

# CV

## **Dipl.-Ing. Florian Hoffmann**

**2004 - 2010 RWTH Aachen**

Werkstoffinformatik (Computational Material Science)

**2007 Student research assistant at IOB**

Finite Element Analysis

**2013 Research project at University of Bristol (UK)**

Residual Stresses due to Quenching

**2008/09 Student research assistant at IBF**

- Inverse Modeling of Heat Transfer Coefficients
- Advanced Rolling Model for AG der Dillinger Hüttenwerke

**2018 Diplom Thesis**

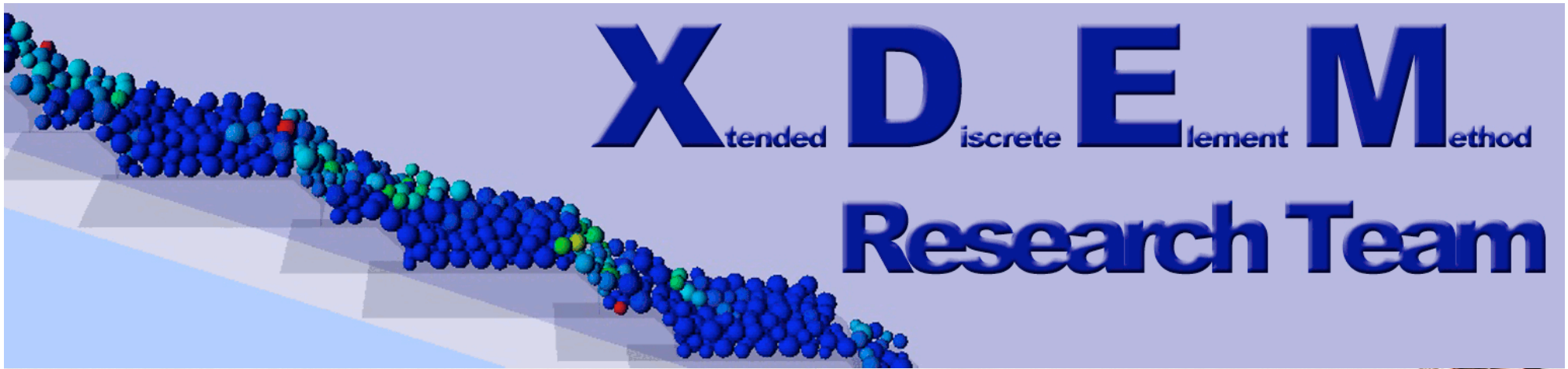
Effects of Chemistry on Forgeability of 21Cr-9Mn-6Ni Austenitic Steel,  
Saarschmiede GmbH Freiformschmiede Völklingen

**2021 University of Luxembourg**

PhD student at the Department of Engineering

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# Modeling Thermochemical Processes in Granular Media



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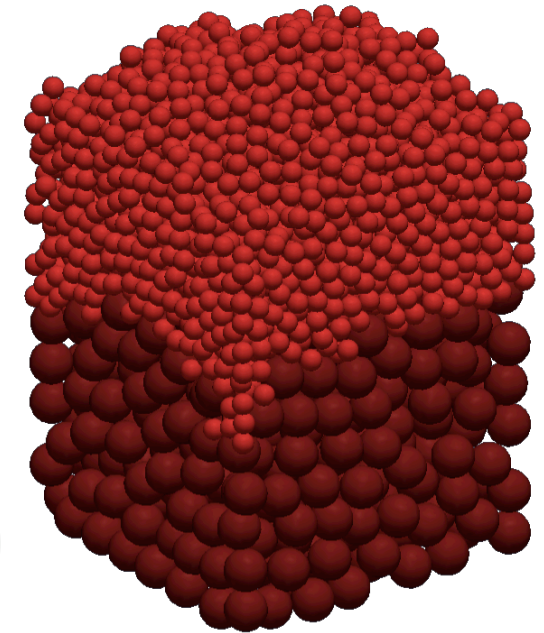
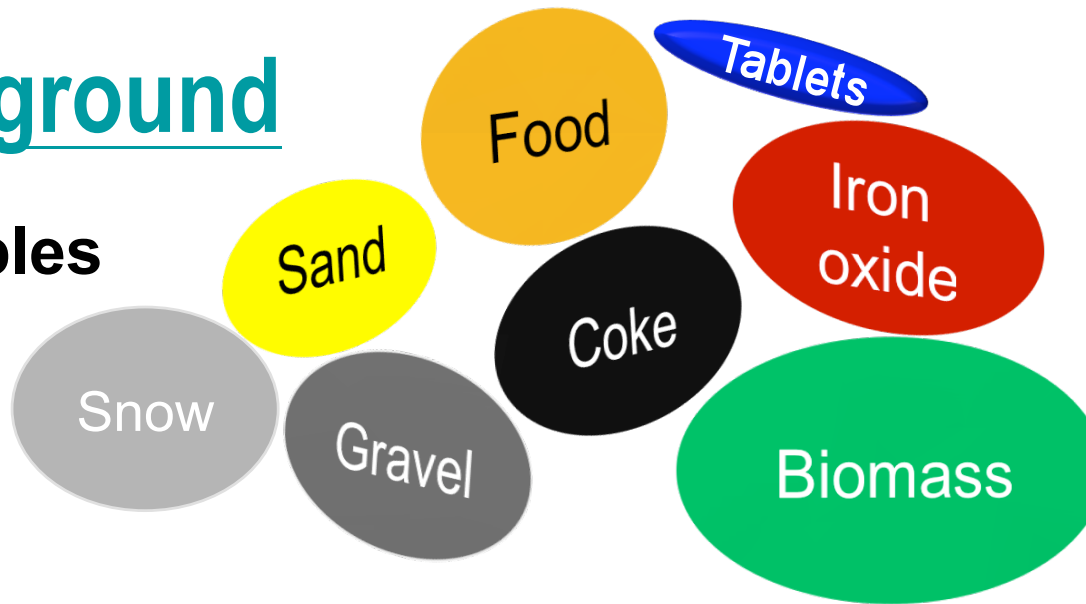


# Outline

- **Motivation**
  - Background Granular Media
  - Thermo Chemical Reactors
- **eXtended Discrete Element Method (XDEM)**
- **Multiphase Modeling**
  - Single Particle Model
  - Granular Medium/Packed Bed Model
- **Conclusion and Outlook**

# Background

- **Examples**



- The processing of granular media consumes **10% of the world energy production.**

*[Duran, J., Sands, Powders and Grains. Springer. New York. 2000].*

- Particle technology accounts for **40% of all money investments** of the U.S. chemical industry.

*[Ennis, B. J. and Green, J. and Davies, R., 1994. Chem. Eng. Prog. 90, 32-43].*

- The science of granular flow is **not yet well understood** and well developed as other class of materials.

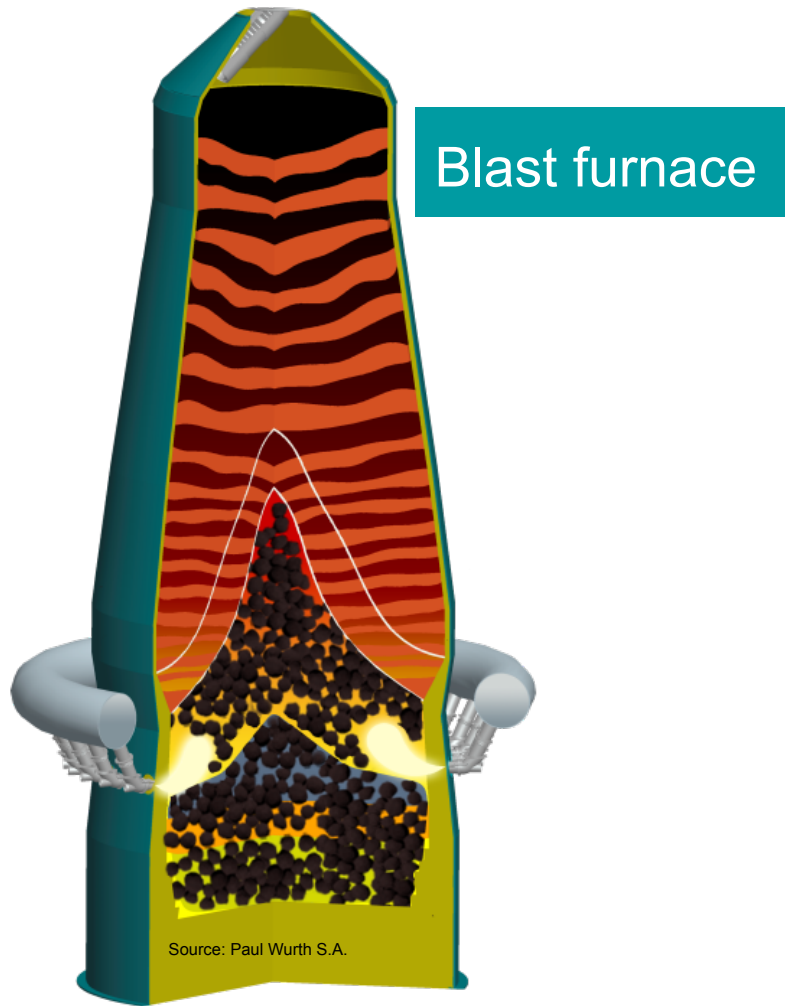
*[Poschel, T. and Schwager, T. Computational Granular Dynamics. Springer. Berlin. 2005].*

