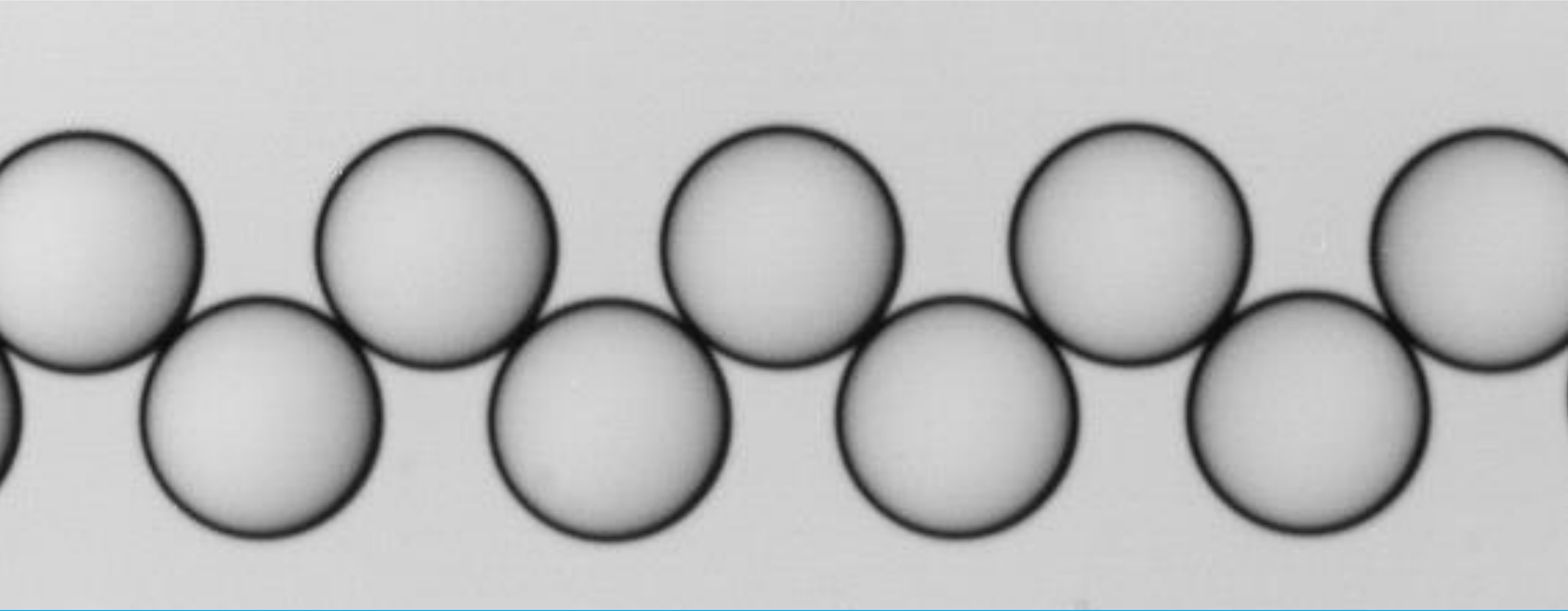

Coalescence propagation in concentrated emulsions flowing through constrictions

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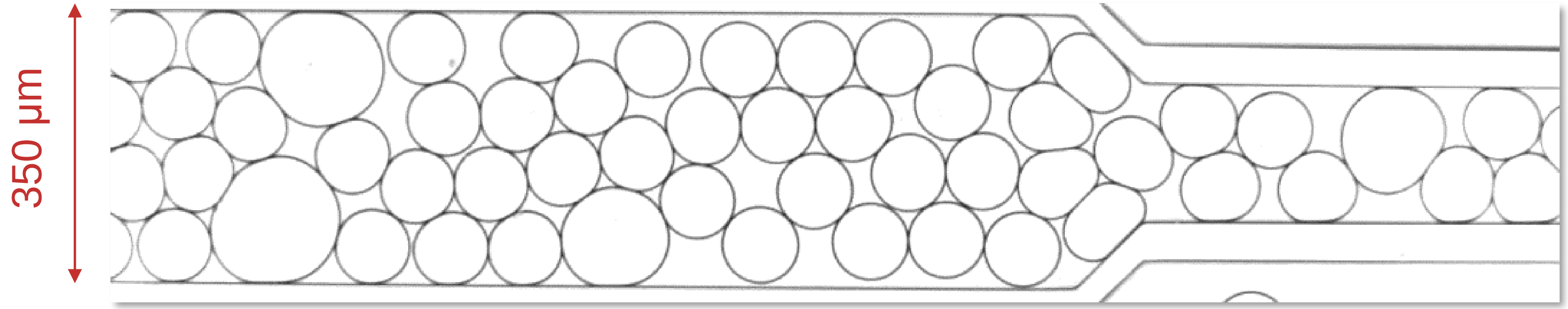

Recorded: 1000 fps
Playback: 5 fps

- Dynamic interfacial tension
- Dynamic interfacial stabilisation

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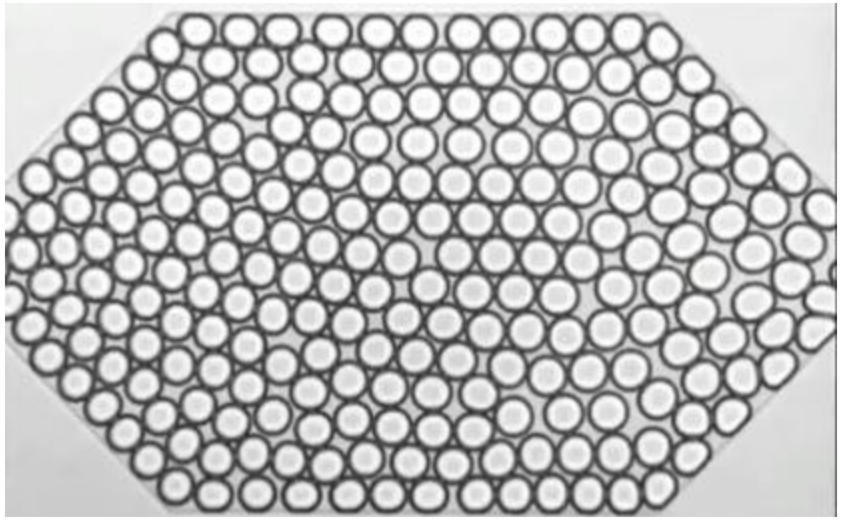
Emulsion stability - coalescence

