CFD-DEM Model for High-Temperature Processes

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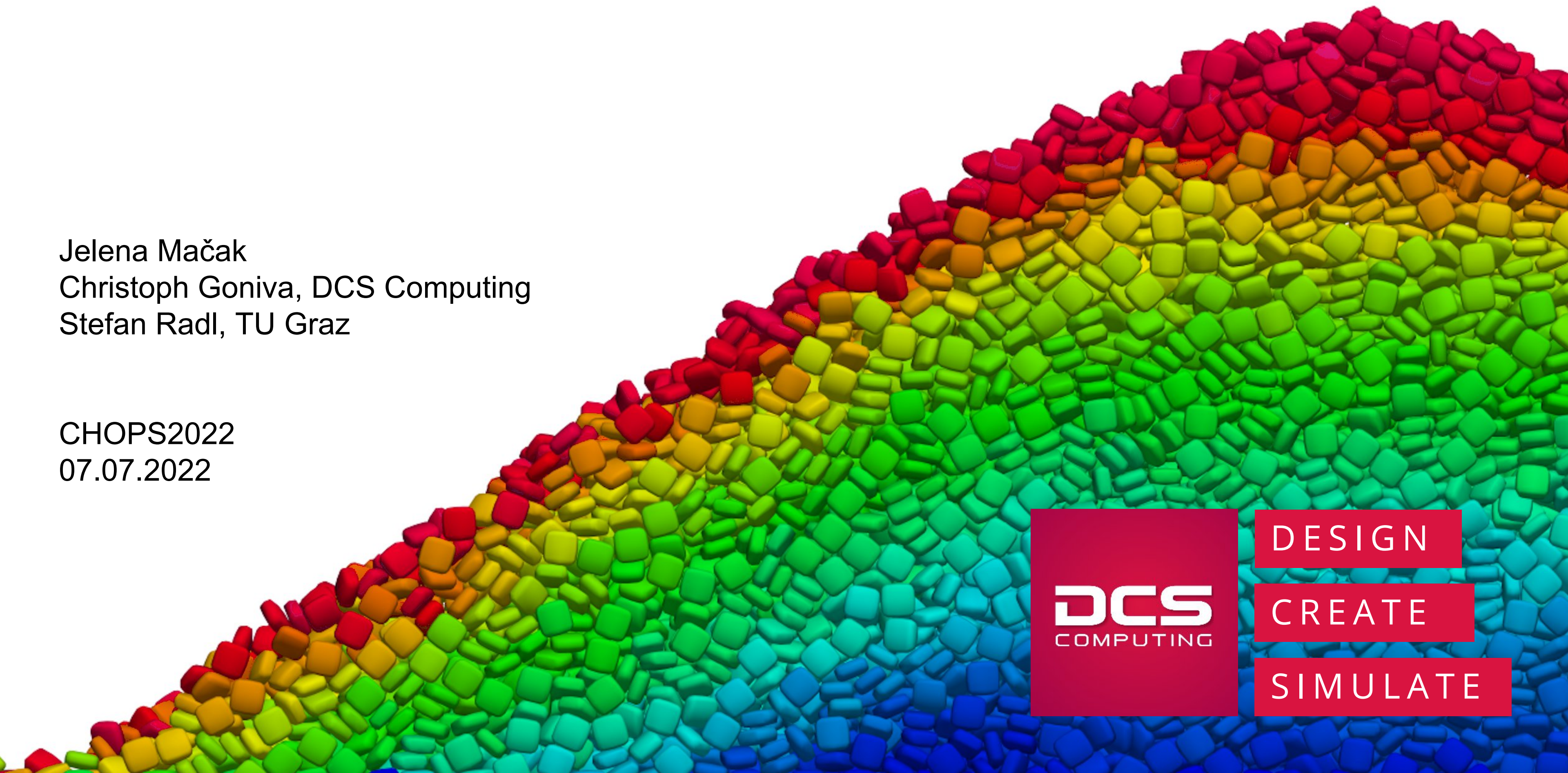
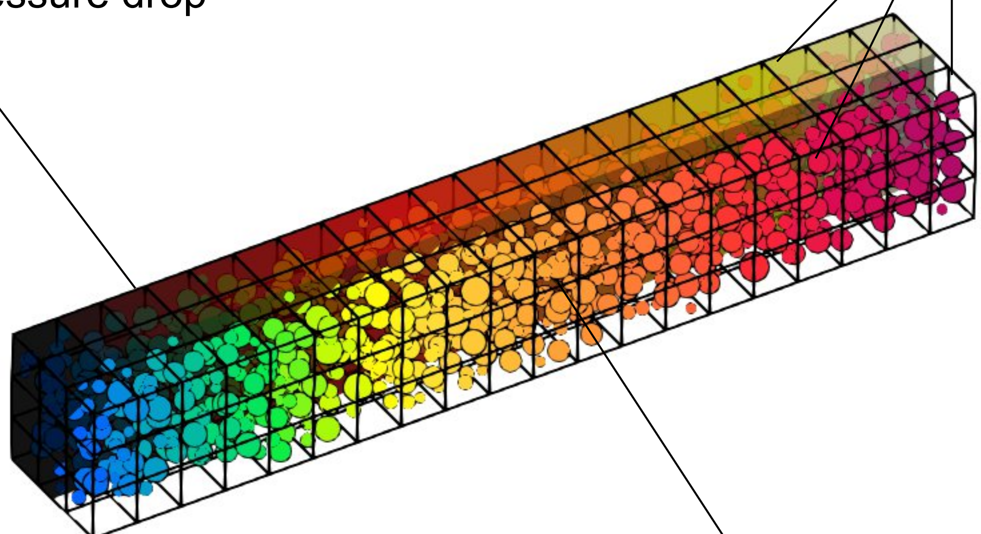


DCS COMPUTING
DESIGN
CREATE
SIMULATE

CFD-DEM Model for High-Temperature Processes

P1 radiation model
particles, fluid, walls

compressible fluid
- free convection
- non-linear pressure drop



discrete particles

Your high-temperature application:

1. needs a compressible solver?
2. can use P1-radiation model?

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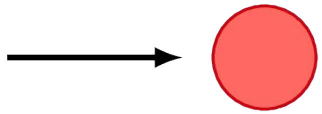
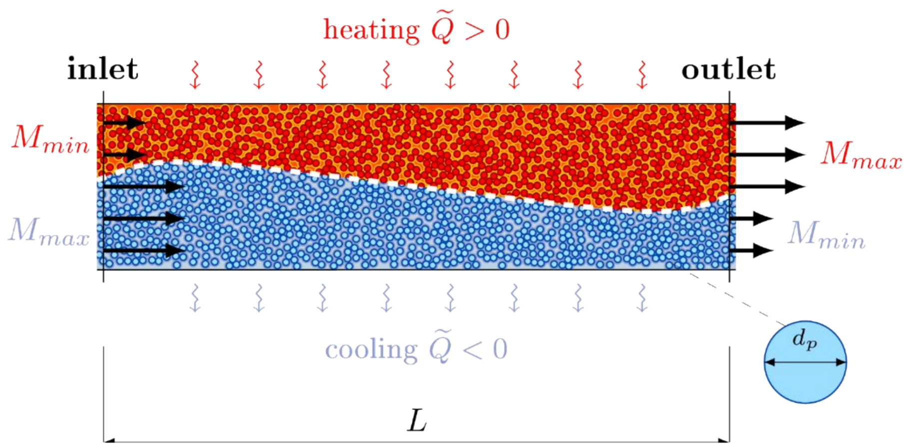
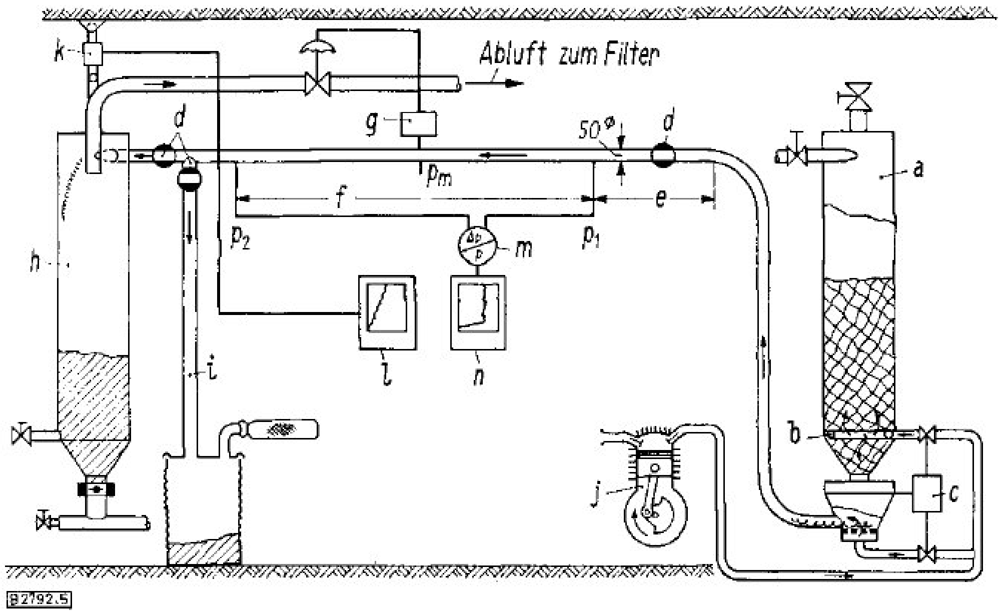


