Structure de flamme diphasique Euler/Lagrange dans la chambre MERCATO

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CERFACS – Projet européen TECC

Mots clés: Structure de flamme diphasique, Euler/Euler, Euler/ Lagrange, Allumage

Intro

Two phase flow simulations are performed at CERFACS

Euler/Euler model is well developed

But Euler/Lagrange is a recent formalism

Non reactive Lagrangian simulations have already been performed[1 2 3 4]

Here we performed reactive Lagrangian simulations

> Validation

> Analysis

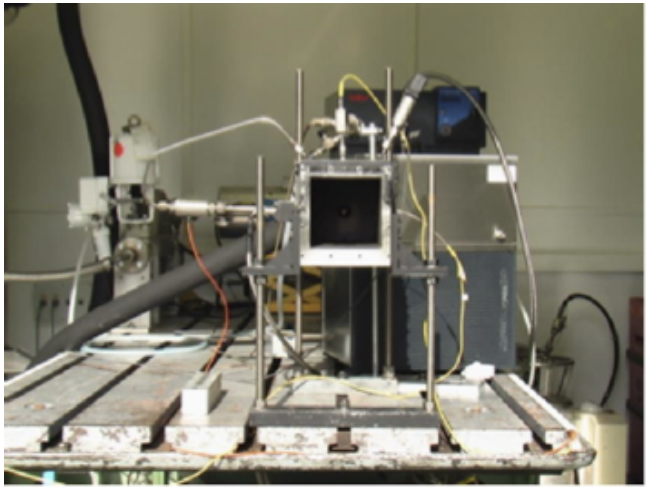
1 Jaegle « LES of two-phase flow in aero-engines » 2009

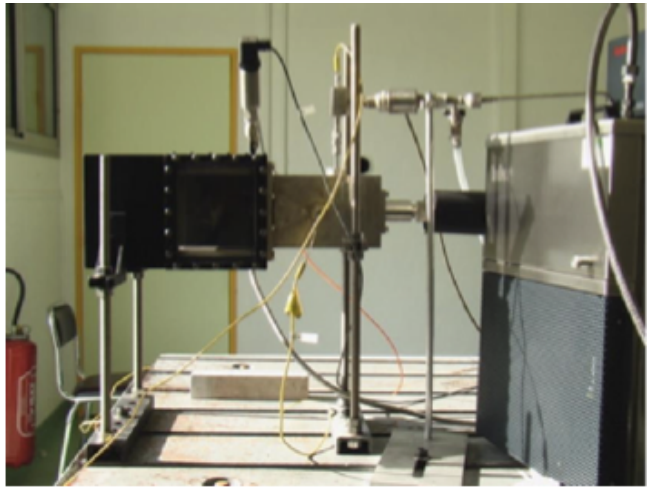
2 Jaegle « Lagrangian and eulerian simulations of evaporating fuel spray in an aeronautical multipoint injector » *Proc. Combust. Inst.* 2011

3 Garcia « Comparison between Euler/Euler and Euler/Lagrange les approaches for confined bluff-body gas-solid flow » *Int. Conf. Multiphase Flow* 2007

4 Gouesbet « Eulerian and Lagrangian approaches for predicting the behaviour of discrete particles in turbulent *flows* » *Prog. Energy Comb. Sci.* 1999

The MERCATO bench / Operating point





< Images of the MERCATO bench in ONERA Fauga-Mauzac (Lecourt 2009)

Operating point:	
Air mass flow rate	35,5 g/s
Liquid mass flow rate	2,36 g/s
Pressure	1 atm
Gas temperature	285 K
Liquid temperature	285 K
Half angle of spray	40 °
Diameter distribution	Monodisperse Polydisperse (lognormal)

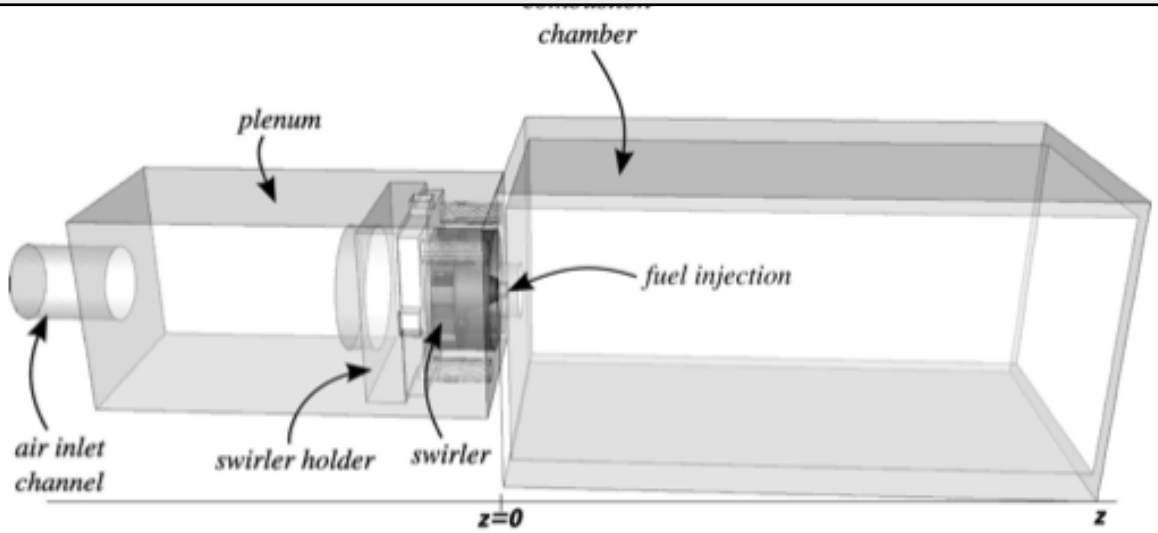
>> Measurements of stationary combustion:

– Axial velocities for gas/liquid phases (PIV)

– Flame visualisation

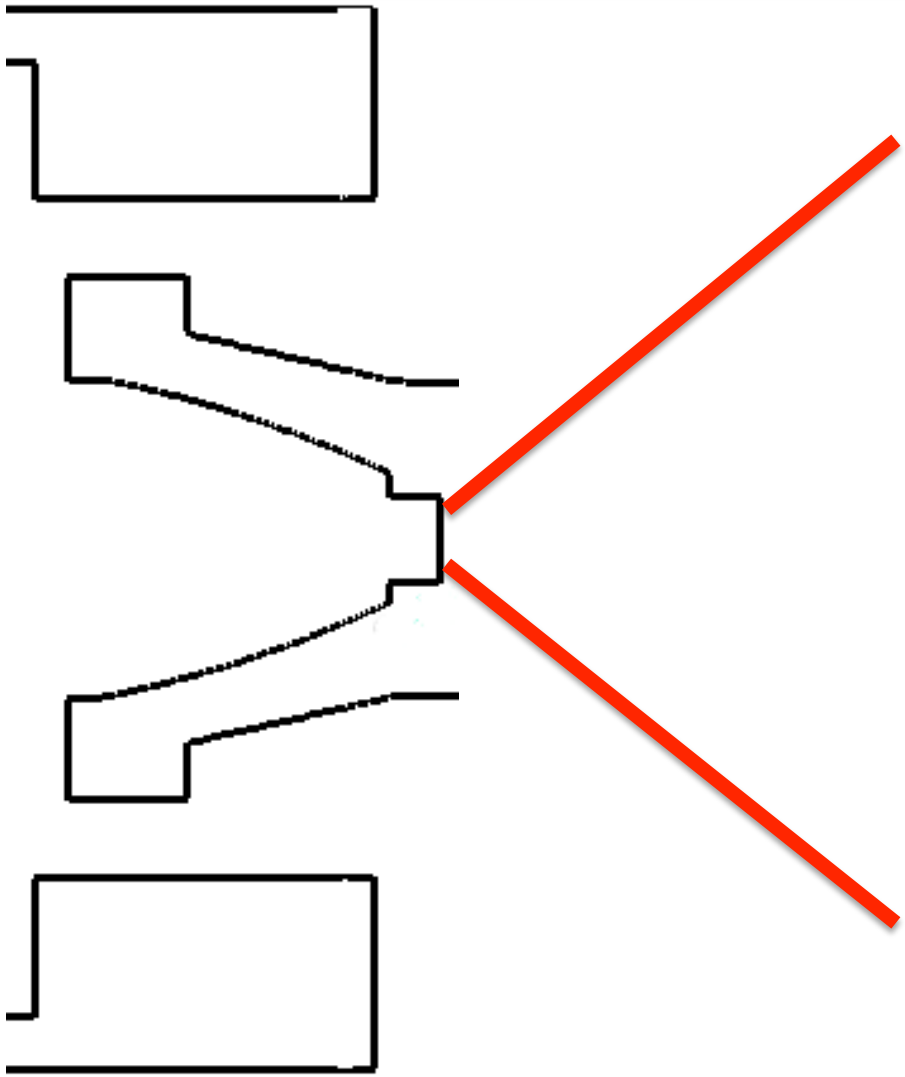
LES models

Numerical parameters (AVBP code) :
Numerical scheme centered TTGC (3rd order Taylor-Galerkin) (Colin 2000)
Two-step chemistry for Kerosene BFER (Franzelli 2010) **KERO_LUCHE + 10 O2 => 10 CO + 10 H2O** **CO + 0.5 O2 <=> CO2**
Dynamic thickening model (Charlette 2001)
Euler/Lagrange monodisperse and polydisperse Elastic rebound for drops at boundaries



Schematic of the numerical domain

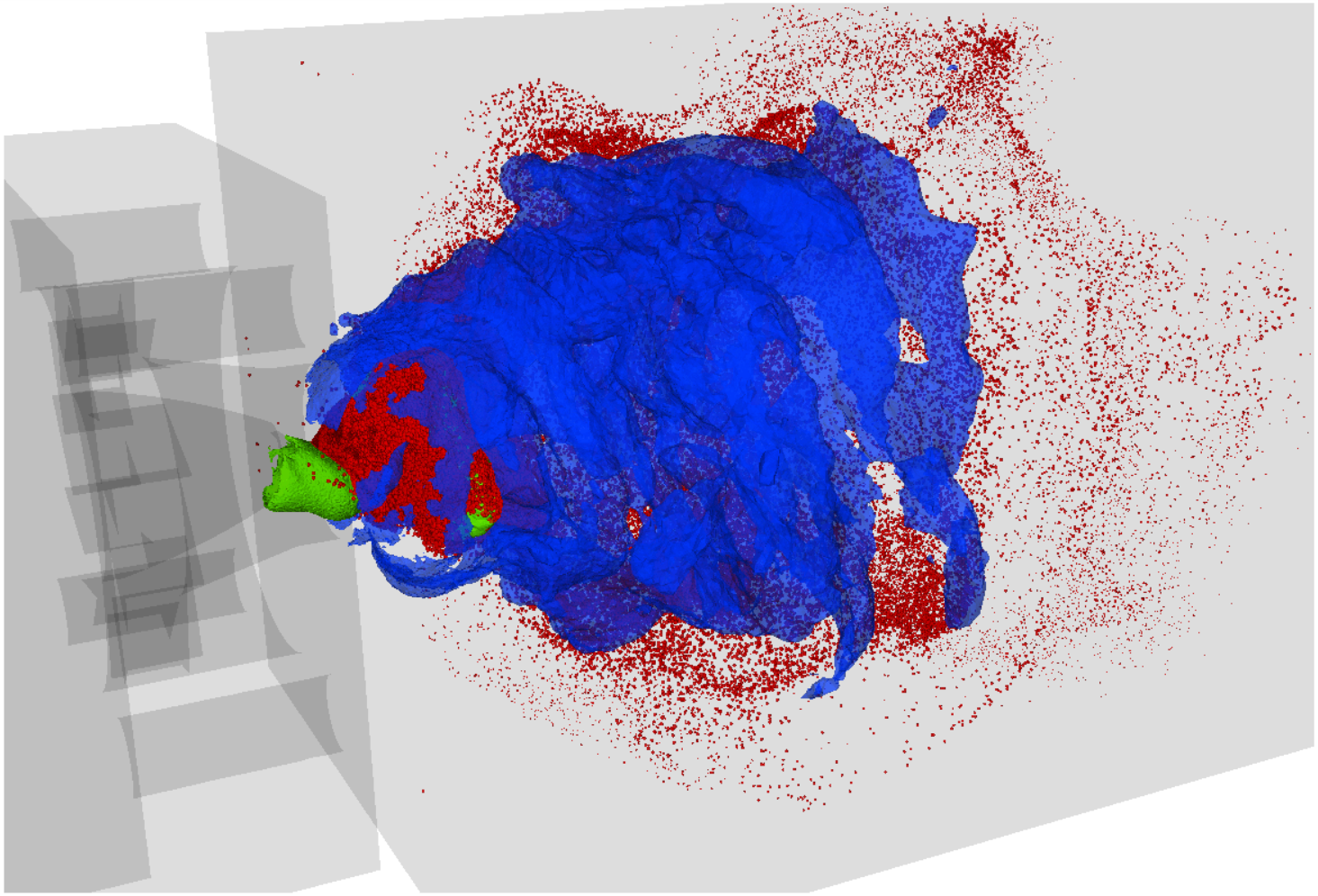
Injection FIM-UR



Impose a pdf and velocity profiles to mimic primary break up [5]