- ✓ Dilute emulsions in homogenous flows
- ○ Concentrated emulsions in heterogeneous flows

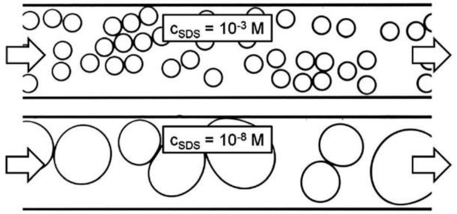


flow

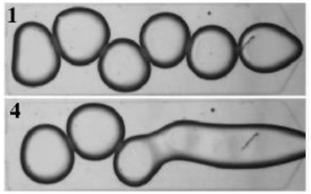
Concentrated emulsion –

Droplets and interstitial space interconnected

Droplet stability



Krebs et al., Soft matter (2012)

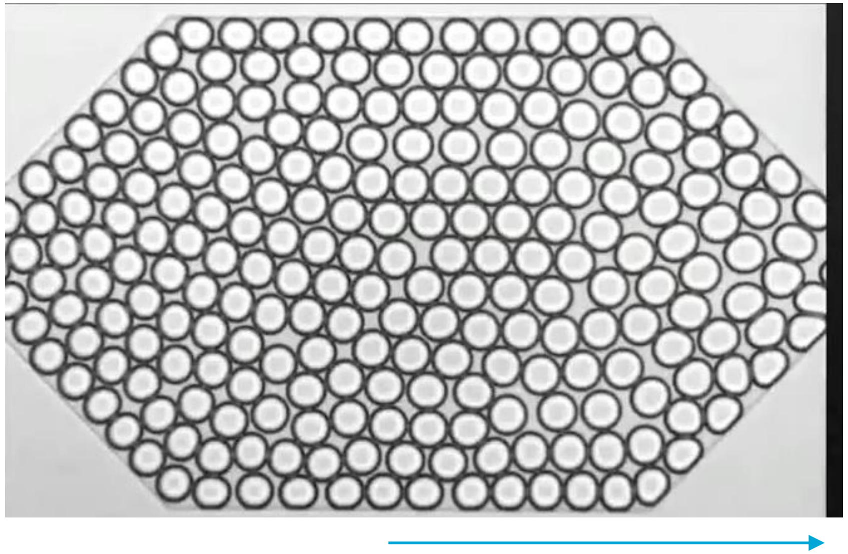


Gunes et al., Soft matter (2013)

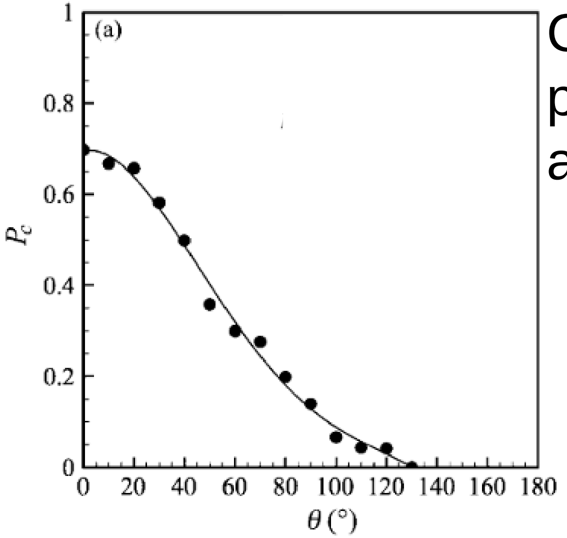
Bremond et al., Phys. Rev. Let (2011)

Emulsion stability - coalescence

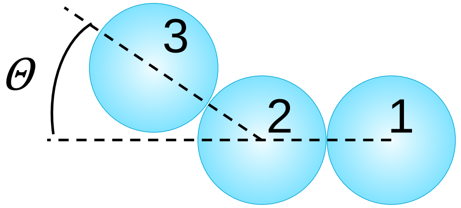
Coalescence starts at the exit of the channel
→ Acceleration of droplets



Water-in-hexadecane emulsion
Emulsifier: Span80



Collision angle determines probability for coalescence avalanche



- ✓ Effect of droplet packing
- ○ Involved fluid dynamics

Bremond et al., Phys. Rev. Let (2011)
Raj et al., Soft Matter (2016), The European Physical Journal (2022)