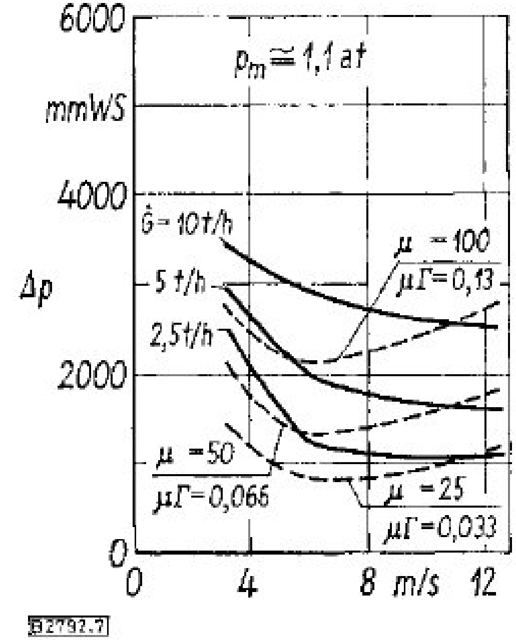
$$M > 0.3$$



~~$M > 0.3$~~

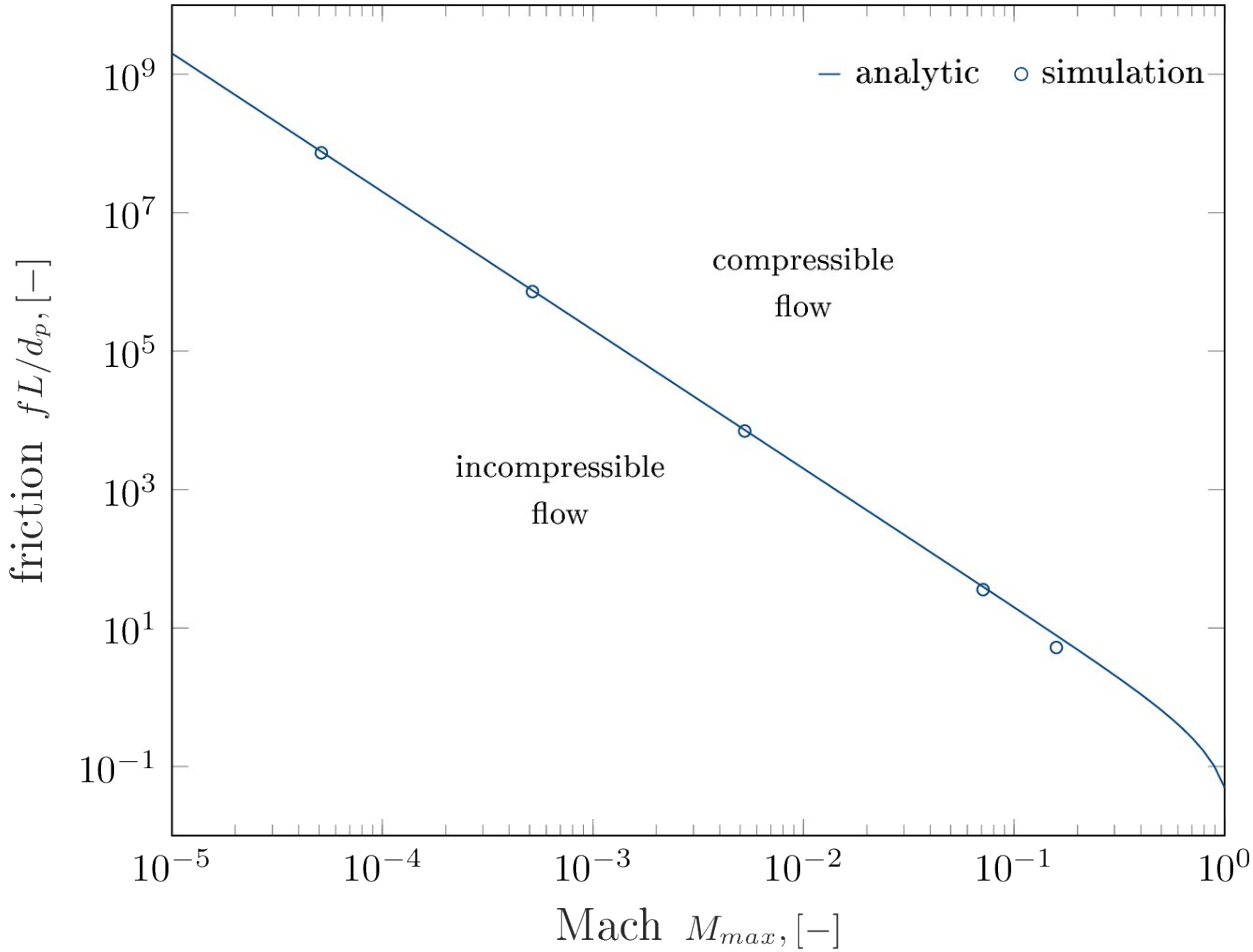
Compressibility criterion for isothermal flow





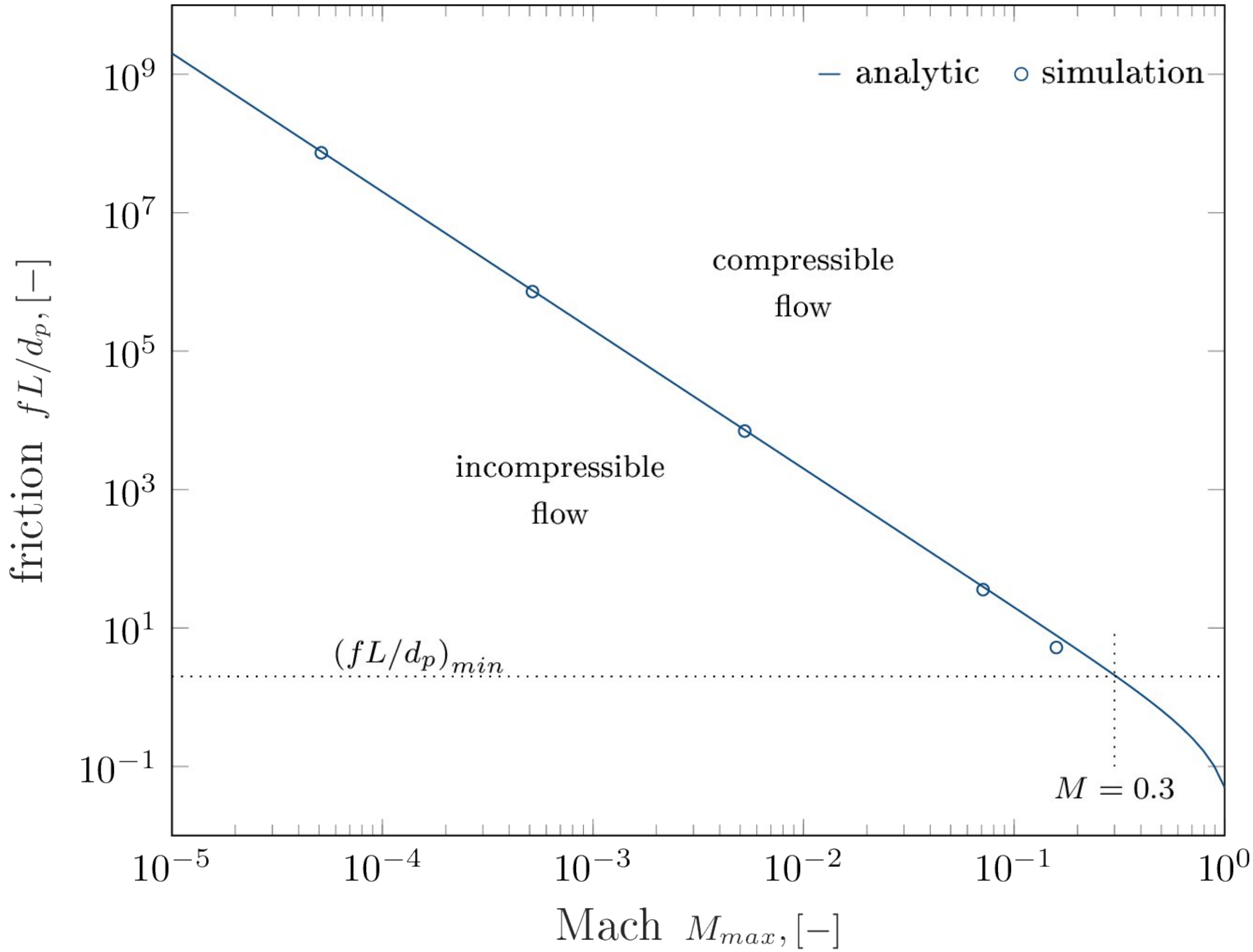
From: E. Muschelknautz, W. Krambrock **Vereinfachte Berechnung horizontaler pneumatischer Förderleitungen bei hoher Gutbeladung mit feinkornigen Produkten** (1969)

