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Mixing induced phase separation at elevated pressures

Смешивание индуцированного разделения фаз при повышенных давлениях

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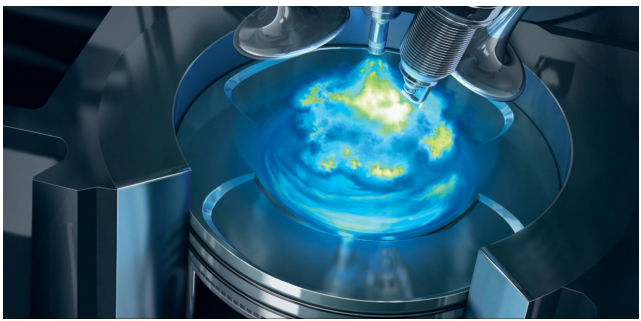
Motivation

- Applications in focus: Engines (gaseous and liquid fuel) and rocket motors
- Elevated pressures (supercritical)
- Numerical investigation (OpenFOAM)
- **Goal: Detailed modeling of the injection process (solver and thermodynamics)**



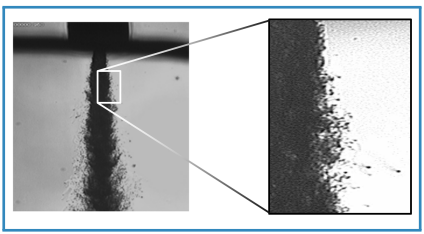
Outline

- Motivation
- Mixing Induced Phase Separation
- Test Cases
- Results
- Conclusion & Outlook

Sub- and supercritical injection - Pure component

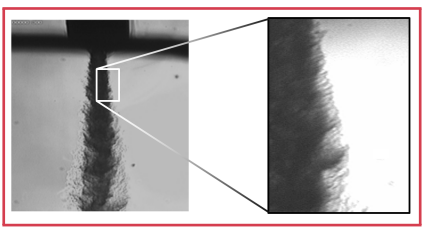
Experimental investigation for cryogenic nitrogen, Chehroudi et al. (2003)

Subcritical



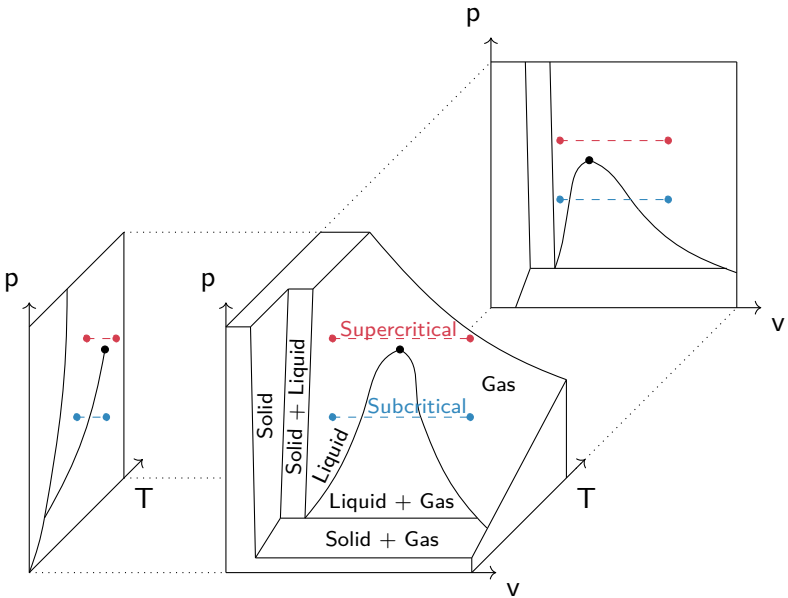
- Atomization
- Surface tension
- Vaporization

