Dr. Andrej Sternin
4 element simulation group
www.4e-simulation.com

School of Engineering and Design
Technical University of Munich
Department of Aerospace & Geodesy
Sustainable Future Mobility

CFD of Combustion Chambers

Introduction:
Project schedule, Challenge, Evaluation

- Object of Interest
- Theory Overview
- Task distribution
- Evaluation
- Calendar

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Object of Interest

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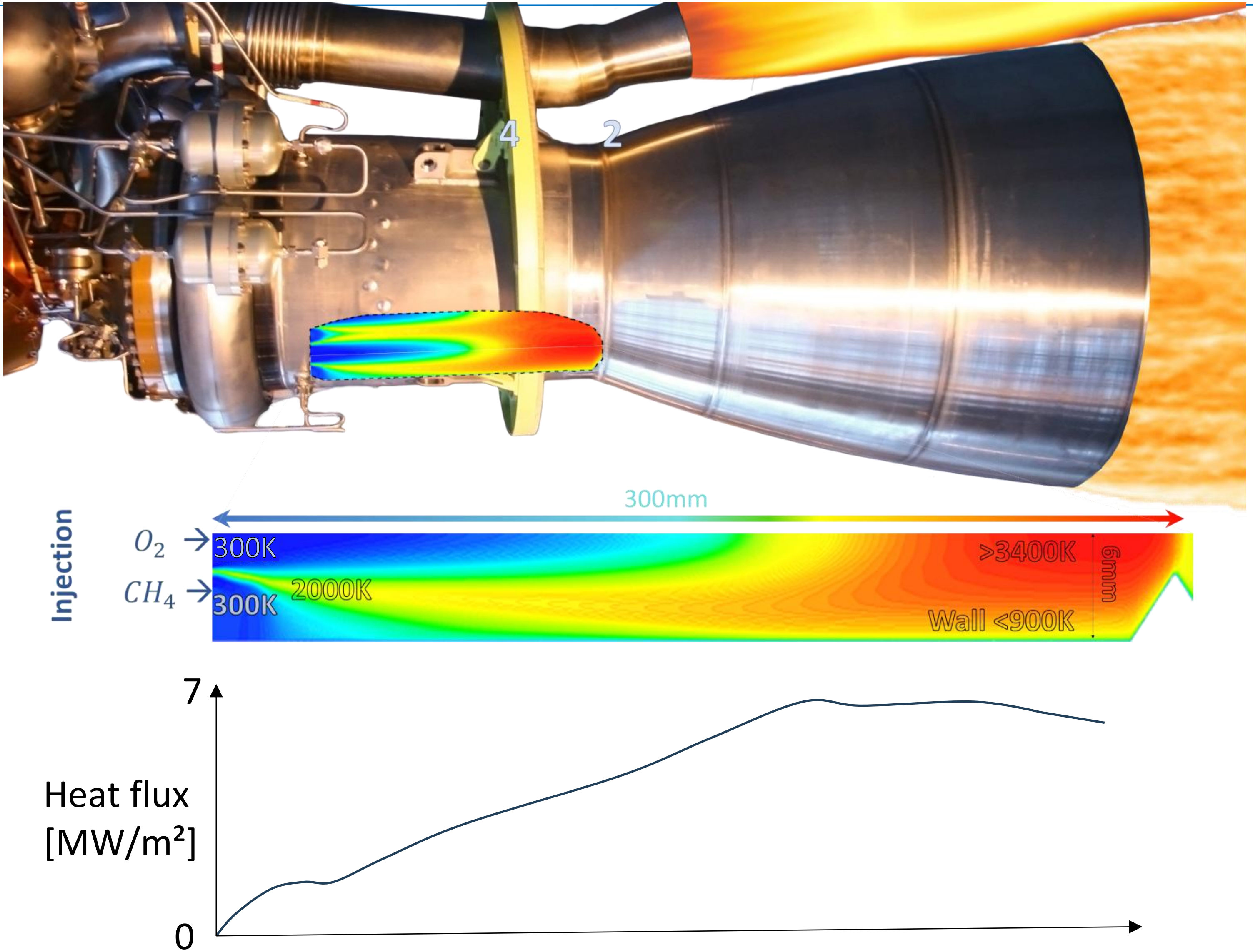

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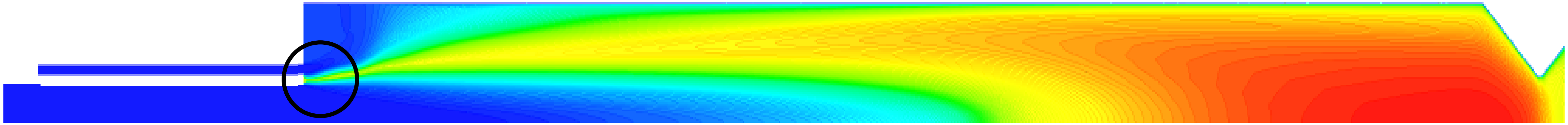