Compressibility criterion for isothermal flow



$$\left(5\, f\, \frac{L}{d_p} - \frac{1}{5}\right) M_{max}^2 > 1$$

Compressibility criterion for isothermal flow



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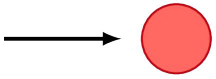
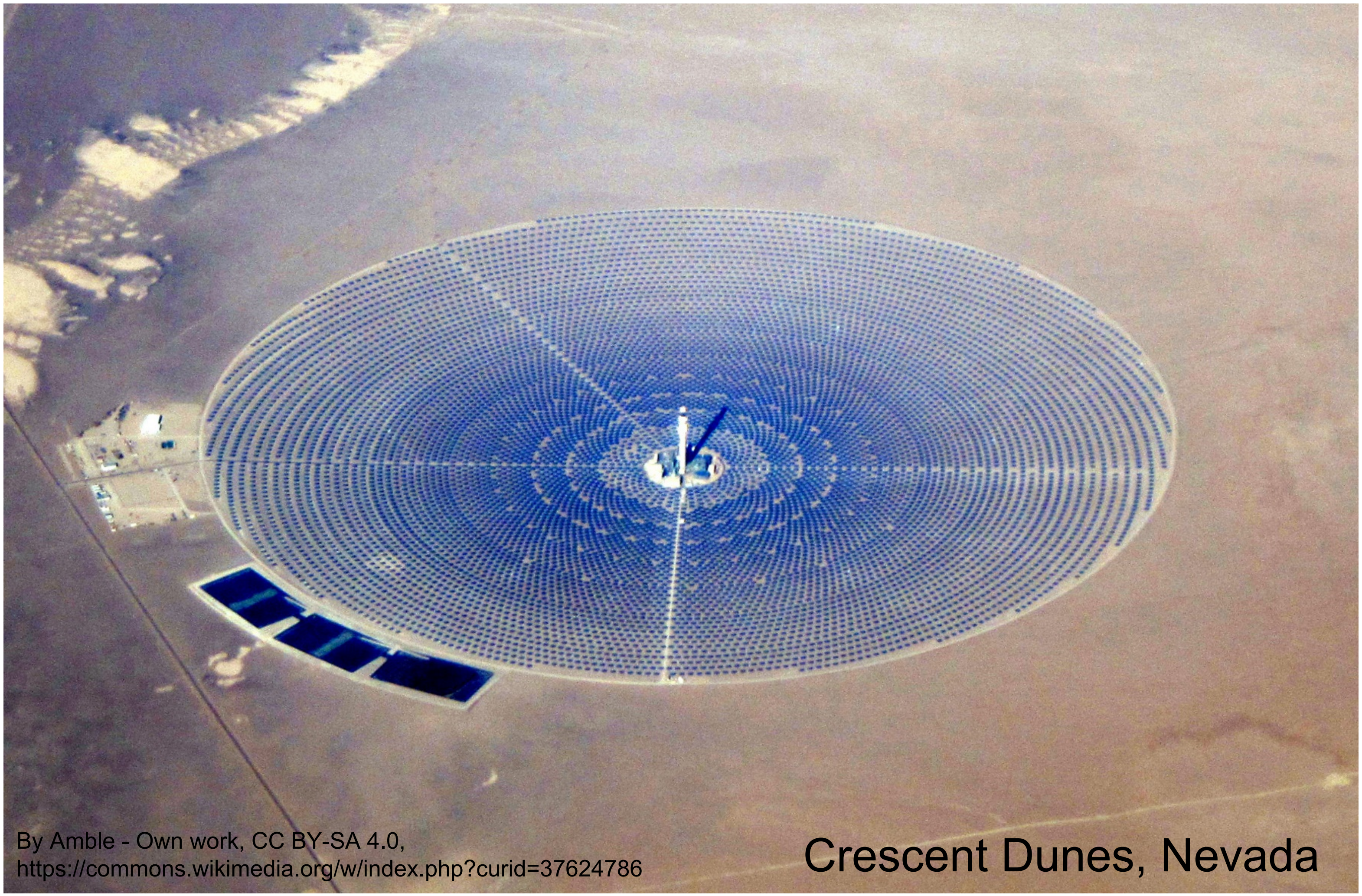