Supercritical

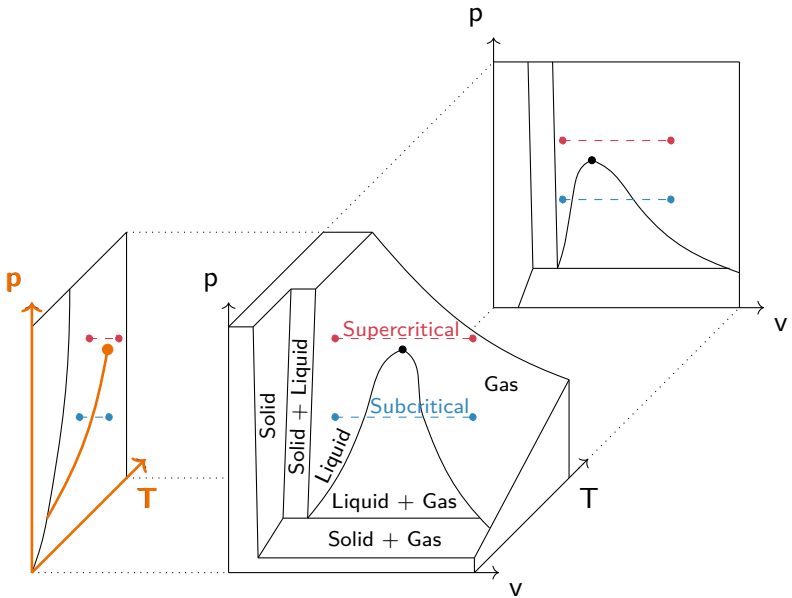


- Diffuse mixing
- No surface tension
- Finger-like structures

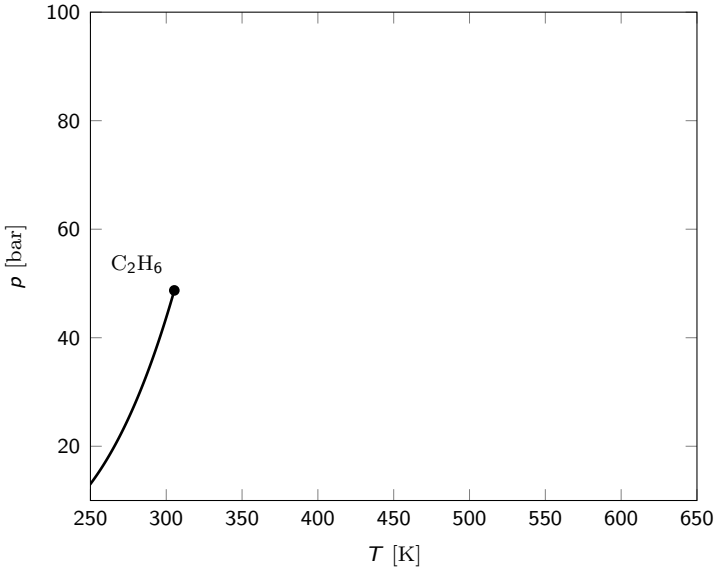
Sub- and supercritical injection - Pure component



Sub- and supercritical injection - Pure component



Phase separation in multi-component mixtures



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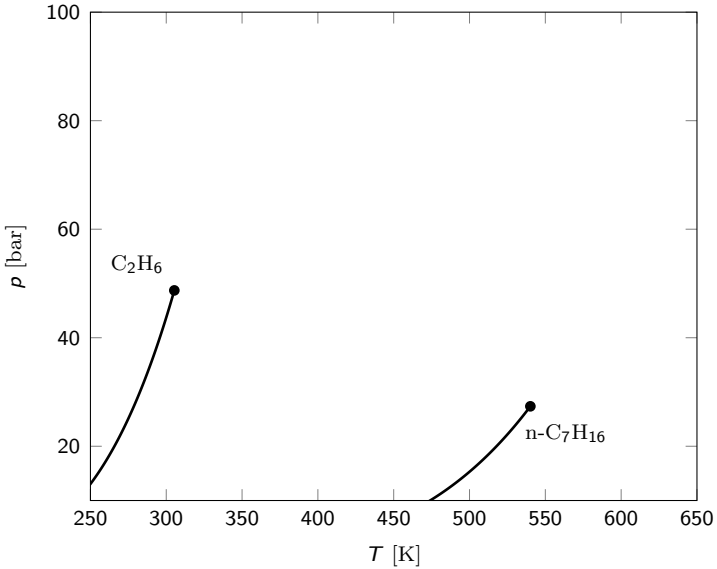

