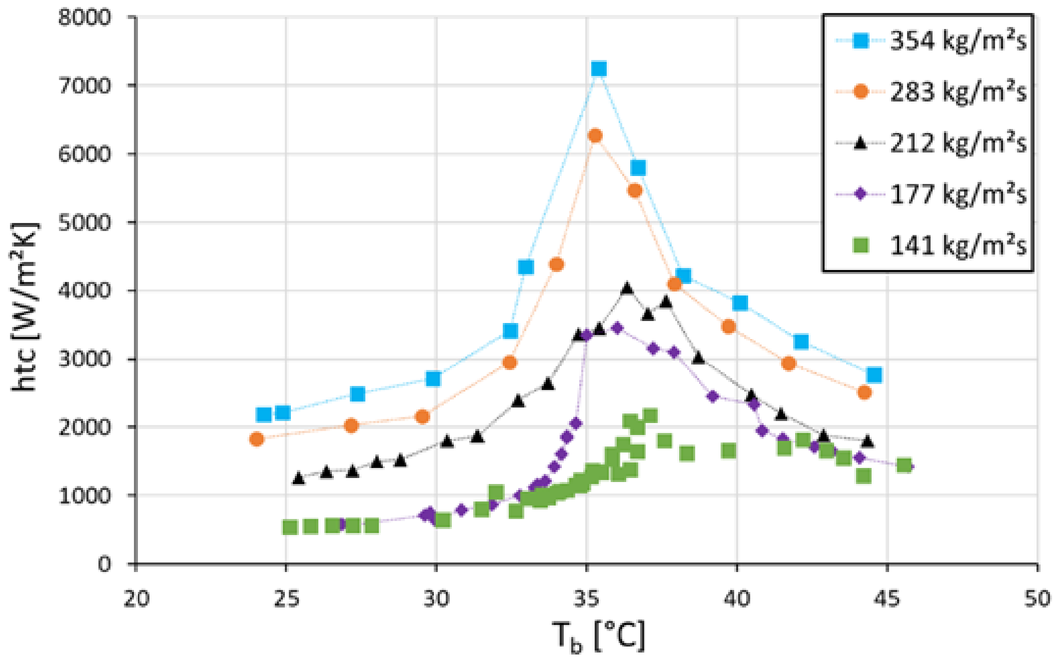




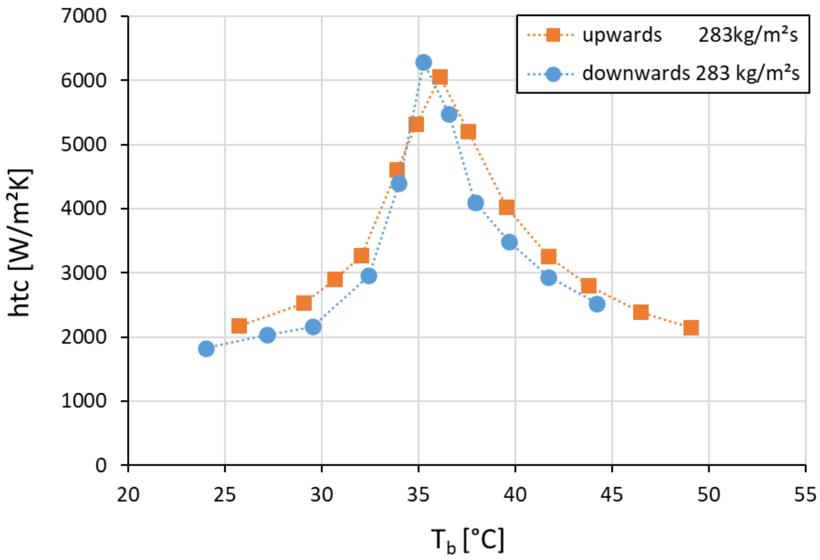
Heat transfer in the upwards flow

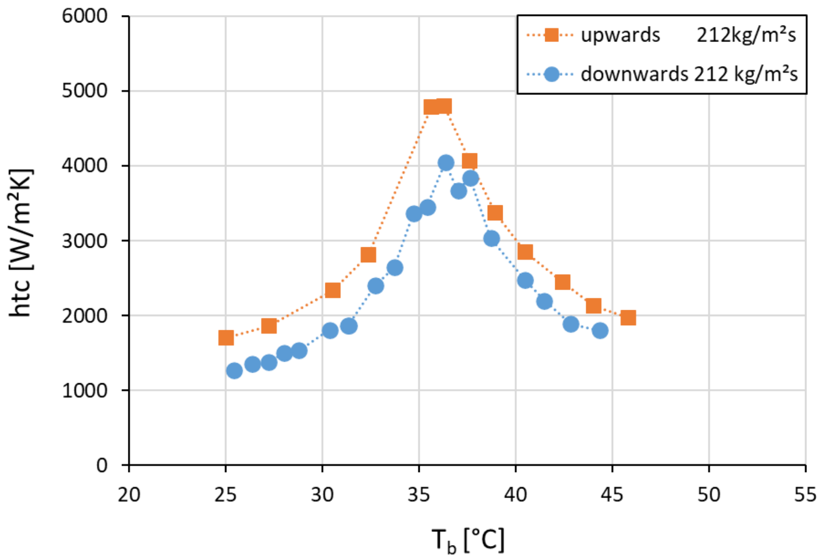