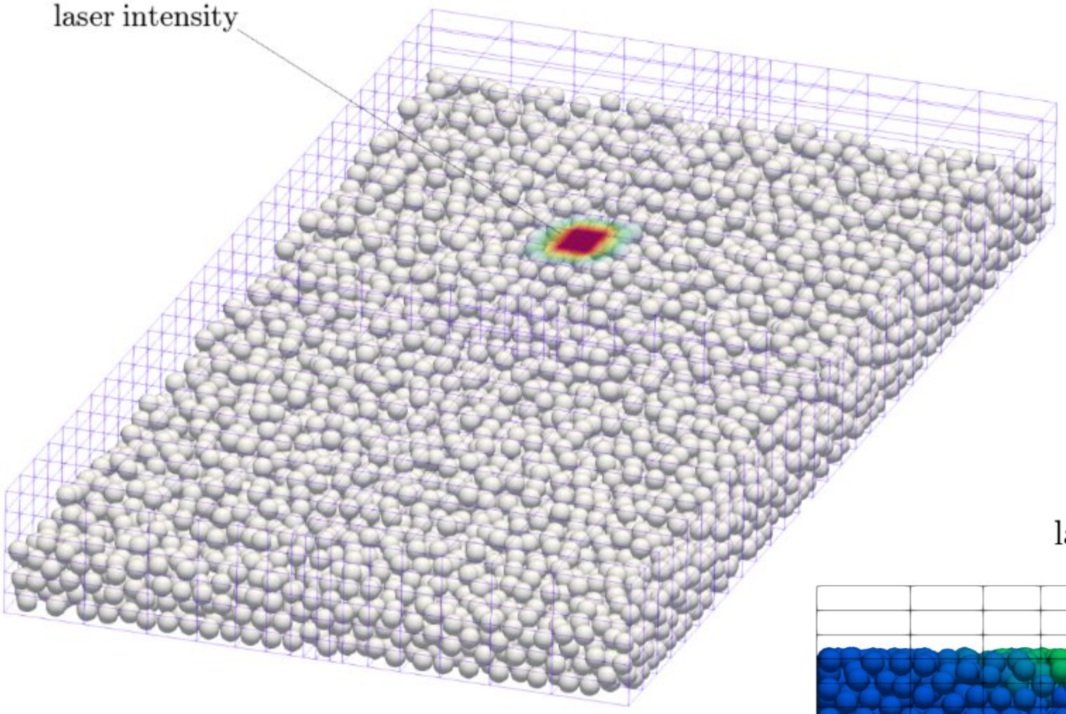
Solar particle receiver

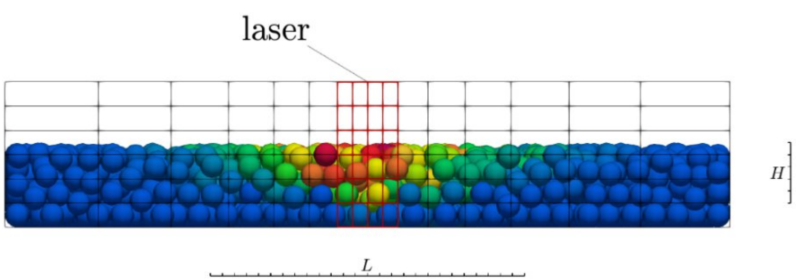


Pebble bed nuclear reactor

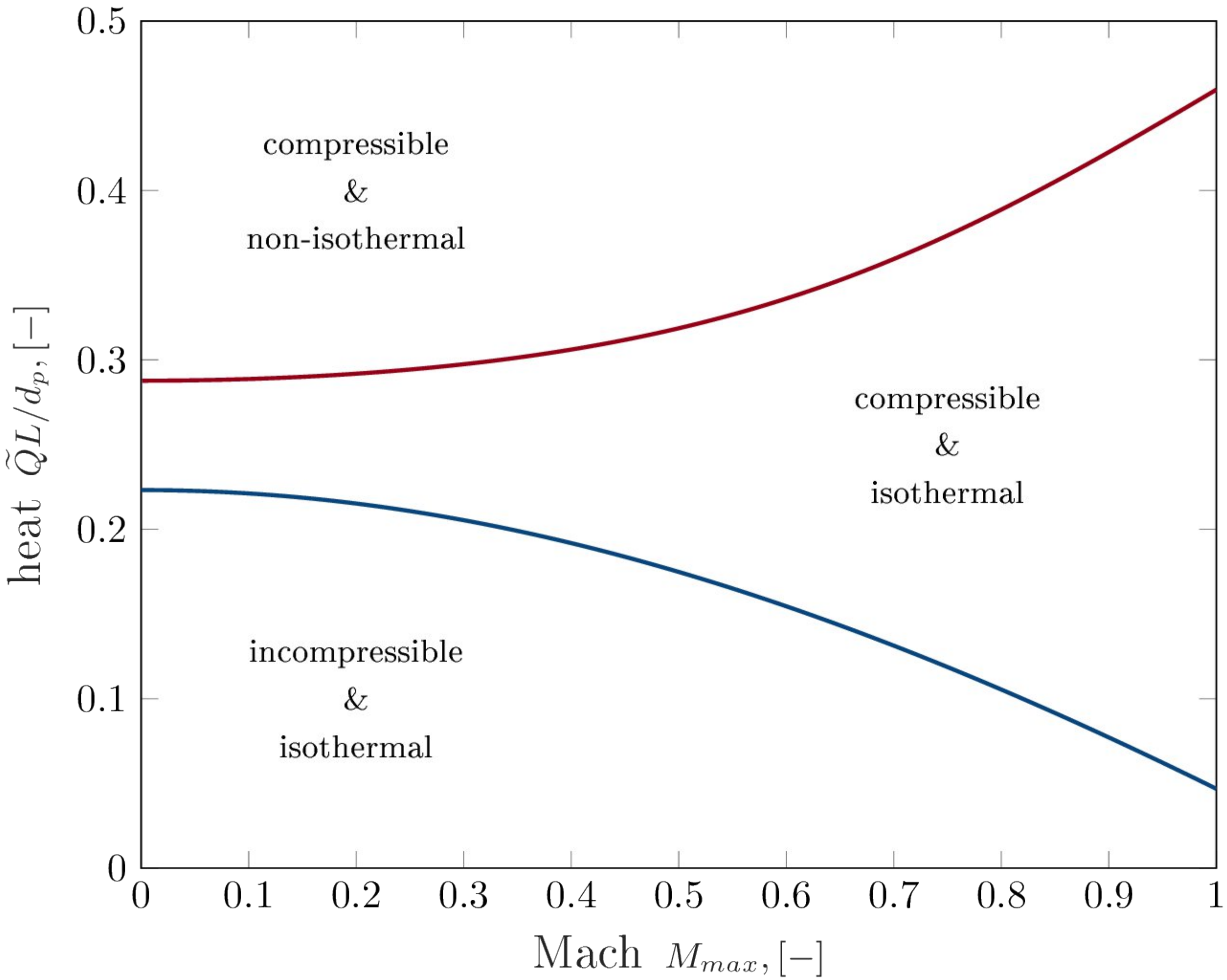
De Beer **Characterisation of thermal radiation in the near-wall region of a packed pebble bed** (2014)

Laser melting/sintering





Compressibility criterion for heated flow



non-isothermal flow:

$$\tilde{Q}\frac{L}{d_p} \geq 0.3$$

$$\tilde{Q} = \frac{6\,\phi_p}{Pr}\frac{Nu}{Re}\left(\frac{T_p}{T_{fluid}} - 1\right)$$

compressible flow:

$$\tilde{Q}\frac{L}{d_p} \geq 0.2$$

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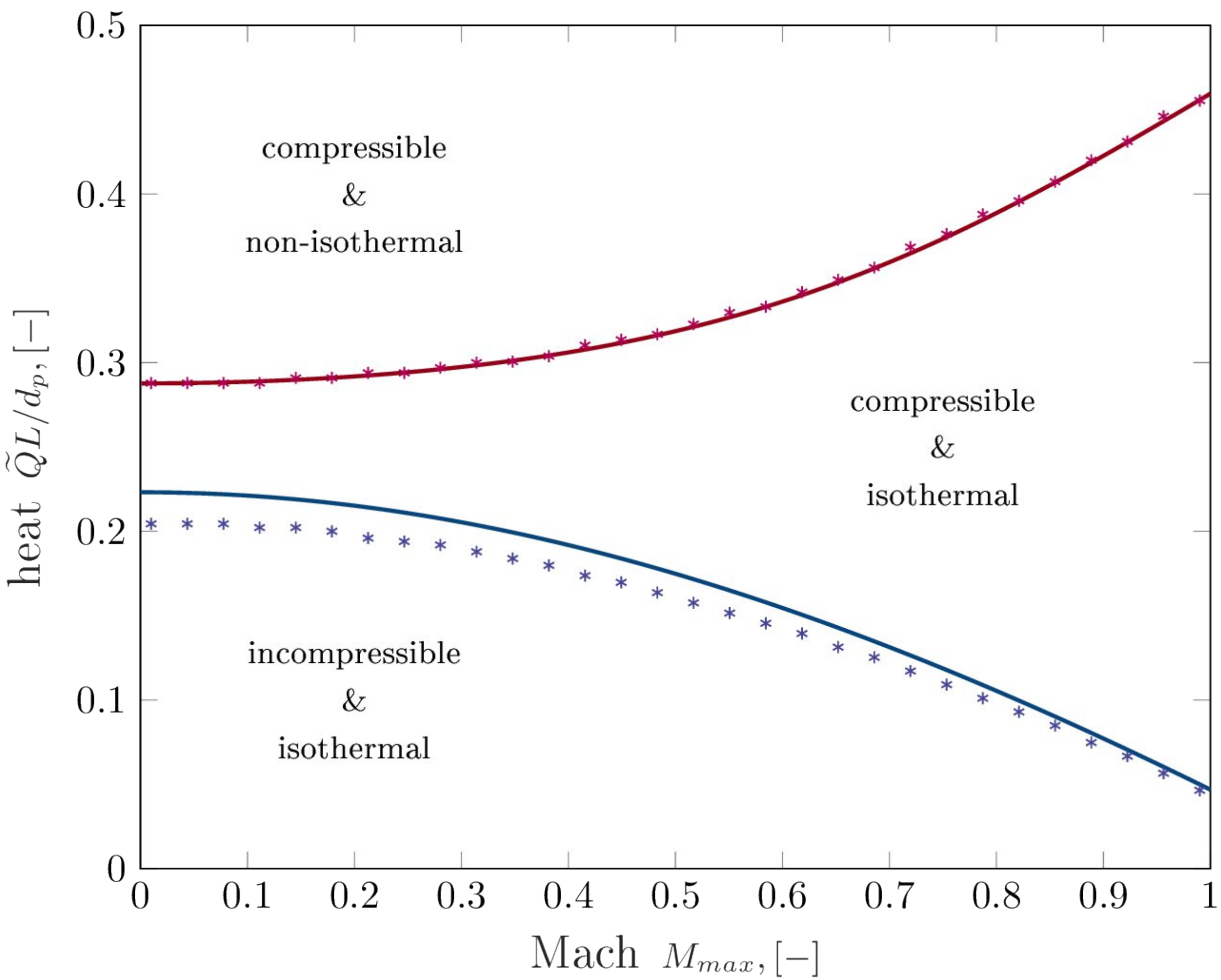