5 Sanjose et al Fuel injection for Euler-Euler and Euler-Lagrange large eddy simulations of an evaporating spray inside an aeronautical combustor , *International Journal of Multiphase flow* 2011

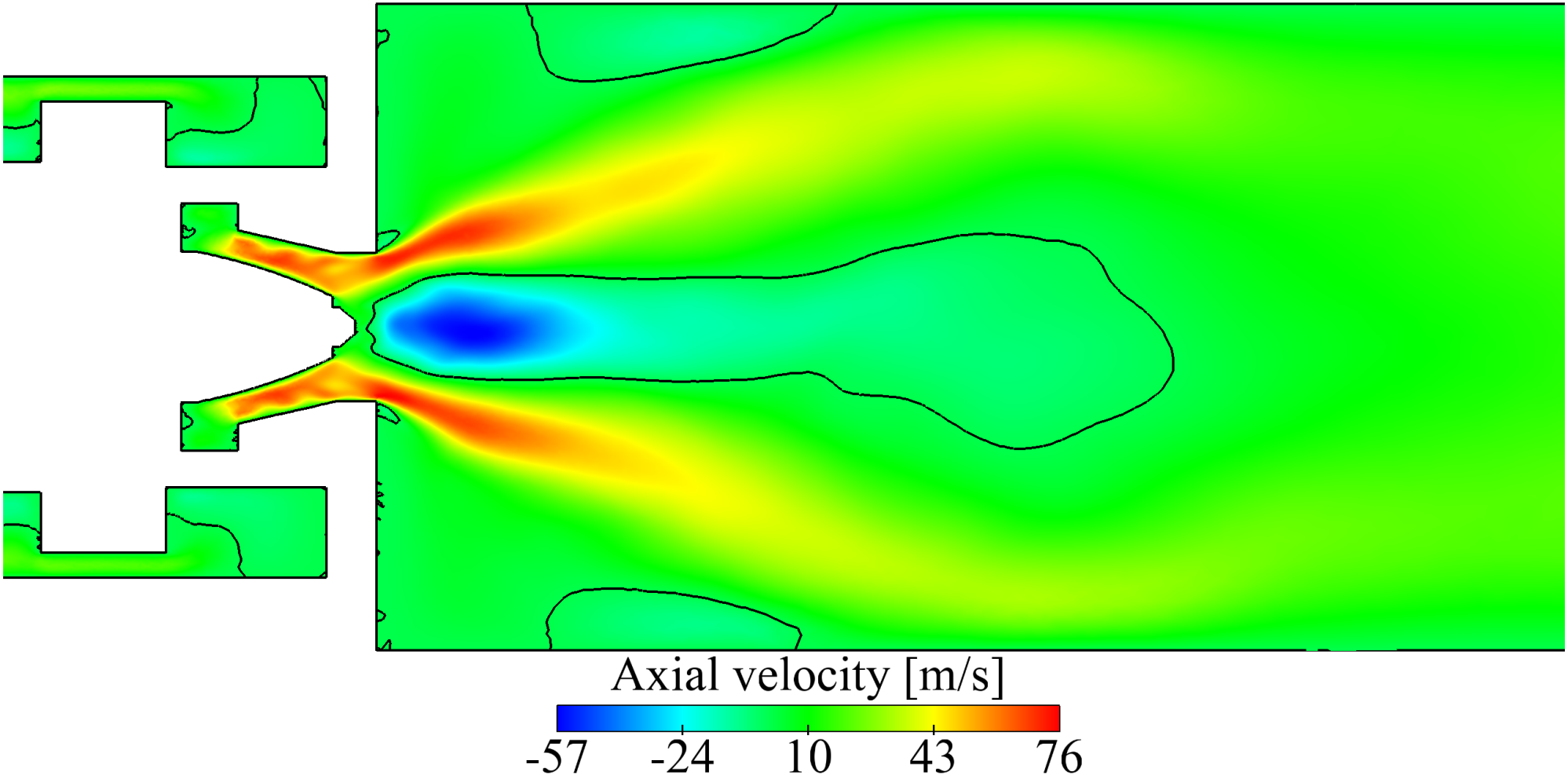
Monodisperse
Instantaneous Flame structure



Lagrangian Flame

Green isosurface of pressure (PVC)/ Blue isosurface of Heat release/ Red part for dispersed phase.

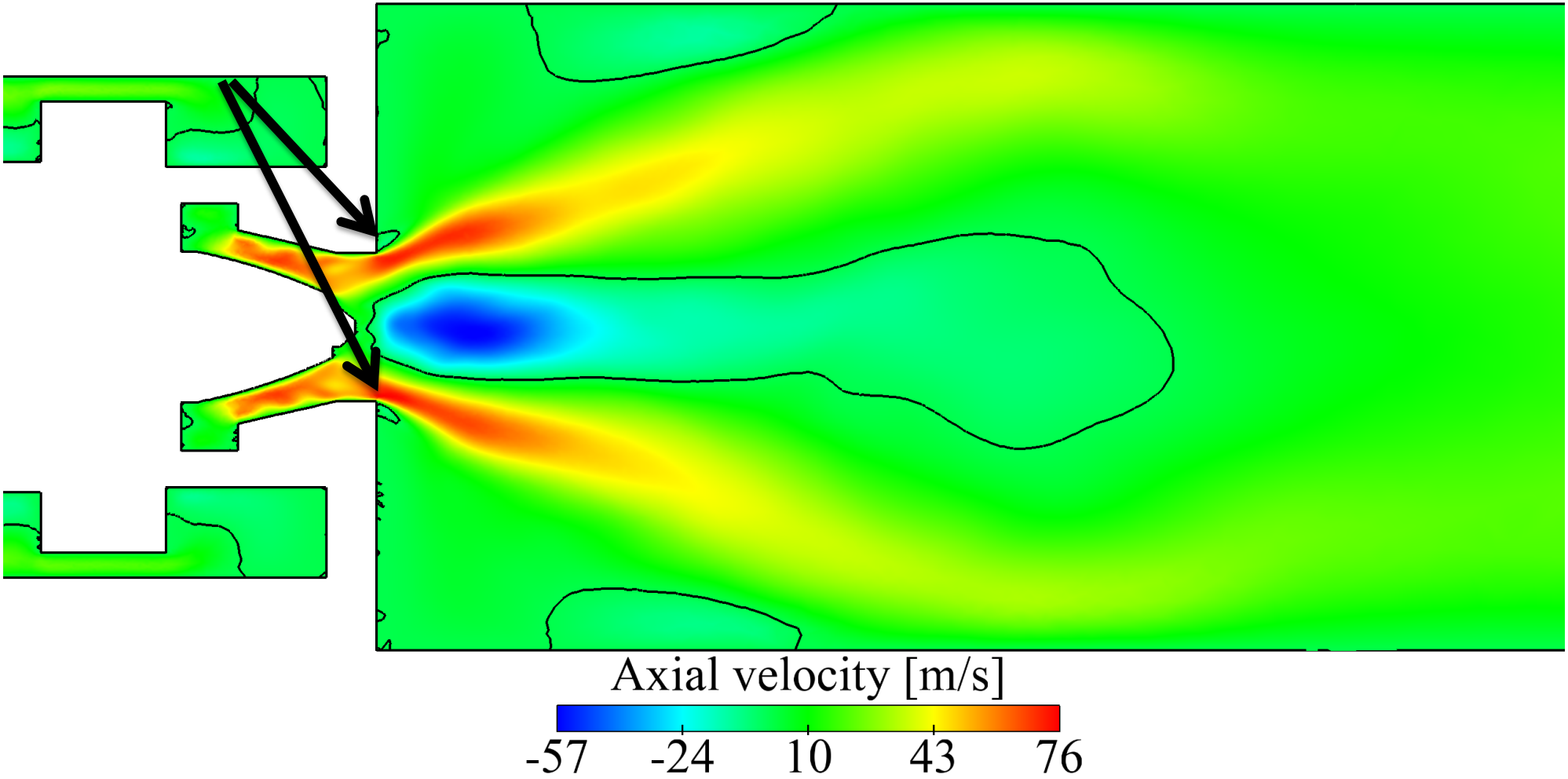
Monodisperse
Reactive gaseous flow structure



