CFD–SIMULATION OF NATURAL GAS COMBUSTION

AND IST APPLICATION TO TUNNEL KILN FIRING

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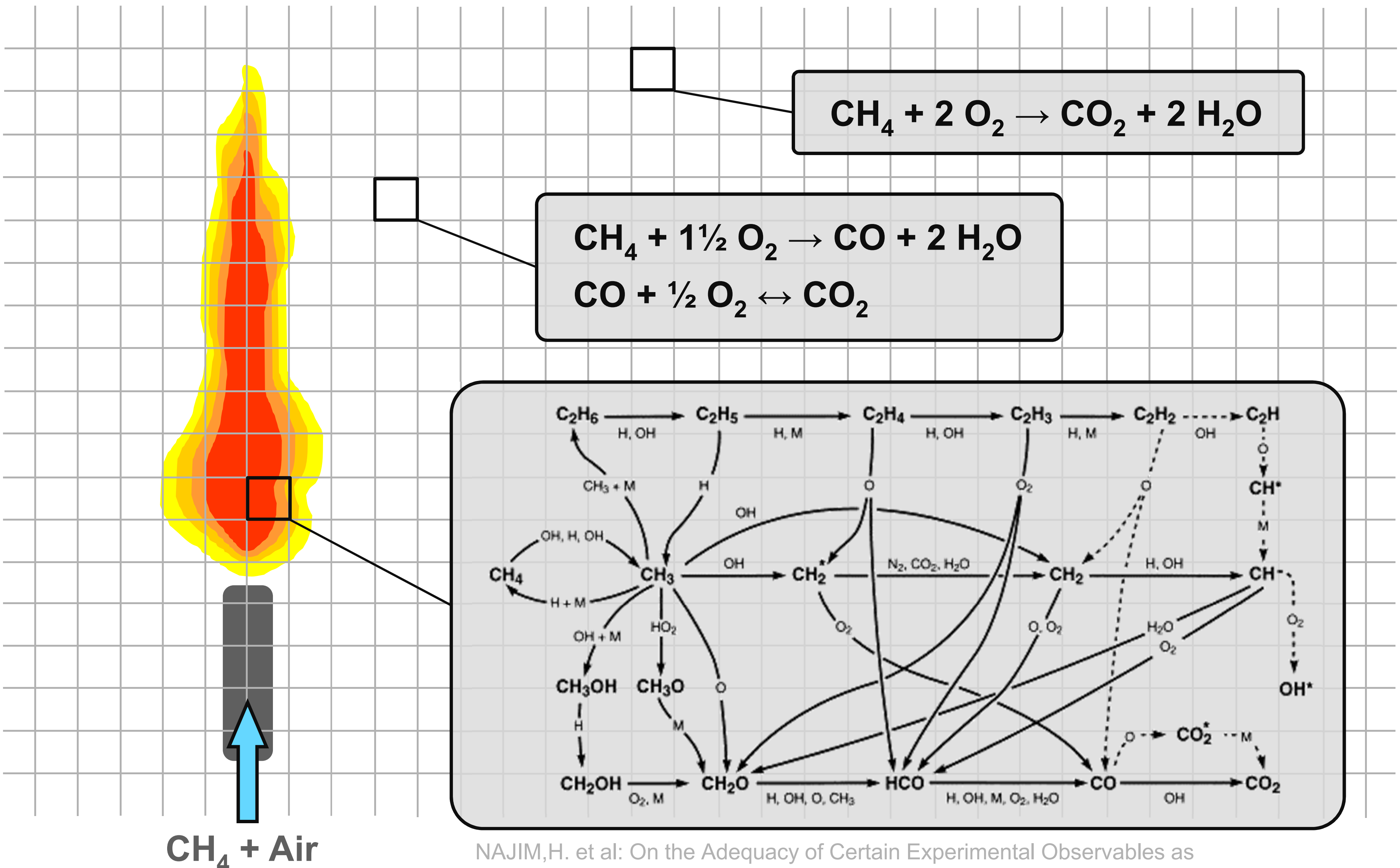
Contents

1. Introduction to combustion models in OpenFOAM

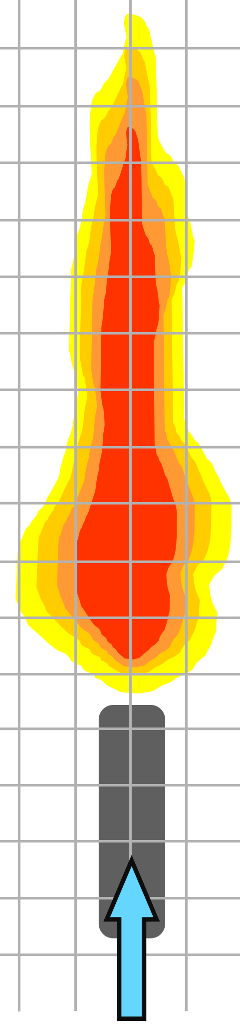
Simple flame – Reactions and species



NAJIM,H. et al: On the Adequacy of Certain Experimental Observables as Measurements of Flame Burning Rate. Combustion and Flame 113 (1998), pp 312–332