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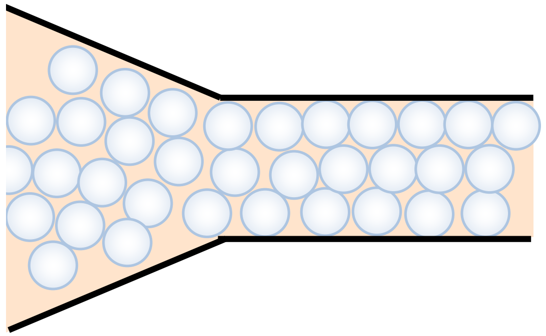
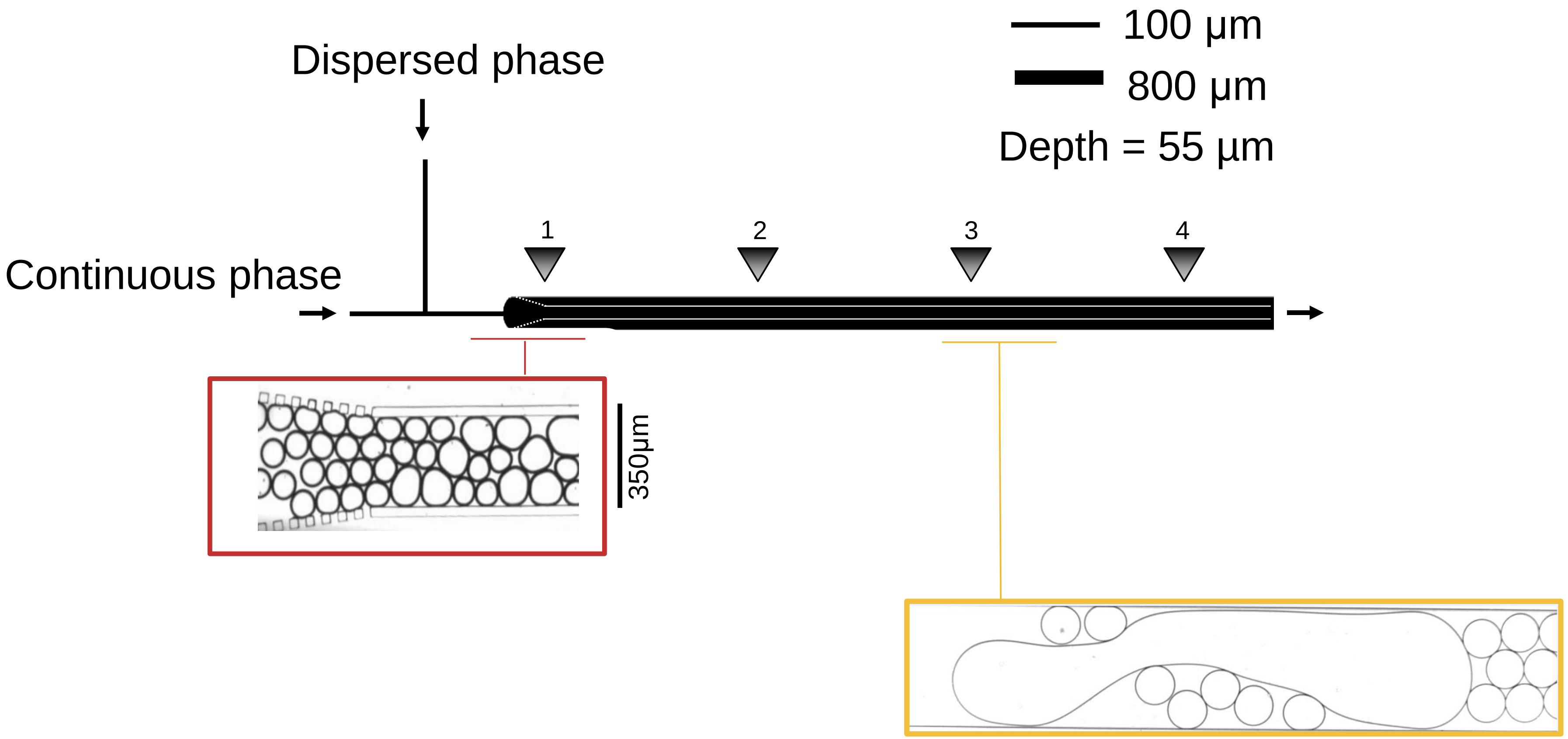
Goals

Predict and control the features of concentrated emulsions after downstream processing

1. How do local events (e.g., coalescence) influence the global structure of the emulsions?
2. What is the effect of **flow conditions,** channel geometries and fluid properties on emulsions properties.



Reference chip



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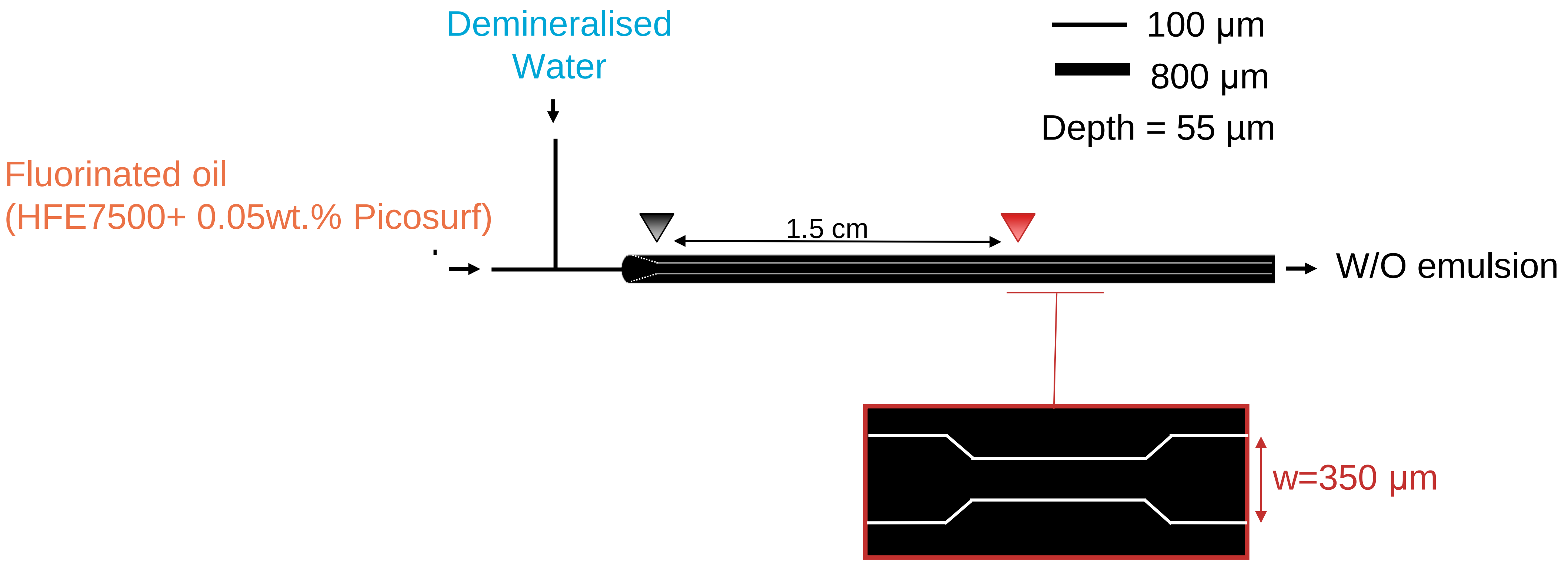
Constriction chip



Do the constrictions enhance film drainage?