Mean axial velocity field in the median plane

Black isoline of zero velocity

Monodisperse
Reactive gaseous flow structure



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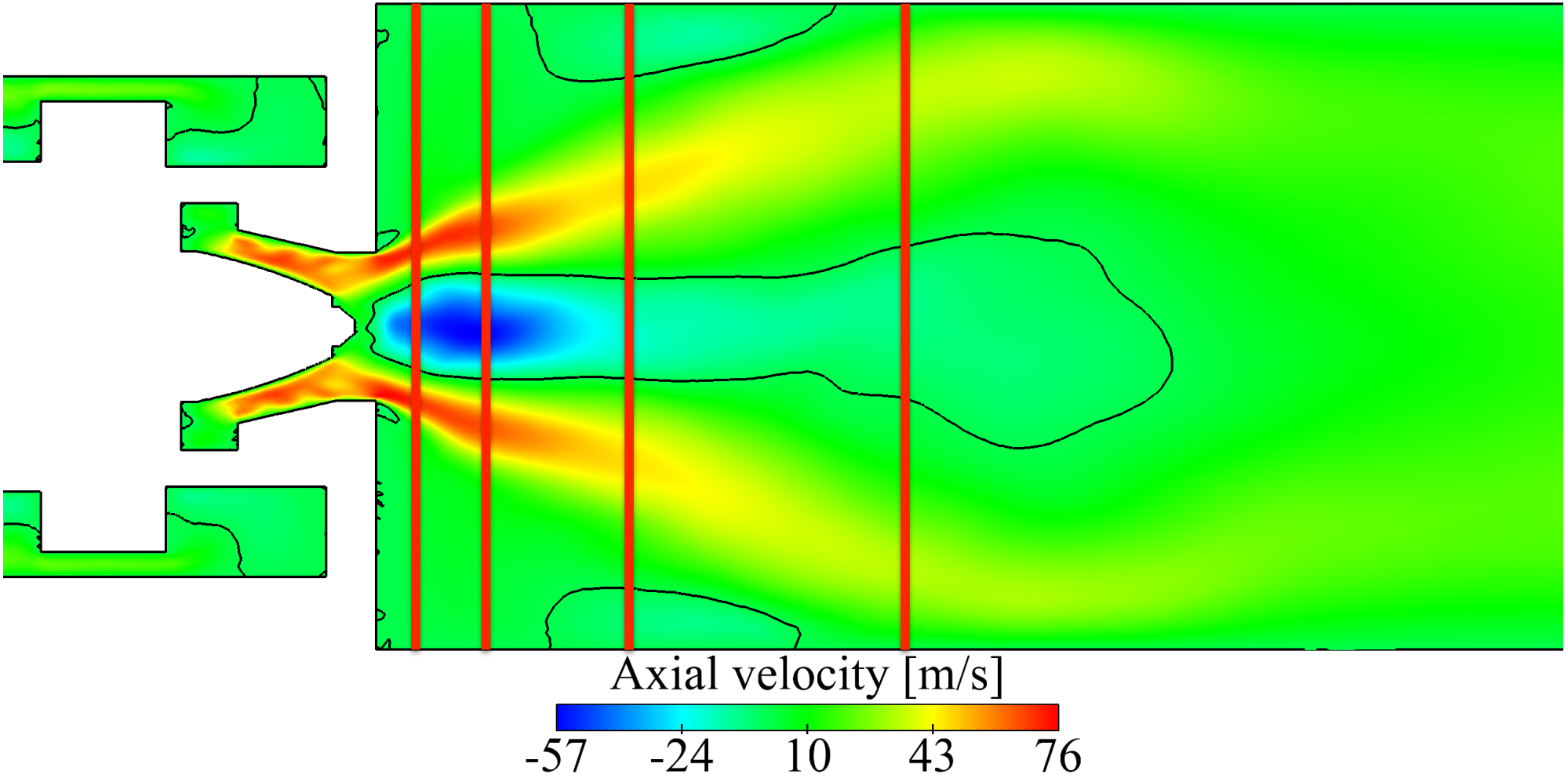
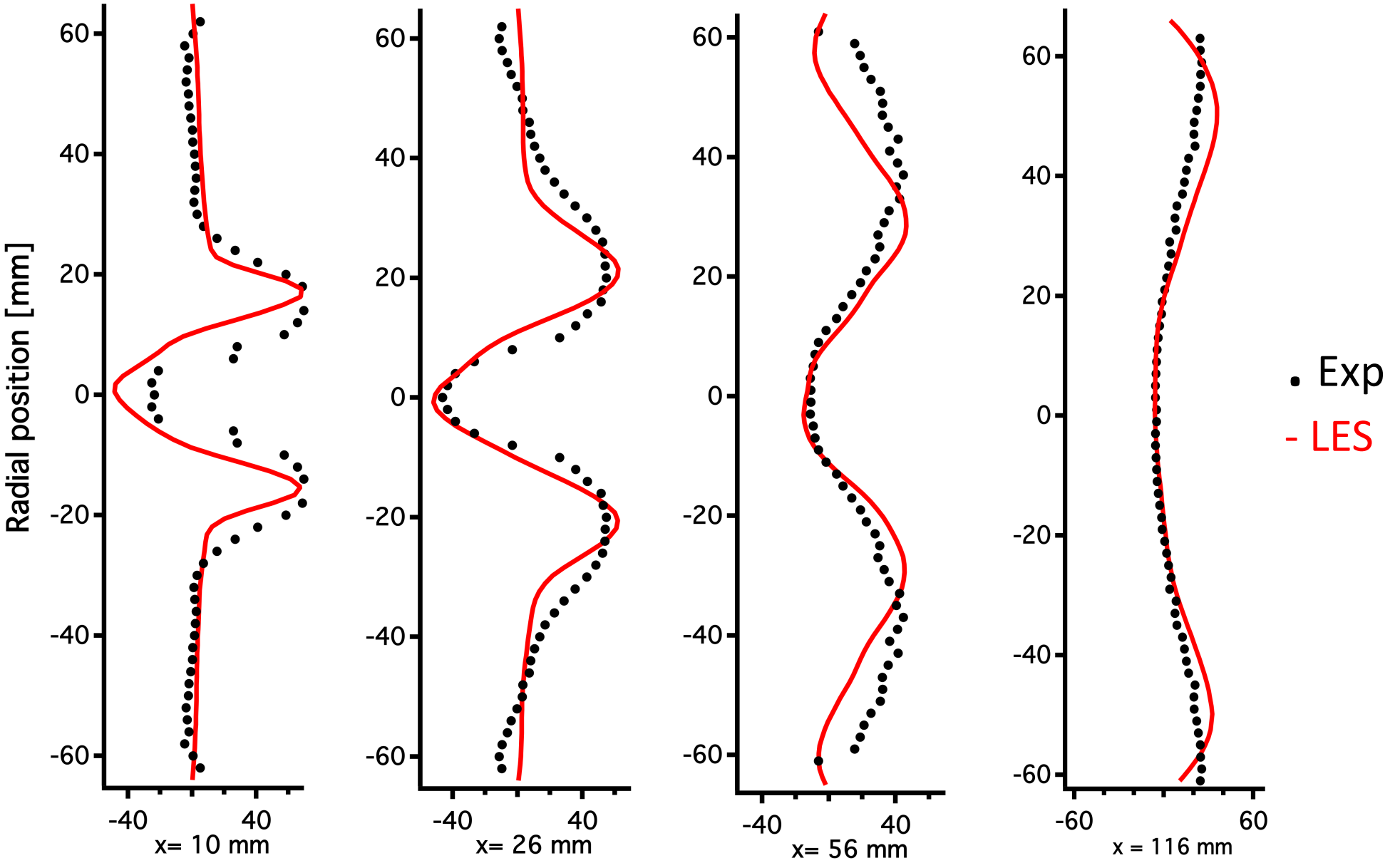


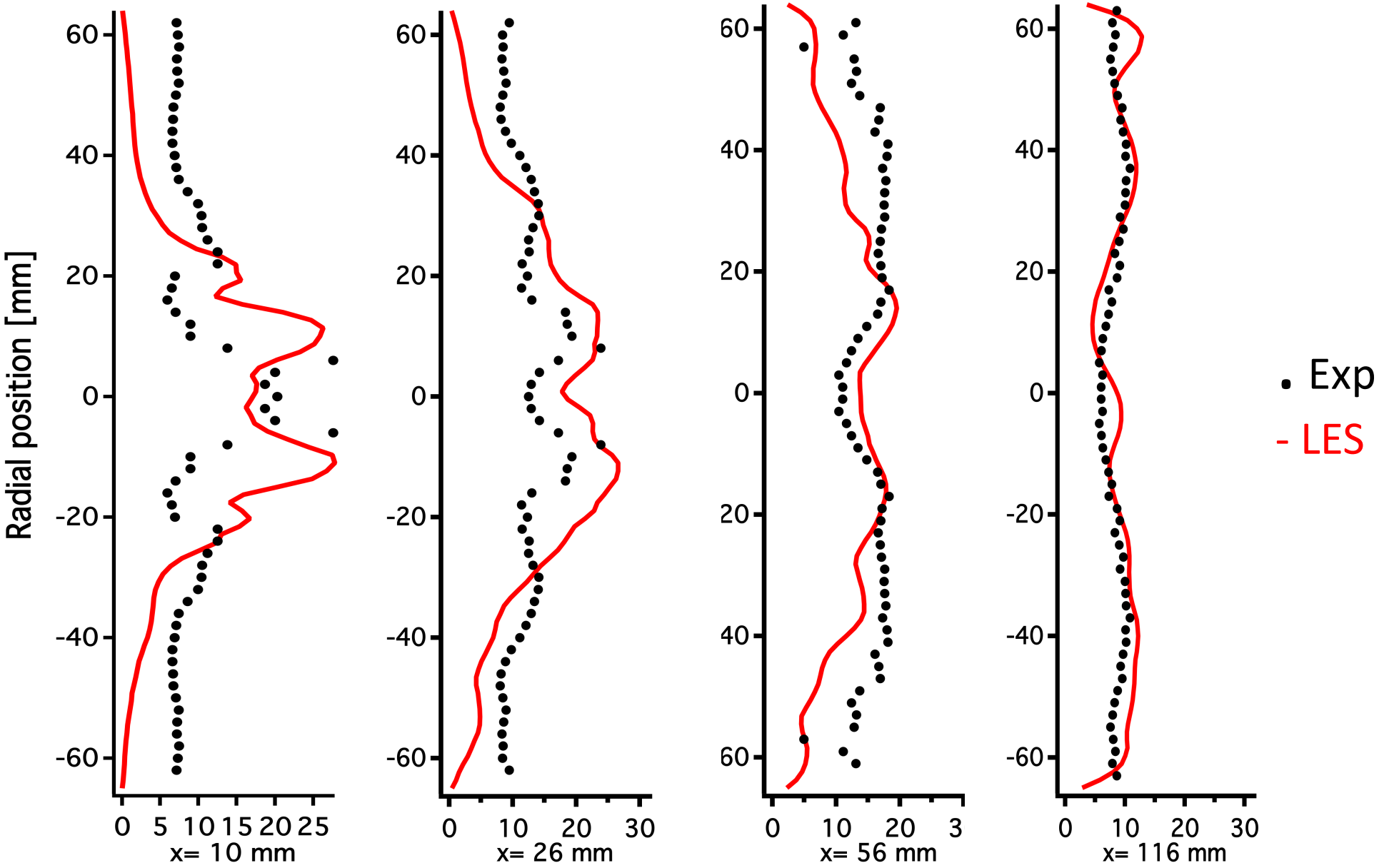
Mean axial velocity field in the median plane

Black isoline of zero velocity / Red axial positions for comp.