1. Introduction to combustion models in OpenFOAM

Simple flame – Reaction Model



$CH_4 + 2\ O_2 \rightarrow \ldots \rightarrow CO_2 + 2\ H_2O$

GRI22 reaction mechanism:

22 species (+ N_2, Ar)
104 reactions

Reaction Model:

Equilibrium calculation for each cell

☺ Easy implementation

☹ (Very) slow calculation

2. Flamelet model

Simplified model description

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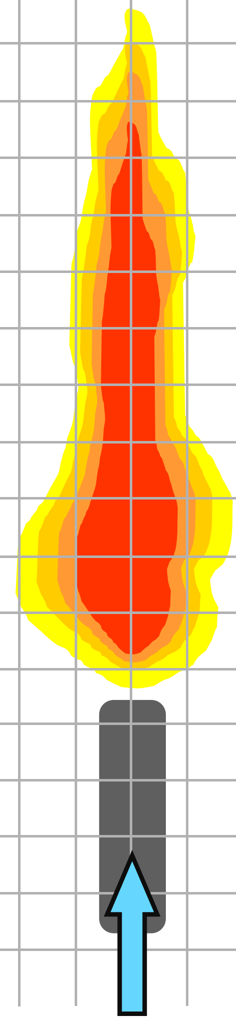


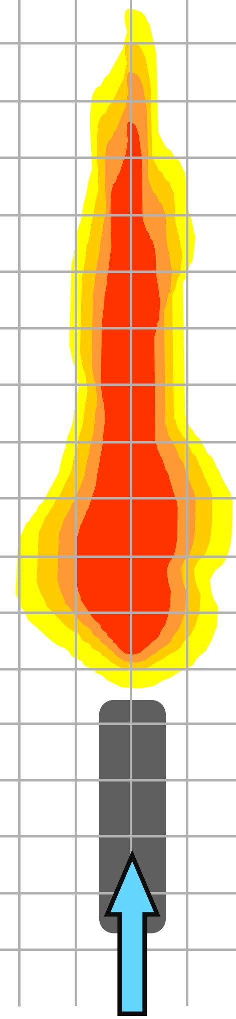
CH_4 + Air

Flamelet Model:

- Pre-calculation of possible reactions
- Generation of lookup-tables
- ☺ Fast calculation
- ☹ High memory consumption
- ☹ More difficult implementation

2. Flamelet model

Simplified model description – Lookup-tables



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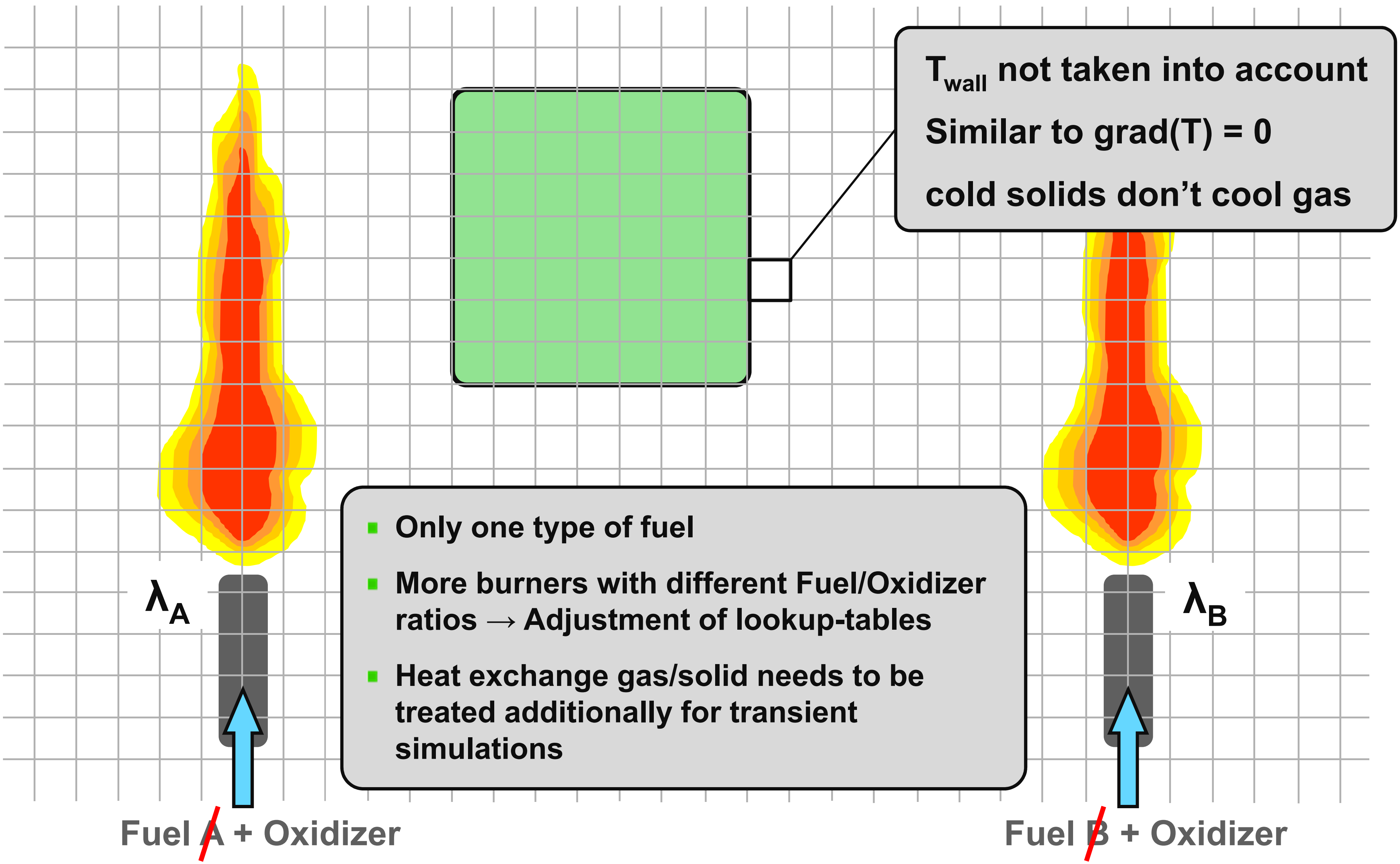
scalar Dissipation χ [s^{-1}]