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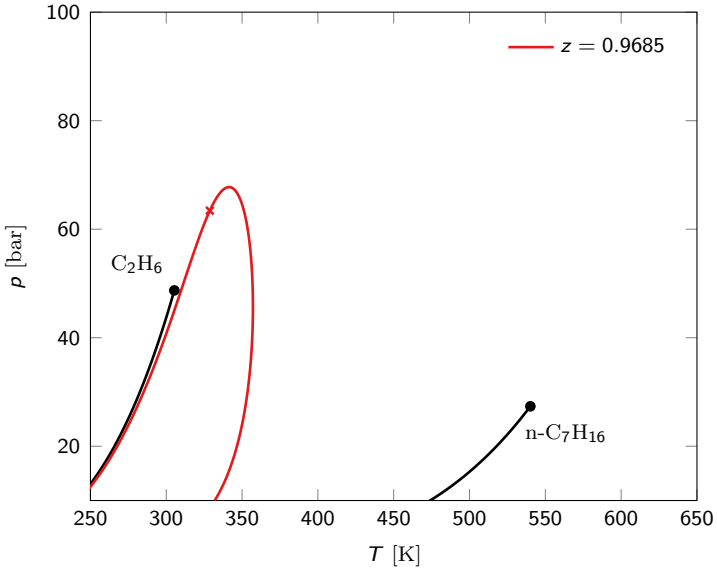

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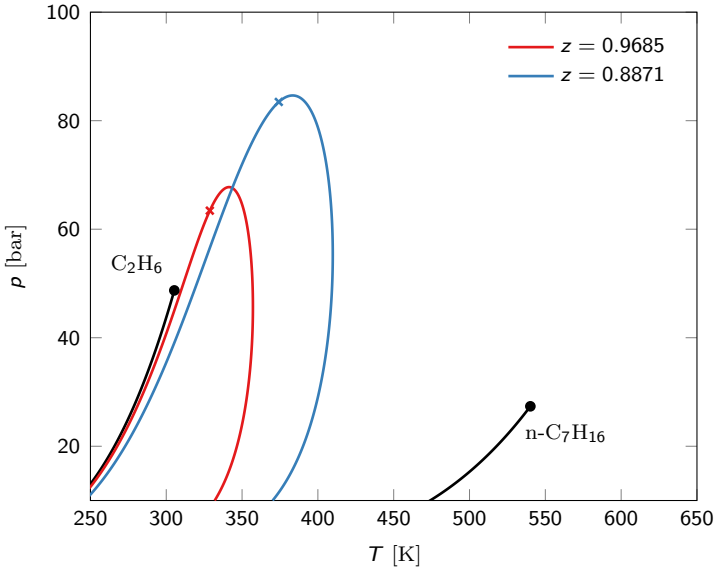

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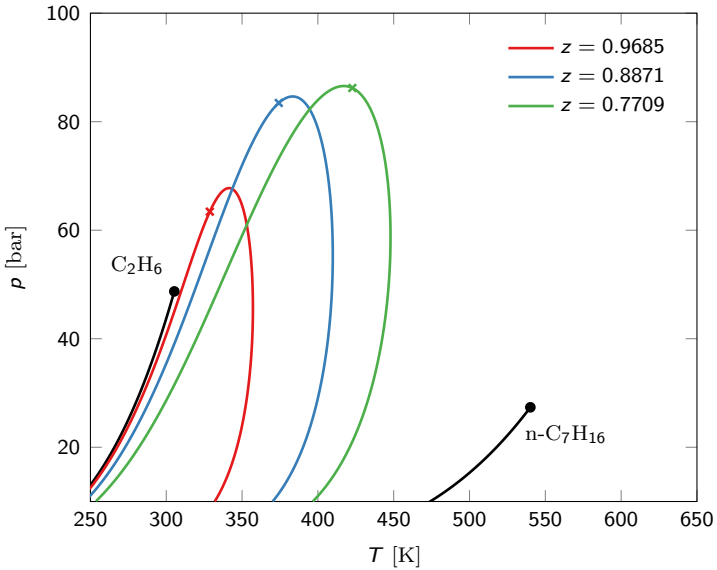

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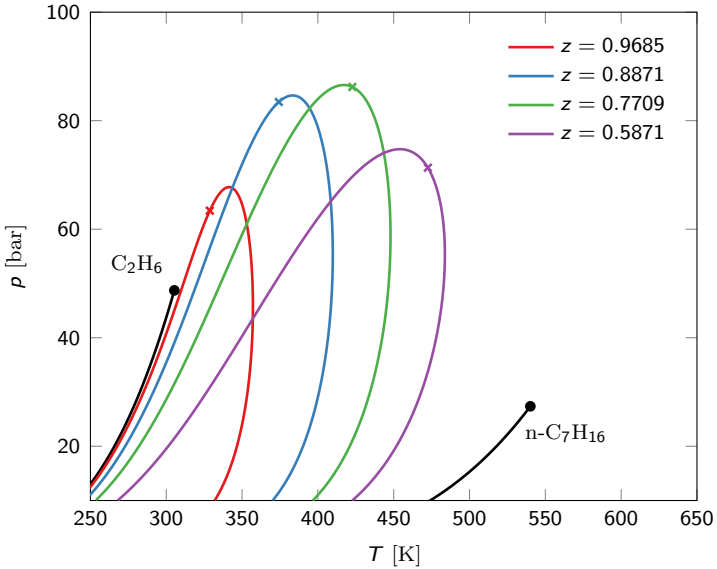