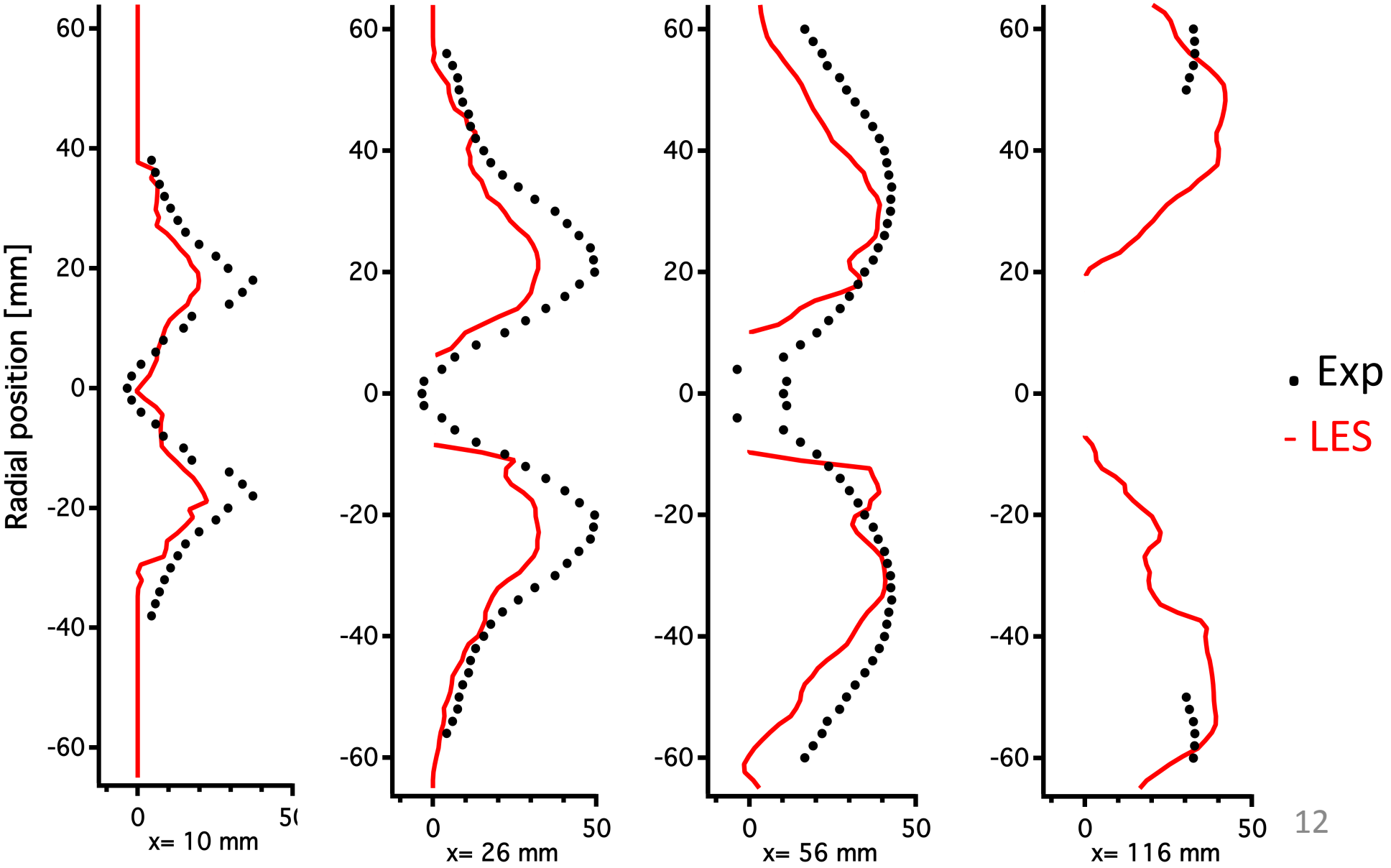
Results: Axial velocity profiles



Results: Axial RMS velocity profiles

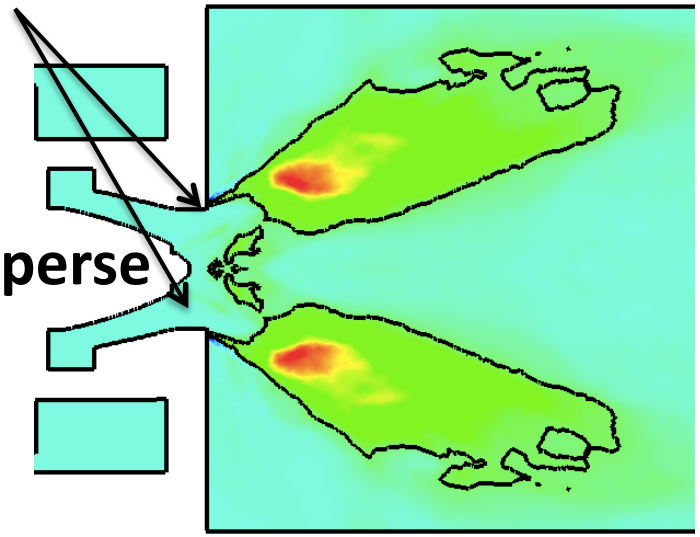


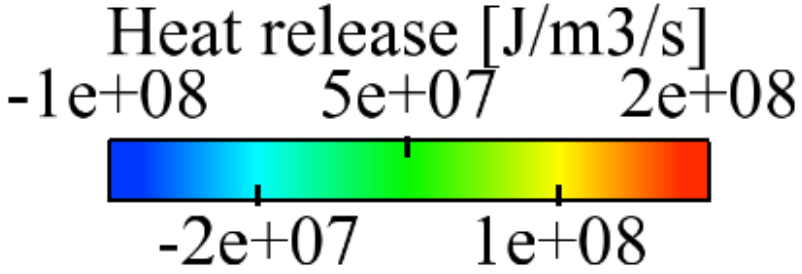
Results: Axial liquid velocity profiles



Results: Mean Flame structure

Monodisperse

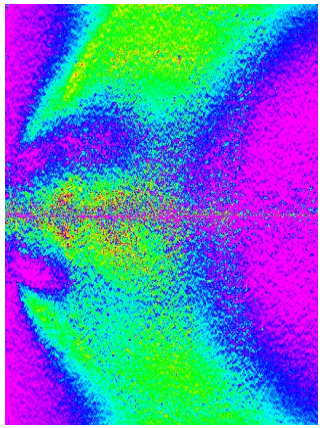




Two anchored positions

Dilute spray

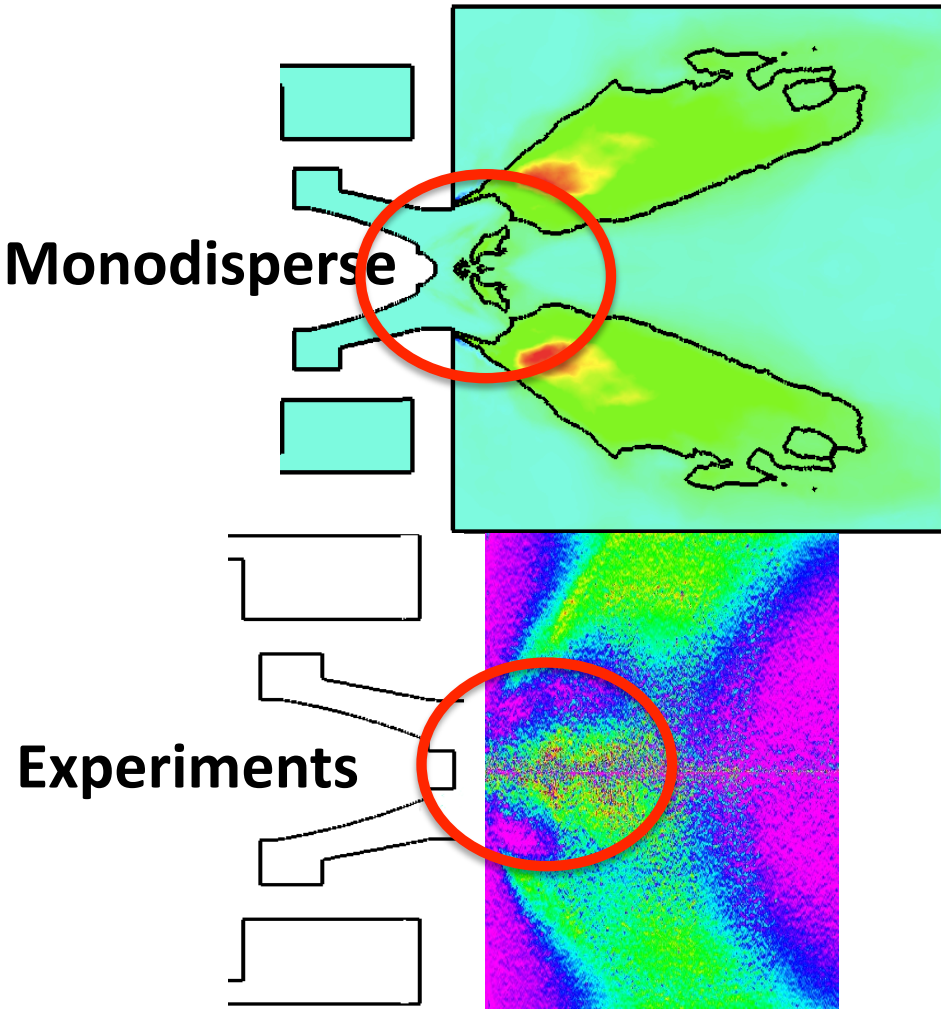
Experiments

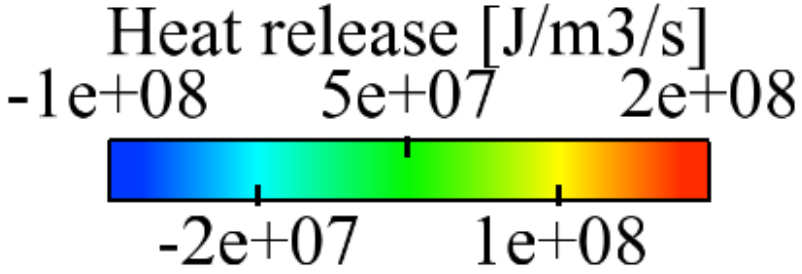


Strong flame in the center

Heat release field in the median cut plane for monodisperse simulation and Flame visualization *Black isoline of Heat release*

Results: Mean Flame structure





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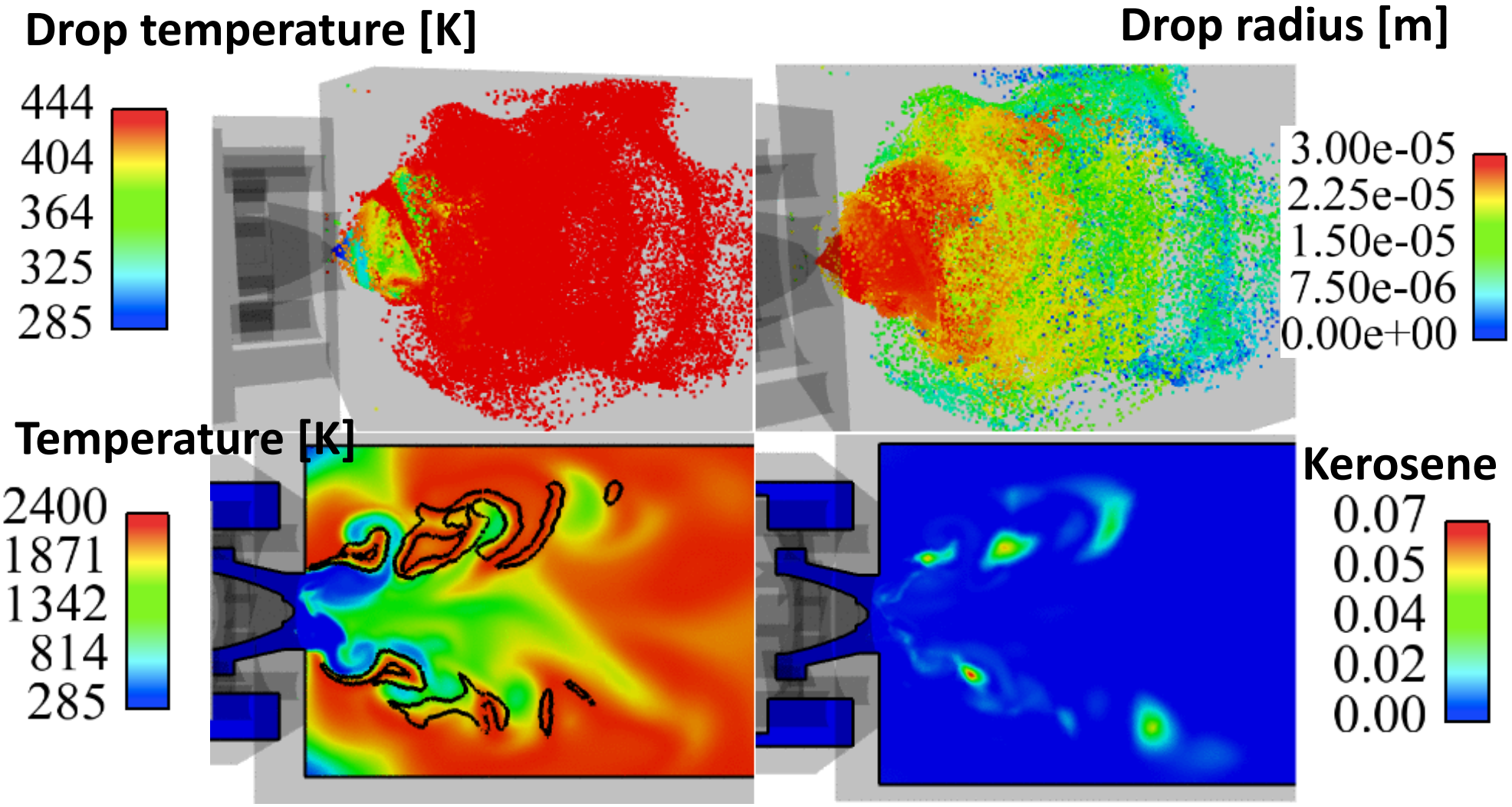
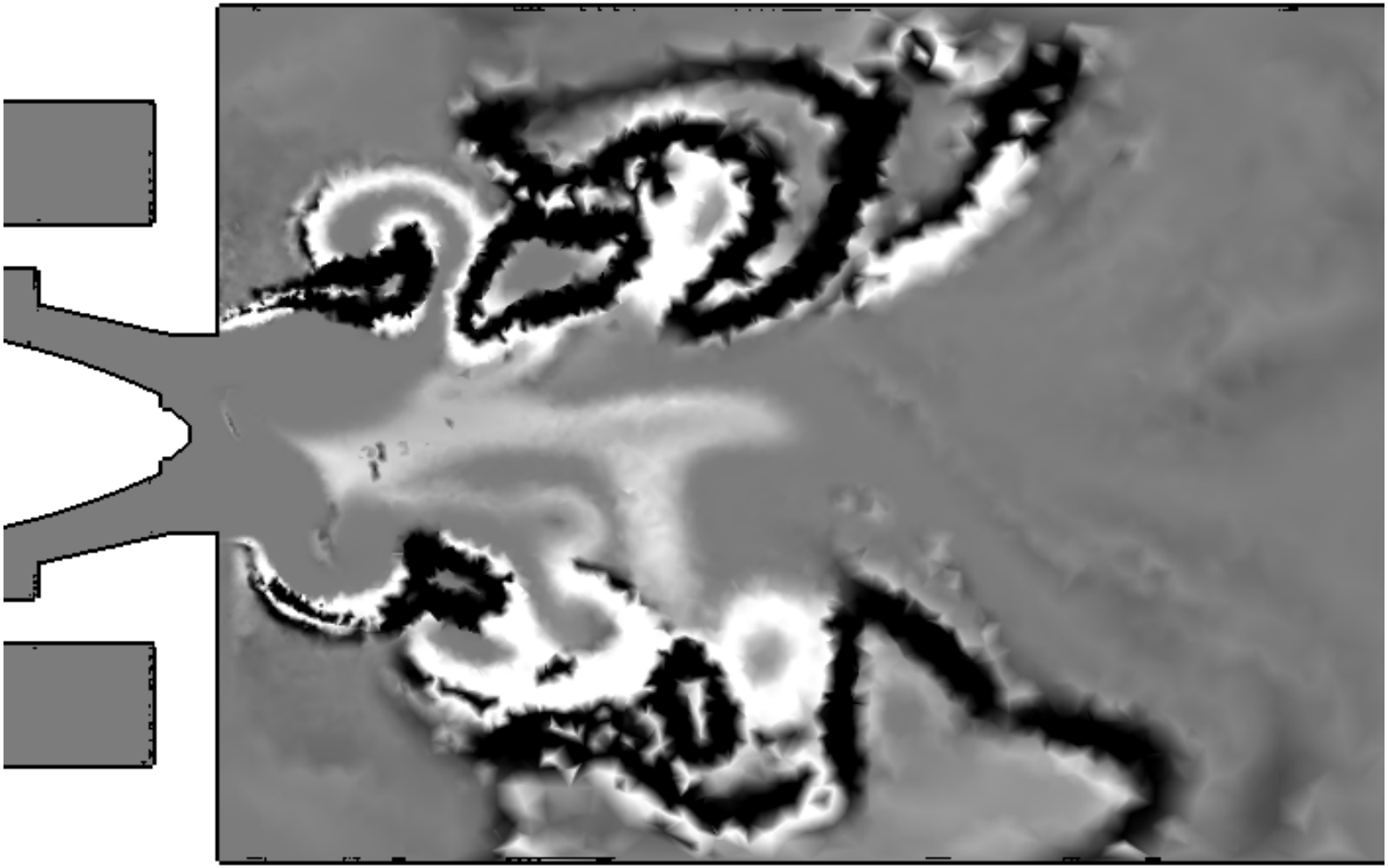
Results: Monodisperse simulation