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# Thermo Chemical Reactors



Forward/Backward acting grates

# Blast Furnace Process

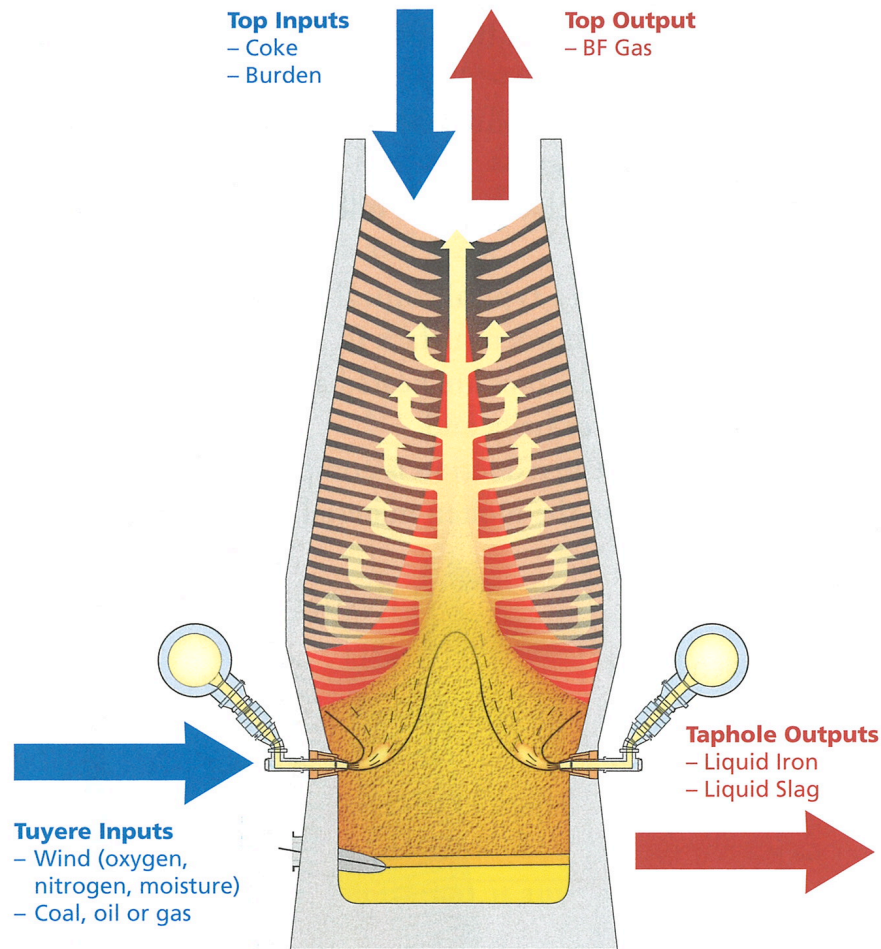


Image source: "Modern Blast Furnace Ironmaking – An introduction", M. Geerdes et al.

- Hostile Environment (300-1400 C)
- Multiphase
  - Solid (coke, iron ores, dust, ...)
  - Gas
  - Liquid (liquid iron, slag)
- Processes
  - Chemical reactions
  - Heat transfer
  - Mass transfer
  - Fluid flow
  - Solid motion

# eXtended Discrete Element Method (XDEM)

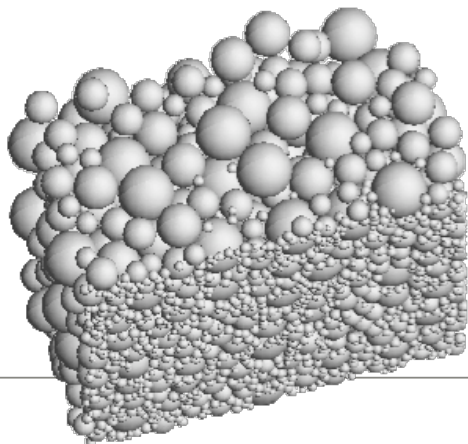
Multi-physics simulation toolbox modelling granular materials and processes:

# eXtended Discrete Element Method (XDEM)

Multi-physics simulation toolbox modelling granular materials and processes:

## Particle Motion

- Sand
- Snow
- ...



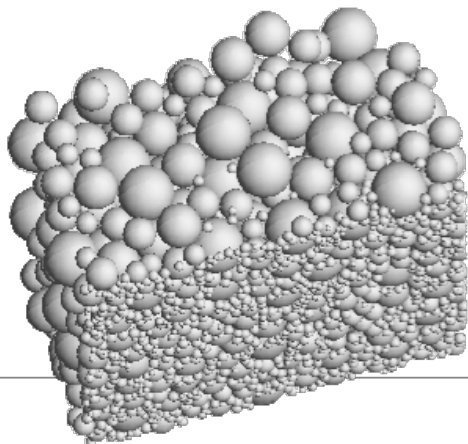


# eXtended Discrete Element Method (XDEM)

Multi-physics simulation toolbox modelling granular materials and processes:

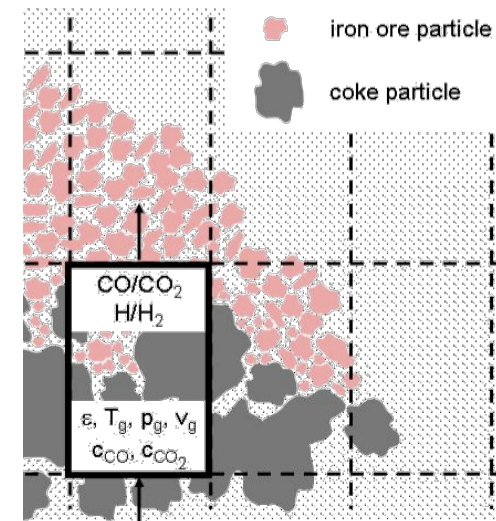
## Particle Motion

- Sand
- Snow
- ...



## Chemical Reactions

- Coke
- Iron ore
- Biomass
- Waste
- ...

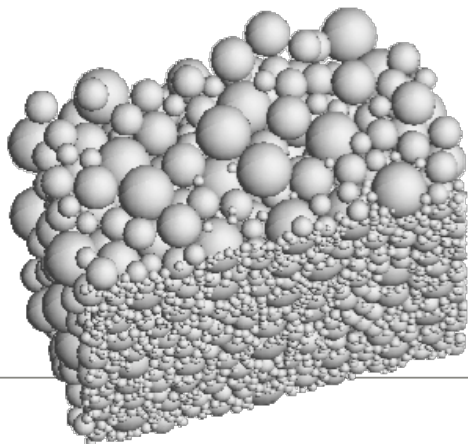


# eXtended Discrete Element Method (XDEM)

Multi-physics simulation toolbox modelling granular materials and processes:

Particle Motion

- Sand
- Snow
- ...

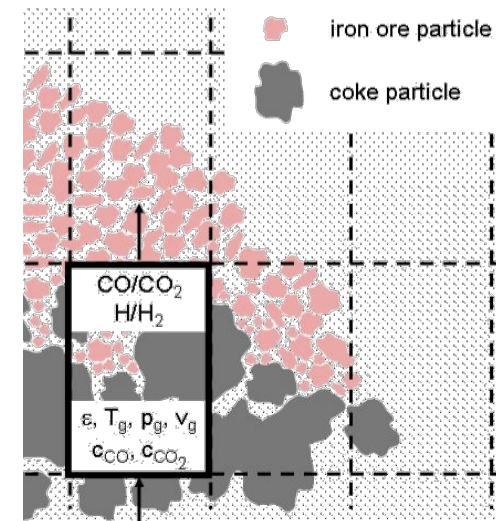


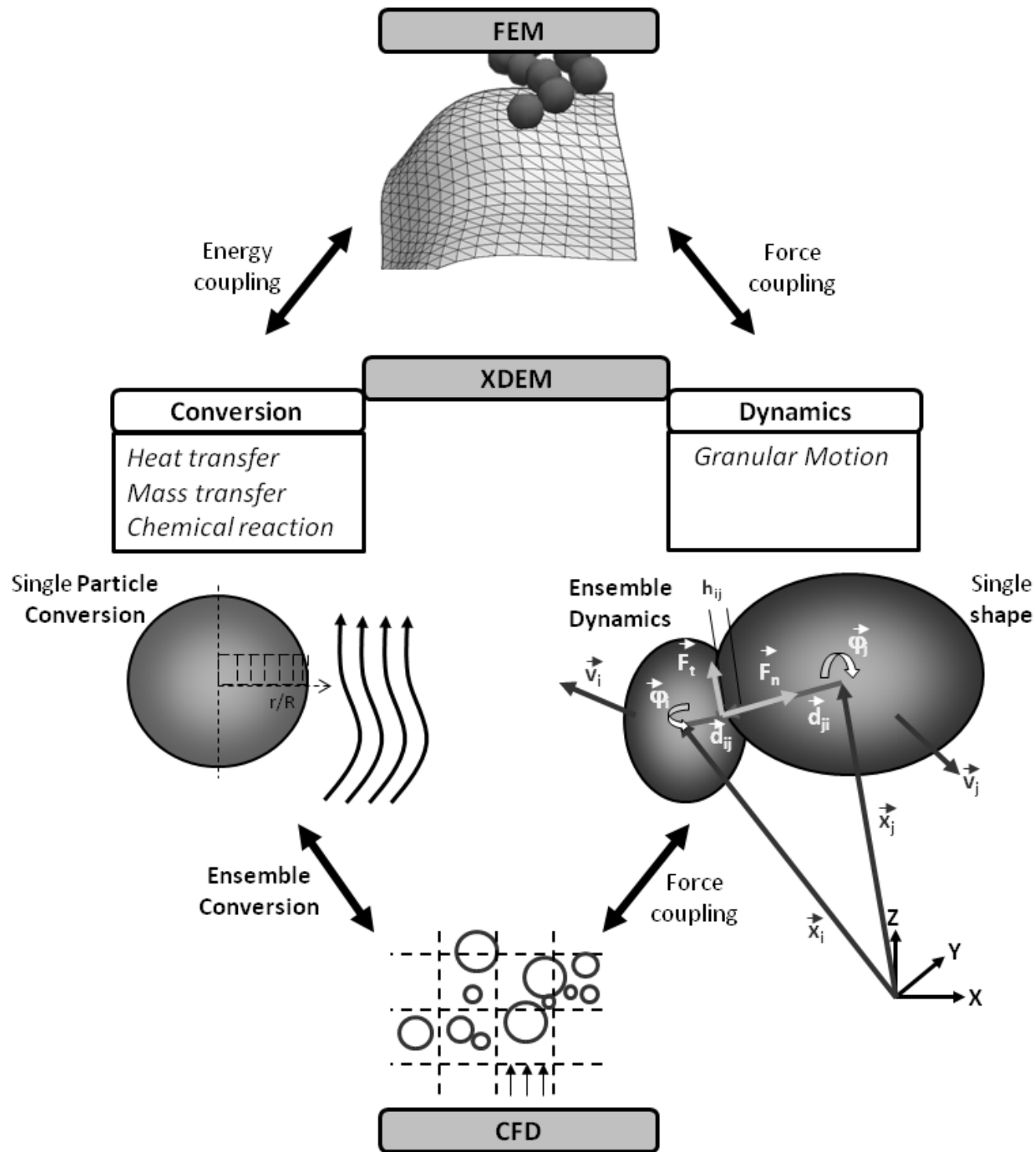
**&/or**



Chemical Reactions

- Coke
- Iron ore
- Biomass
- Waste
- ...