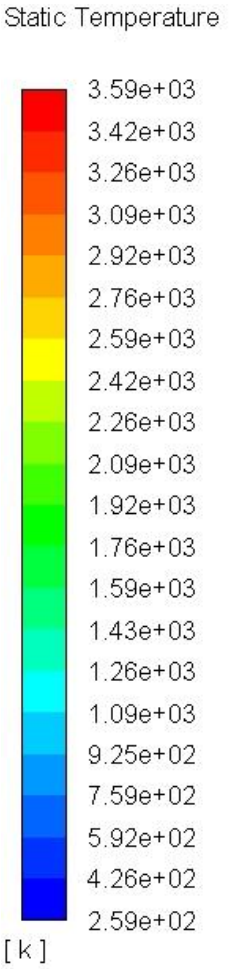

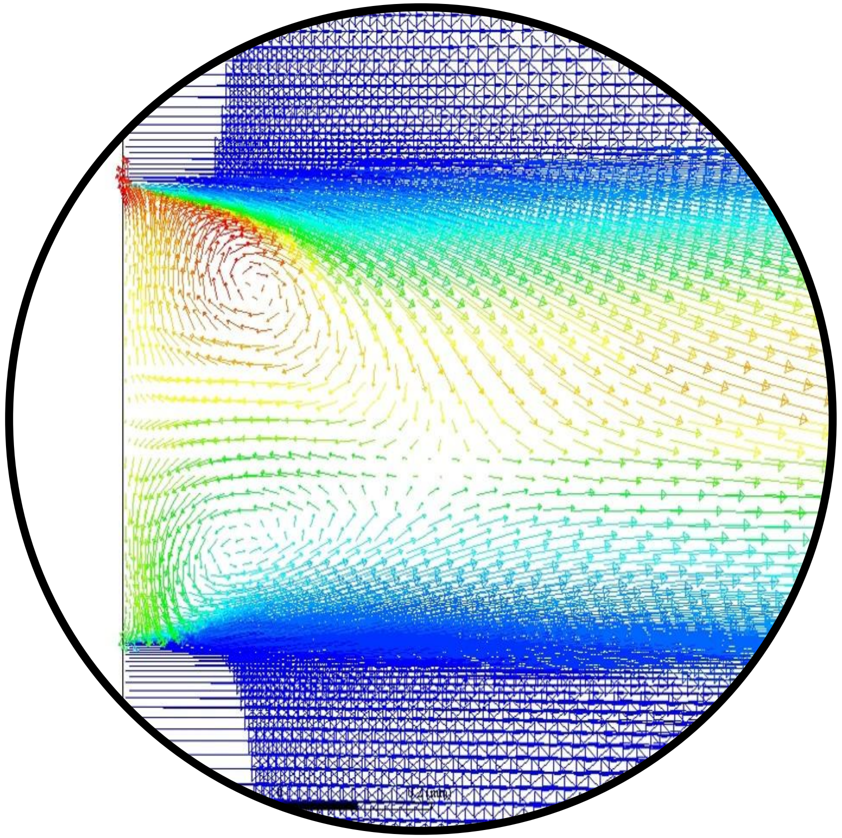

Zone of Interest:

Flame anchoring through recirculation

Characteristics:

- Primery fast chemistry
- Also slow chemistry in outer regions.
- Anisotropic Flow.

„Of interest could be the orientation of the recirculation vortex, would methane be entrained into the reacting shear layer (clockwise) or oxygen towards the methane with the risk of quenching due to too high methane concentrations.”
Prof. Oskar Haidn