Flame visualisation: Drop temperature [K] Drop radius [m]

Temperature field [K] and Kerosene field in the median cut plane

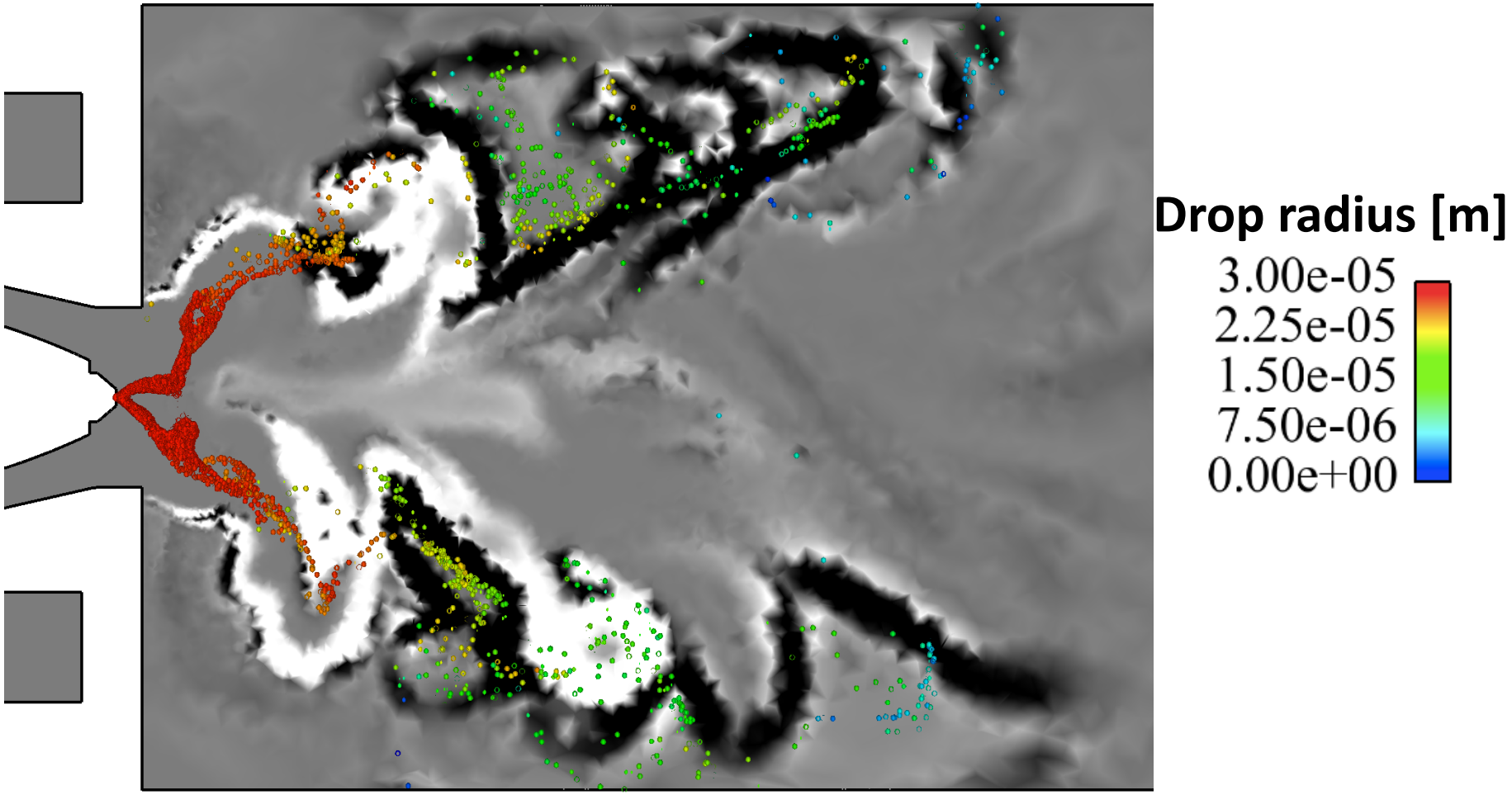
Results: Flame structure: Takeno index



Takeno in the median cut plane: Takeno = Grad(F) . Grad(O)