# Blast Furnace Process: Shaft Model

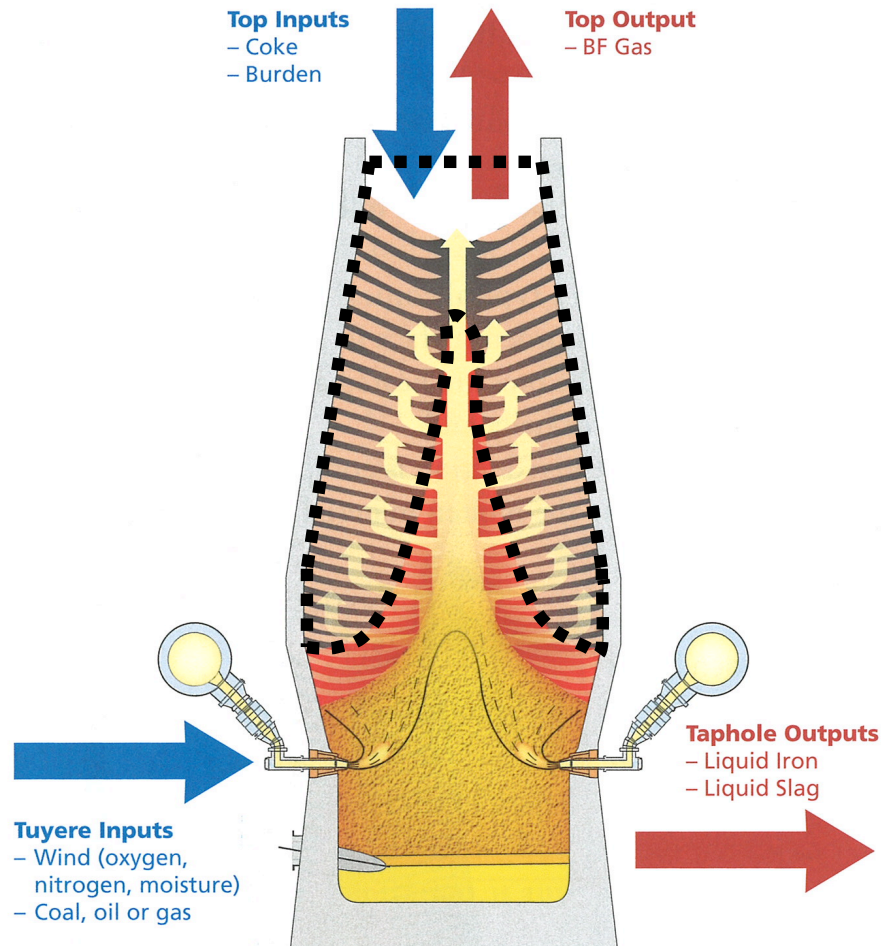
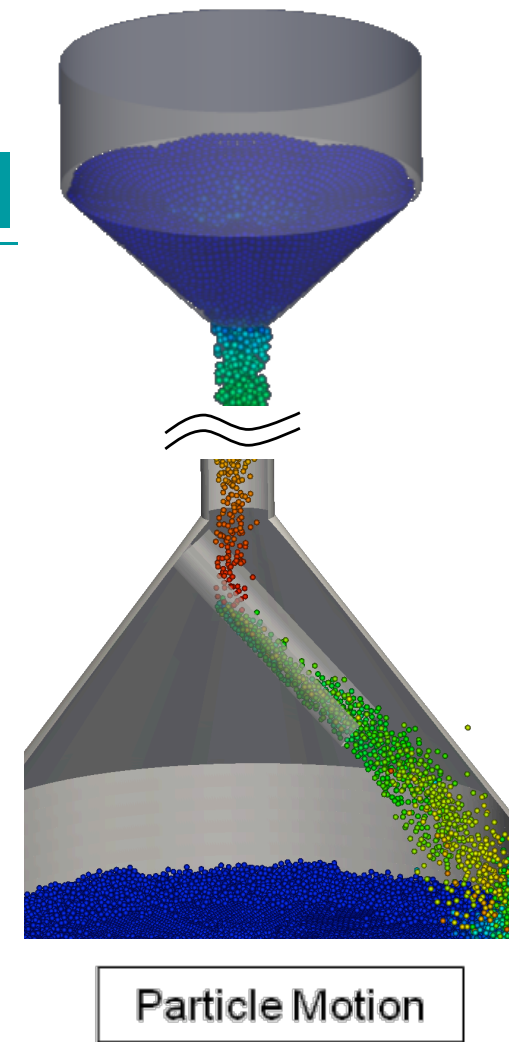
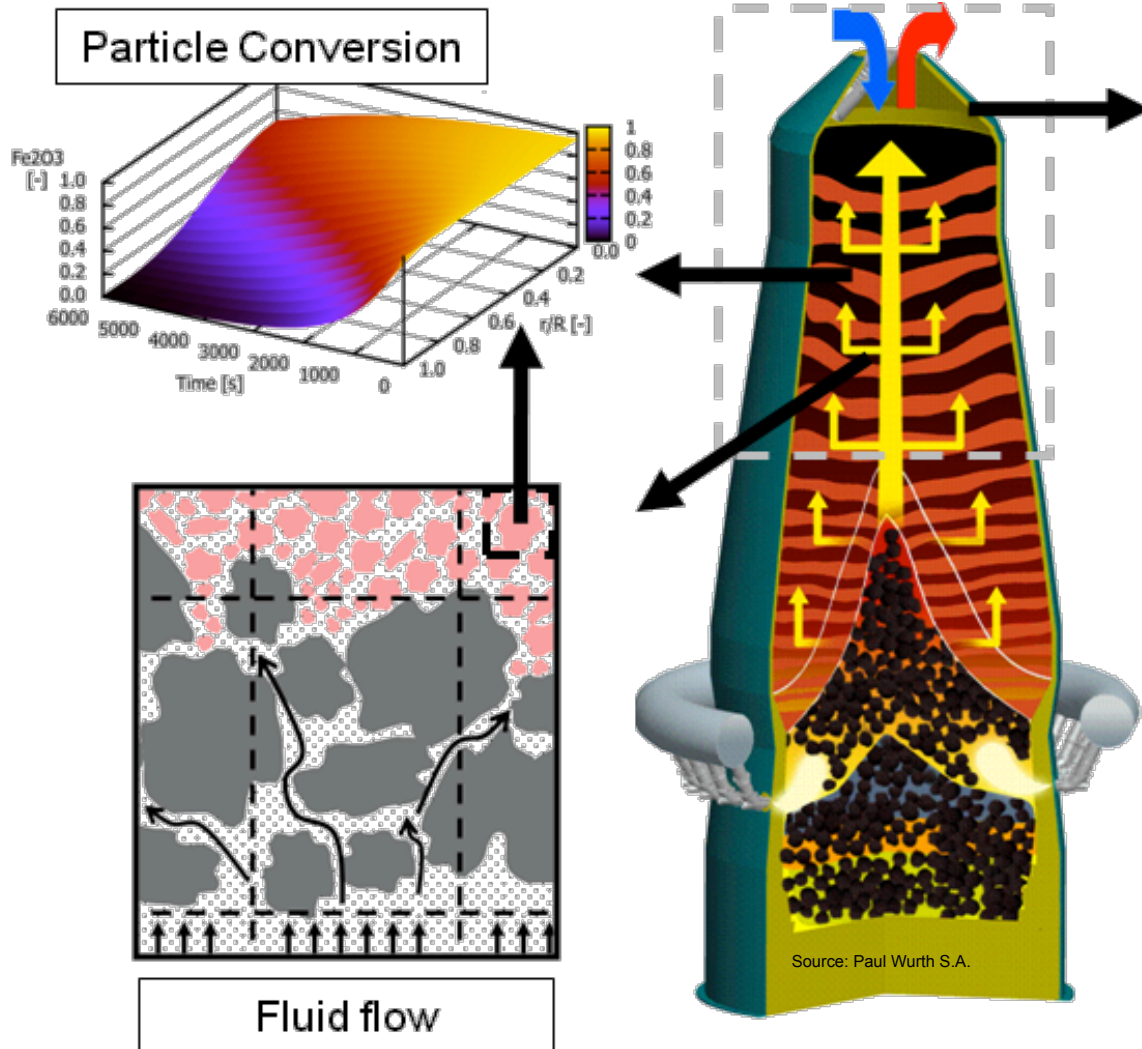


Image source: "Modern Blast Furnace Ironmaking – An introduction", M. Geerdes et al.

