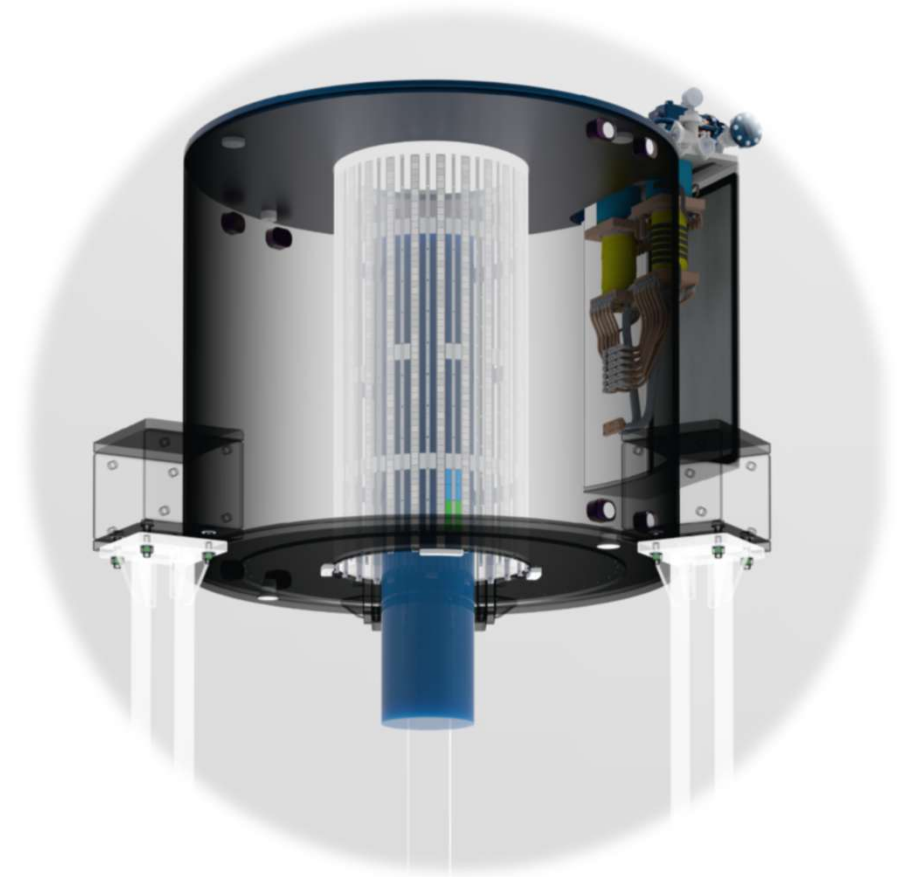


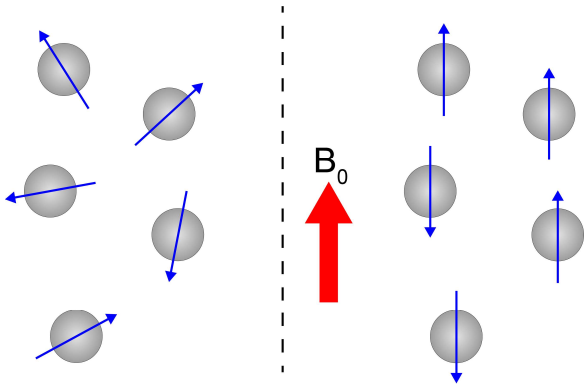
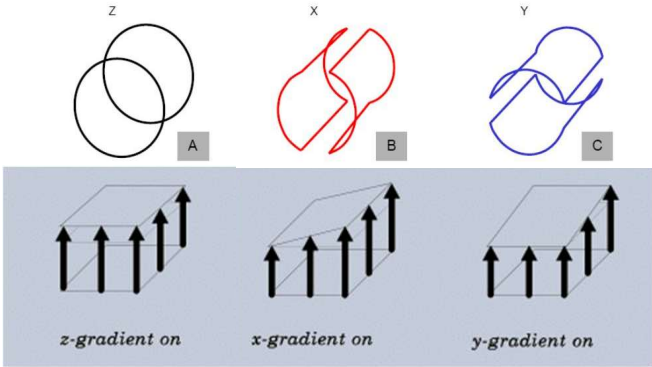
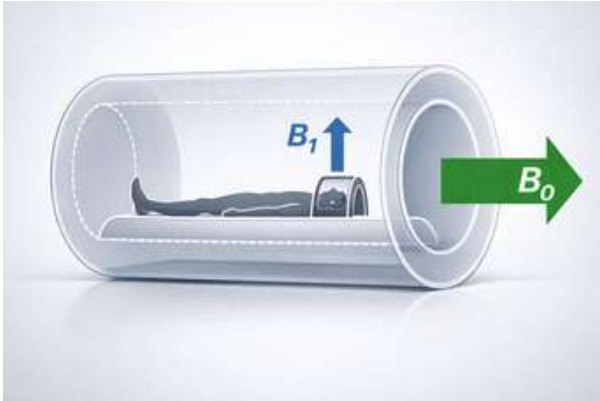
# A novel view into aerated stirred tanks: Magnetic resonance imaging (L25)