Fuel + Oxidizer → Fuel fraction z ... [0…1]

2. Flamelet model

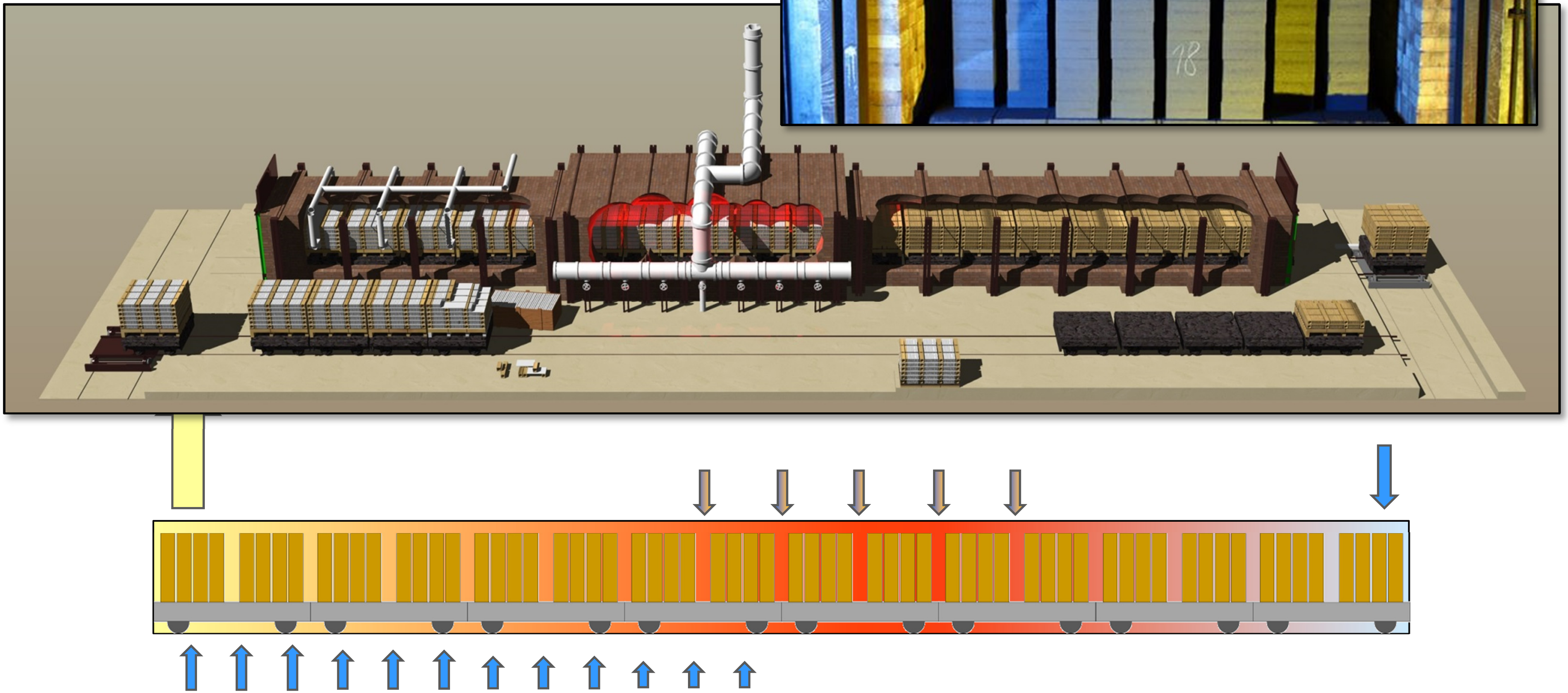
Implementation issues



- Only one type of fuel
- More burners with different Fuel/Oxidizer ratios → Adjustment of lookup-tables
- Heat exchange gas/solid needs to be treated additionally for transient simulations