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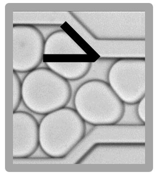
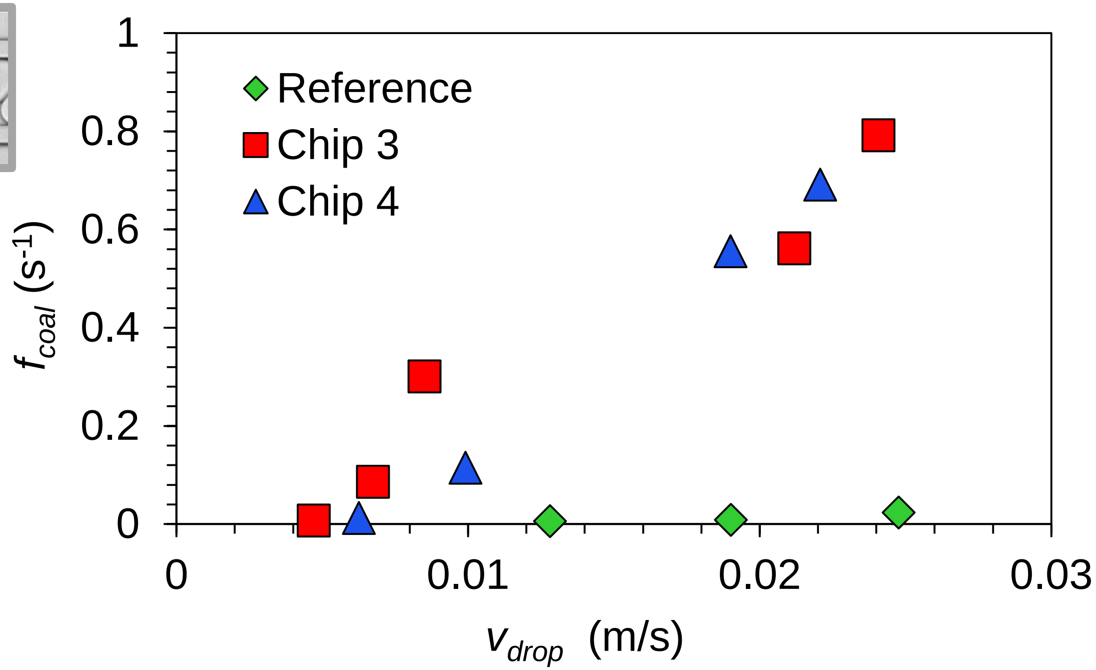
Continuous phase = 0.05wt.% Picosurf in HFE7500
Dispersed phase = demineralised water

f_{coal} at the end of the channels

45°





Metastable emulsion

- **Stable** in **reference chip**
- **Coalescence** induced by **constriction**
- Independent of location

What happens at the constriction?

$$N_{coal} = \frac{V_{initial}}{V_{coal}} - 1$$

$$f_{coal} = \frac{N_{coal}}{t_{res}}$$

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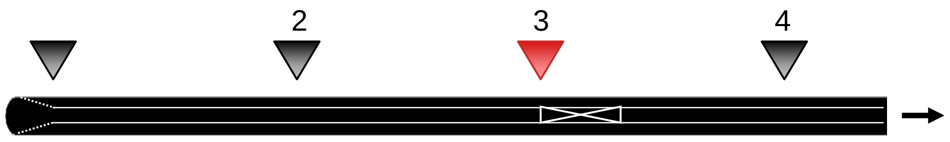
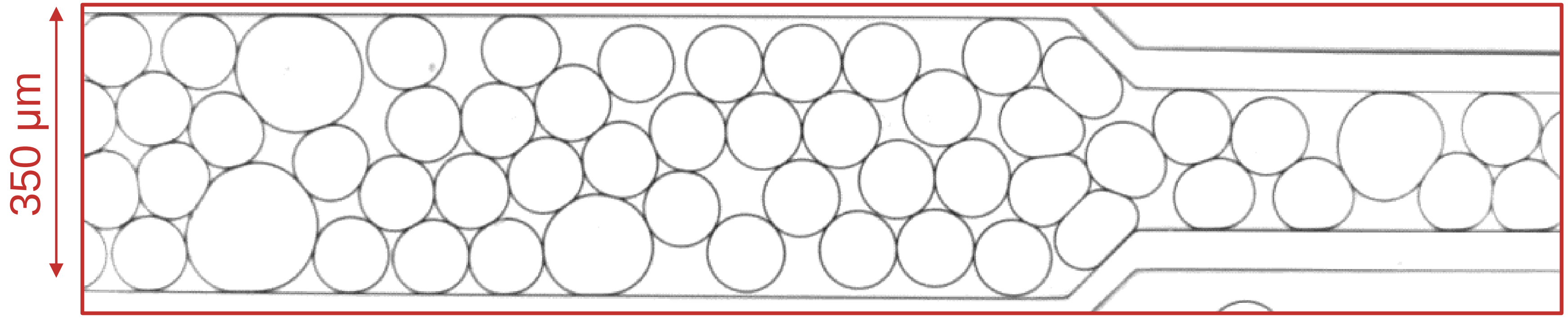
Coalescence avalanche