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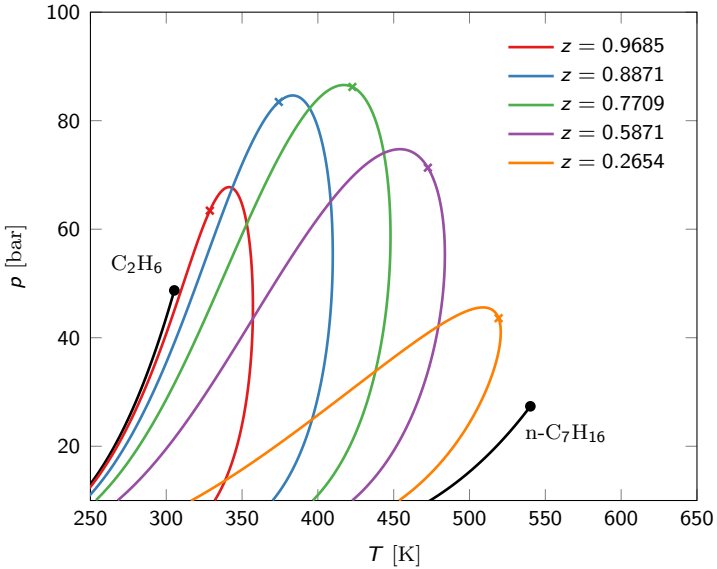
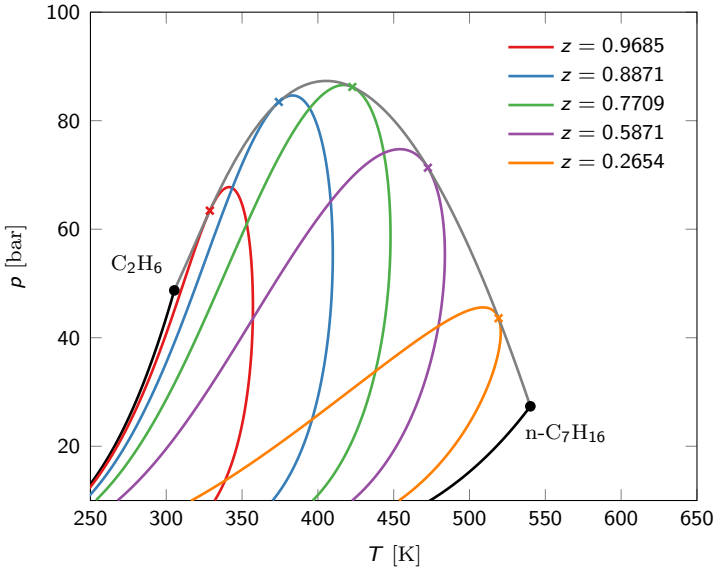


Phase separation in multi-component mixtures



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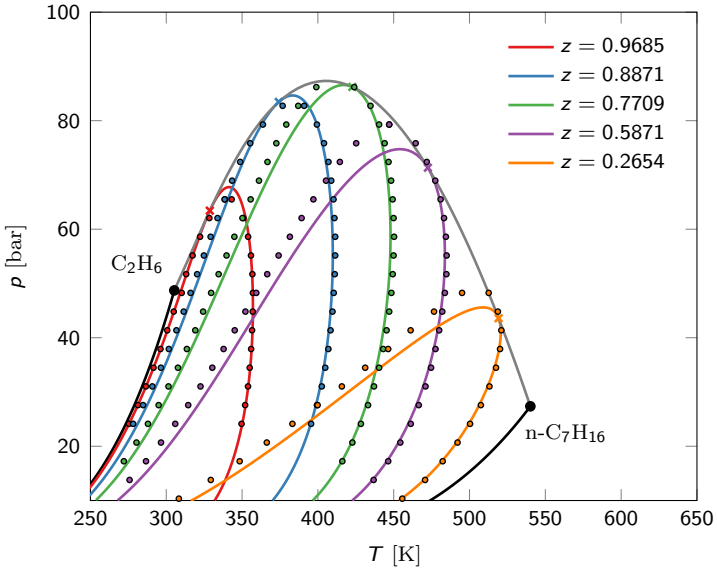