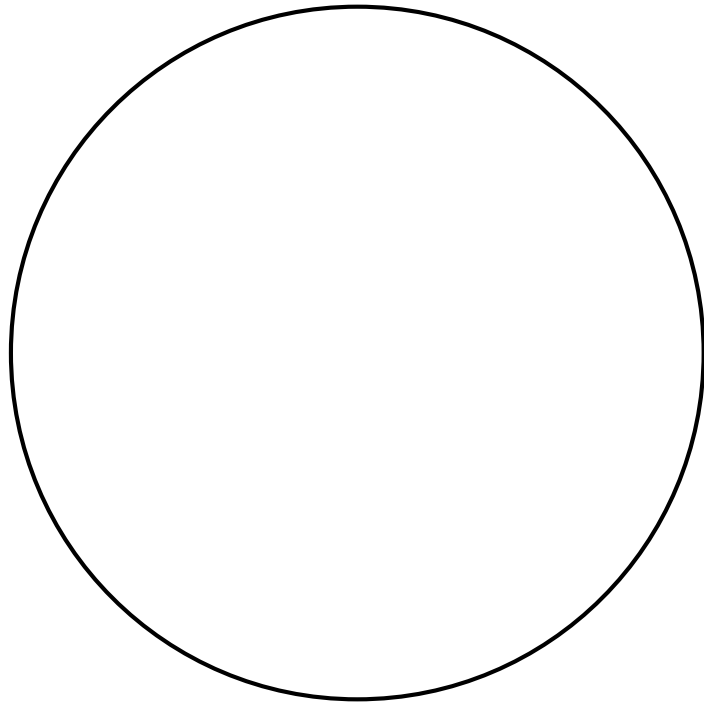
- Domain:  
Charging -> Cohesive Zone
- High resolution (locality)
- Processes
  - Chemical reactions
  - Heat transfer
  - Mass transfer
  - Gas flow
  - Solid motion

# XDEM BF Shaft Process Model



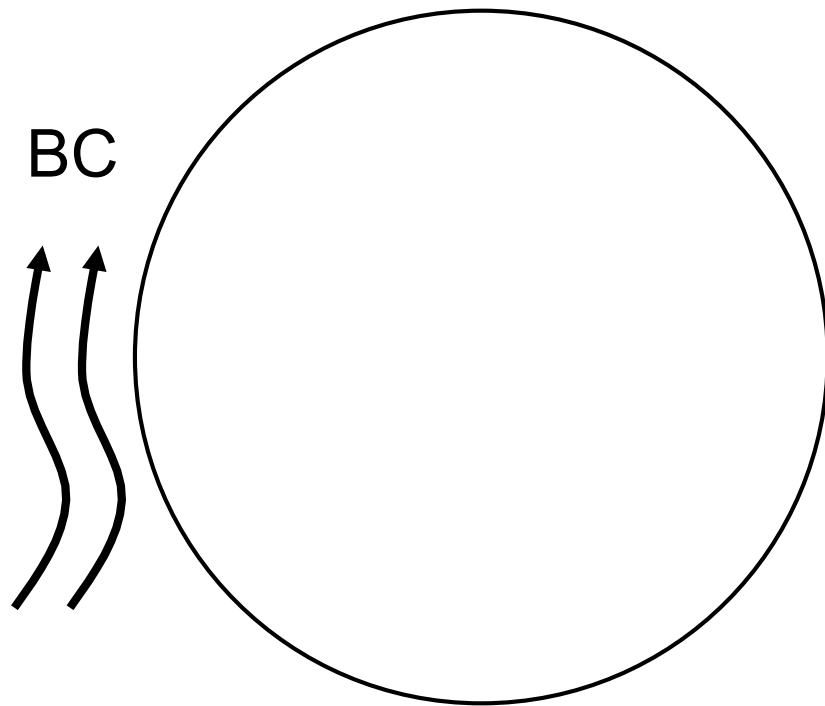
# XDEM Conversion – Single particle model

Particle  
(for example  $\text{Fe}_x\text{O}_y$ )



# XDEM Conversion – Single particle model

Particle  
(for example  $\text{Fe}_x\text{O}_y$ )



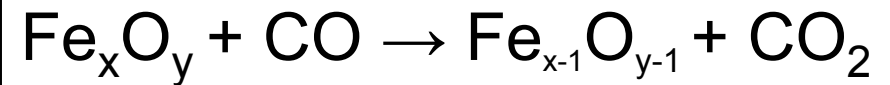
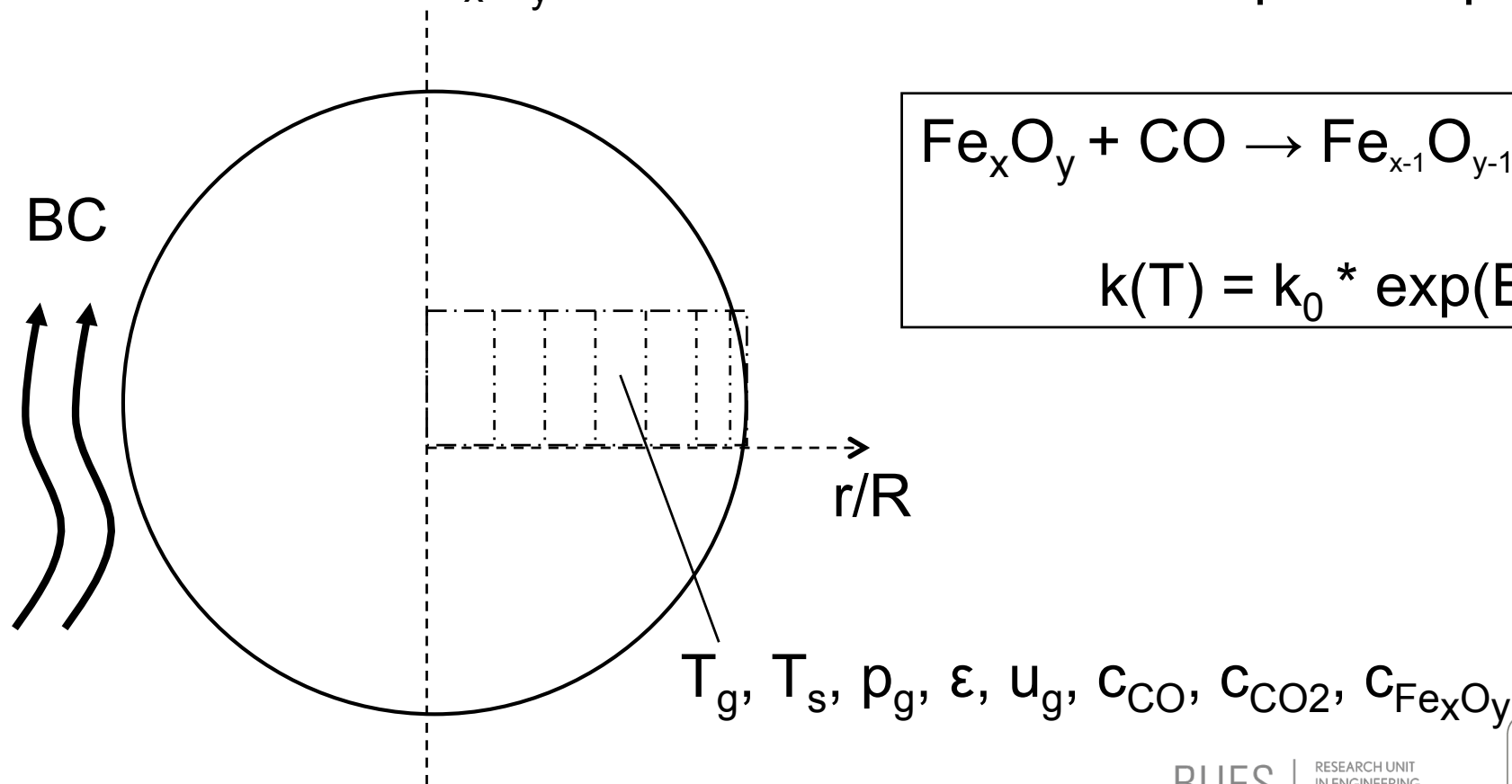
calculation of inner-particle processes  
by PDE for

- Mass
- Species
- Energy

# XDEM Conversion – Single particle model

Particle  
(for example  $\text{Fe}_x\text{O}_y$ )