Metastable emulsion



Recorded: 1000 fps
Playback: 5 fps

flow

Dispersed phase
- Droplet rearrangements
- Droplet coalesce/break up

Continuous phase
- Flow profile
- Film drainage

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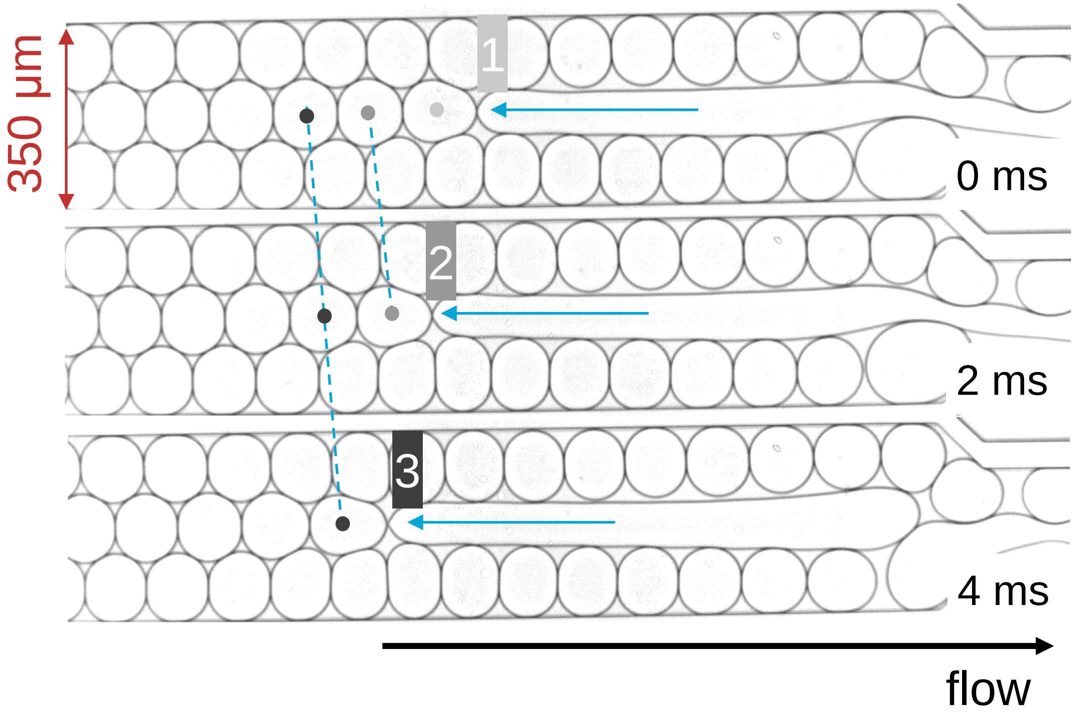
Coalescence avalanches



1. <u>Contraction</u> of leading droplet due to interfacial tension effects
2. Pressure drop in film between trailing and leading drop

➢ <u>Acceleration</u> of trailing drop

➢ Deformation of trailing drop → dilution of surfactants at interface?

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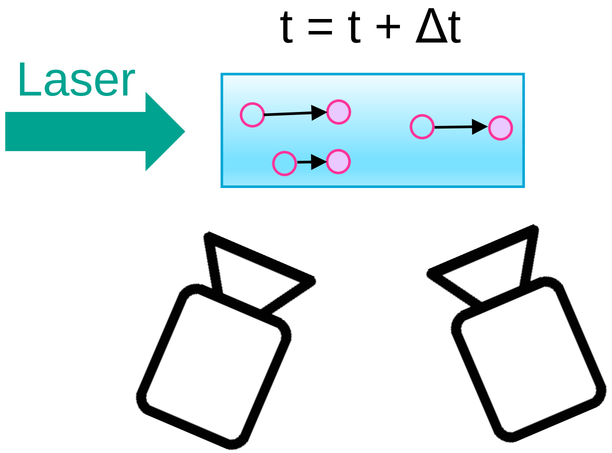
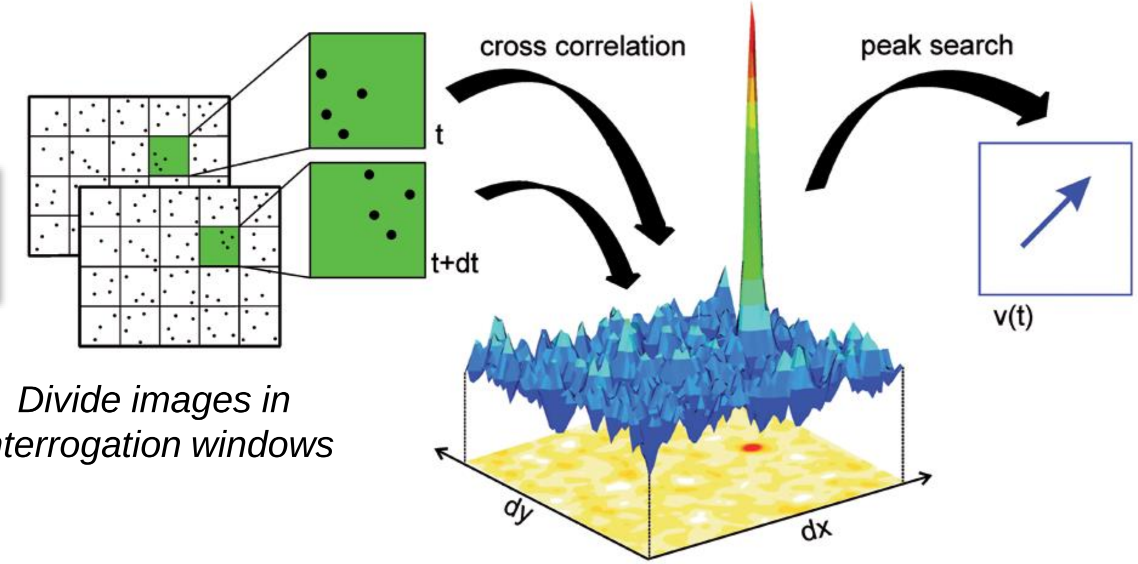
Particle Image Velocimetry (PIV)