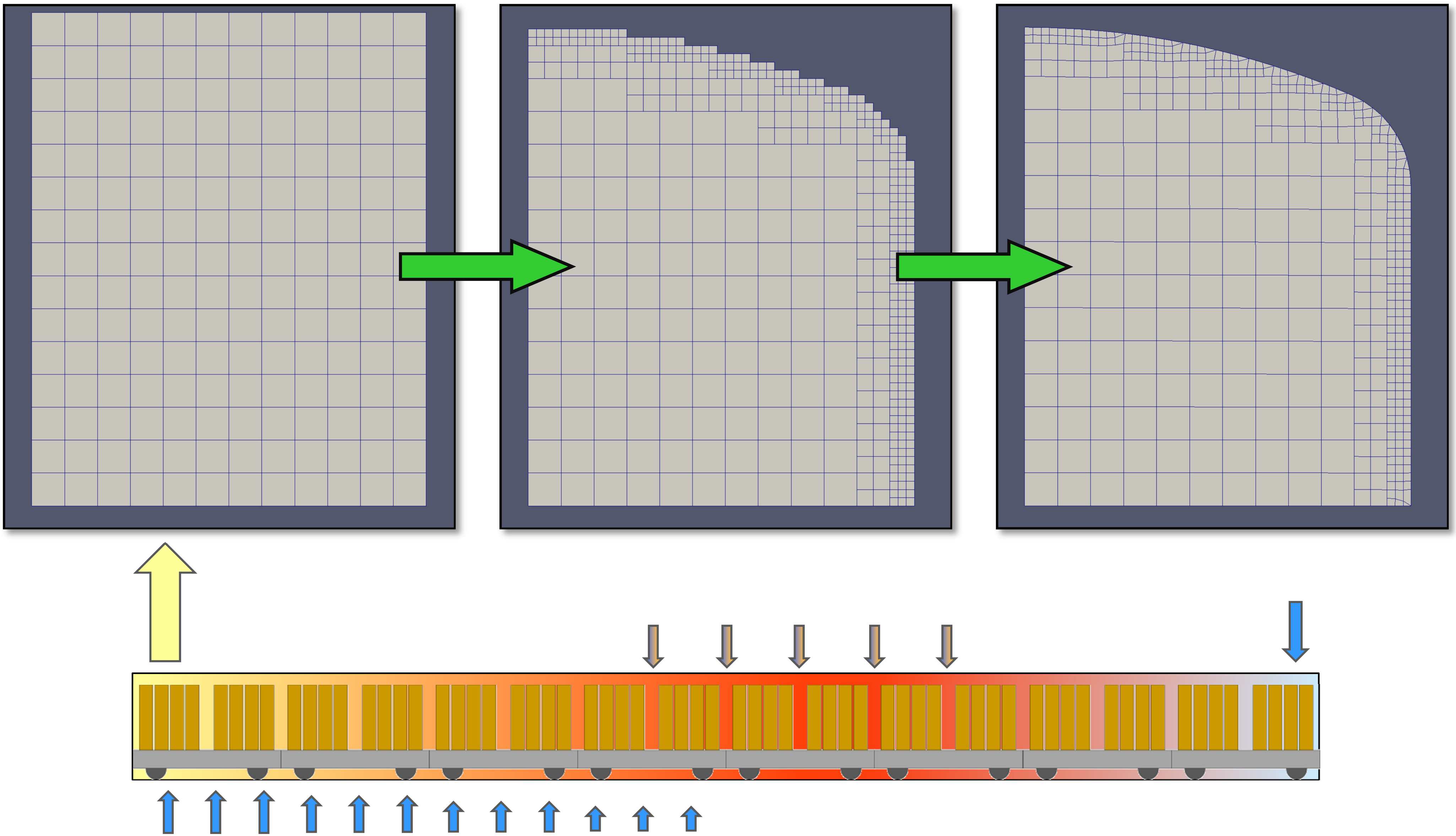
3. Tunnel kiln firing

Overview



3. Tunnel kiln firing

Mesh generation – SnappyHexMesh



3. Tunnel kiln firing