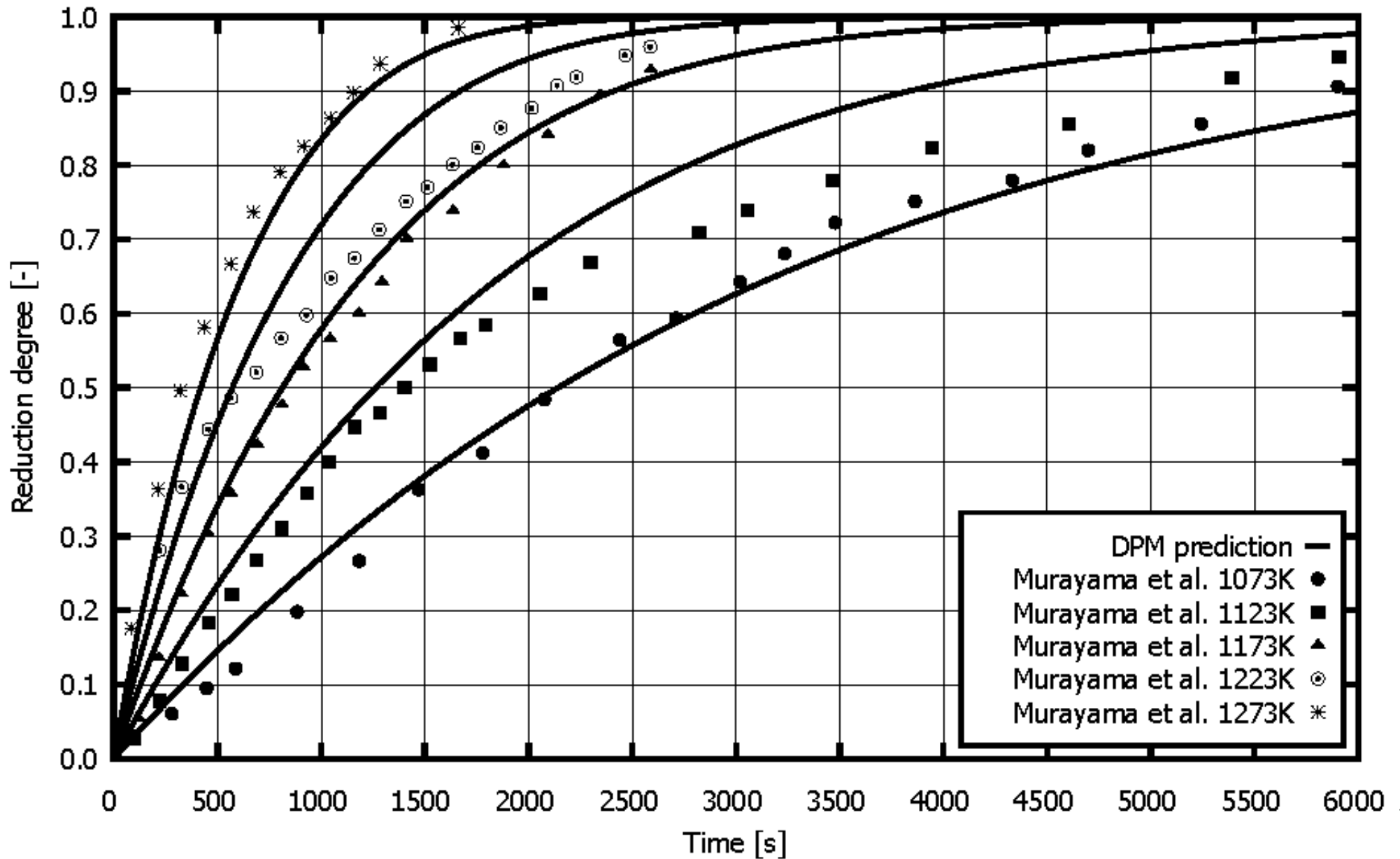
calculation of inner-particle processes



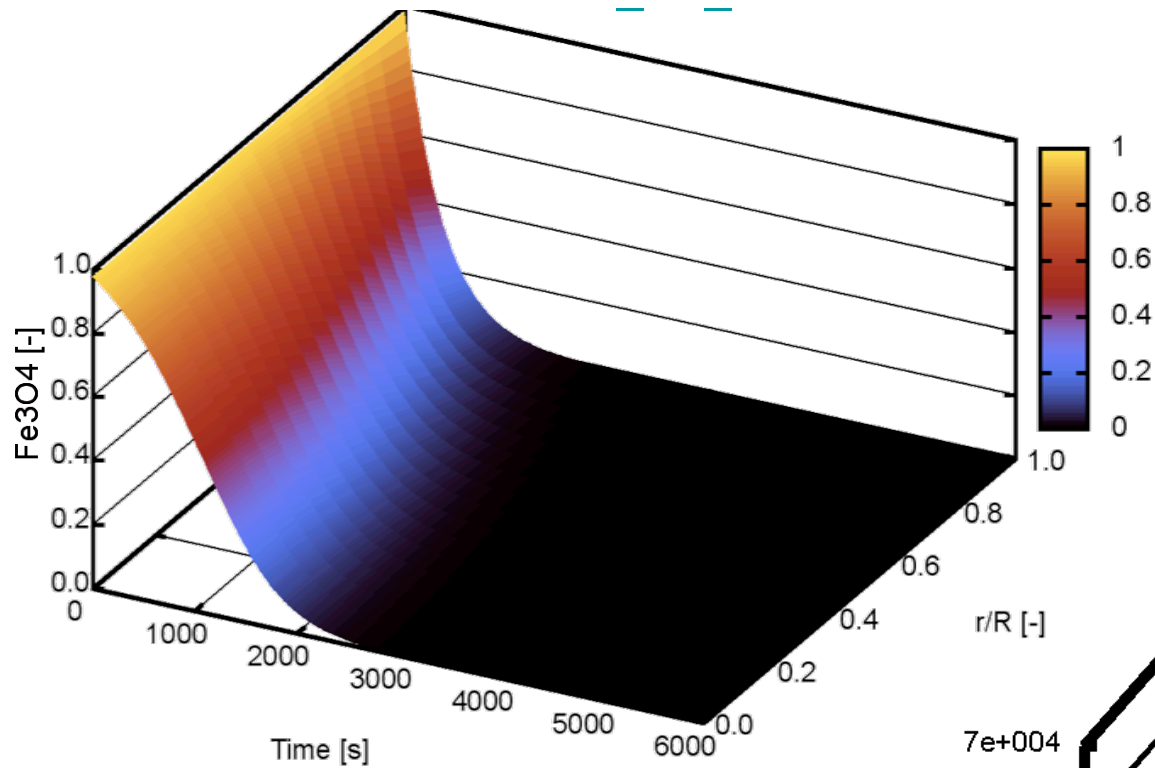
$$k(T) = k_0 * \exp(E_a/RT)$$



# Validation: $\text{Fe}_3\text{O}_4 + \text{CO} \rightarrow 