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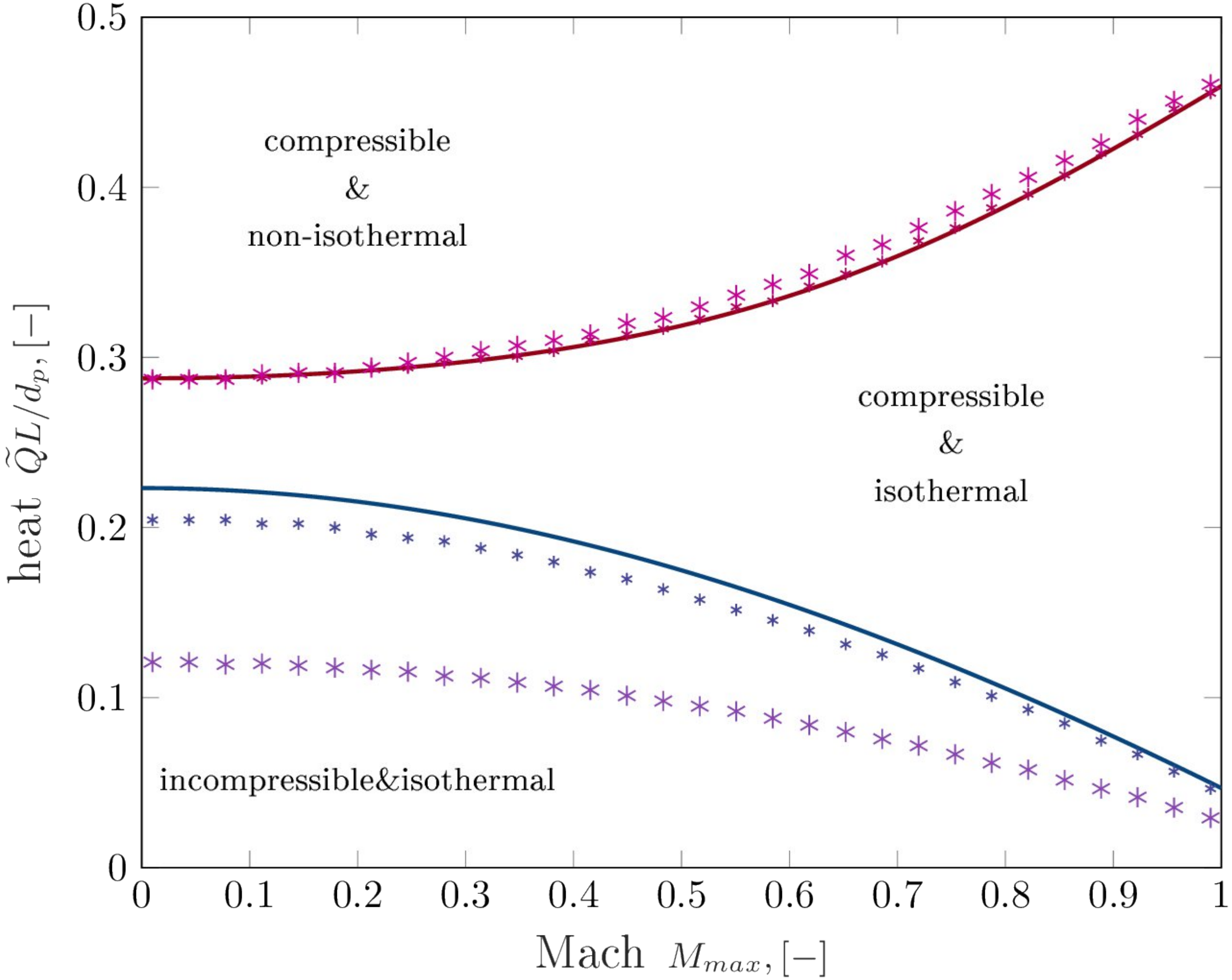

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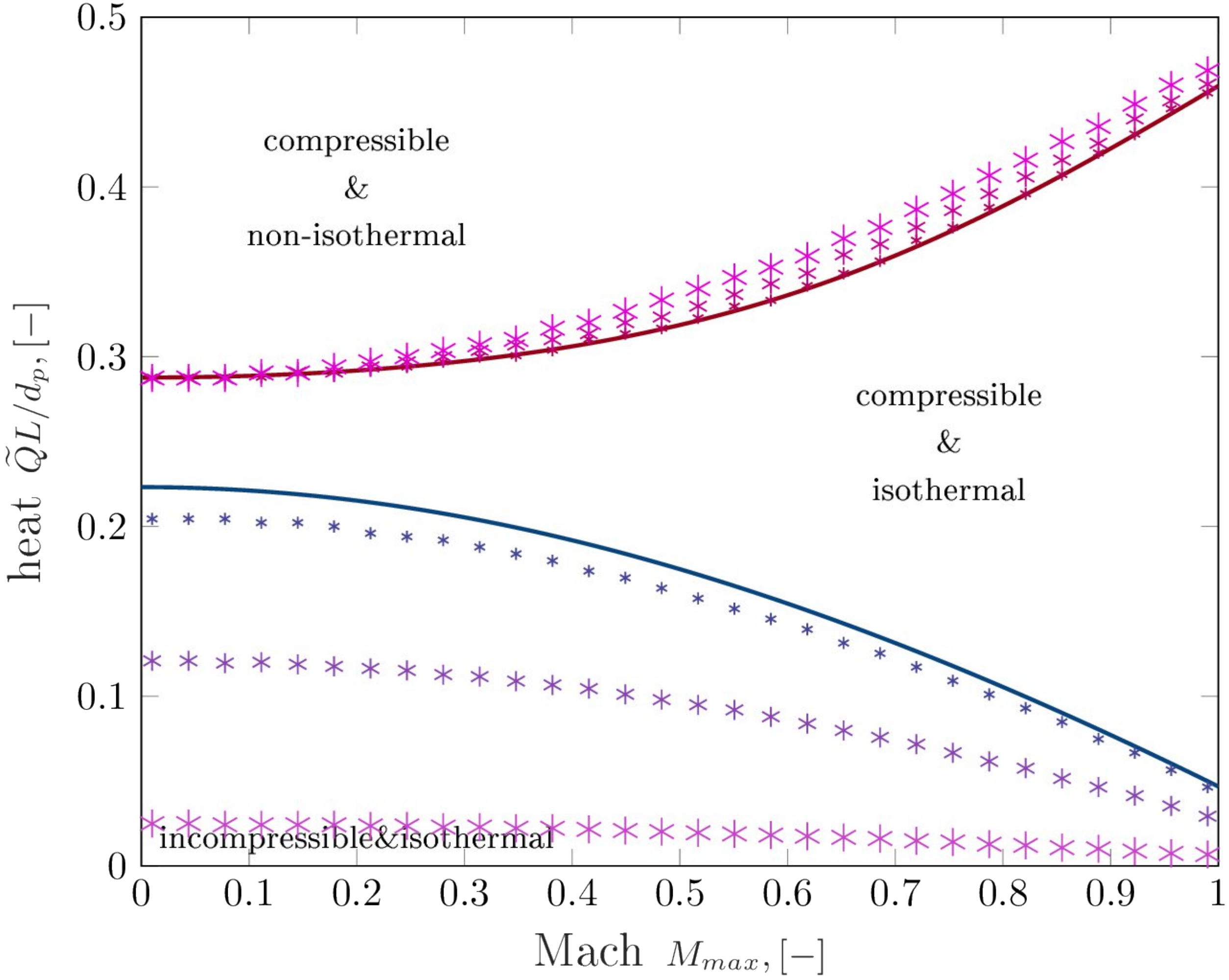

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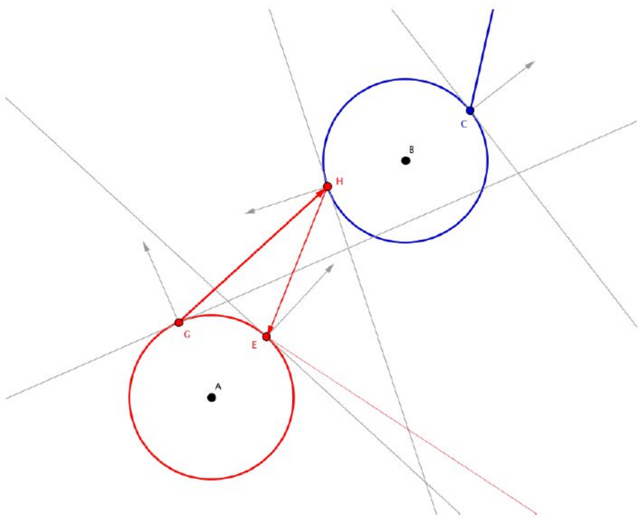
Conclusion

All non-isothermal heated flows are compressible.