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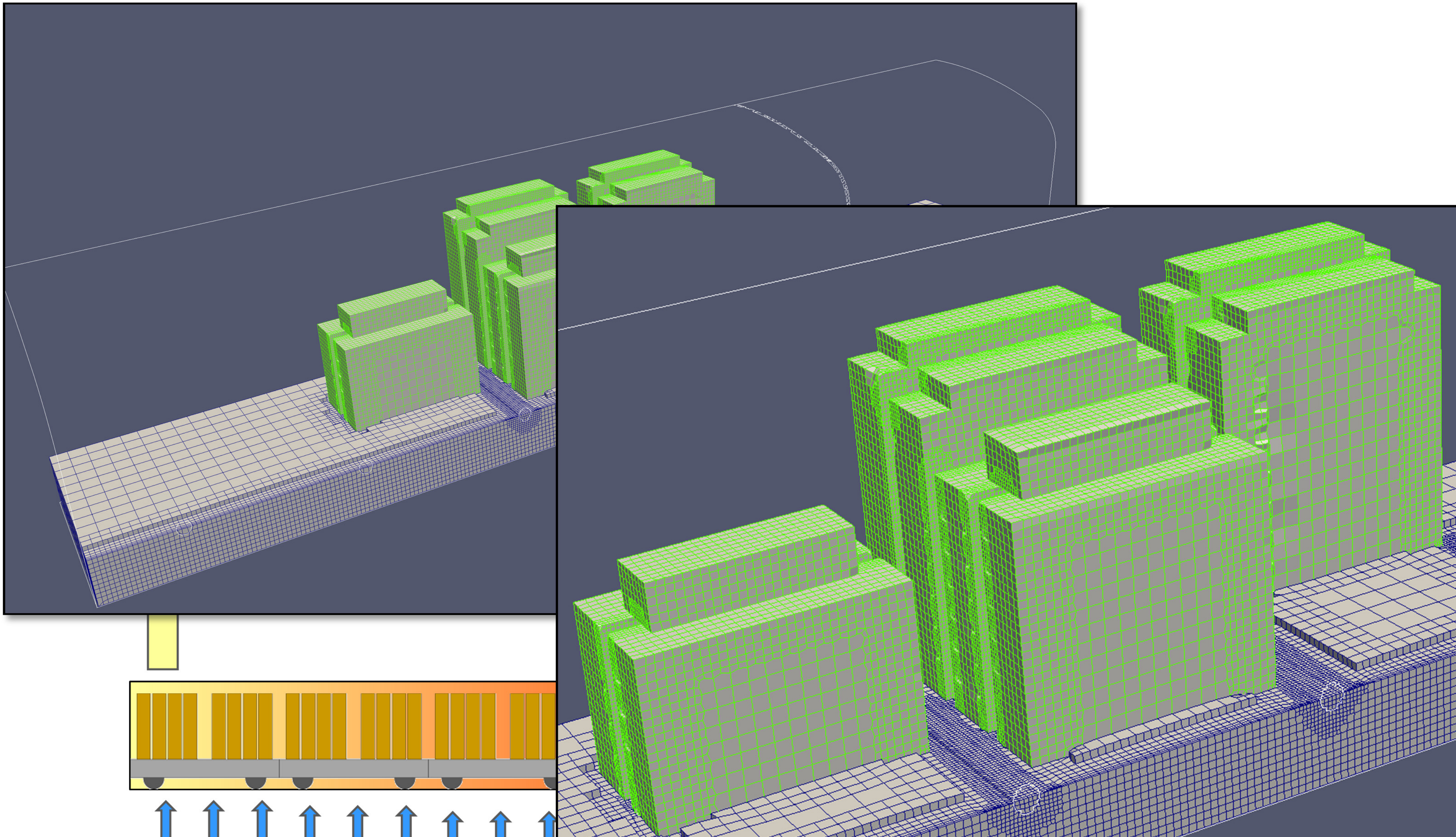
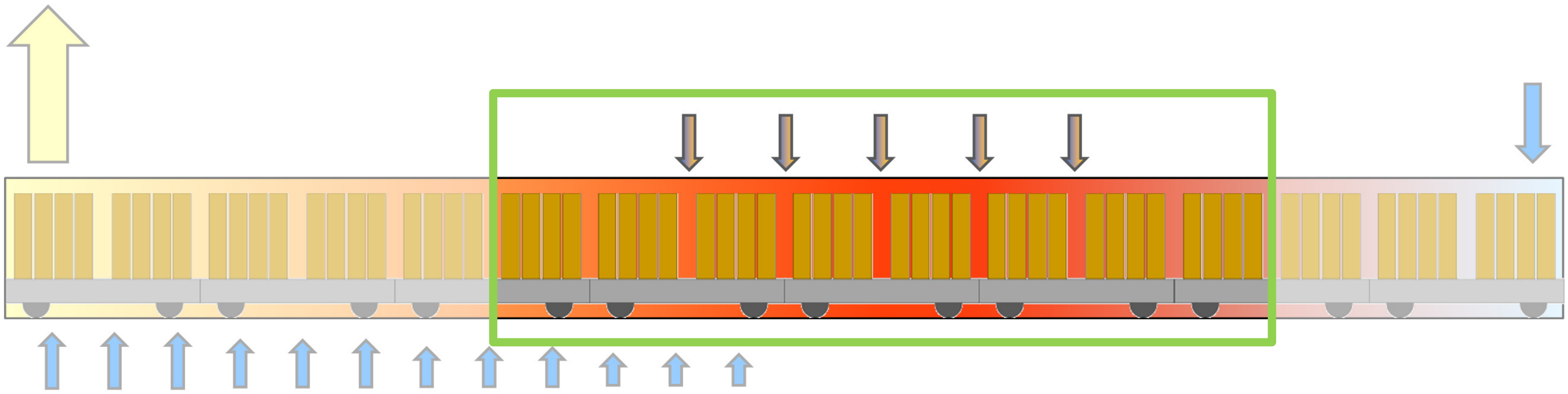