3\text{FeO} + \text{CO}_2$ (isothermal)

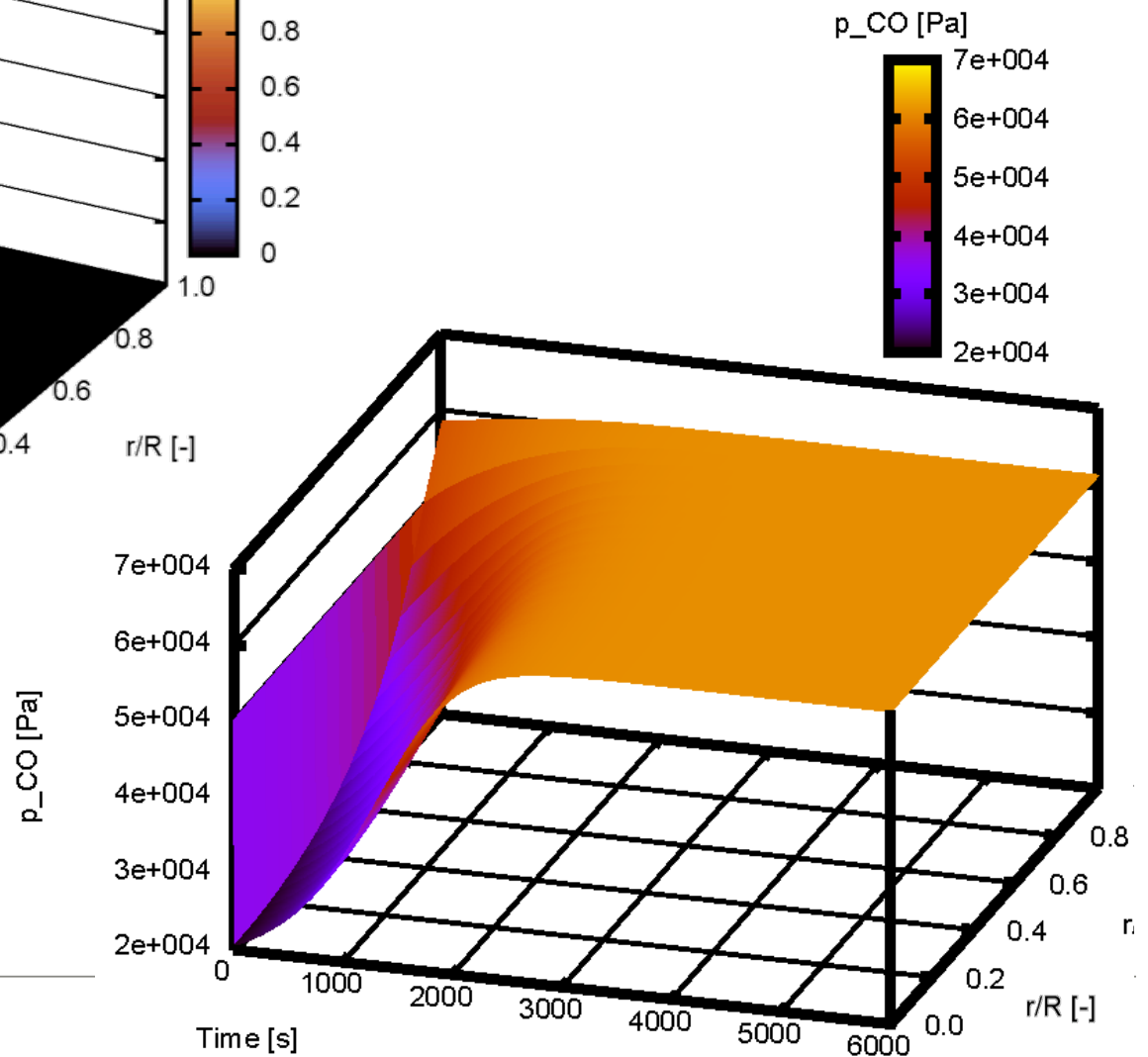


# Validation: $\text{Fe}_3\text{O}_4 \rightarrow \text{FeO}$ (1273 K)

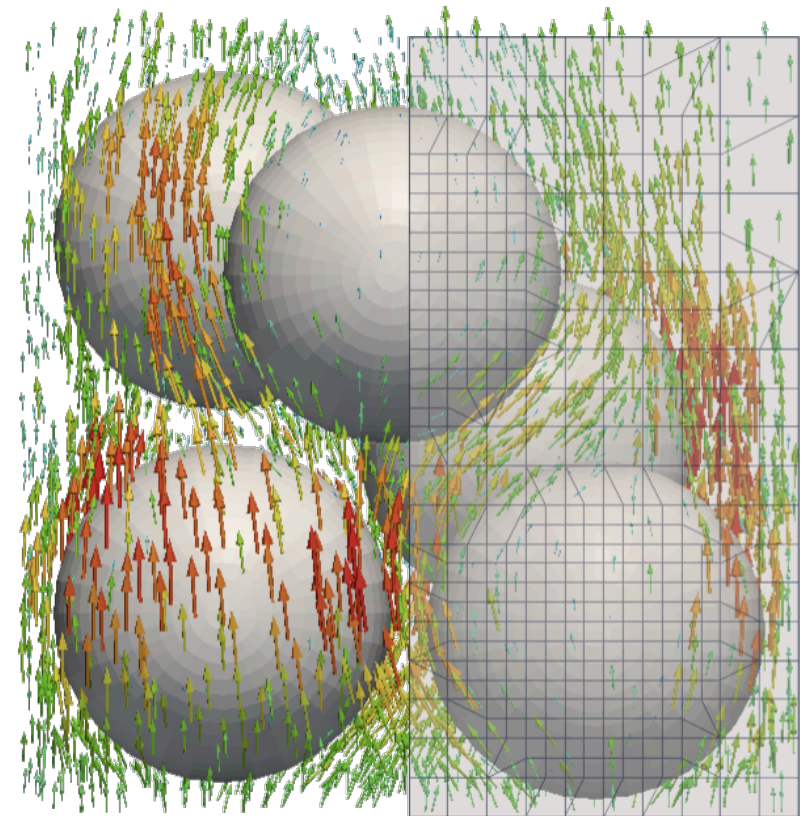
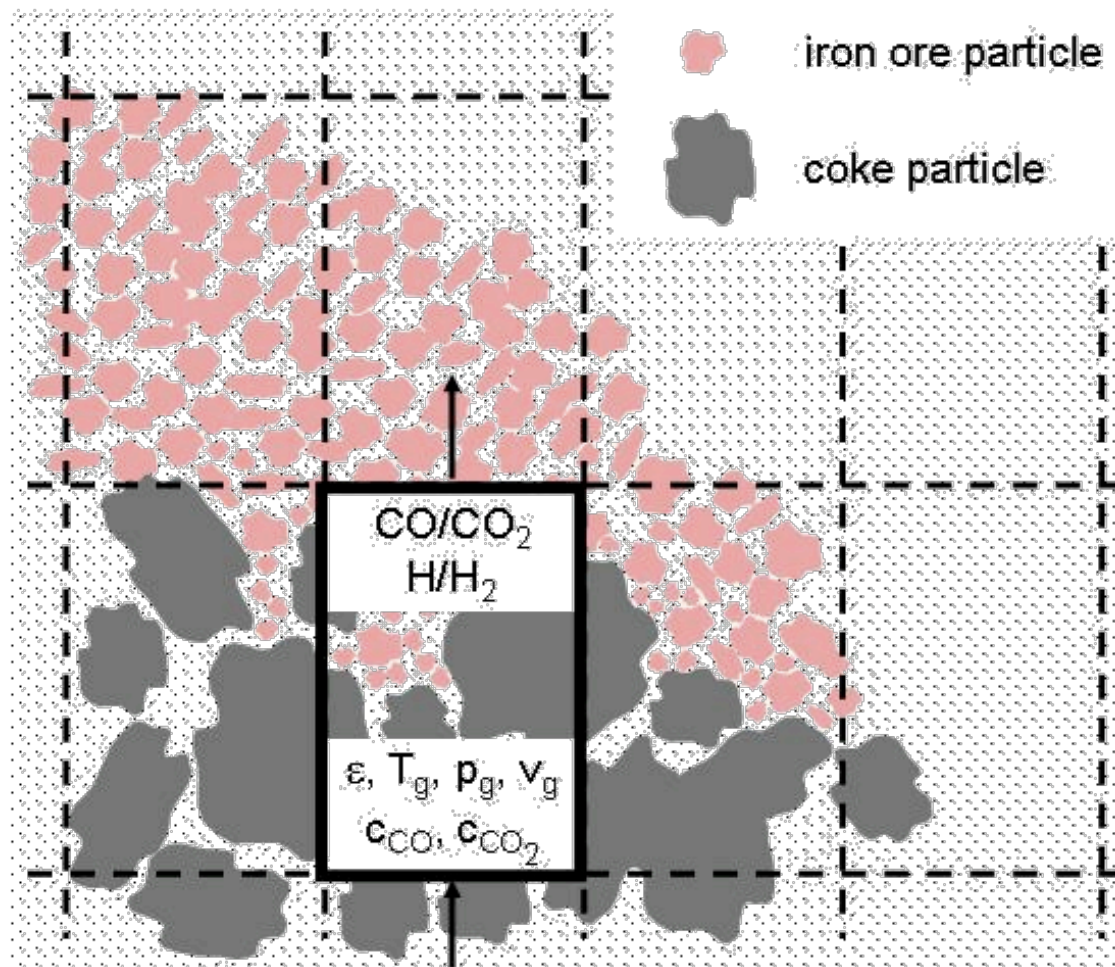