White = Takeno positive = premixed / Black = Takeno negative = non premixed

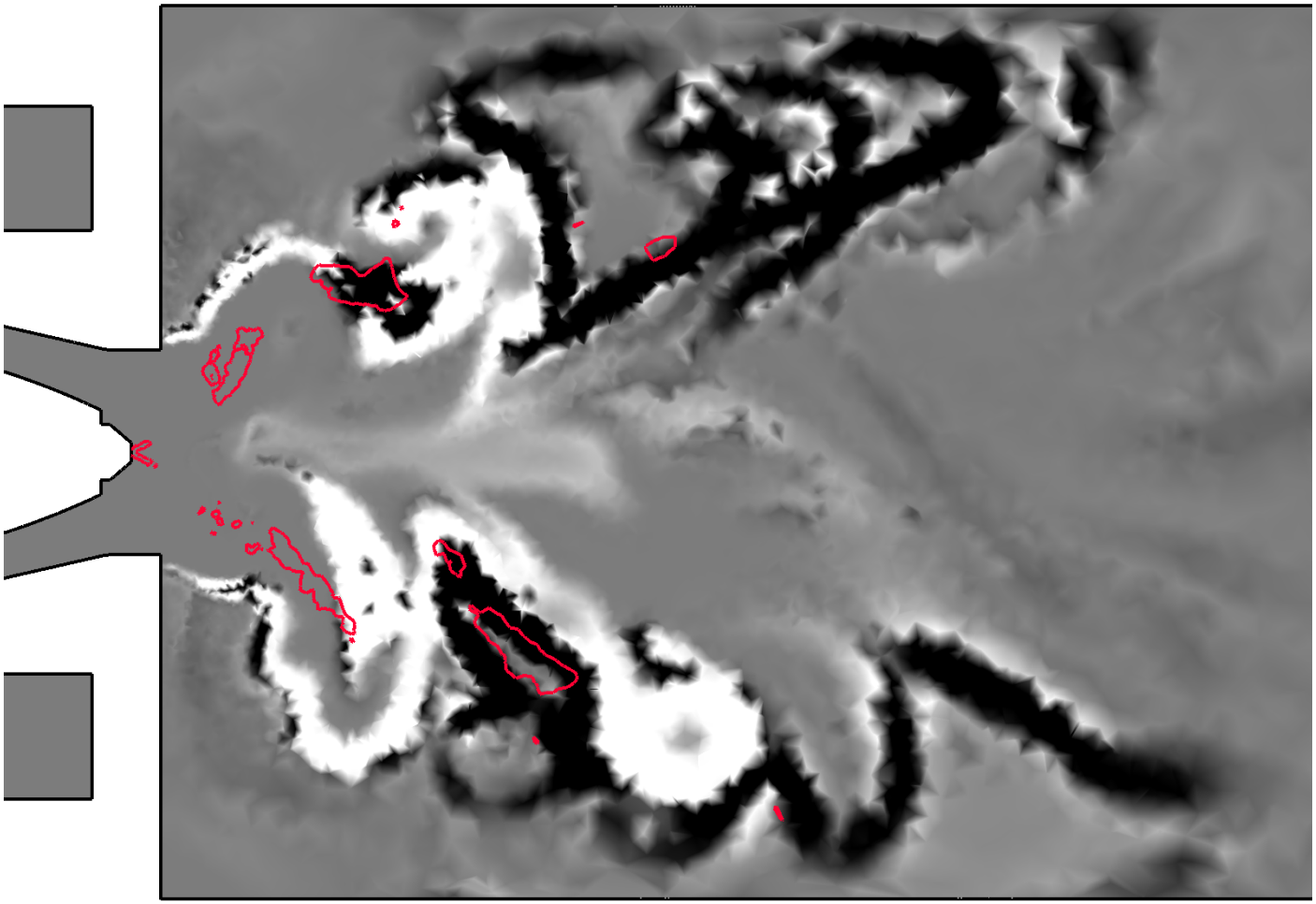
Results: Flame structure: Takeno index



Takeno in the median cut plane with drops coloured by radii

White = Takeno positive = premixed Black = Takeno negative = non premixed

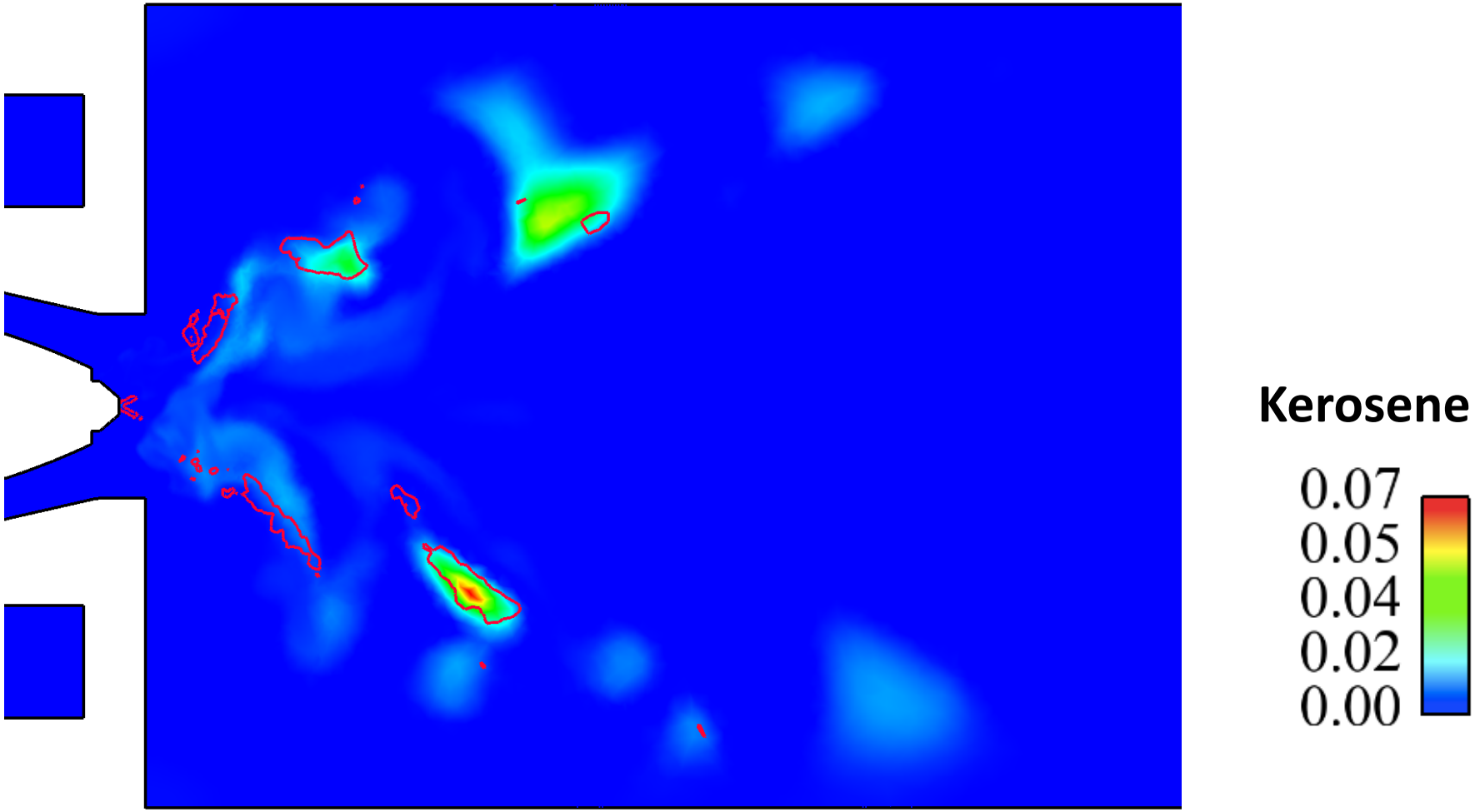
Results: Flame structure: Takeno index



Takeno in the median cut plane

Red isosurface of mass transfer

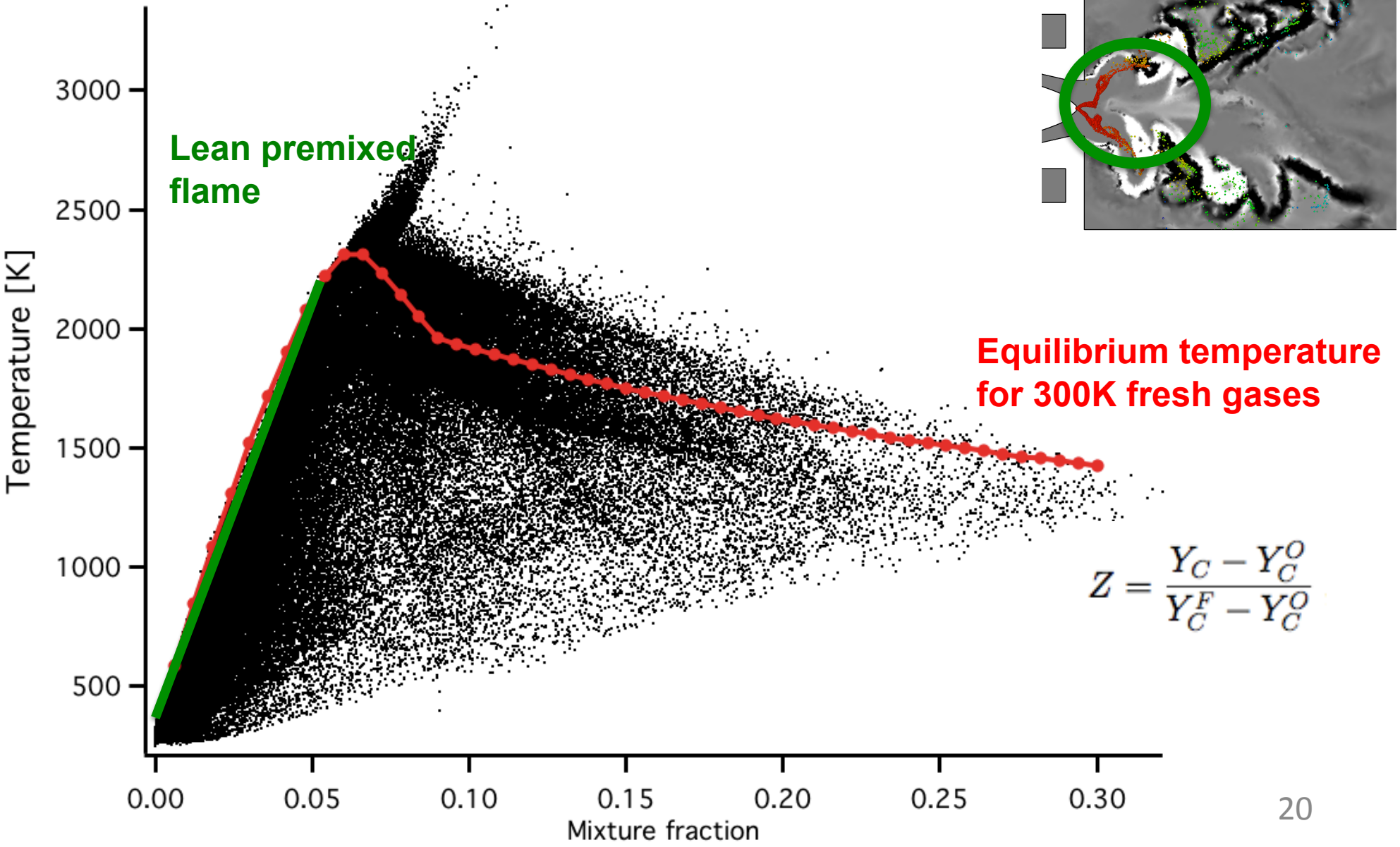
Results: Flame structure: Takeno index



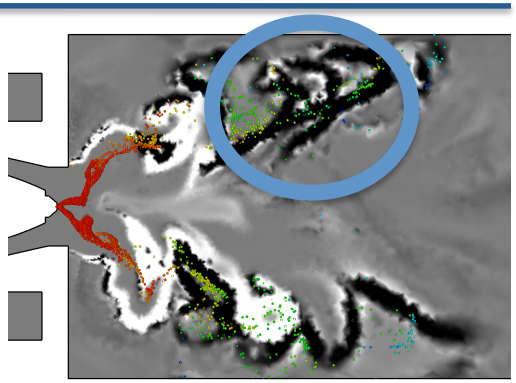
Kerosene mass fraction field in the median cut plane

Red isosurface of mass transfer

Results: Flame structure: scatterplots



Results: Flame structure: scatterplots



Temperature [K]