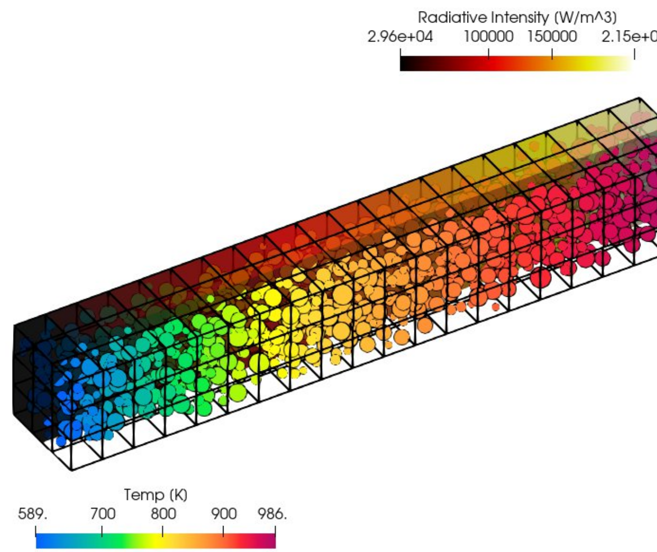
Your high-temperature application:

1. needs a compressible solver?
2. can use P1-radiation model?



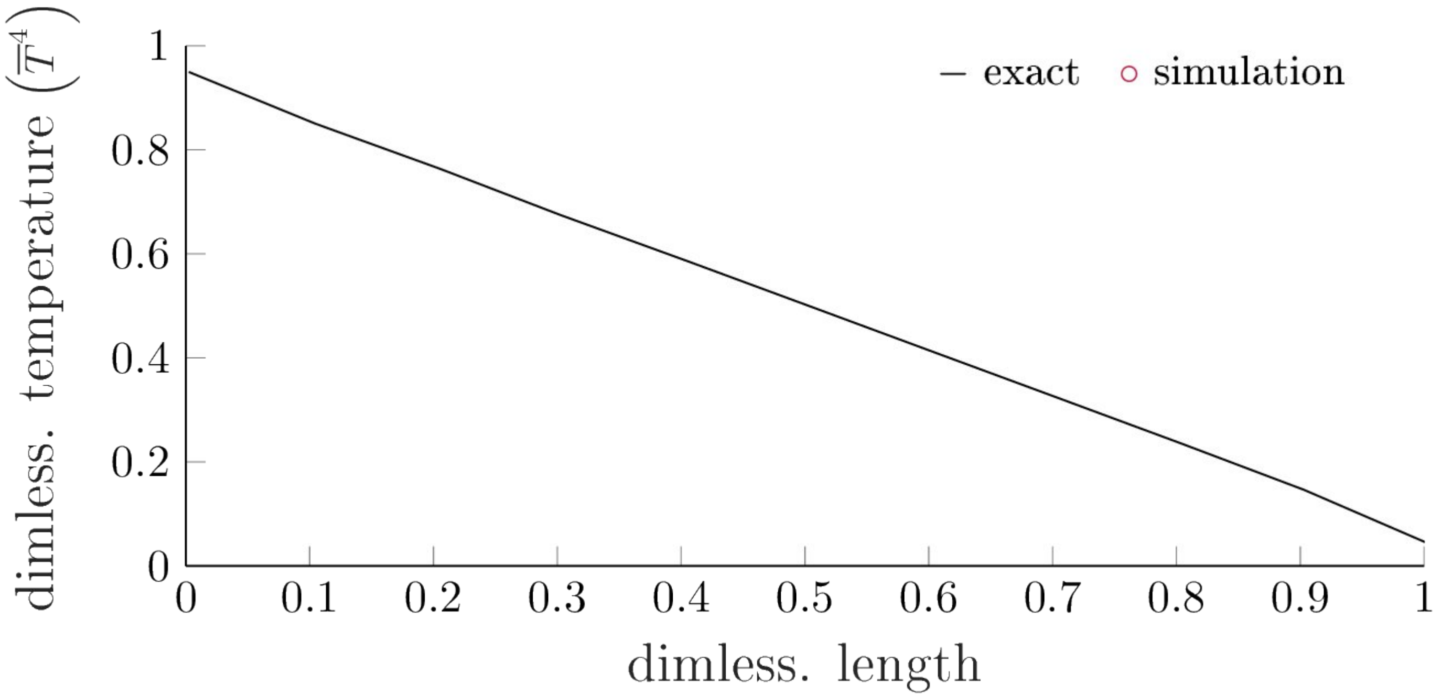
Monte-Carlo, view-factors

from Amberger *et al*: **Thermal Radiation Modeling Using Ray Tracing in LIGGGHTS** (2013)