Heat transfer in the downwards flow

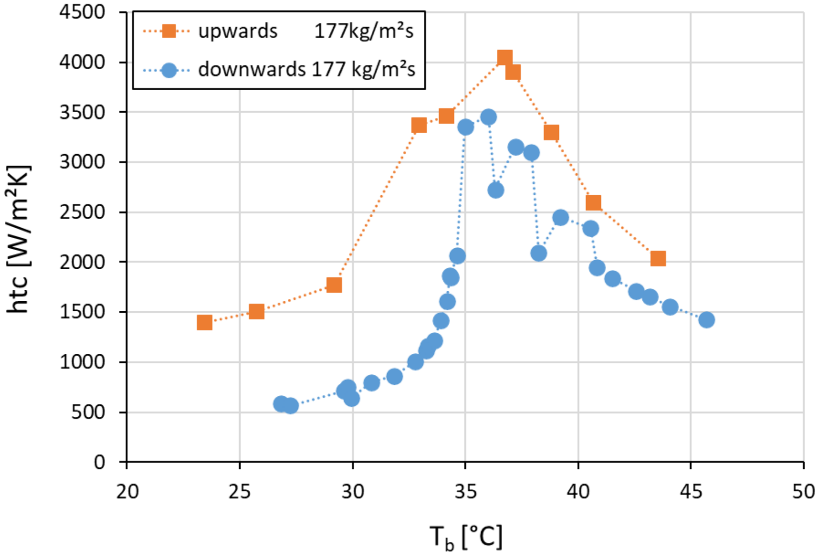


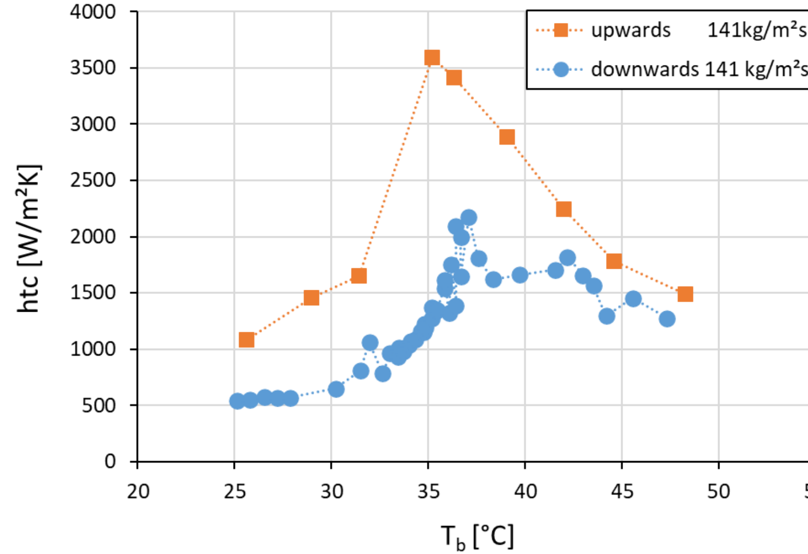
direct comparison of up- and downwards flow