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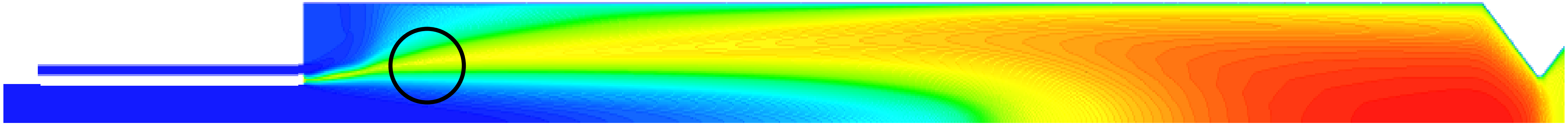
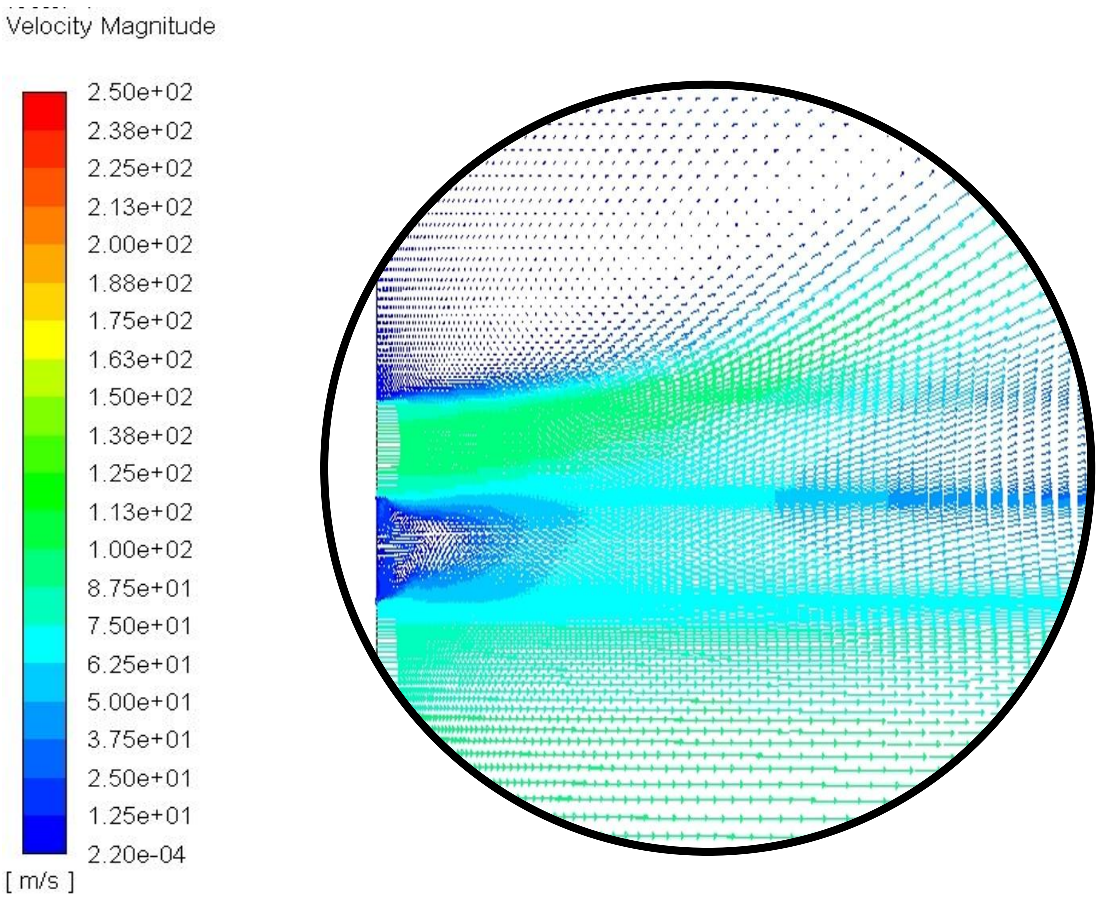




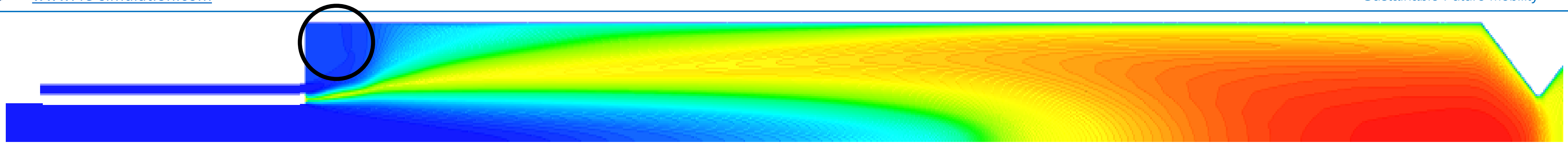
Zone of Interest:

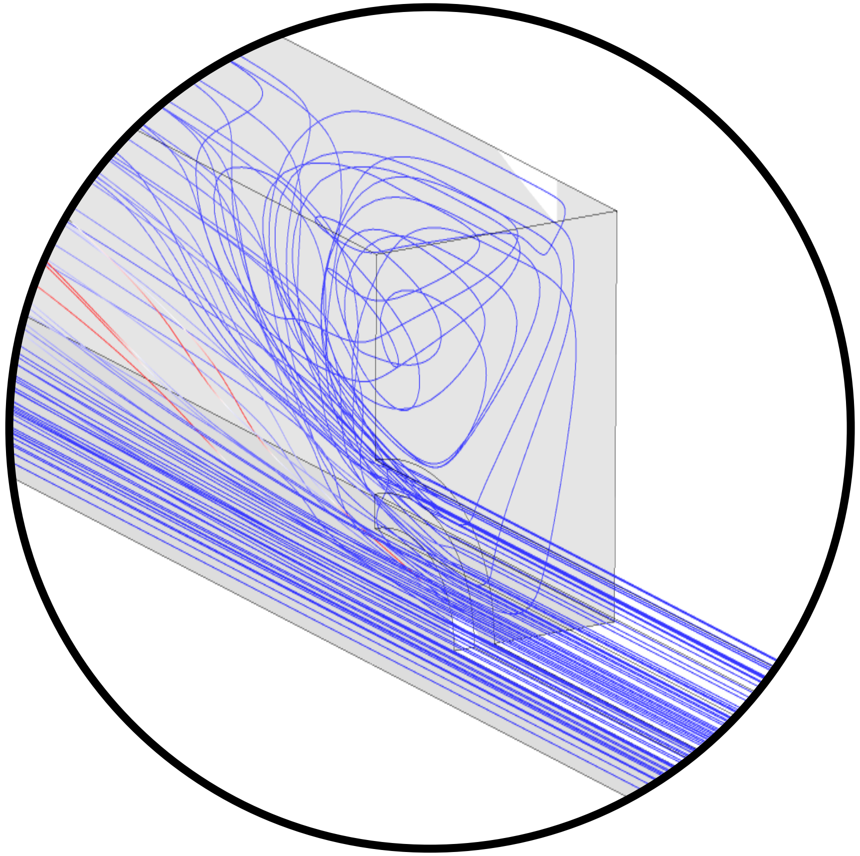
Shear Flow

Characteristics:

- Primery fast chemistry
- But also slow chemistry regions.
- Strong velocity gradients.
- Main driving force is mixing
- Steep gradients of species concentration and temperature

Object of Interest





Zone of Interest:

Recirculation in the Corner

Characteristics:

- Almost no chemistry
- Rather complex flow field (Recirculation)
- Anisotropic Flow

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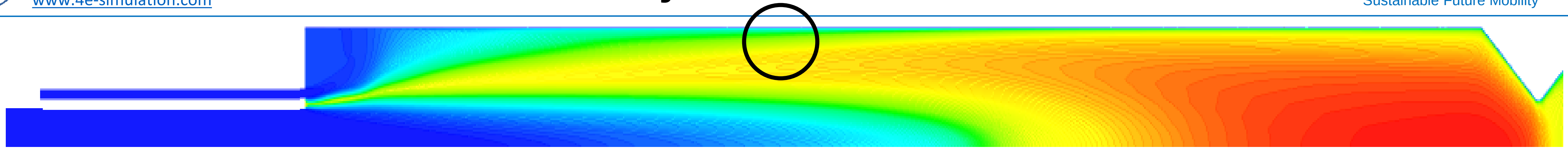

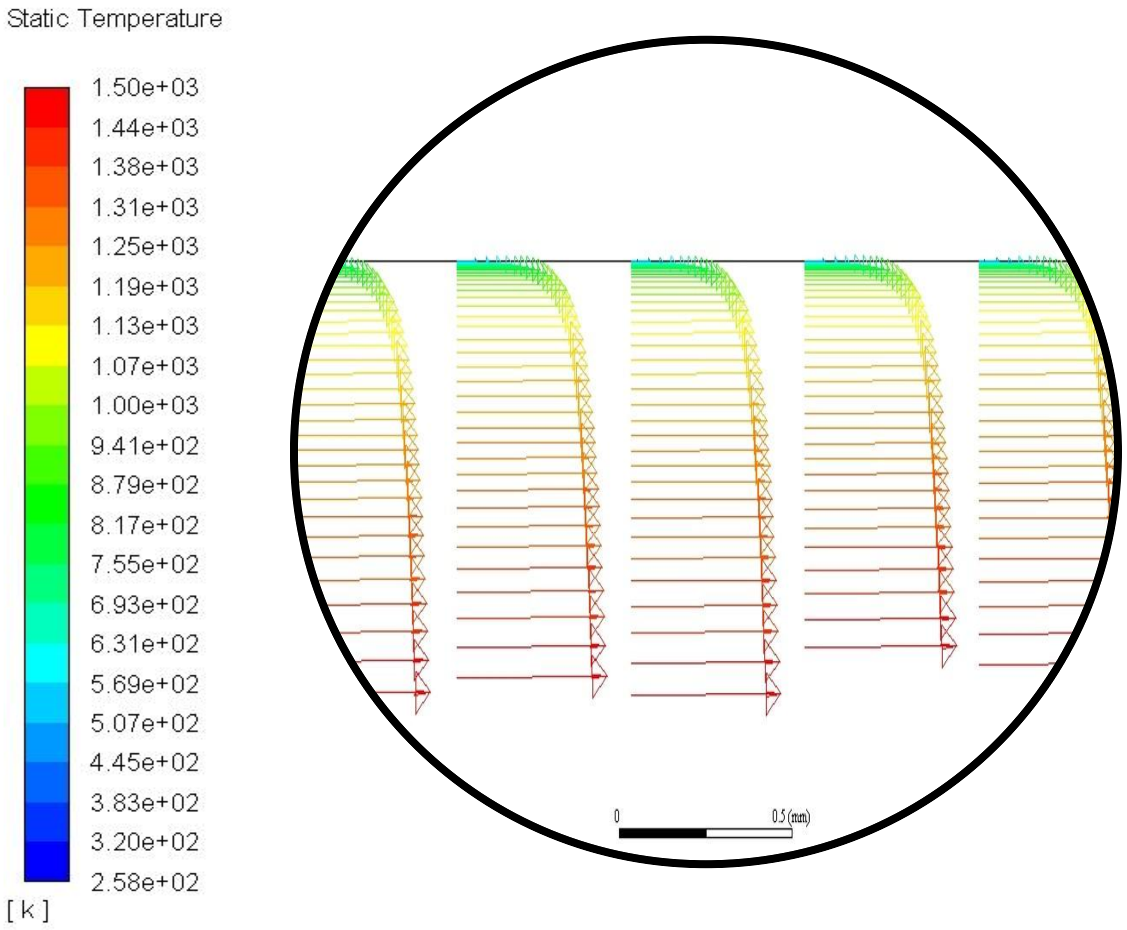

Zone of Interest:

Boundary layer

Characteristics:
- Slow chemistry
- Chemical recombinations
- Strong gradients of temperature and material properties.
- Accelerated layer ($\frac{dp}{dx} < 0$)

=> Influence on the shape?