- **350 µm**
- **1000 fps**



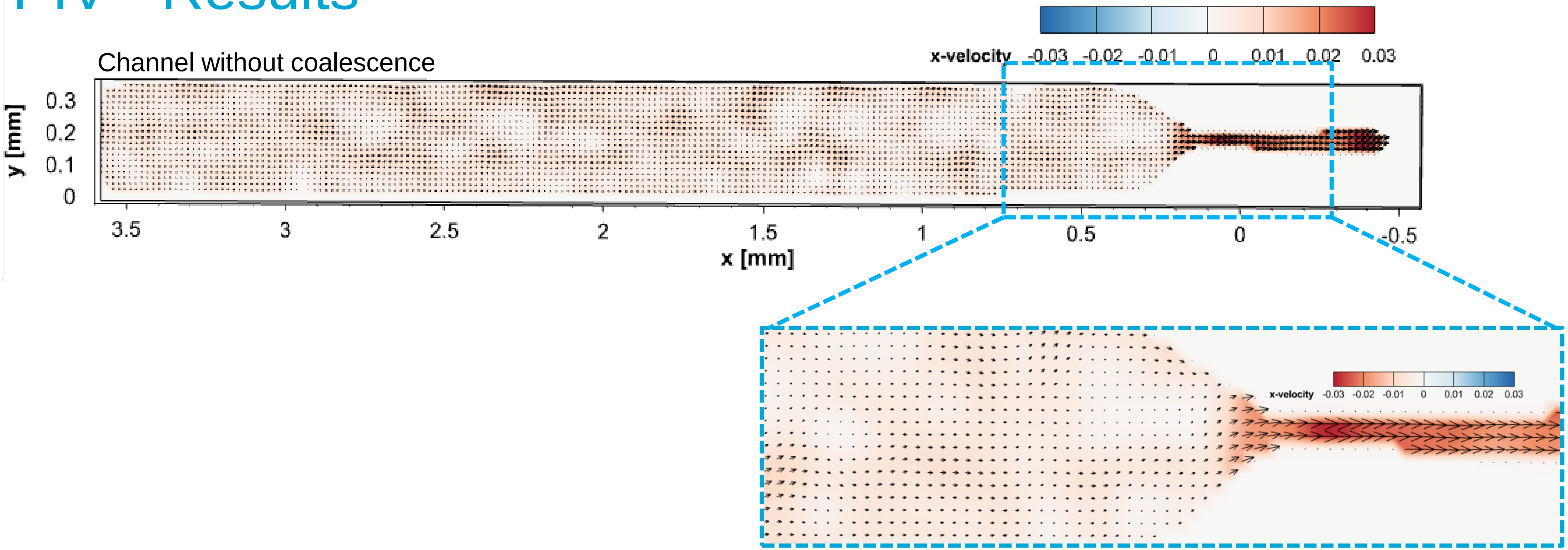
Divide images in interrogation windows

Source: PIV Poster, lavision.de

Track particles in three dimensions
→ Resolve x, y and z direction

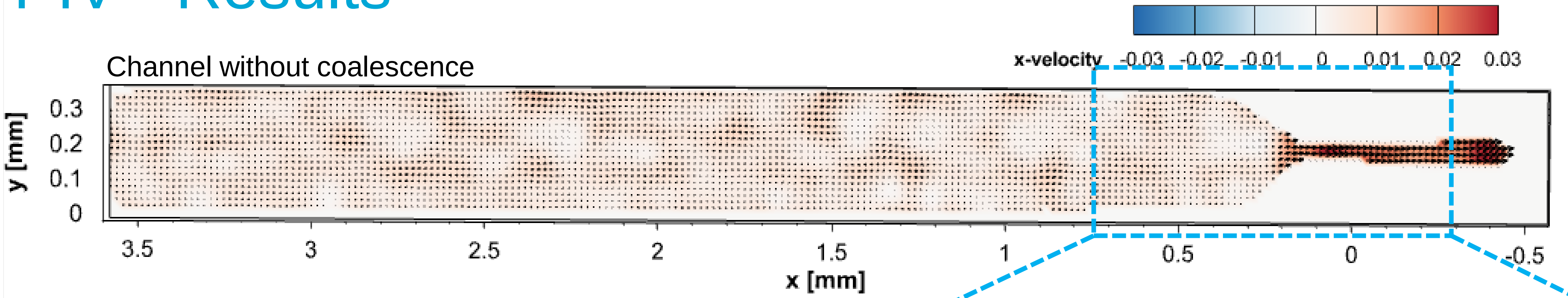
Height of channel = 55 µm
→ All particles are in the working distance

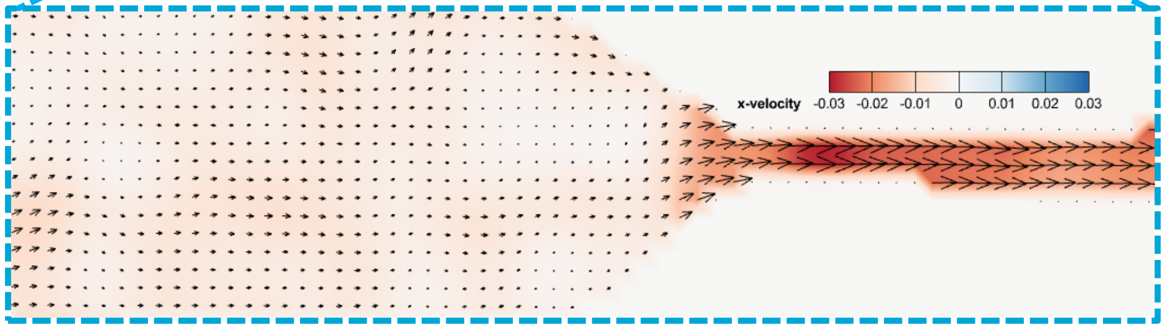
PIV - Results


Channel without coalescence
x-velocity -0.03 -0.02 -0.01 0 0.01 0.02 0.03
y [mm]
0.3
0.2
0.1
0
3.5 3 2.5 2 1.5 1 0.5 0 -0.5
x [mm]
x-velocity -0.03 -0.02 -0.01 0 0.01 0.02 0.03

PIV - Results

Channel without coalescence





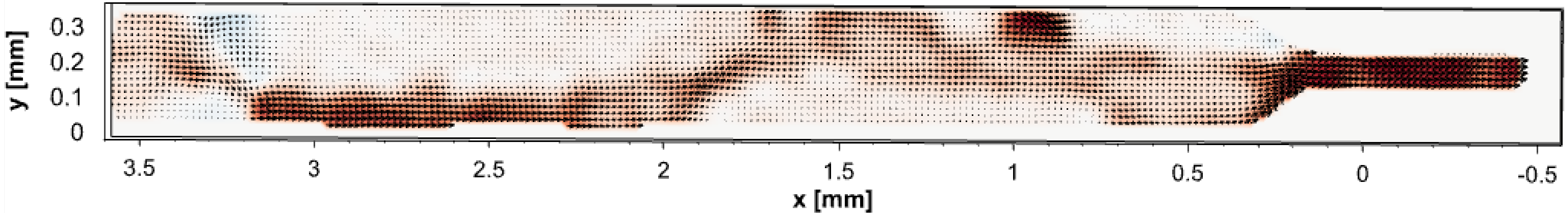
- Leading and trailing droplet accelerate
- Rotation of neighbouring droplet