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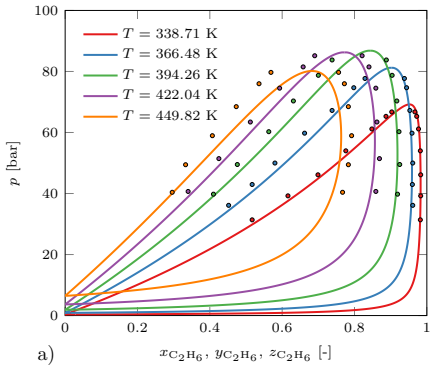
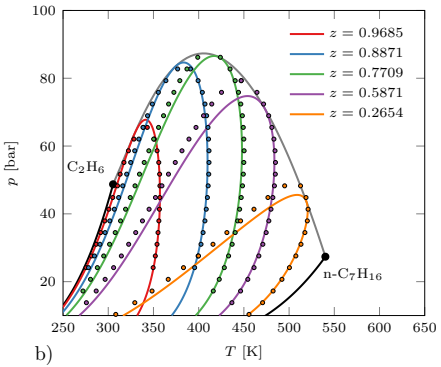
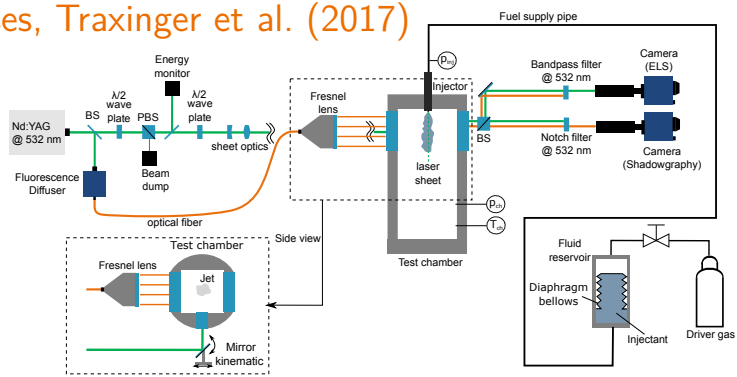




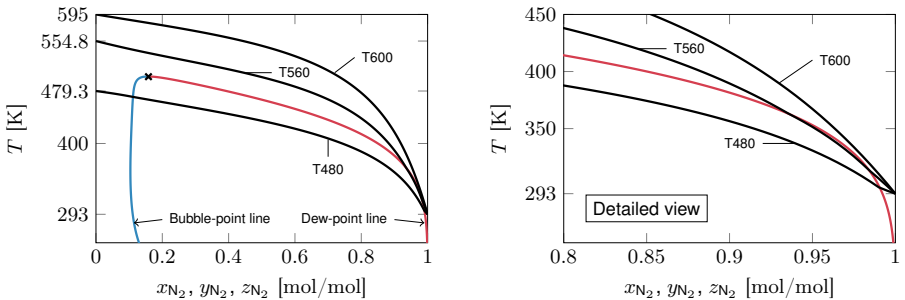
Test Cases, Traxinger et al. (2017)



Test case details:

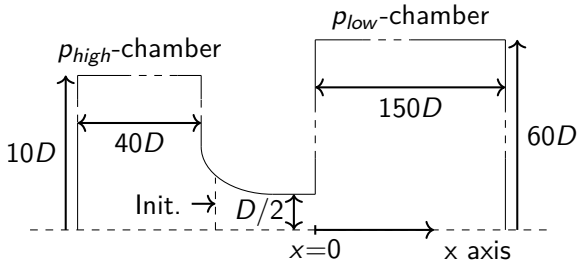
- Experimental investigation done by ITLR, University of Stuttgart
- Injector diameter $D = 0.236$ mm
- Simultaneous shadowgraphy and light-scattering
- Injectant: n-hexane; Chamber gas: nitrogen

Injection Conditions



- Isobaric injection (Focus on two-phase effects)
- Constant chamber conditions: $p = 50$ bar, $T = 293$ K
- Nitrogen: $p_c = 33.96$ bar; Hexan: $p_c = 30.34$ bar
- Variation of the injection temperature: 600 K, 560 K and 480 K