3000
2500
2000
1500
1000
500

0.00 0.05 0.10 0.15 0.20 0.25 0.30

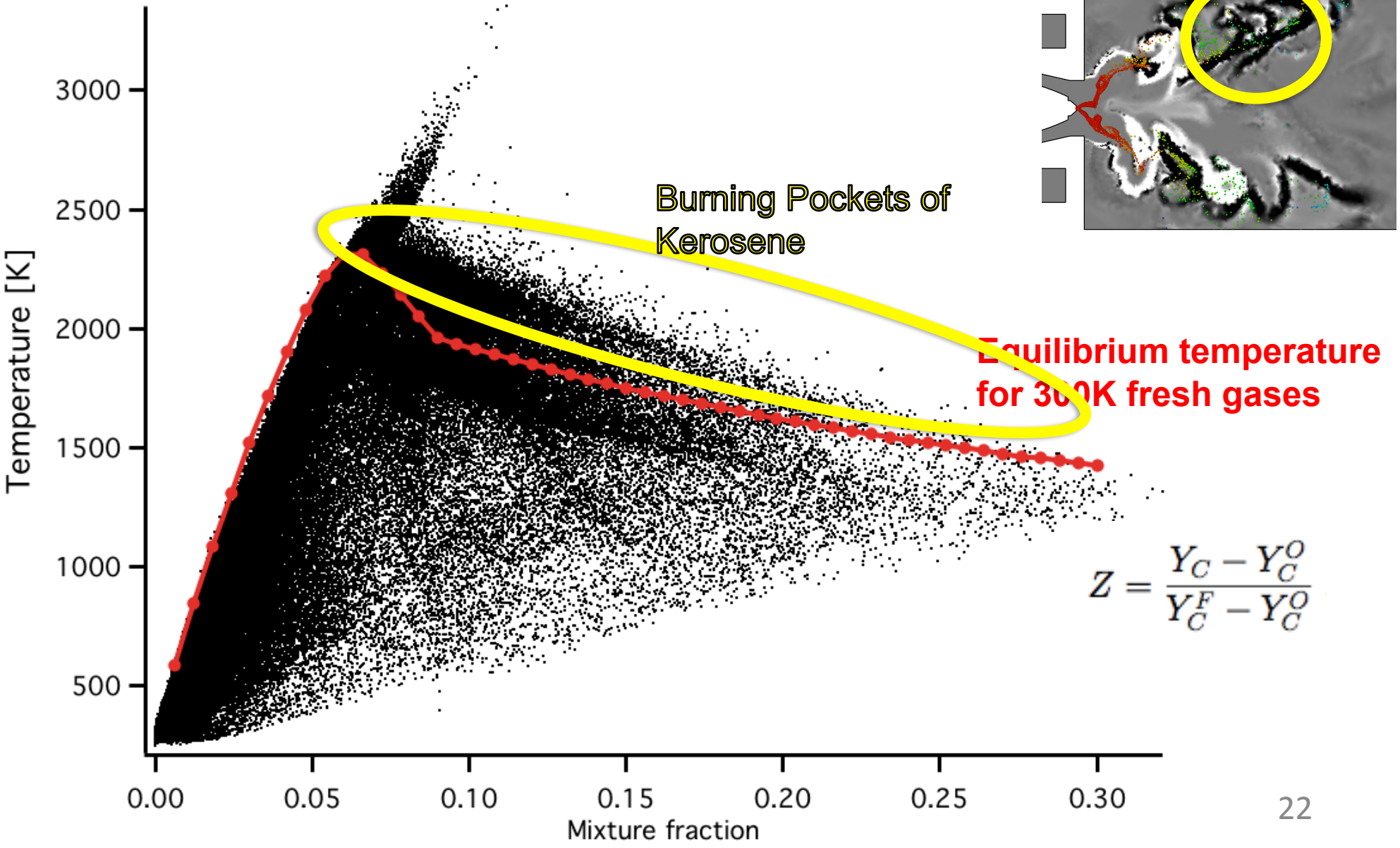
Mixture fraction

Equilibrium temperature for 300K fresh gases

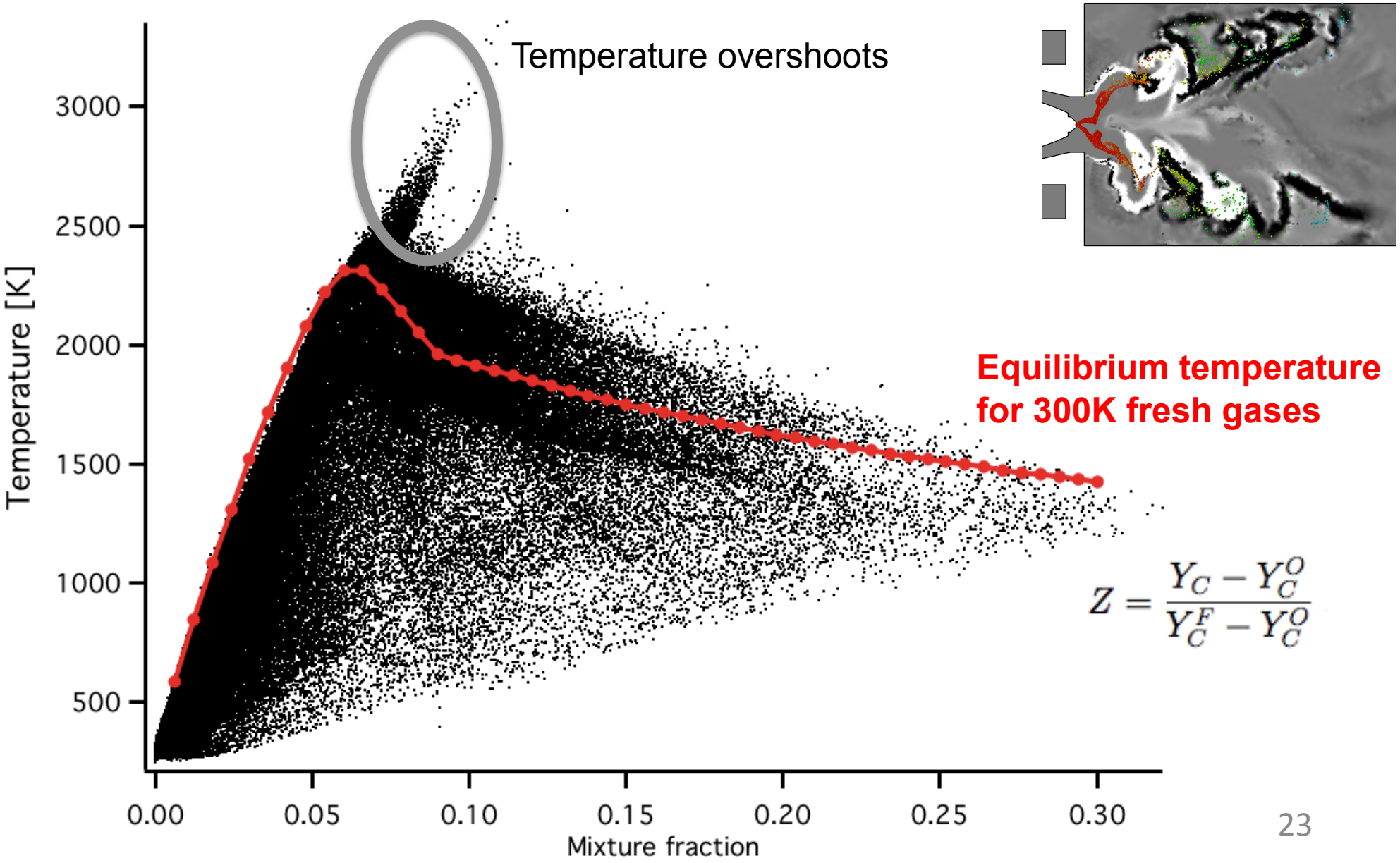
Mixing line

$$Z = \frac{Y_C - Y_C^O}{Y_C^F - Y_C^O}$$

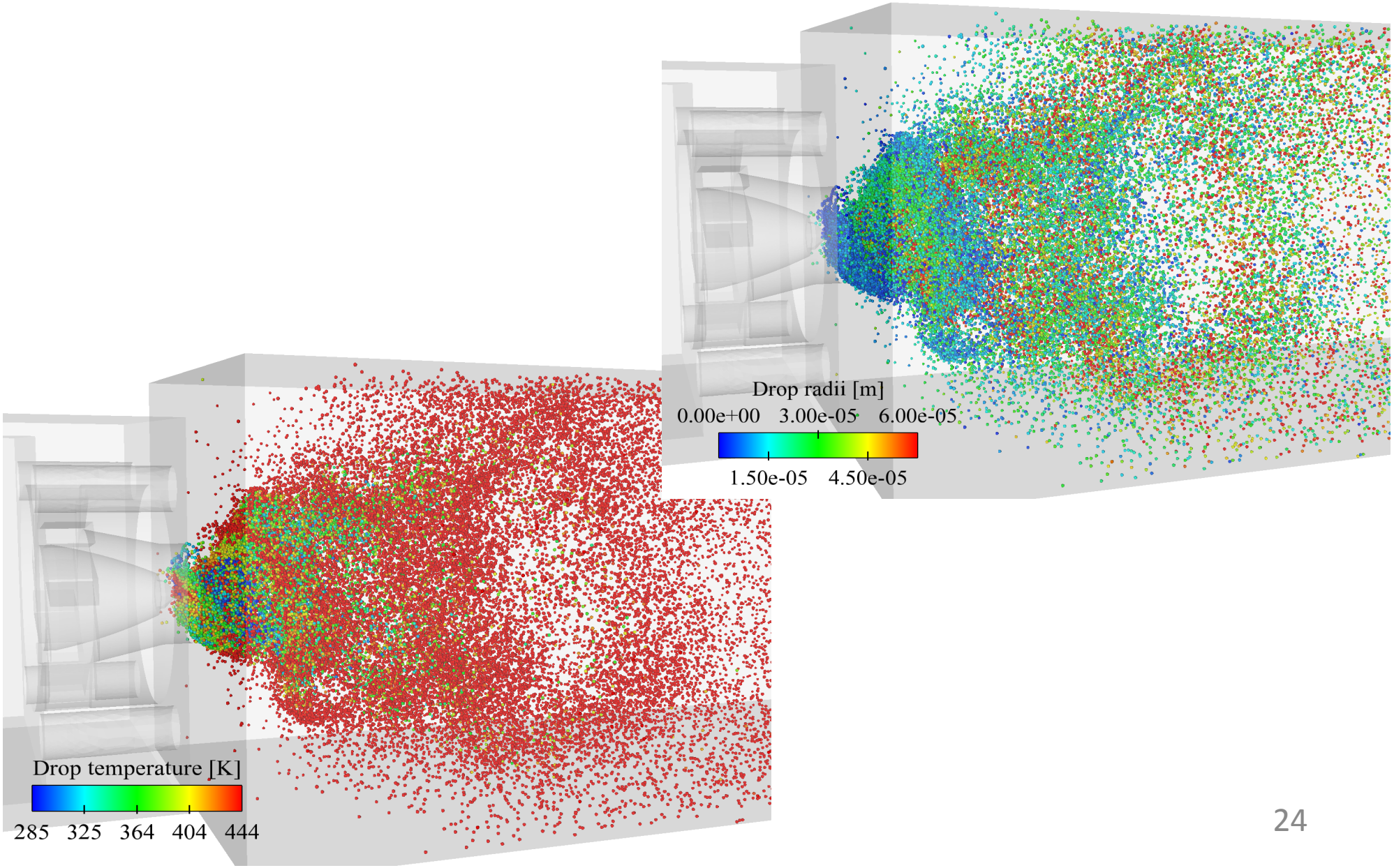
Results: Flame structure: scatterplots



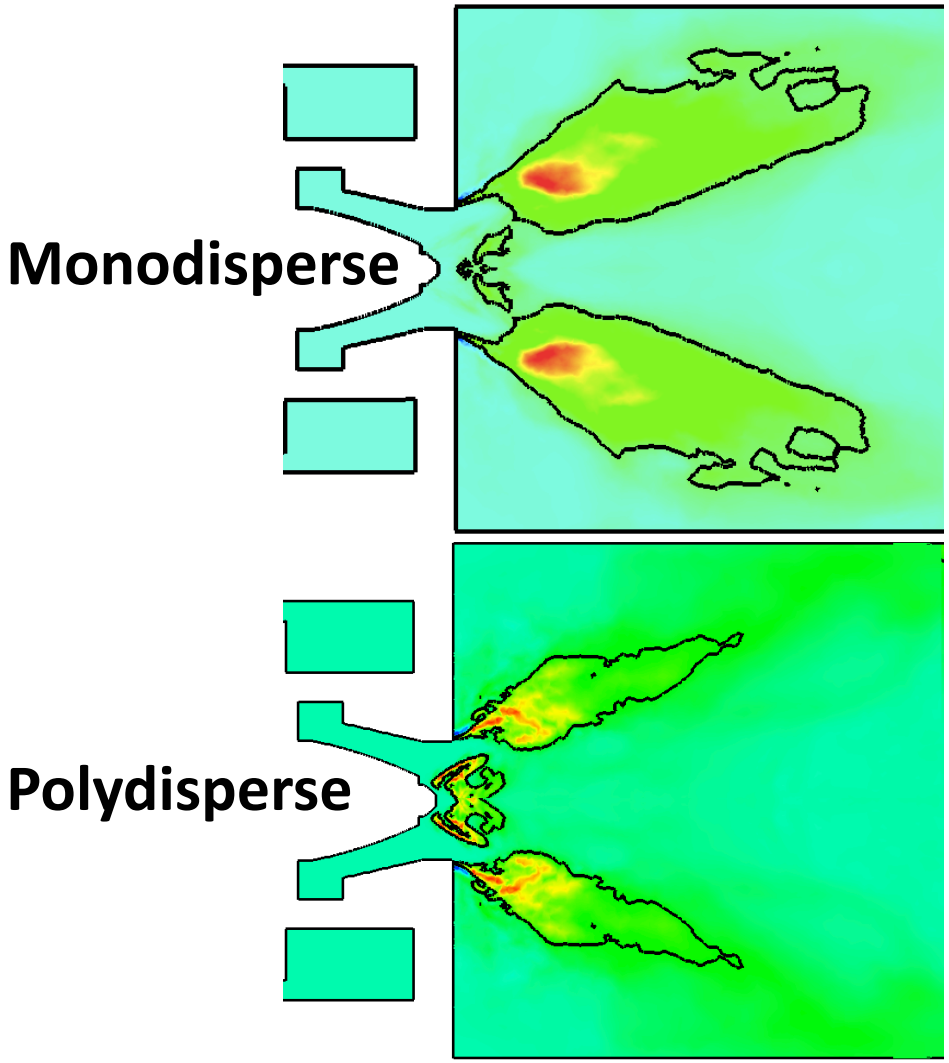
Results: Flame structure: scatterplots

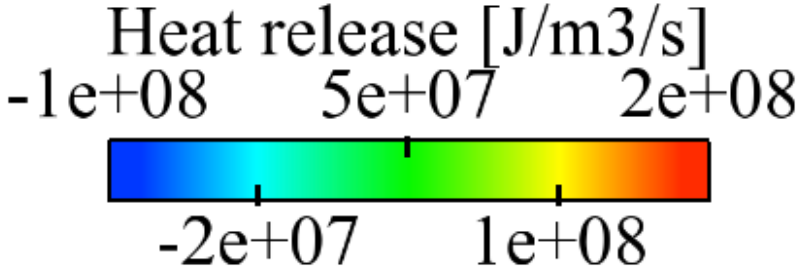


Results: polydisperse simulation



Results: Flame structure: polydisperse





Two anchored positions

Dilute spray

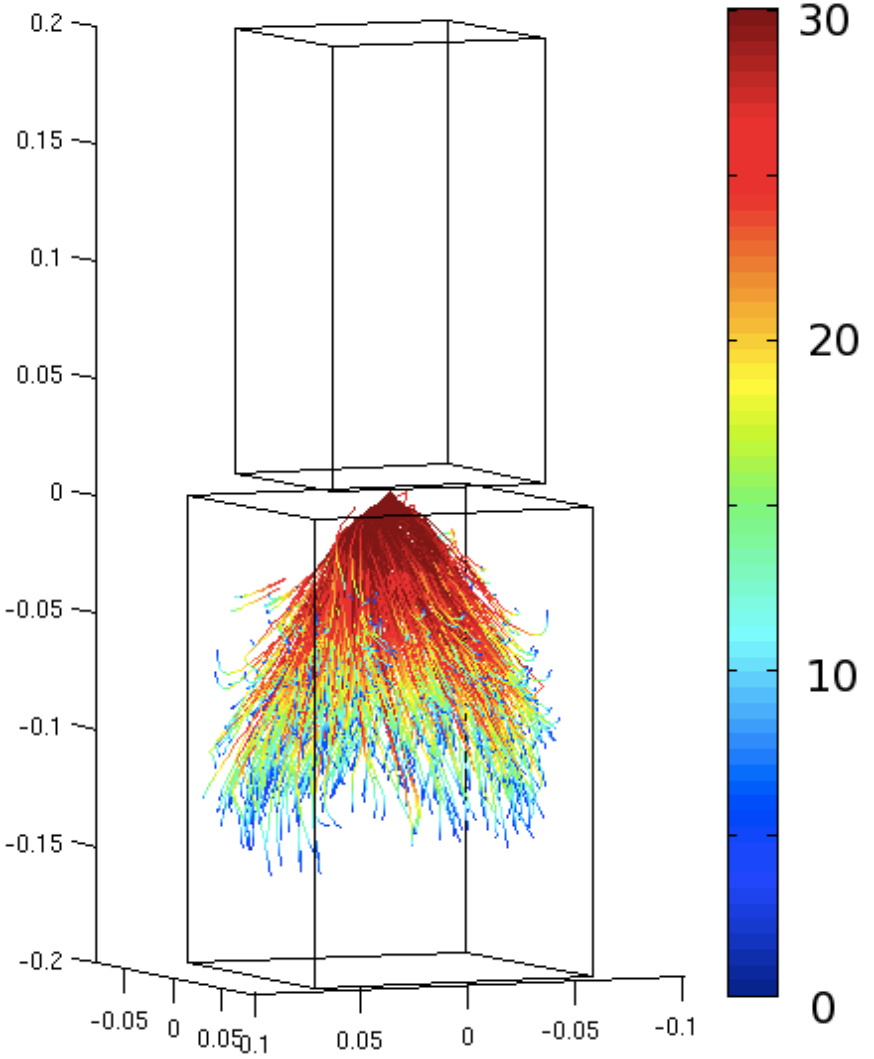
Strong flame in the center

Heat release field in the median cut plane for Lagrangian simulations

Black isoline of Heat release

Results: Drop pathlines

Monodisperse



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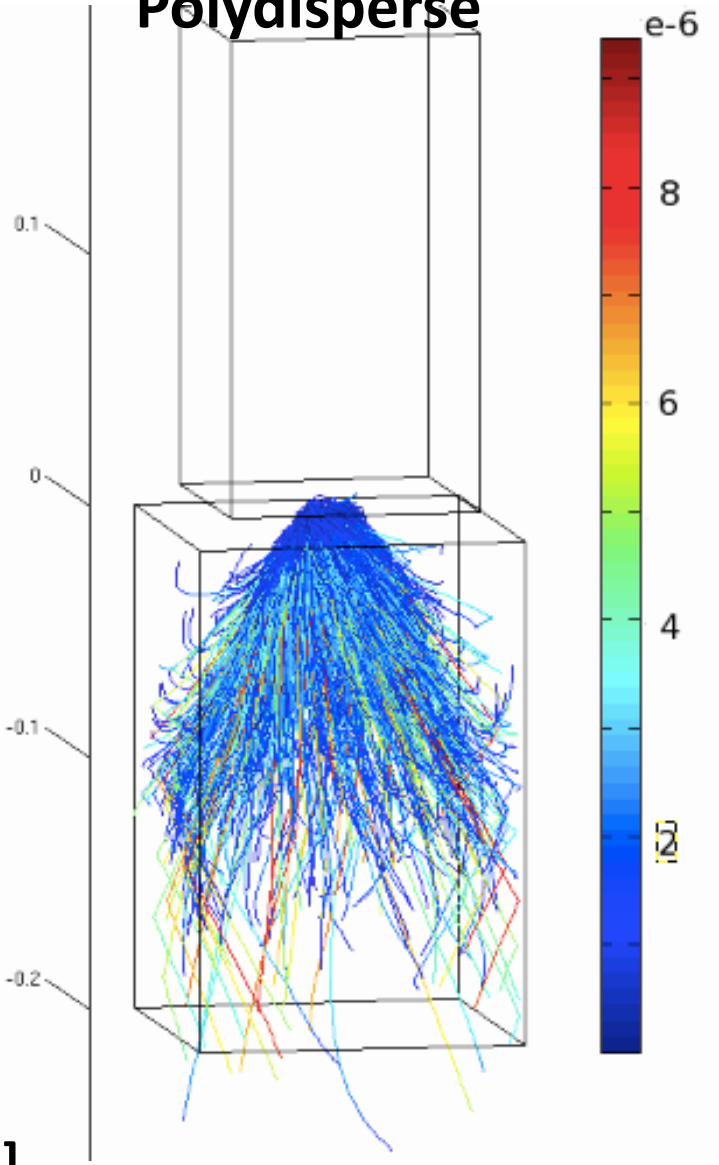
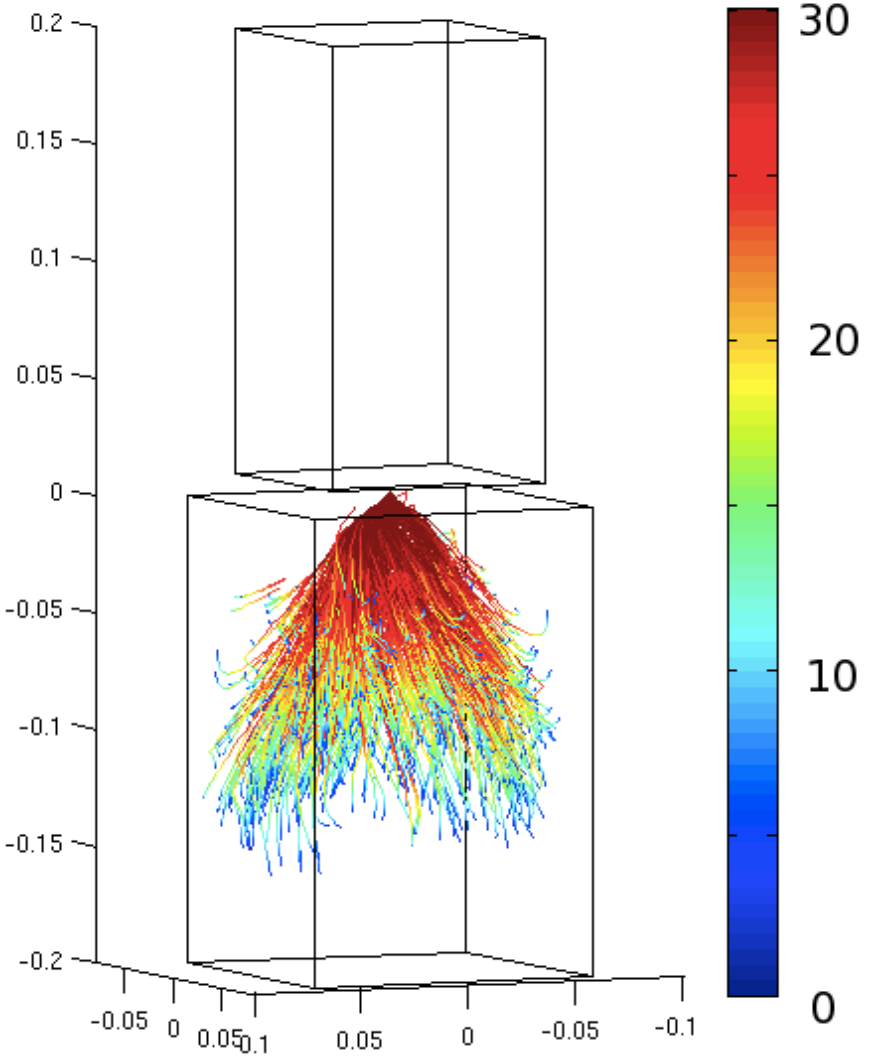


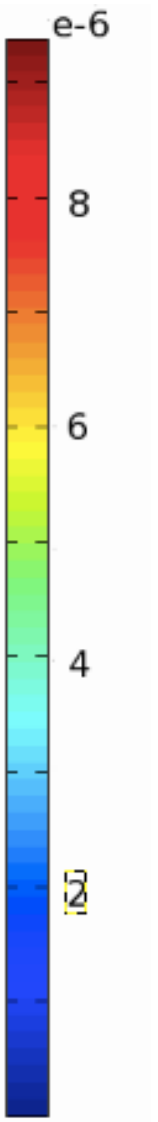