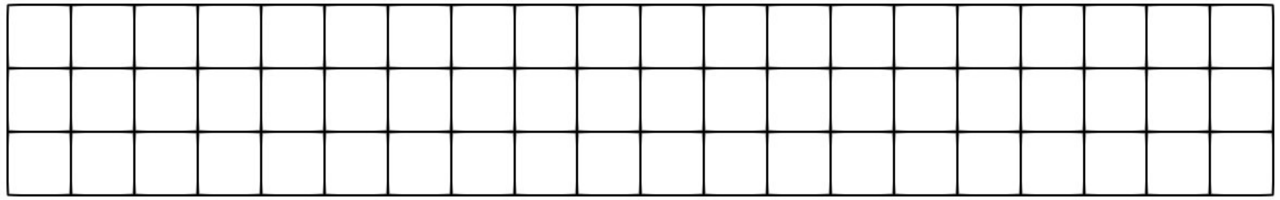


P1-model

P1 & polydispersion

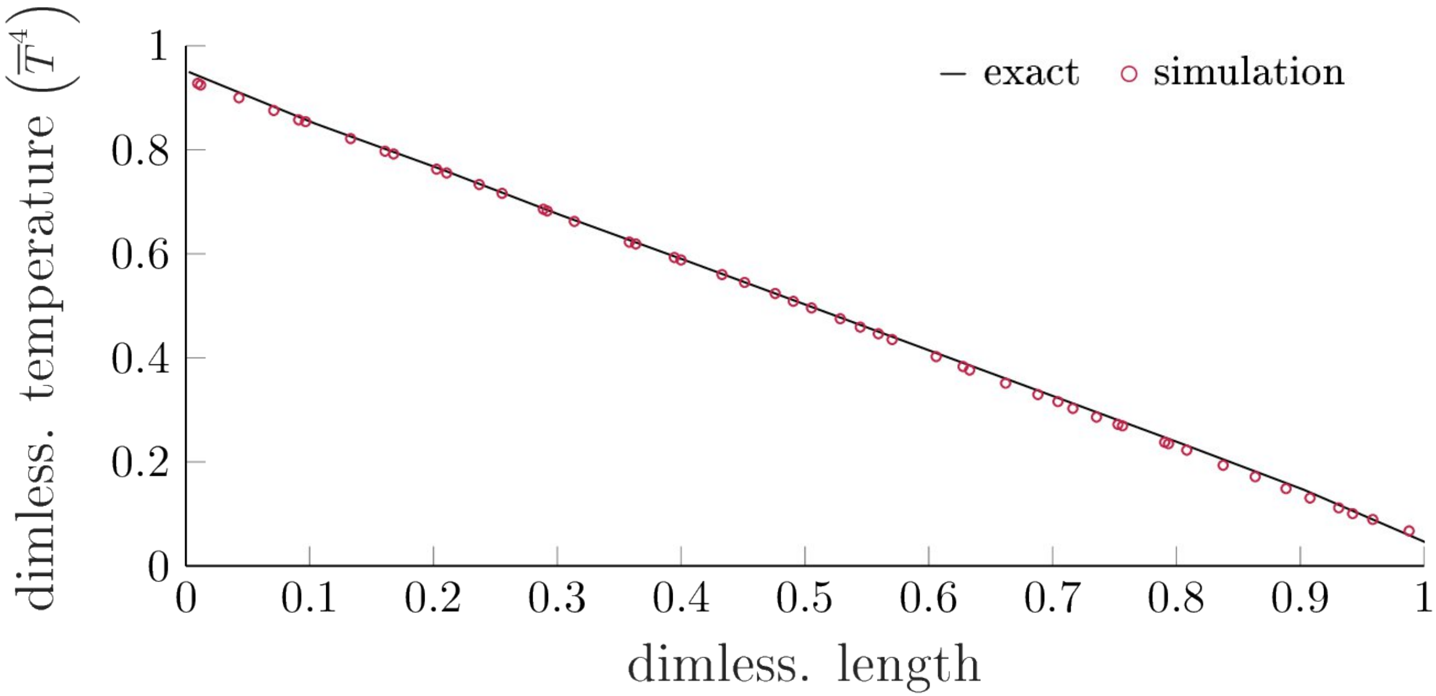


hot wall

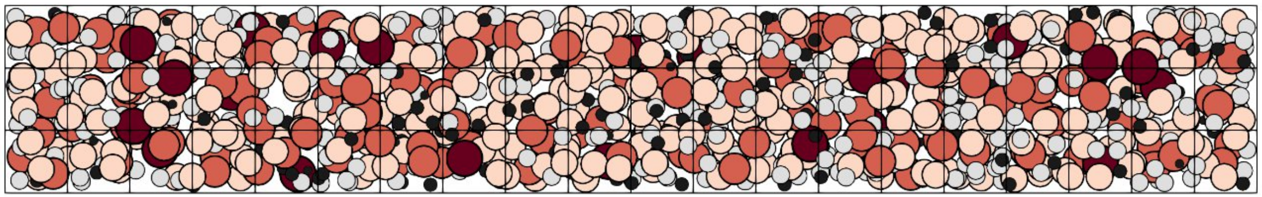


cold wall

P1 & polydispersion

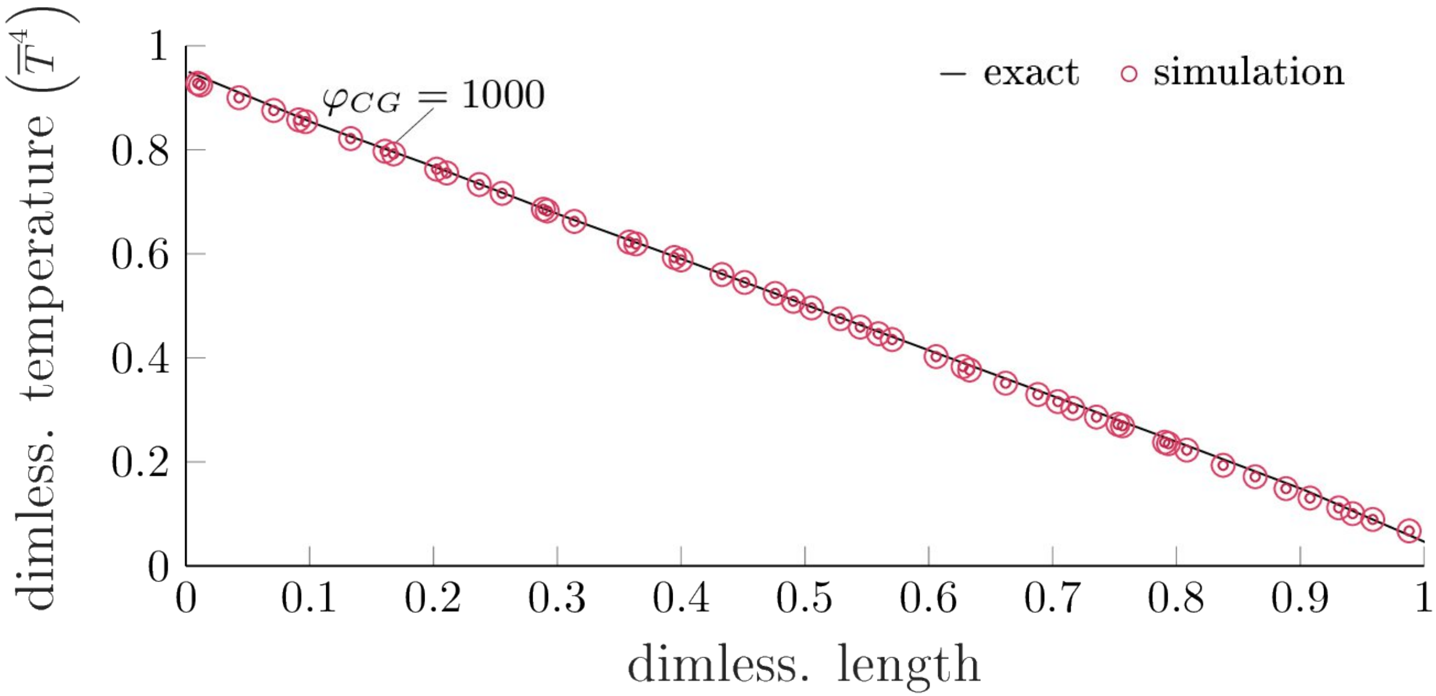


hot wall

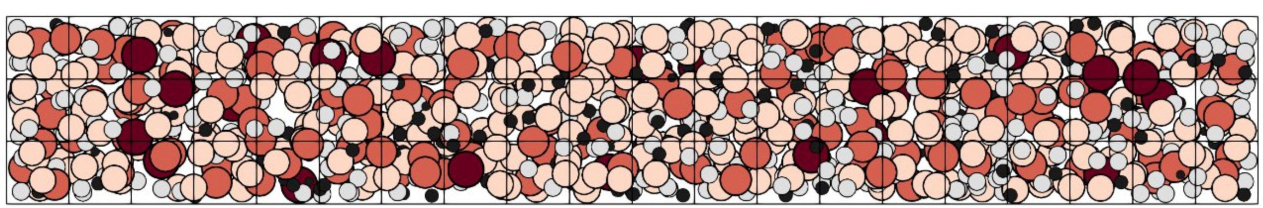


cold wall

P1 & coarse-graining



hot wall



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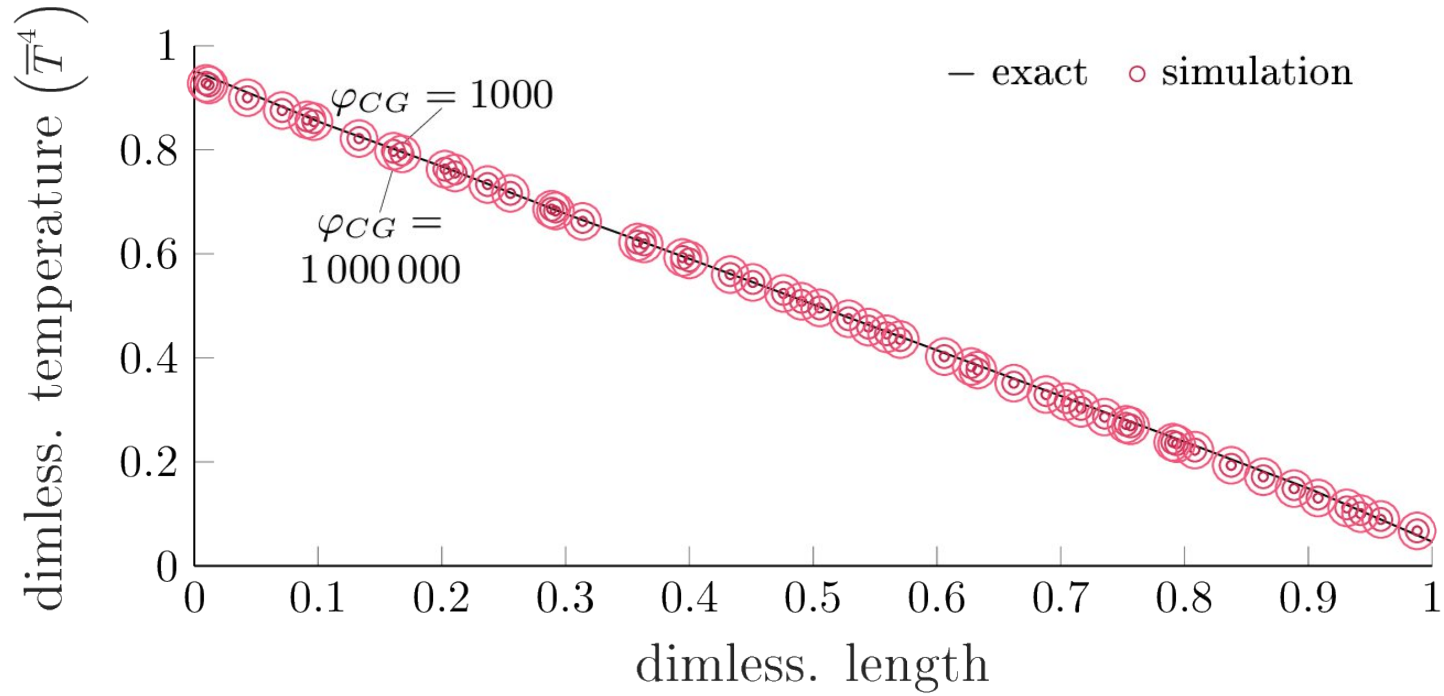