Shift from fast to slow chemistry due to temperature gradient. Variation of species with different heat capacities and heat transport properties. Chemical reactions with heat release generate turbulence at a certain length scale.

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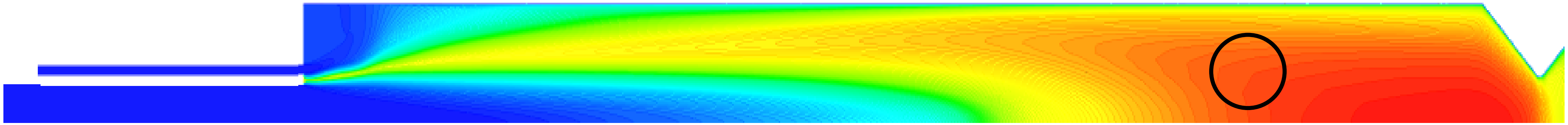
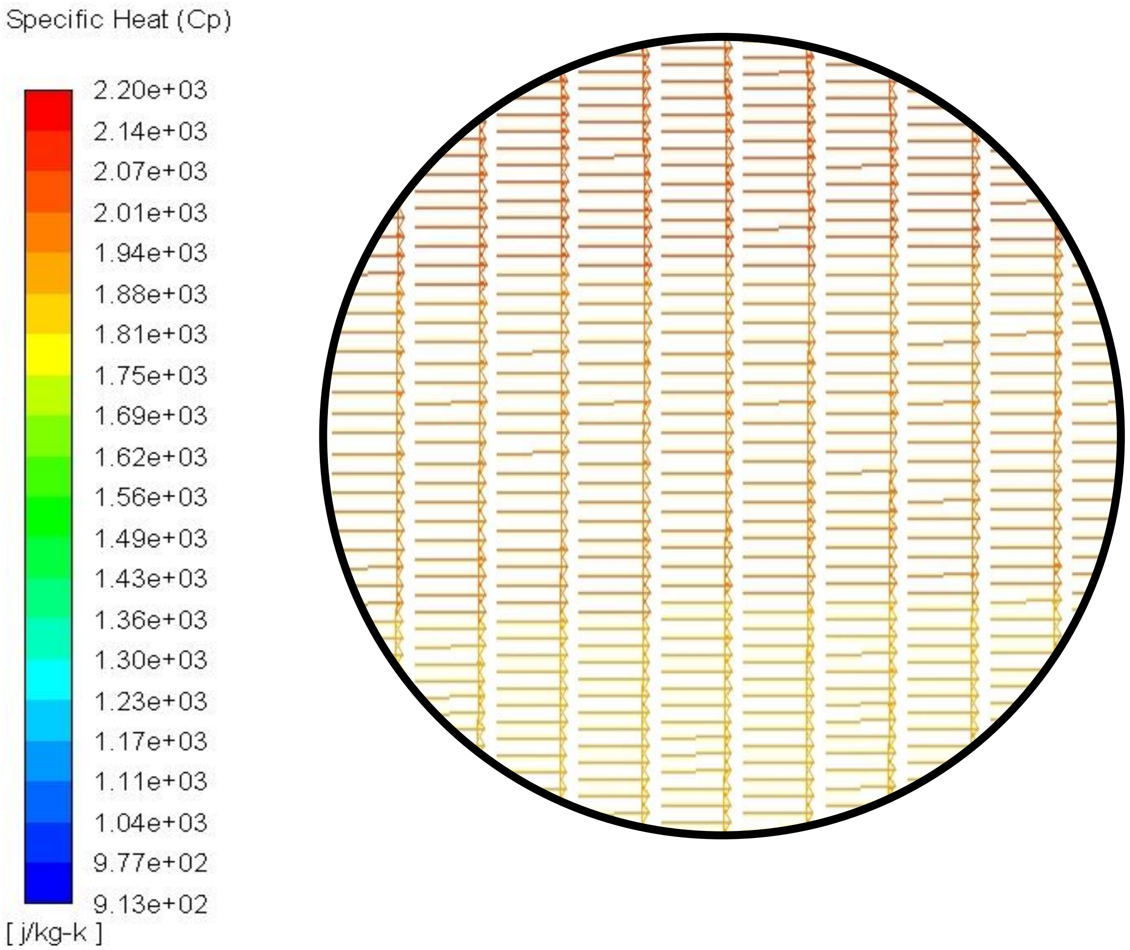