Mass fraction  $\text{Fe}_3\text{O}_4$

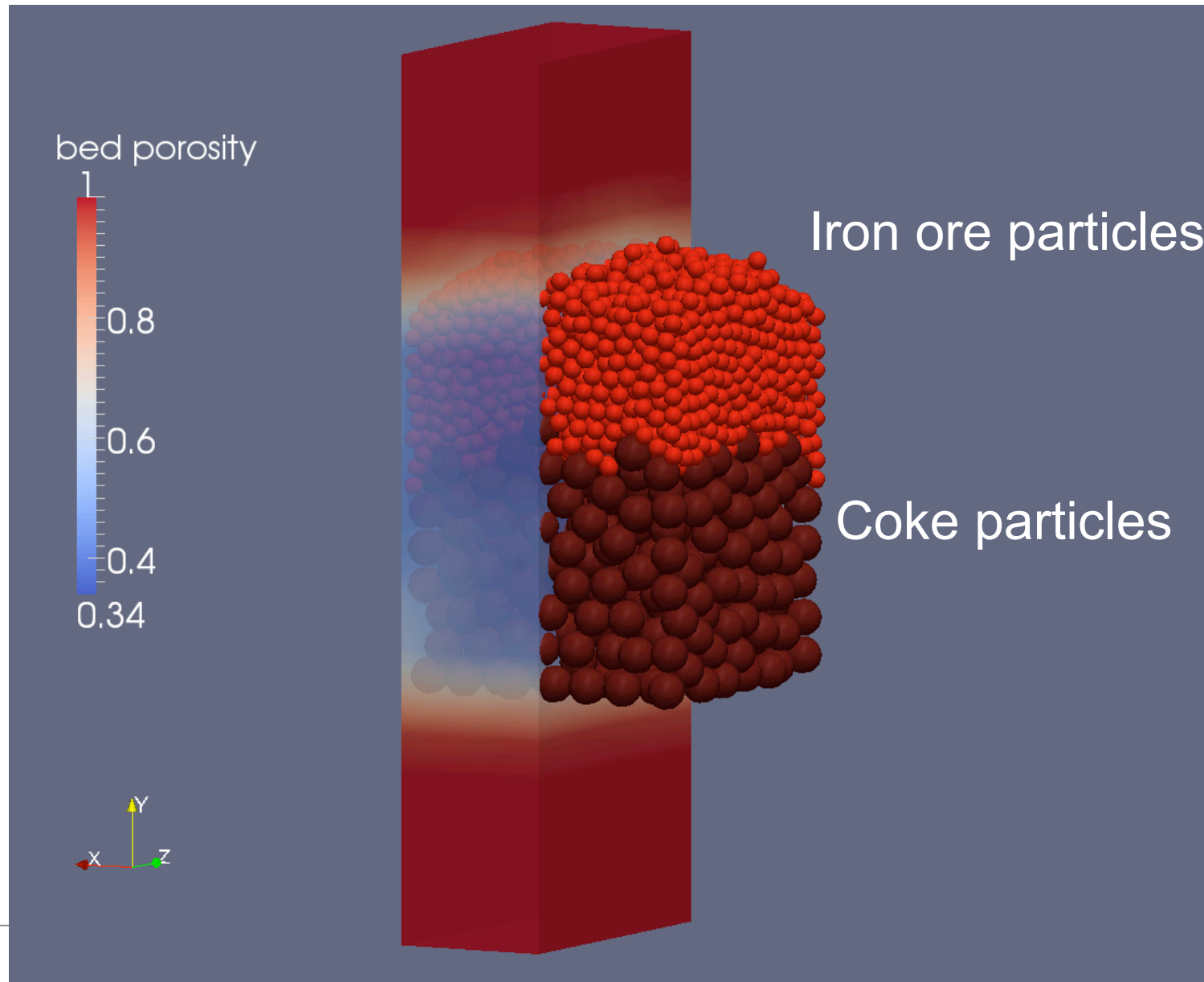
## Partial pressure CO



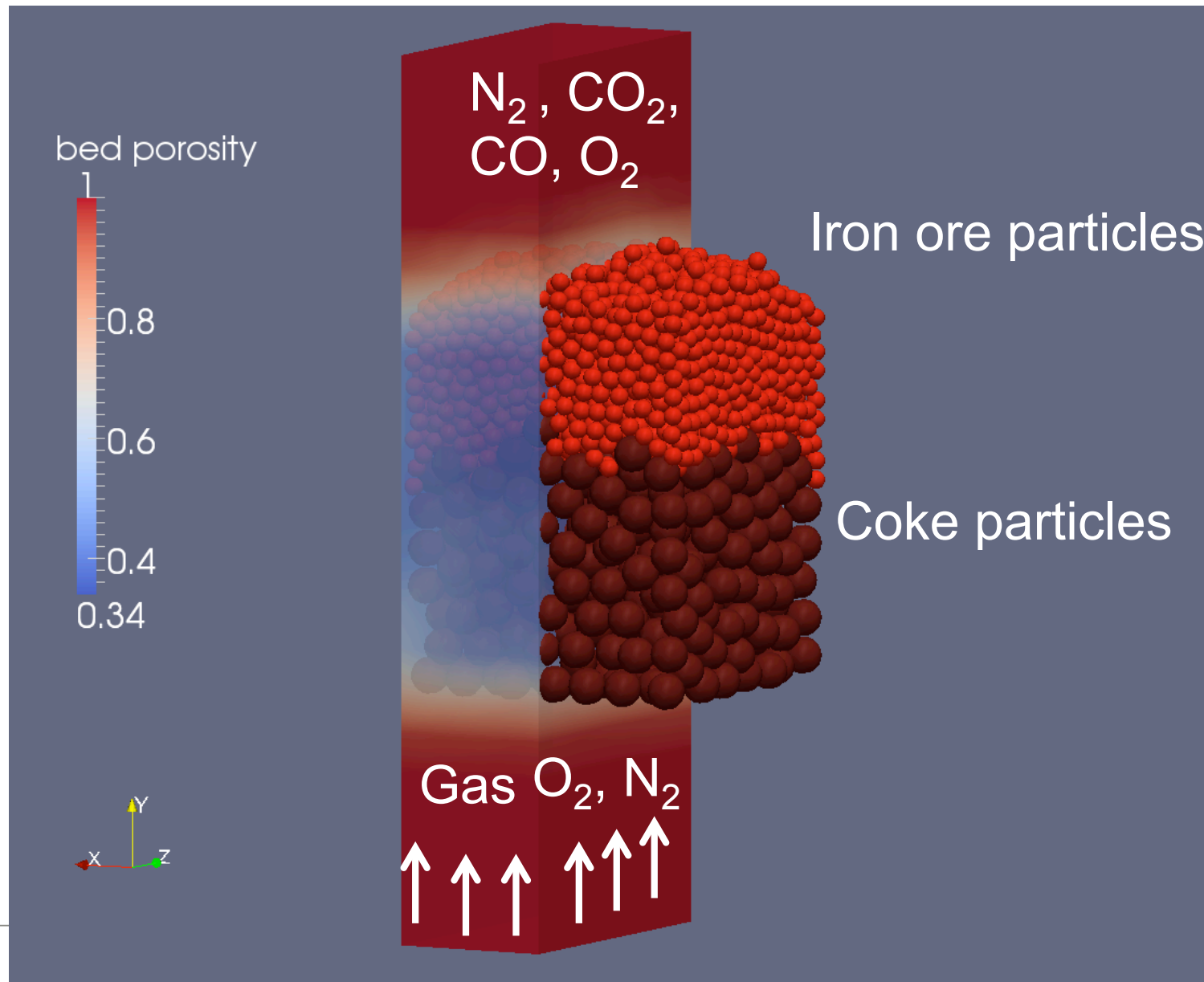
# XDEM Conversion, Ensemble model



# XDEM Conversion, Ensemble model



# Thermal Conversion of Coke and Iron ore



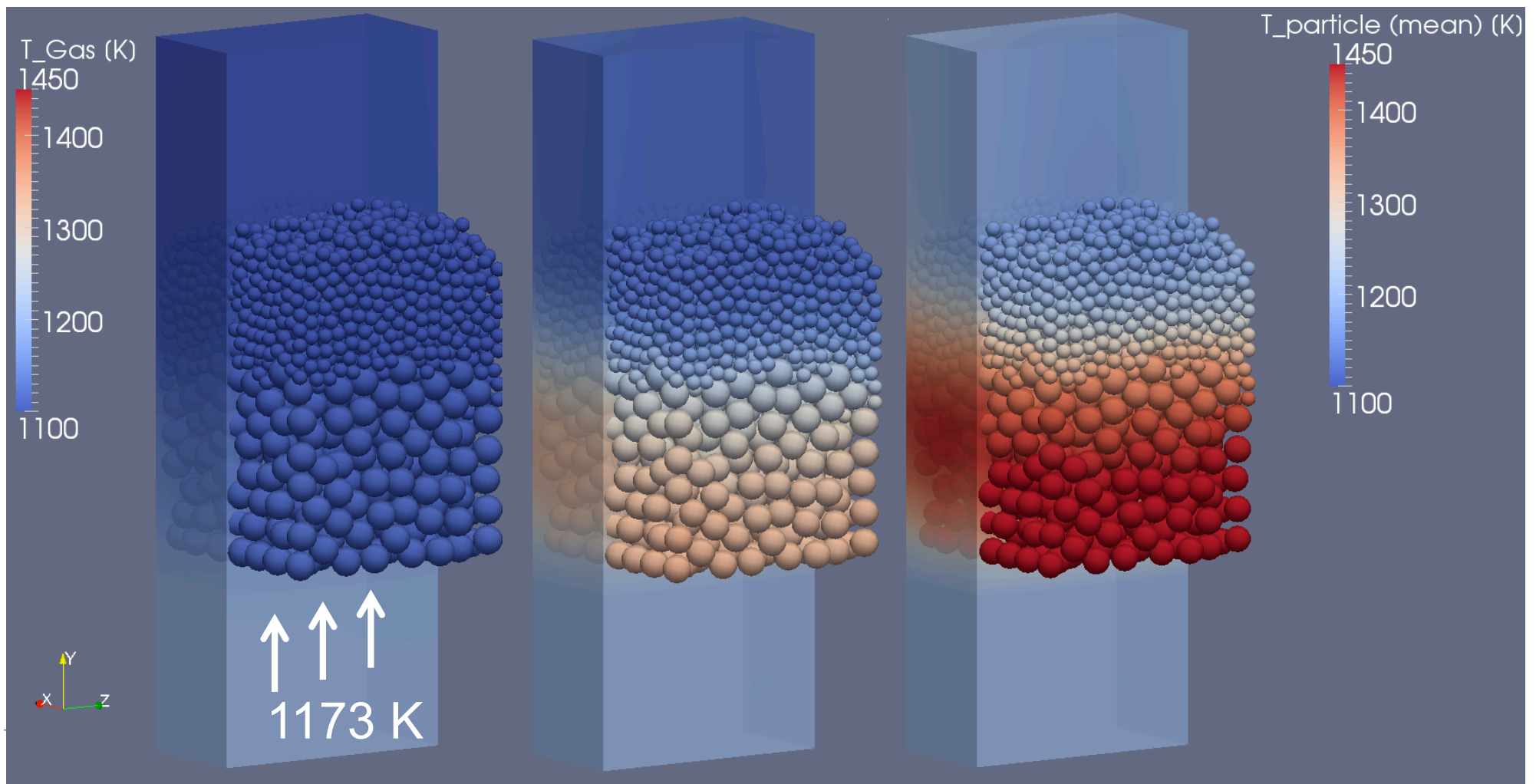
# Thermal conversion

$T_{\text{Inlet}}=1173 \text{ K}$

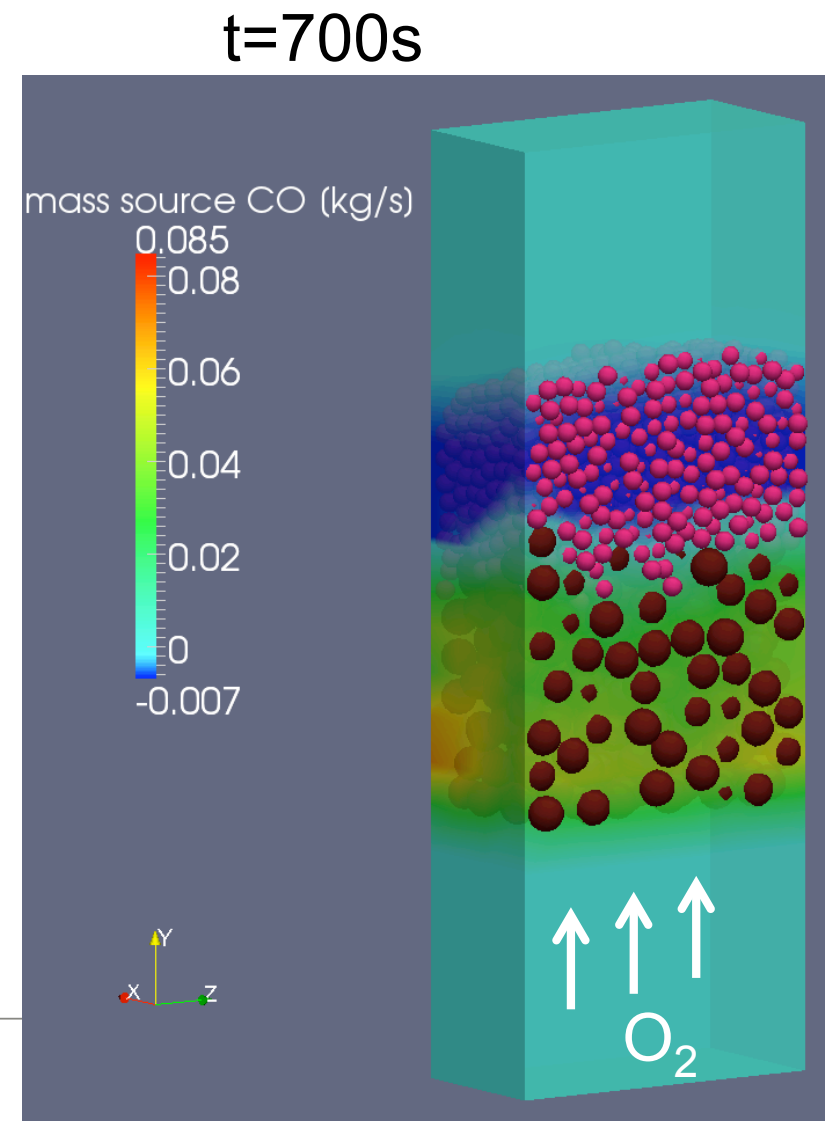
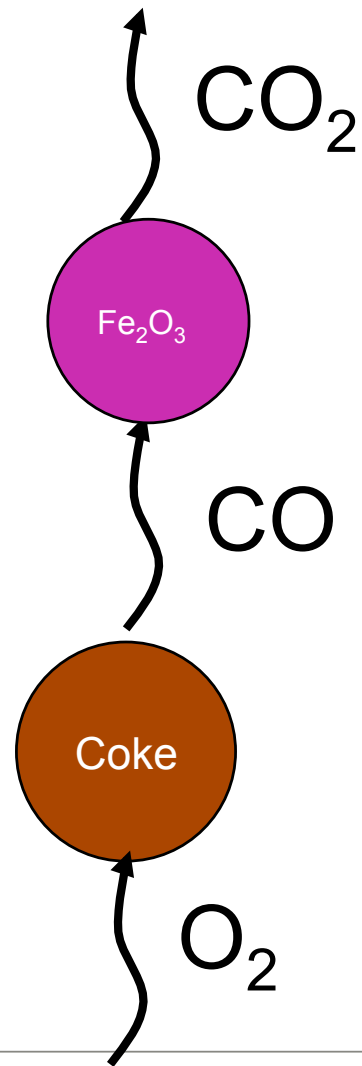
$t=10\text{s}$