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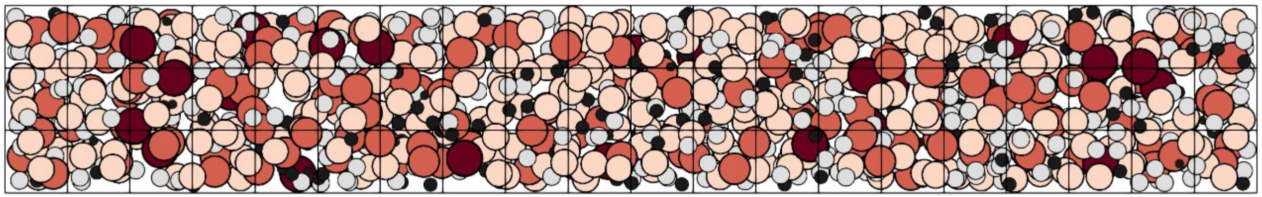
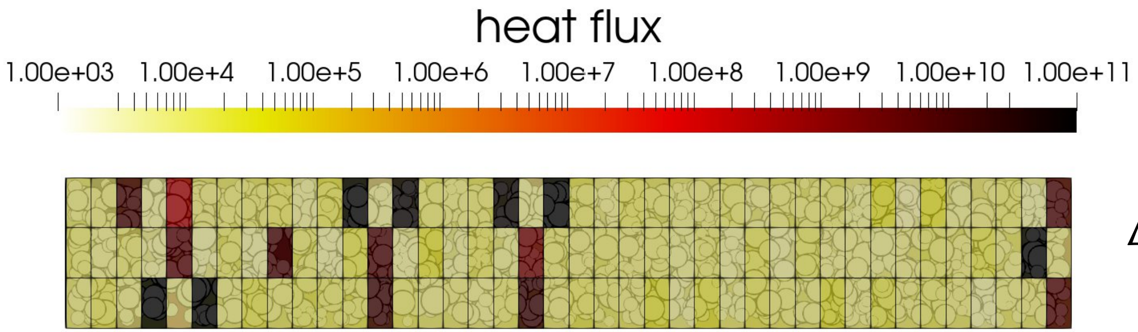


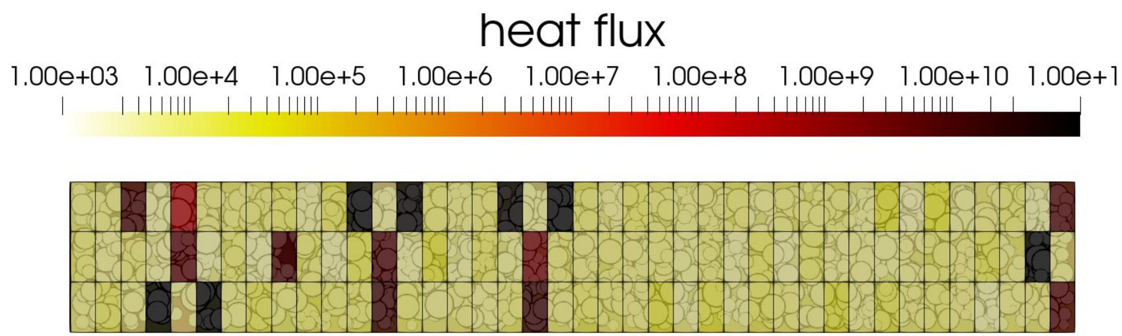
cold wall

Anisotropy: heat flux oscillations



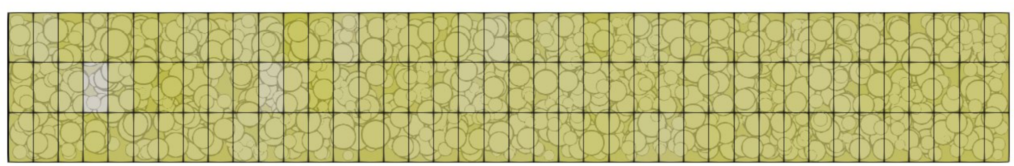
$\Delta q > 10^8\%$

Anisotropy: heat flux oscillations



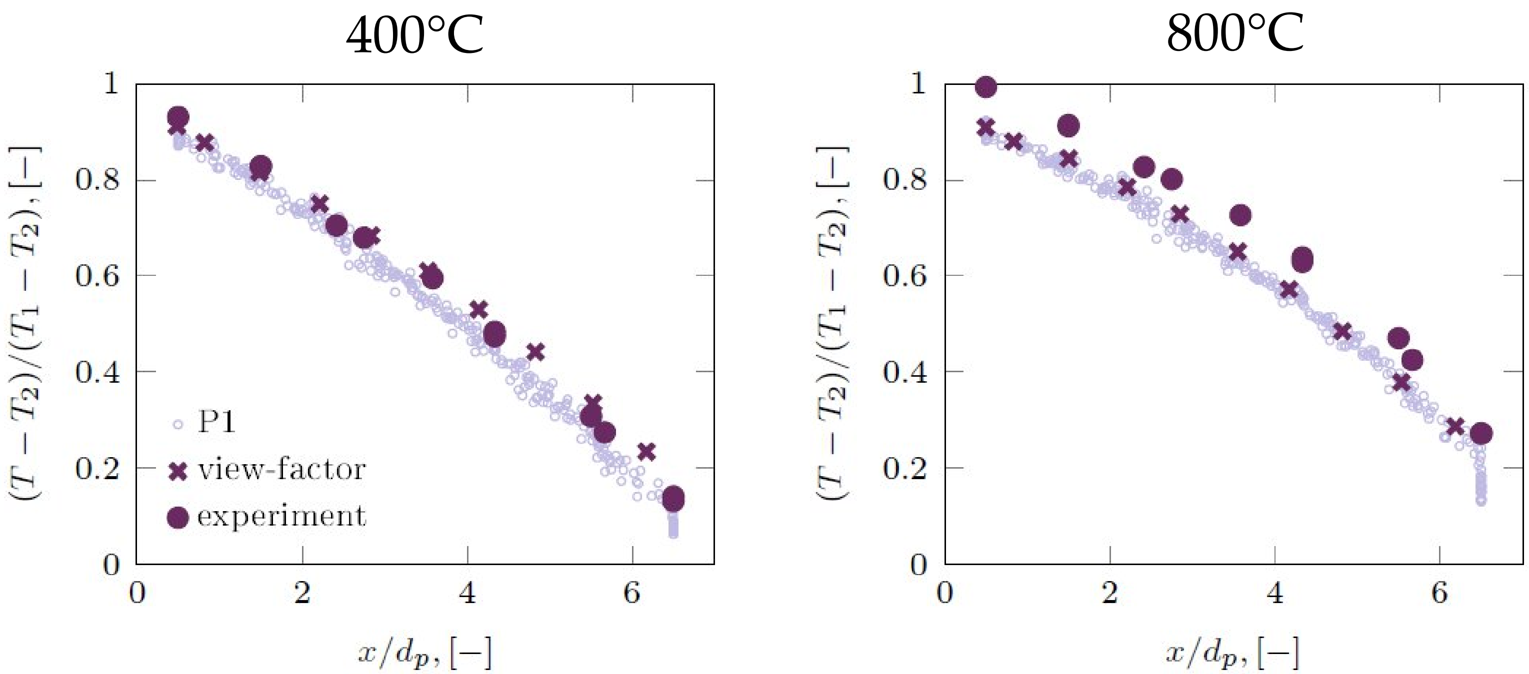
$\Delta q > 10^8\%$

Smoothing function



$\Delta q < 10\%$

Validation with experiments



Tausendschön, Rad **Deep Neural Network-based heat radiation modelling between particles and between walls and particles** (2021)

De Beer **Characterisation of thermal radiation in the near-wall region of a packed pebble bed** (2014)

Summary

- Developed a CFD-DEM tool for high-temperature processes
- Developed compressibility criteria
- Verified P1 for polydisperse and coarse-grained systems
- Smoothed radiative heat flux oscillations

Thank you!

Questions?

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MATHEGRAM

DCS COMPUTING

DESIGN
CREATE
SIMULATE