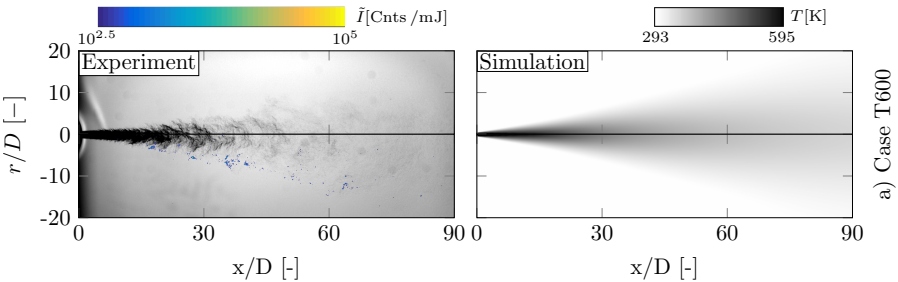
Numerical Setup



Numerical setup details:

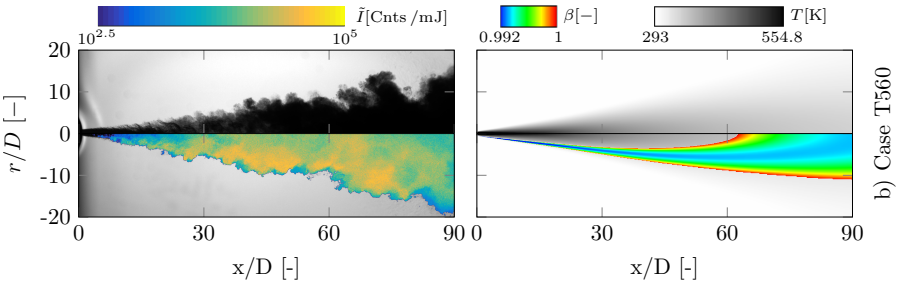
- OpenFOAM 4.1
- Hybrid, pressure-based solver (Kraposhin et al. (2017))
- RANS (k-ω SST)
- Mesh resolution: $\Delta r/D = 20$
- pvT-behavior: Peng Robinson-EoS
- Viscosity and thermal conductivity: Chung
- VLE-model

Test case: 600 K



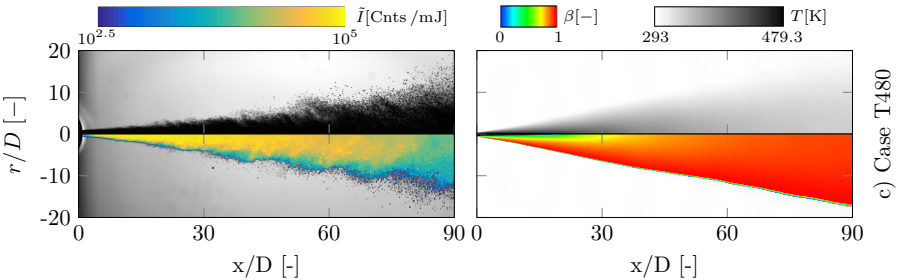
- Finger-like structures
- Dilution into the environment
- No phase separation

Test case: 560 K



- Dense, dark cloud in the experiments
- Strong scattering signal
- Areas of phase separation in CFD

Test case: 480 K



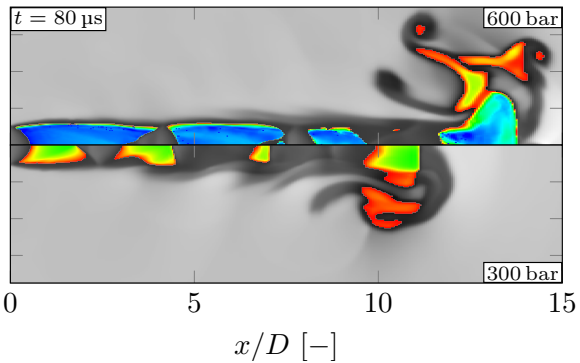
- Distinct droplets, spray-like characteristics
- Very strong scattering signal
- Large areas of phase separation in CFD

Conclusion

- Sub- and supercritical injection for pure components
- Mixture induced phase separation at elevated pressure
- Successful validation of the numerical framework

Outlook

- Investigation of different fluids, injection conditions, ...
- Applying VLE-model in underexpanded jets



Thank you for your attention.