Drops pathlines coloured by drop radius [m]

Results: Drop pathlines

Monodisperse



Polydisperse



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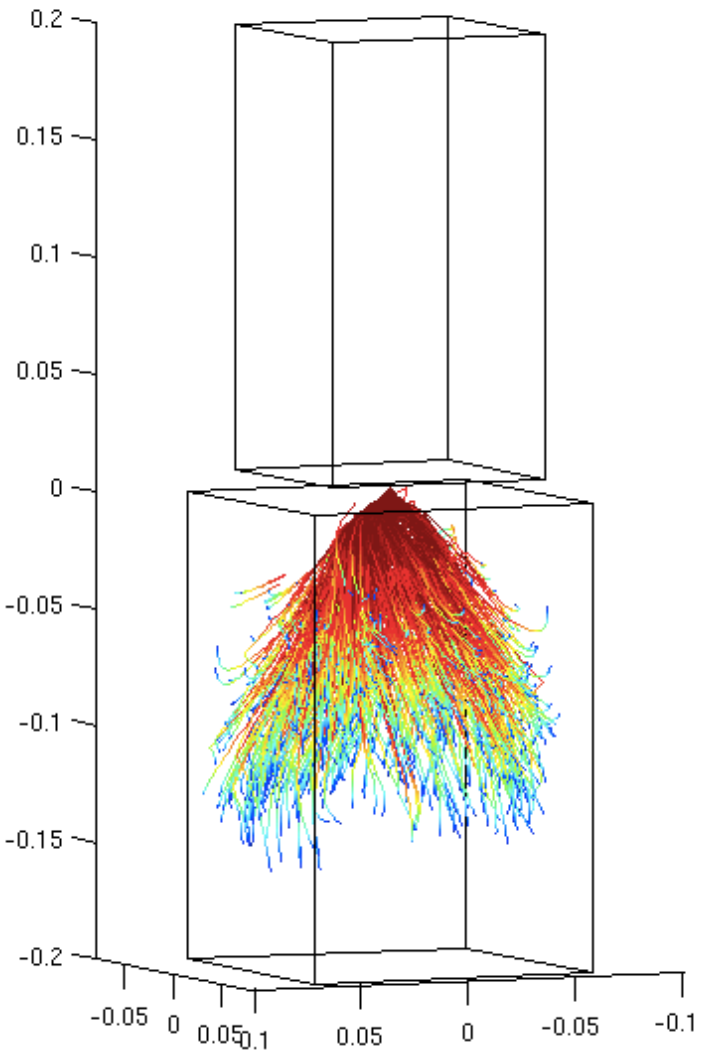
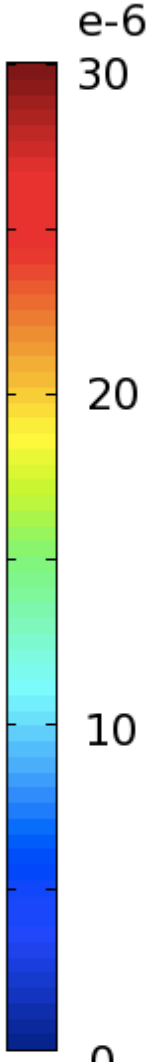
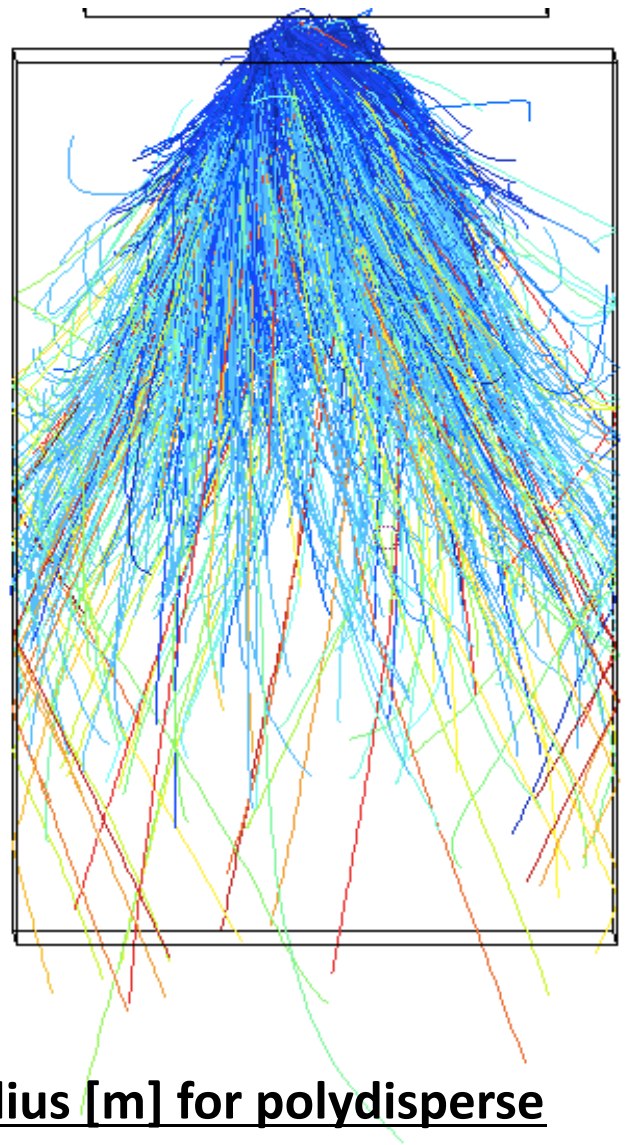
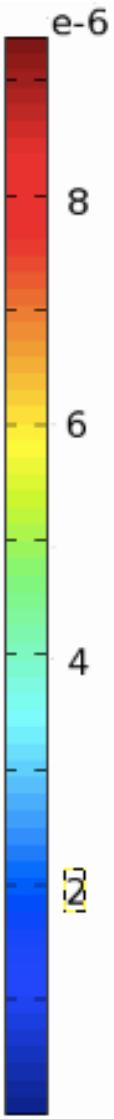




Polydisperse





Drops pathlines coloured by initial drop radius [m] for polydisperse

Conclusion

> Comparisons beetwen Lagrangian two phase flow reactive simulations and experiments

> Good agreements for velocity profiles / Mean flame structure with two anchored positions

> Droplets go through the front flame where a part evaporate and burn like a premixed flame

> Then , pockets of preburnt evaporating drops burn in diffusion regime until disparition

> Evaporation leads to complexe flame structures with premixed, non premixed and mixing regimes (Same Euler/Euler simulation)

> Polydisperse simulation shows that small droplets create a strong flame near the injector

Questions

Back up