3. Tunnel kiln firing

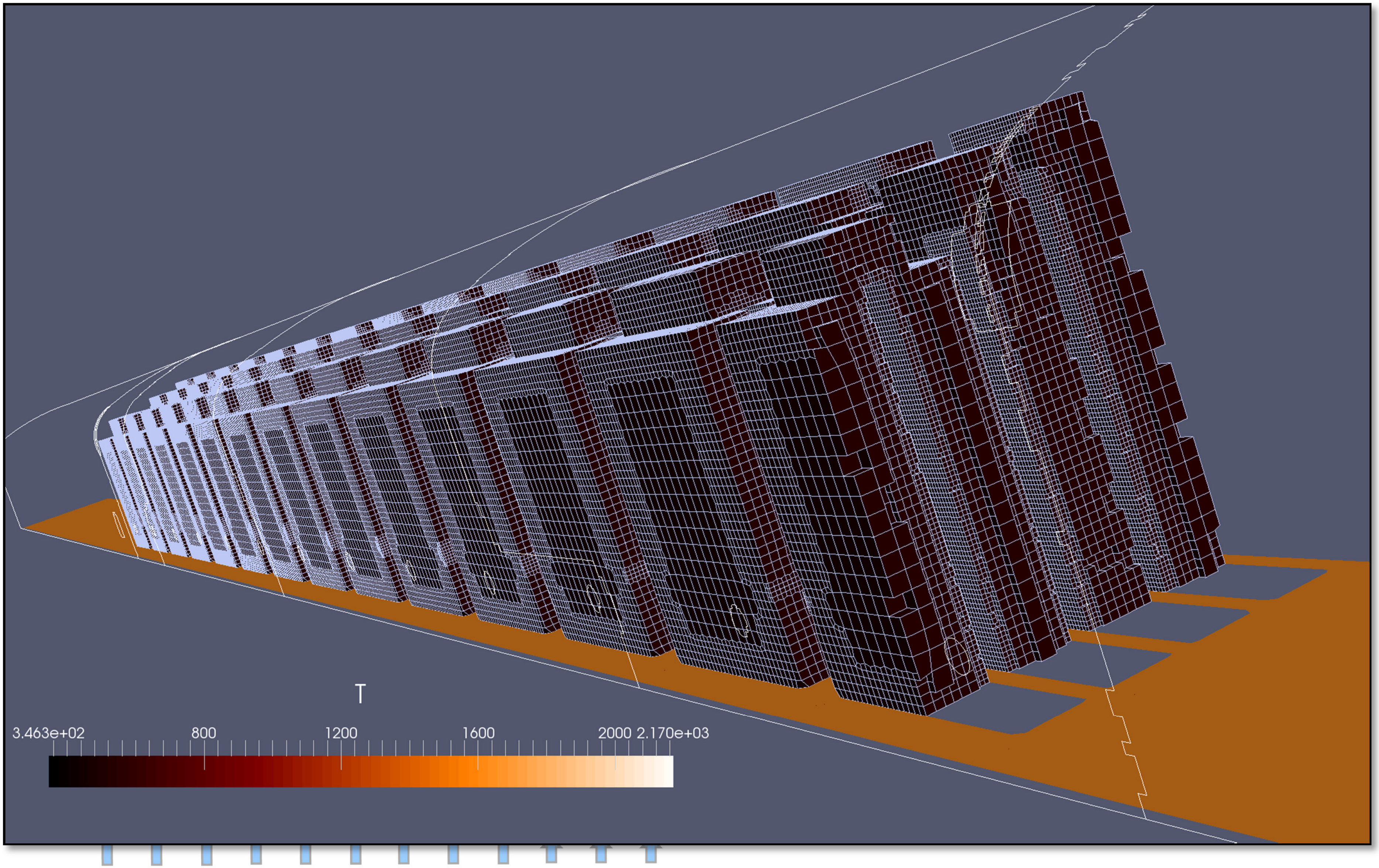
Extended burning zone model – Overview

- Dimensions:
  - Gas: 2,5M cells
  - Solid: 1,5M cells
- Simulation time: ~ 6d for 1s of gas flow on 4 (older) processors
- Solver specifications:
  - Transported species: steady-state
  - Gas: transient
  - Solid: transient with speed-up factor 10^4 → ~ 2,8 h