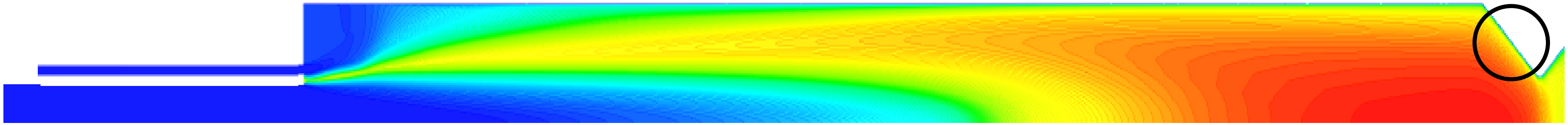


Zone of Interest:
Downstream flow

Characteristics:
- Very slow chemistry
- Close to equilibrium->not much change
- Uniform flow field

- Characterized by high temperatures which means fast chemistry but only small variations of species variations since we have almost equilibrium

Object of Interest



[Mariella Celano 2015]

Zone of Interest:

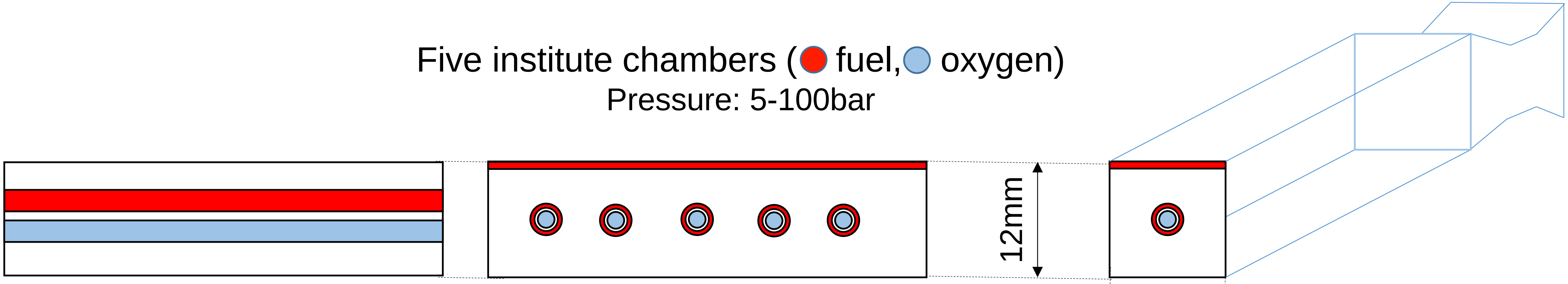
Nozzle Flow

Characteristics:

- Slow chemistry.
- The boundary layer is very thin and so impact of chemistry is only small on overall performance

Object of Interest

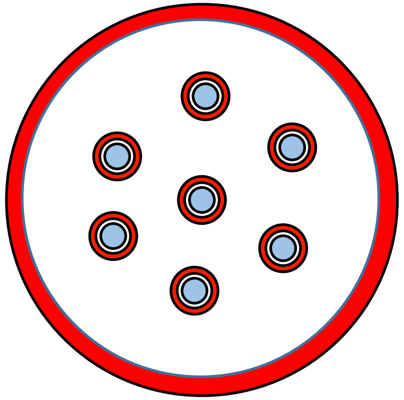
Five institute chambers (fuel, oxygen)
Pressure: 5-100bar



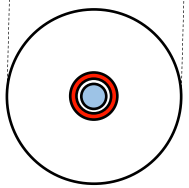
CC-2D
(GOX)

CC-5-rect
Film injection in the middle of the chamber (GOX)

Combustion Chamber (**CC**) with
1 injector element,
squre crosssection (**CC-1-sq**)
(GOX/LOX)



CC-7-round
(GOX/LOX) (Film only with LOX) (->60bar)



CC-1-round
(GOX)

Theory Overview

What you need to know:

- Chemistry
- Turbulence models
- Reaction Models

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Task distribution

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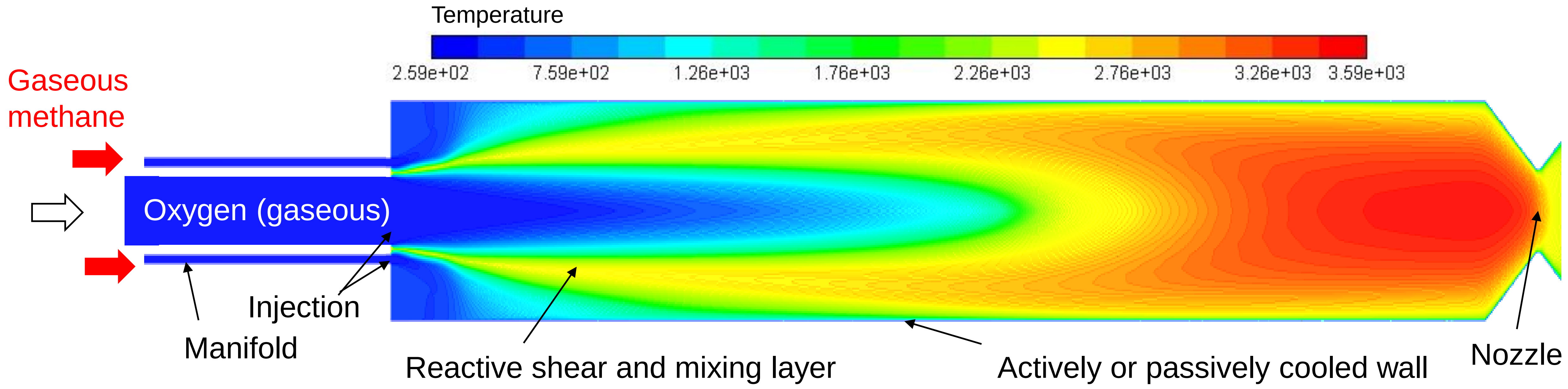
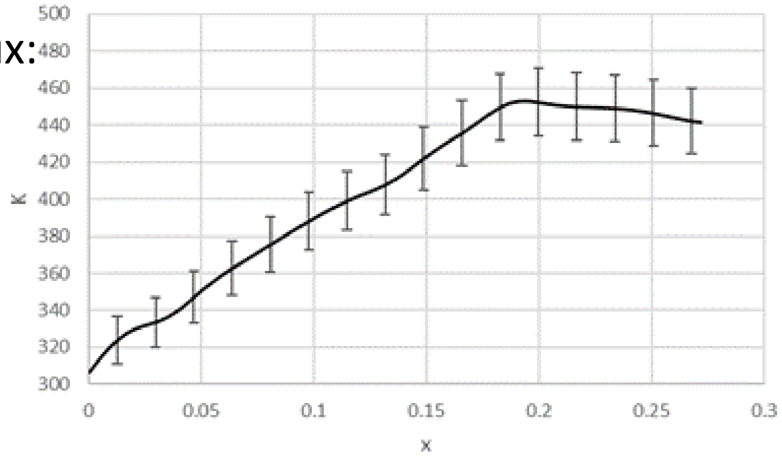
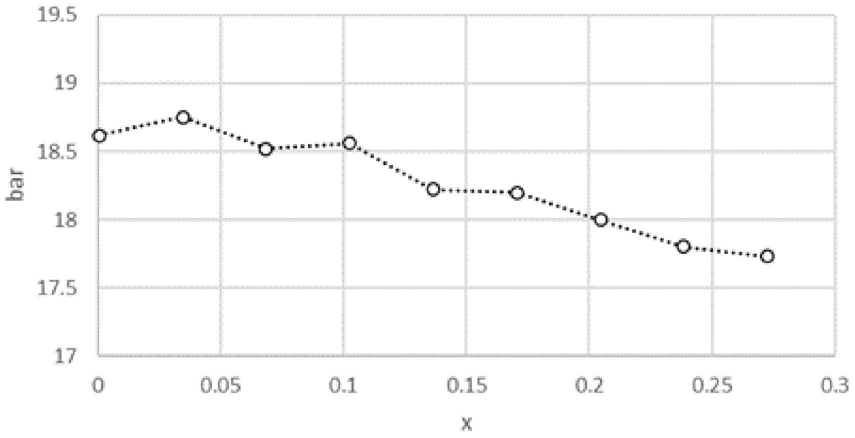
RANS simulation



Heat Flux:

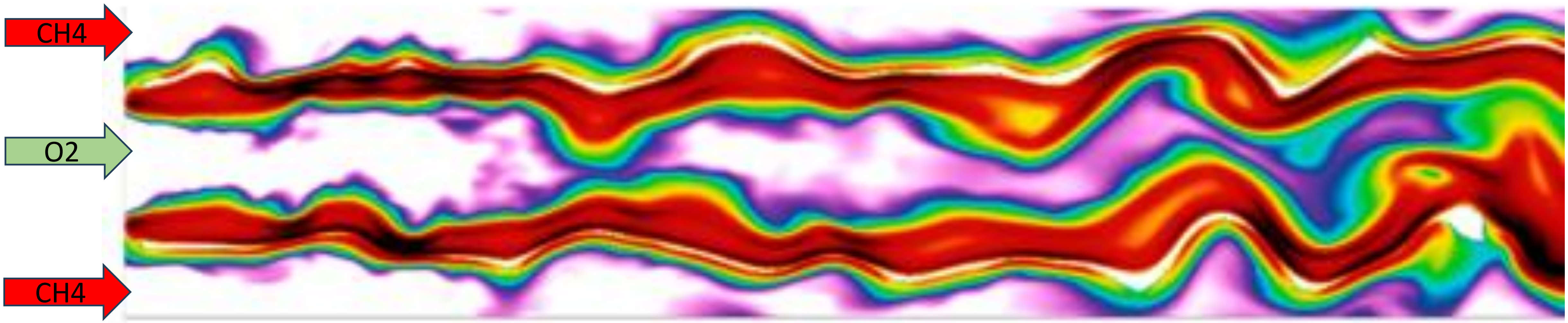


Pressure

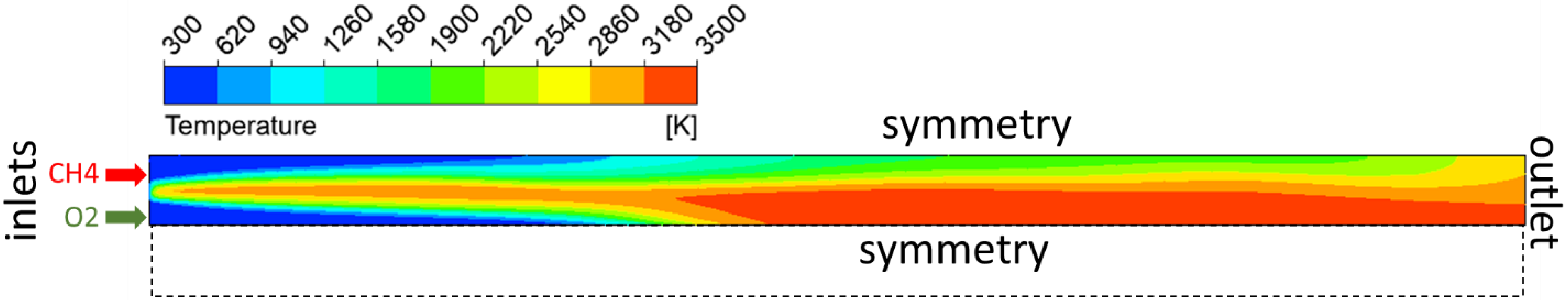


Task distribution

DNS simulation (virtual experiment)

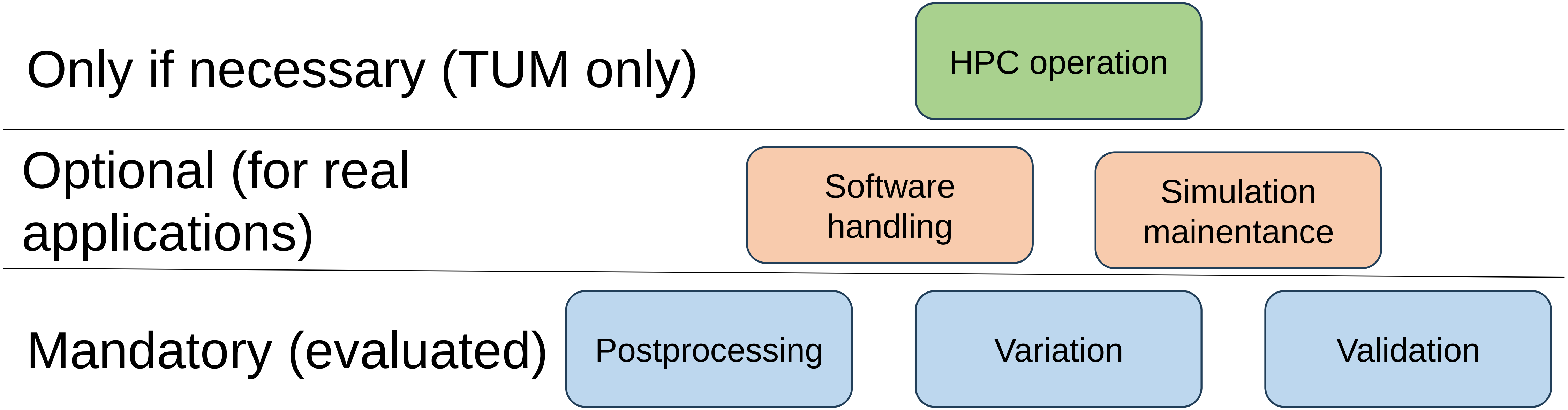


RANS simulation



Task distribution

- Teams of ca. 4-6 People
- 2 Combustion cases
- 5-6 variations each
- Validation with DNS results and experimental measurements



Evaluation

All results are summarized in a short presentation. Small groups may be formed.

Grading is based on…

… 20% understanding of the problem. Here it is required that work is done conscientiously and that the intended benefit of the study is in the foreground.

… 20% project planning. Here, participants must correctly break down the overall objective into sub-objectives.

… 25% the cleanliness of the conducted and analyzed simulations. The evaluation of the simulation must be reproducible.

… 35% the depth of the analysis. The phenomena studied must be correctly interpreted. It must be understood how the individual physical processes interact with each other. This part is carried out without specifications and contributes the most to the overall grade.

Calendar

Dates:

Thursday; 24.04.2025; 4-5:30pm; Introduction; hybrid

Thursday; 08.05.2025; 5-6:30pm; project description; online

Wednesday; 14.05.2025; 5-6:30pm; Lecture 1; hybrid

Wednesday; 21.05.2025; 5-6:30pm; Lecture 2; hybrid

Wednesday; 11.06.2025; 5-6:30pm; Lecture 3; hybrid

Thursday; 26.06.2025; 5-6:30pm; Q&A; online

Thursday; 10.07.2025; 5-6:30pm; Q&A; online

Thursday; 24.07.2025; 5-6:30pm; Q&A; online