→ Emptying of thin film

→ Relaxation of coalesced droplet

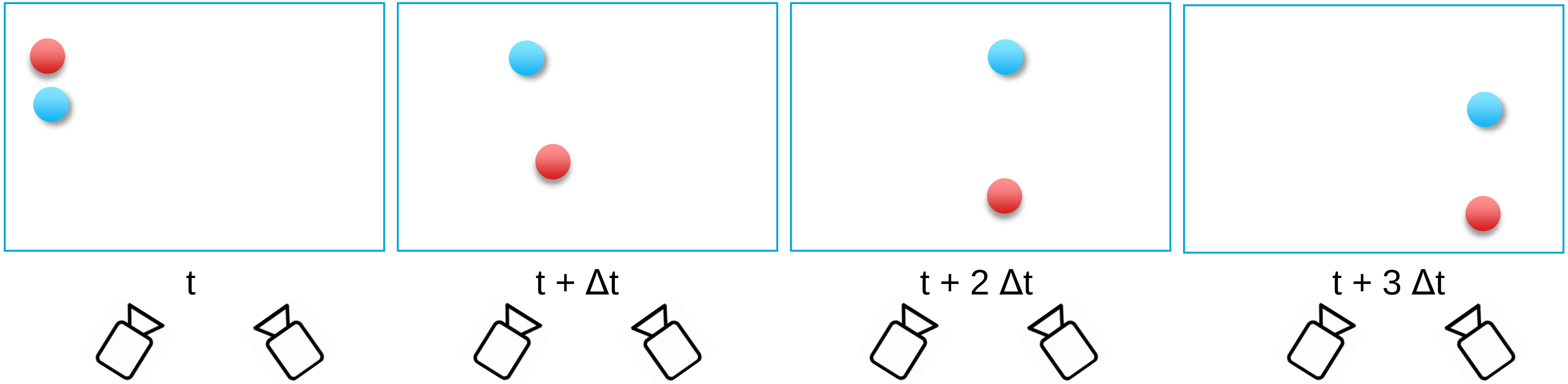
PIV provides insights in overall fluid dynamics

Channel with coalescence avalanche

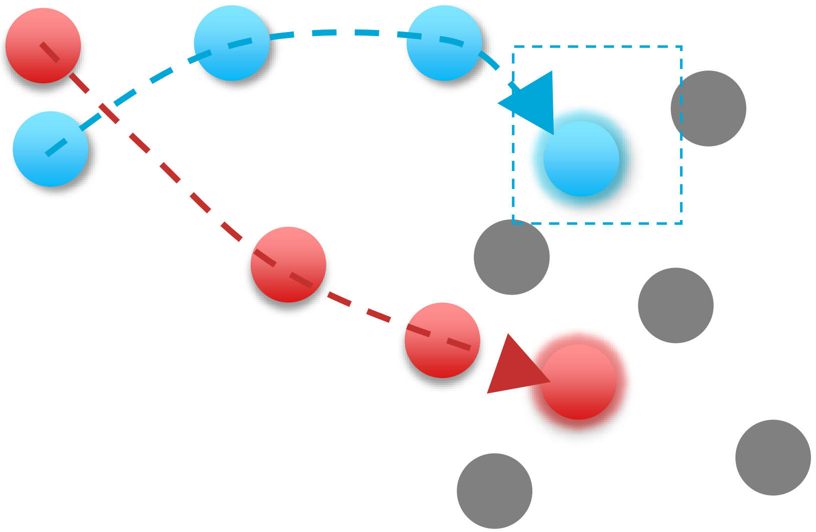


3D Particle Tracking Velocimetry (3D-PTV)