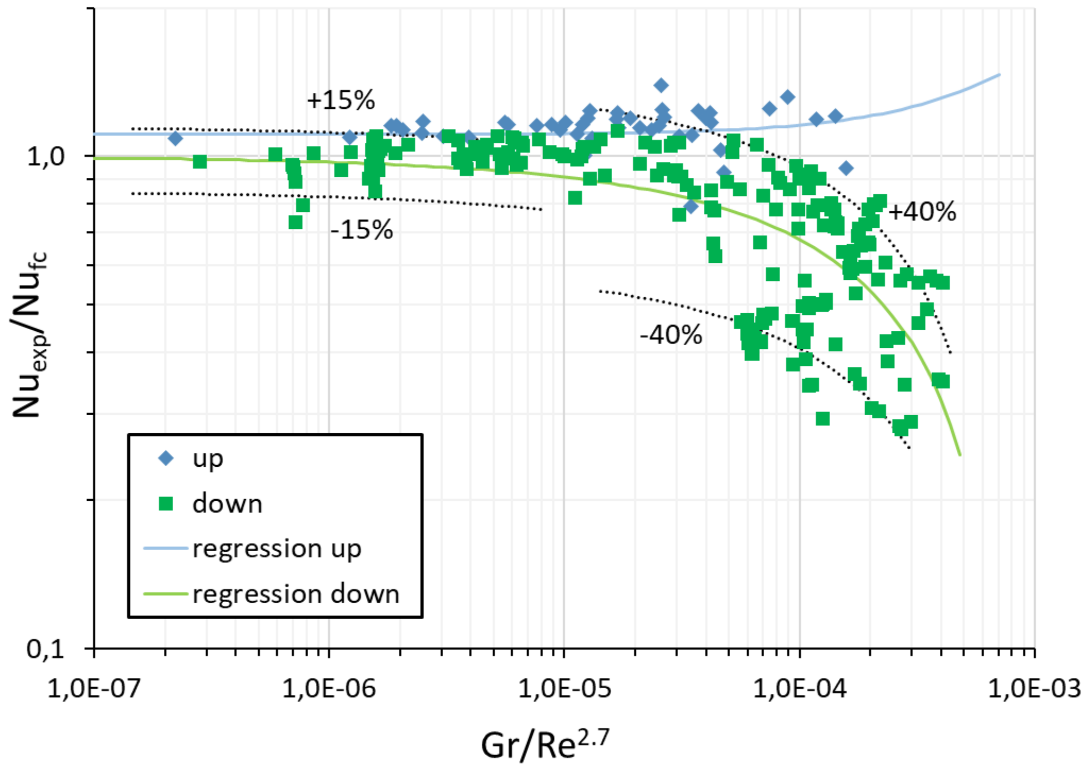


direct comparison of up- and downwards flow

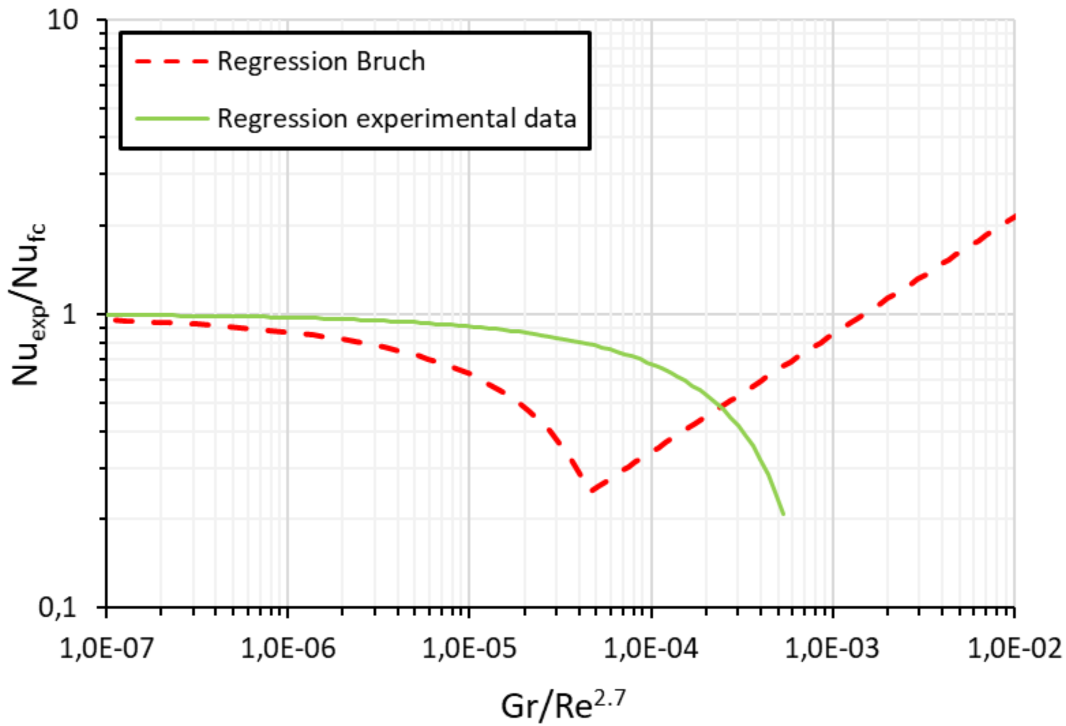




Influence of mixed convection



Comparison with literature data



Conclusion

- ❑ 204 experiments performed at IKE, University of Stuttgart
  - Well known criterion were used to evaluate the heat transfer in vertical flow orientation
  - Heat transfer deterioration was significant at low mass fluxes
  - Deterioration ($\frac{Nu_{exp}}{Nu_{FC}} < 1$) at higher values of $\frac{Gr}{Re^{2.7}}$ in comparison with literature data
- ❑ Outlook:
  - Experimental investigations of different tube diameters
  - Adaptation of criterion

Acknowledgements

This project has received funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 764690

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Thank you!

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