$t=300\text{s}$

$t=700\text{s}$



# Thermal conversion

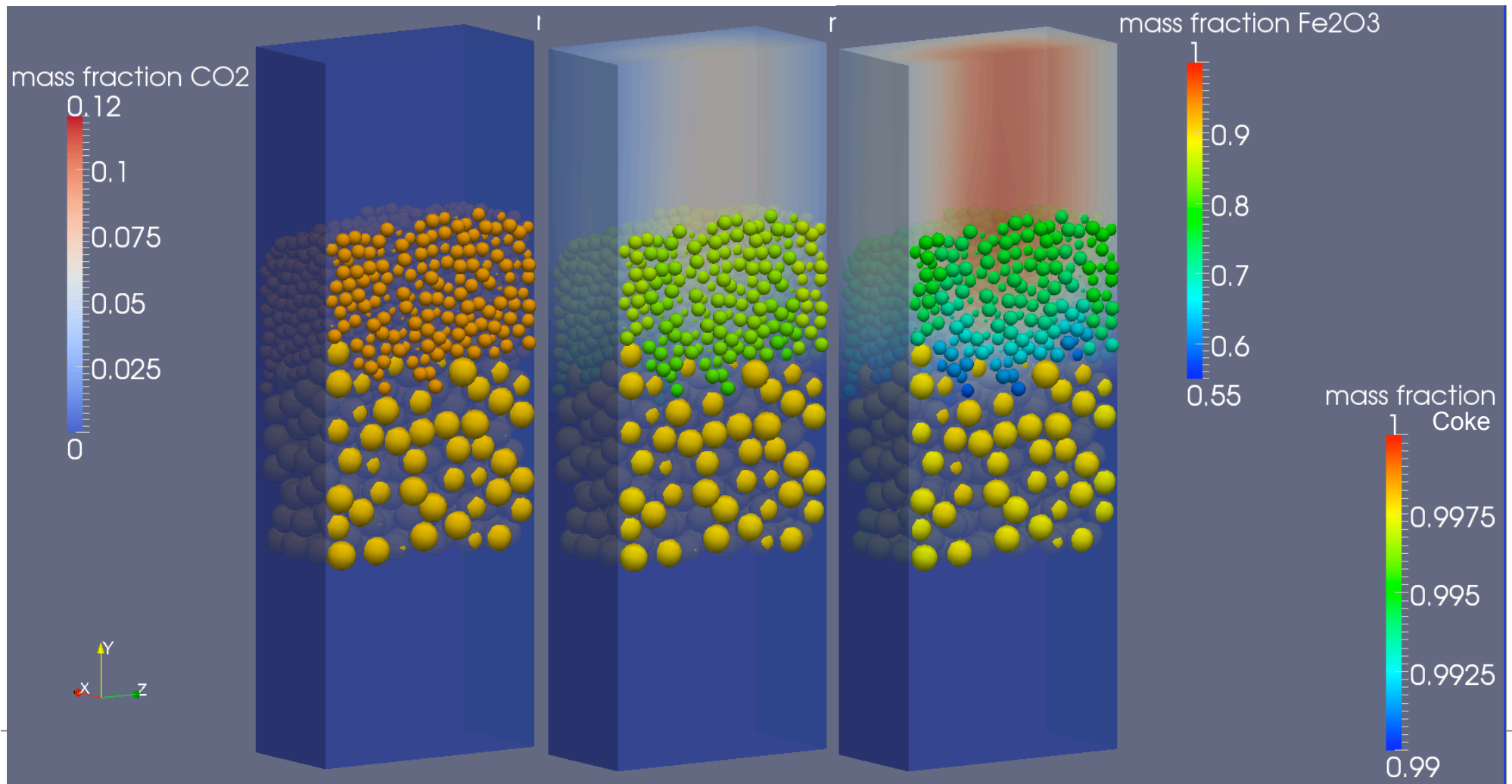


# Thermal conversion

t=10s

t=300s

t=700s



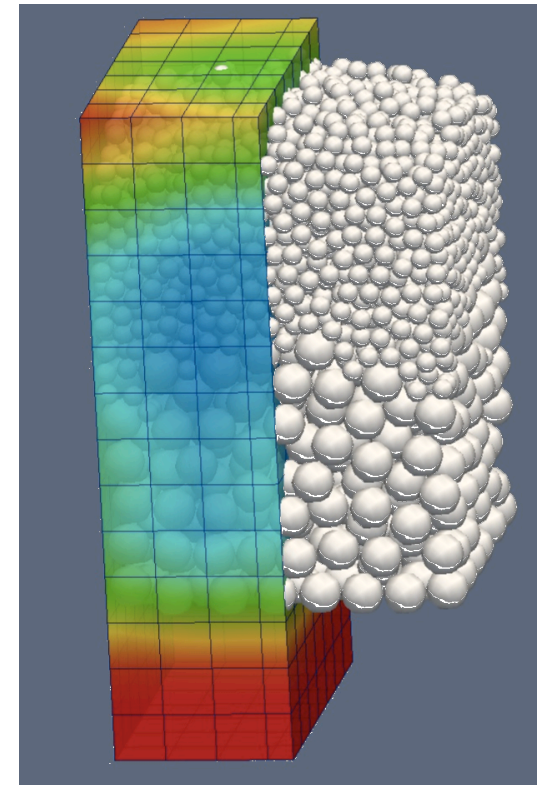
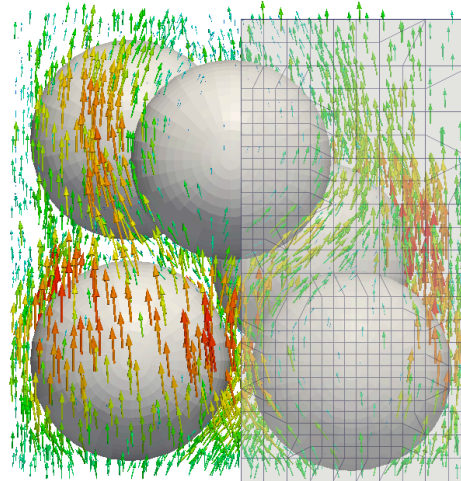
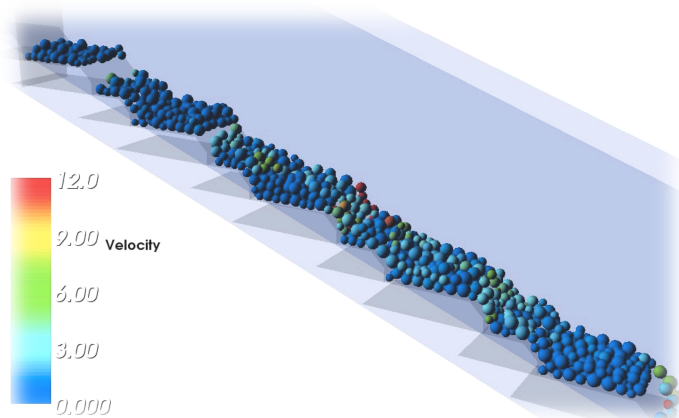
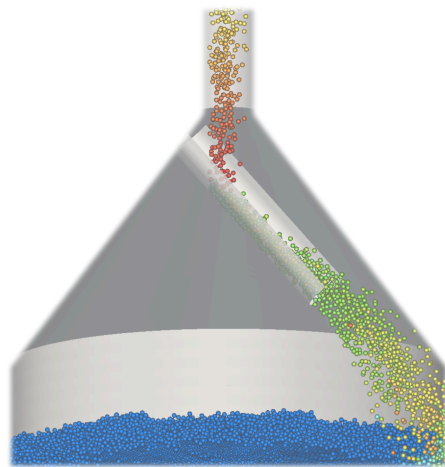


# Conclusion and Outlook

- **Multiphysics -> Coupled Approach**
  - **Granular Medium**
  - **Thermo Chemical Processes**
  - **Fluid Flow**
  
- **Validation of a small scale Packed Bed with experimental data**
- **Shaft Process Model**

# Thank you for your attention

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