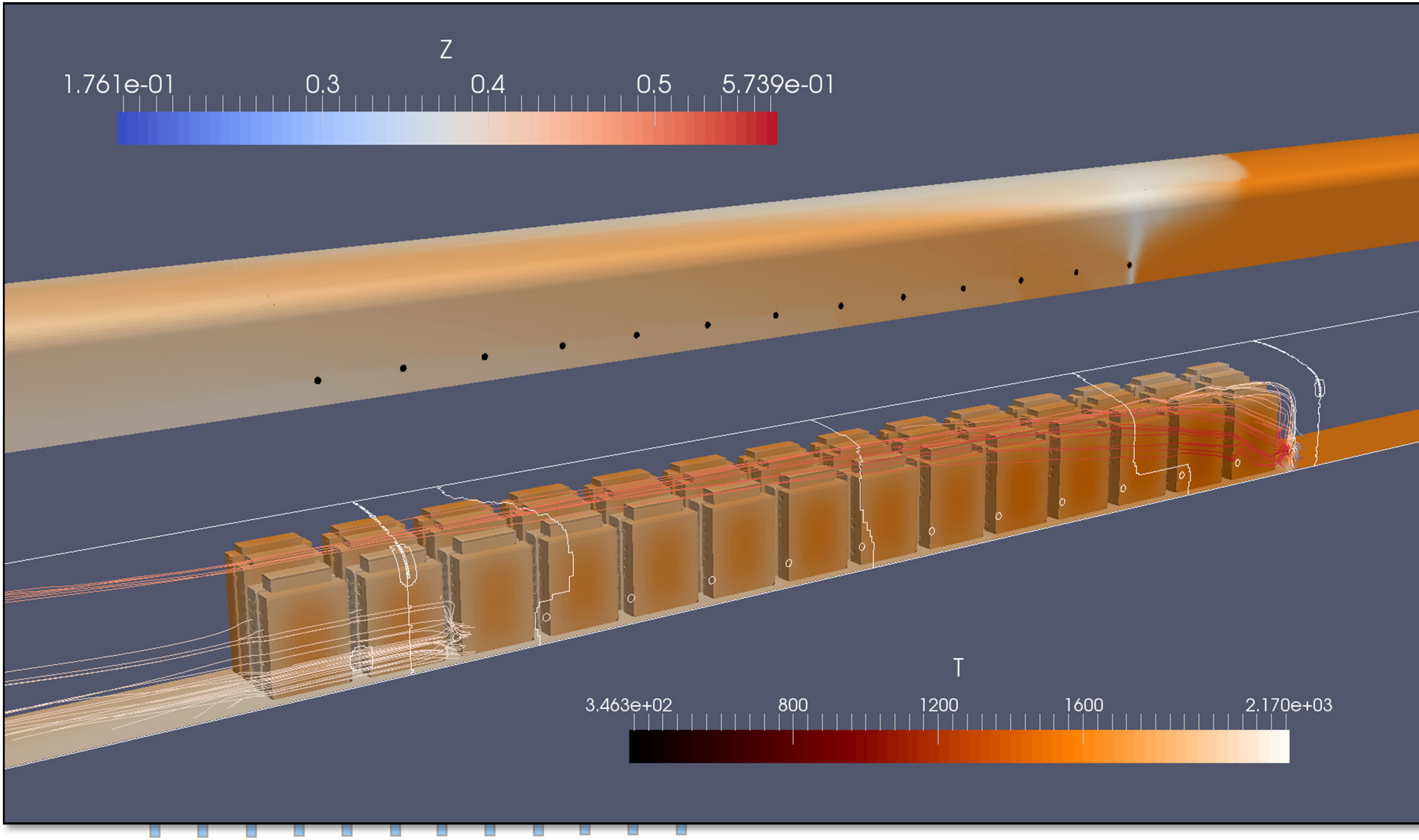
3. Tunnel kiln firing

Extended burning zone model – Overview



3. Tunnel kiln firing

Extended burning zone model – Results after 1s of gas flow



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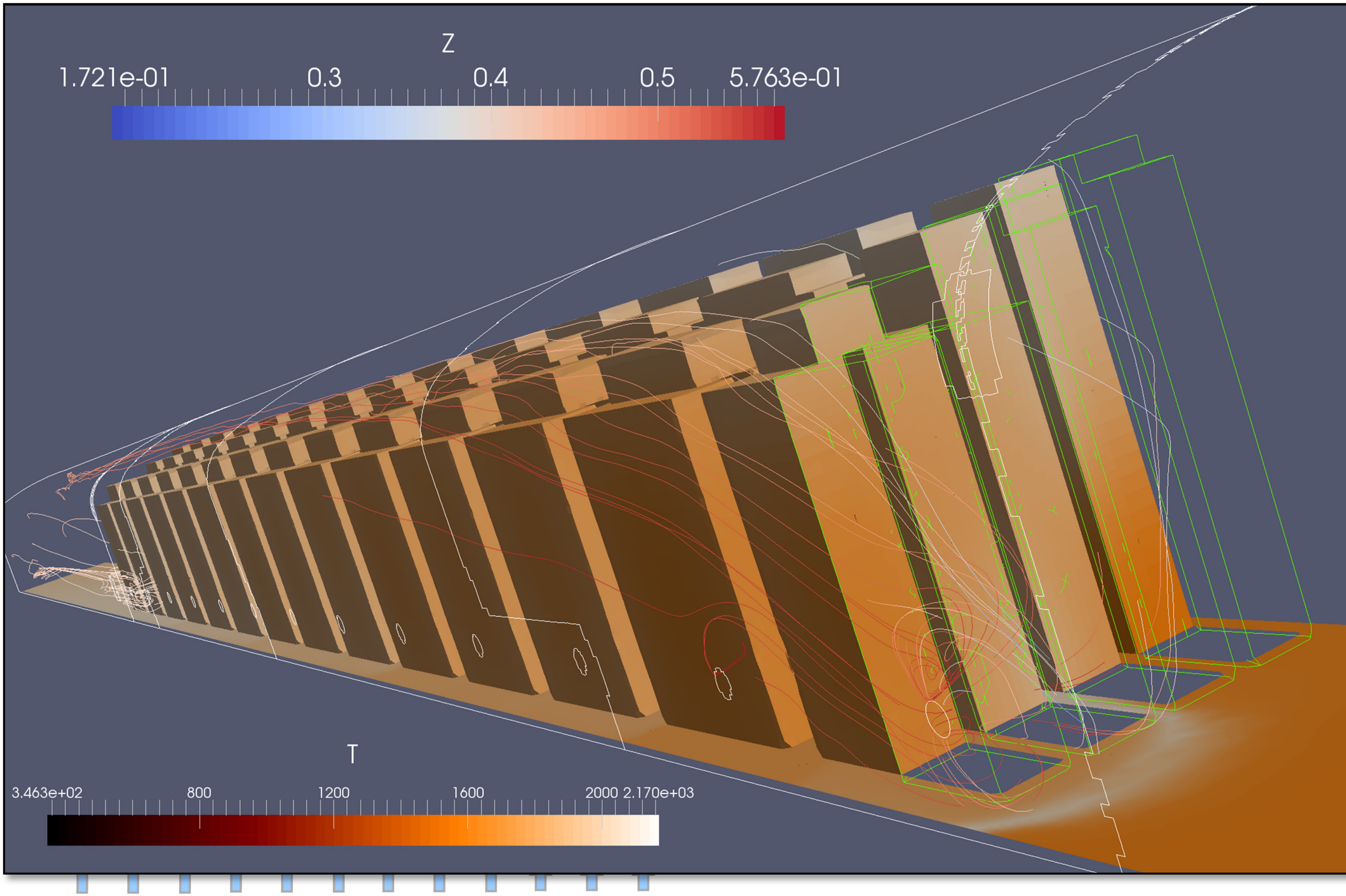