Shake the box



- No interrogation windows
- Tracking of individual particles



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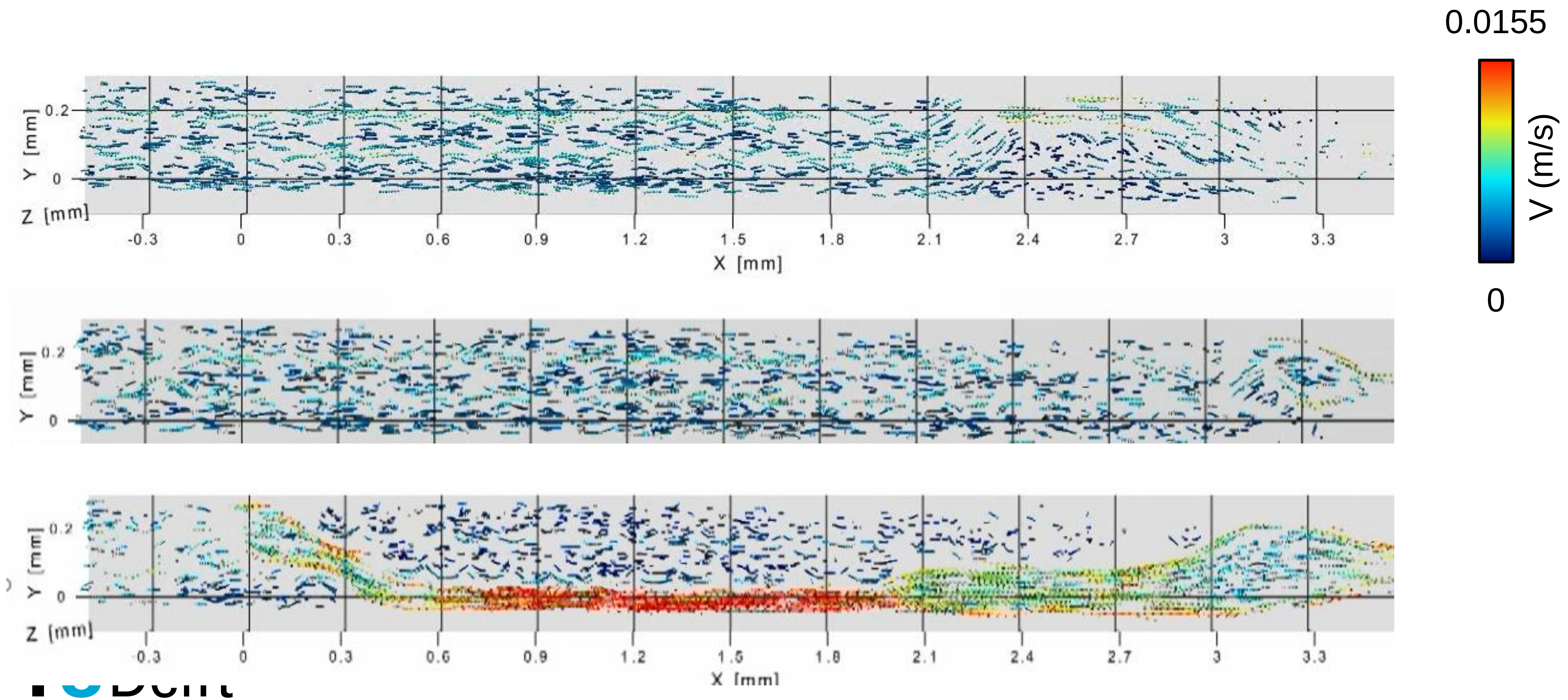
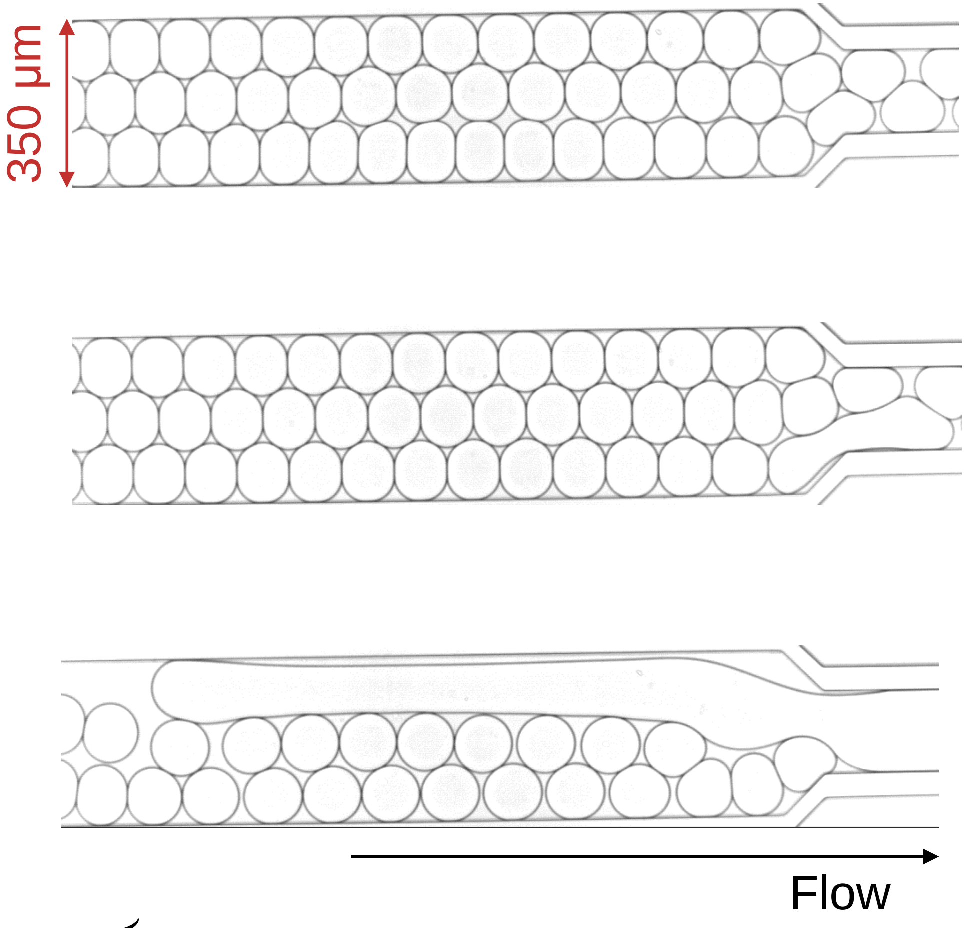
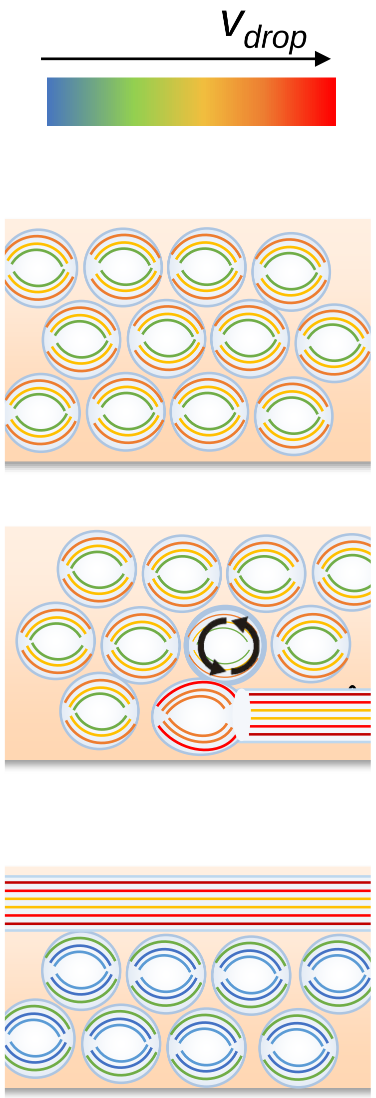
3D Particle tracking velocimetry (3D-PTV)

Shake the box



Conclusion w/o emulsions





1. Acceleration of leading droplet
2. Pressure drop between trailing and leading drop
3. Acceleration & deformation of trailing drop
4. Relaxation of coalesced droplet → propagation

Internal flow coalesced droplet > initial flow

Generalize insights
→ Effect of fluid & surfactant properties on coalescence avalanche?

Thank you!
Questions?

Acknowledgements:

Volkert van Steijn, Bijoy Bera, Christiaan Schinkel

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