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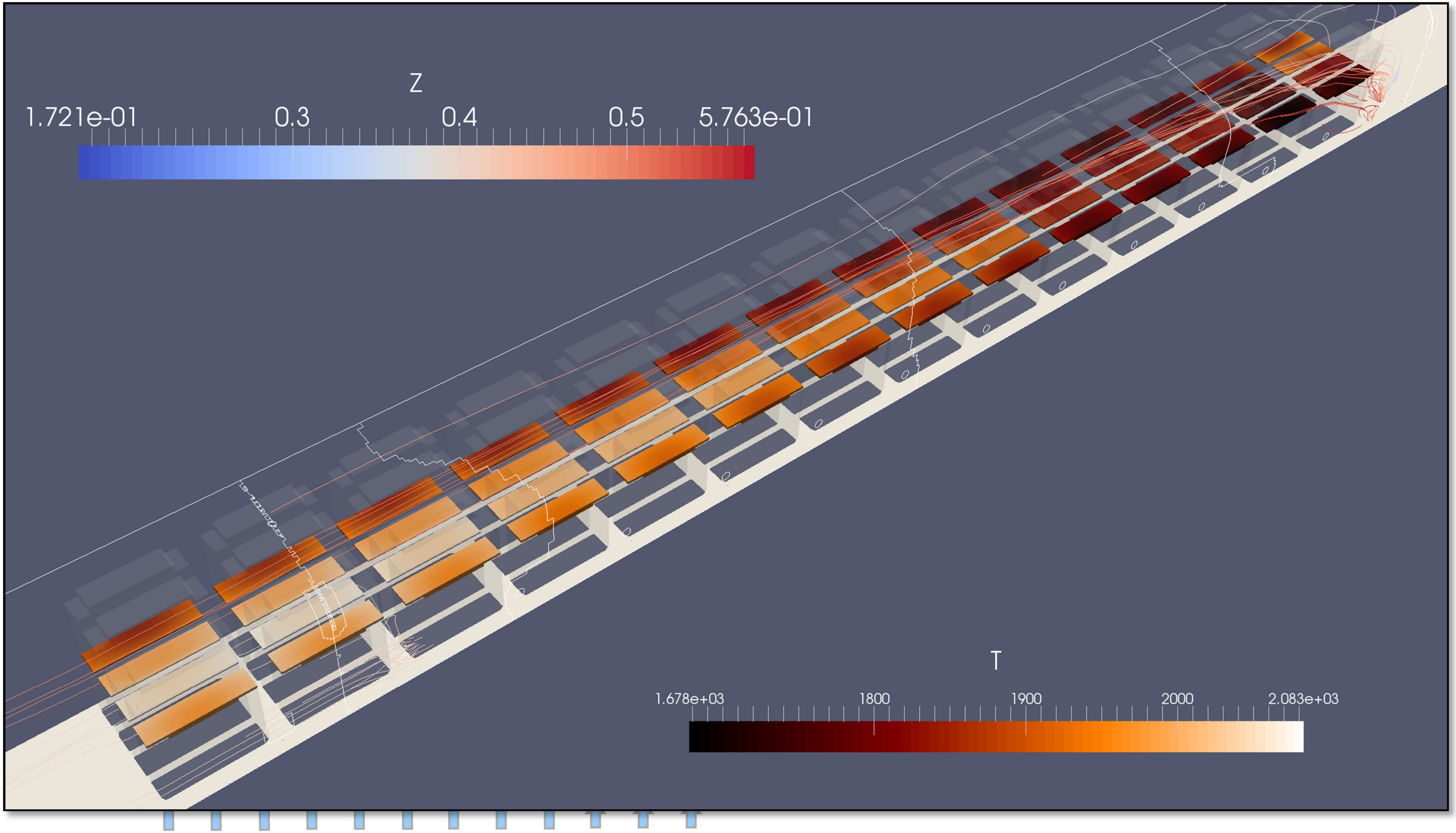
Extended burning zone model – Results after 1s of gas flow



4. Outlook

- Further modifications of the model
  - Fine-tuning of the mesh on the burner patches
  - Mesh refinement in the flame region
- Implementation of a total kiln model
  - Kiln dimensions and setup
  - Process parameters
  - Data for the initialization
  - Transient simulations according to kiln car pushing sequence