**Till Lenczyk<sup>1</sup>, Noah v. Schnitzler<sup>2</sup>, Stefan Benders<sup>1</sup>,  
Michael Schlüter<sup>2</sup>, Alexander Penn<sup>1</sup>**

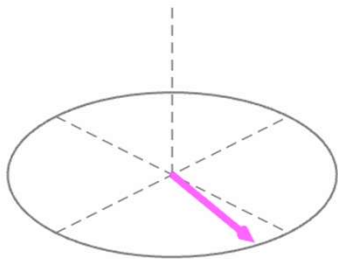
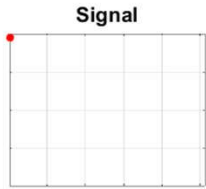
1 Institute of Process Imaging, Hamburg University of Technology (TUHH), Hamburg, Germany  
2 Institute of Multiphase Flows, Hamburg University of Technology (TUHH), Hamburg, Germany



# MRI introduction

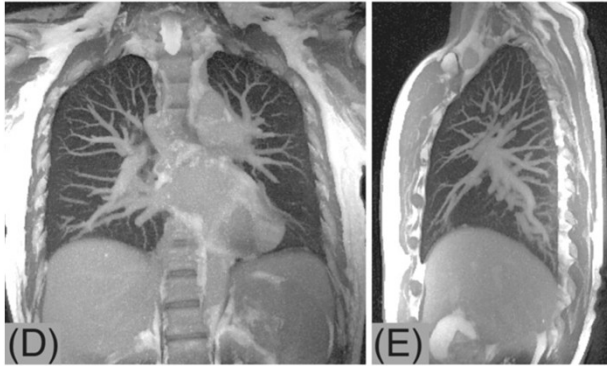


<https://maxfacts.uk/>

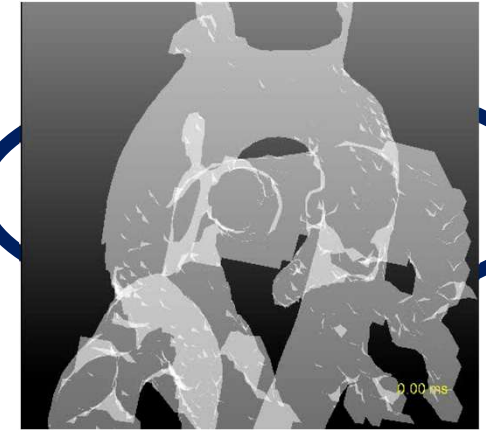


<https://mriquestions.com/>

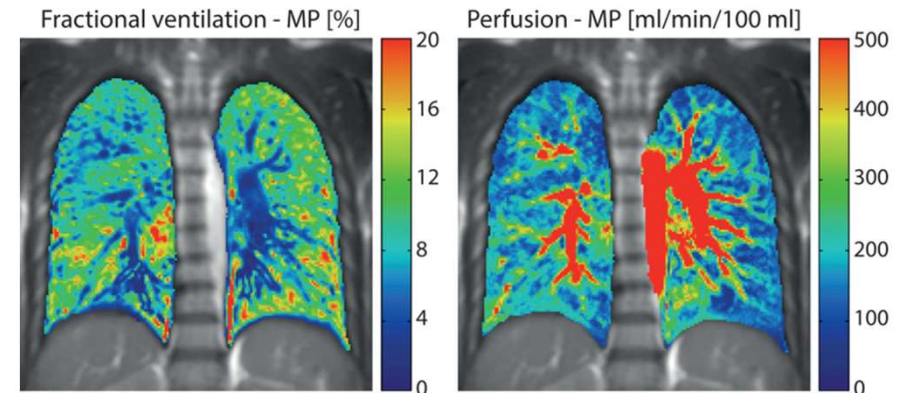
# MRI introduction



G. Baumann, University Basel



G. Crelier, ETH Zürich



G. Baumann, University Basel

TUHH MRI  
setup

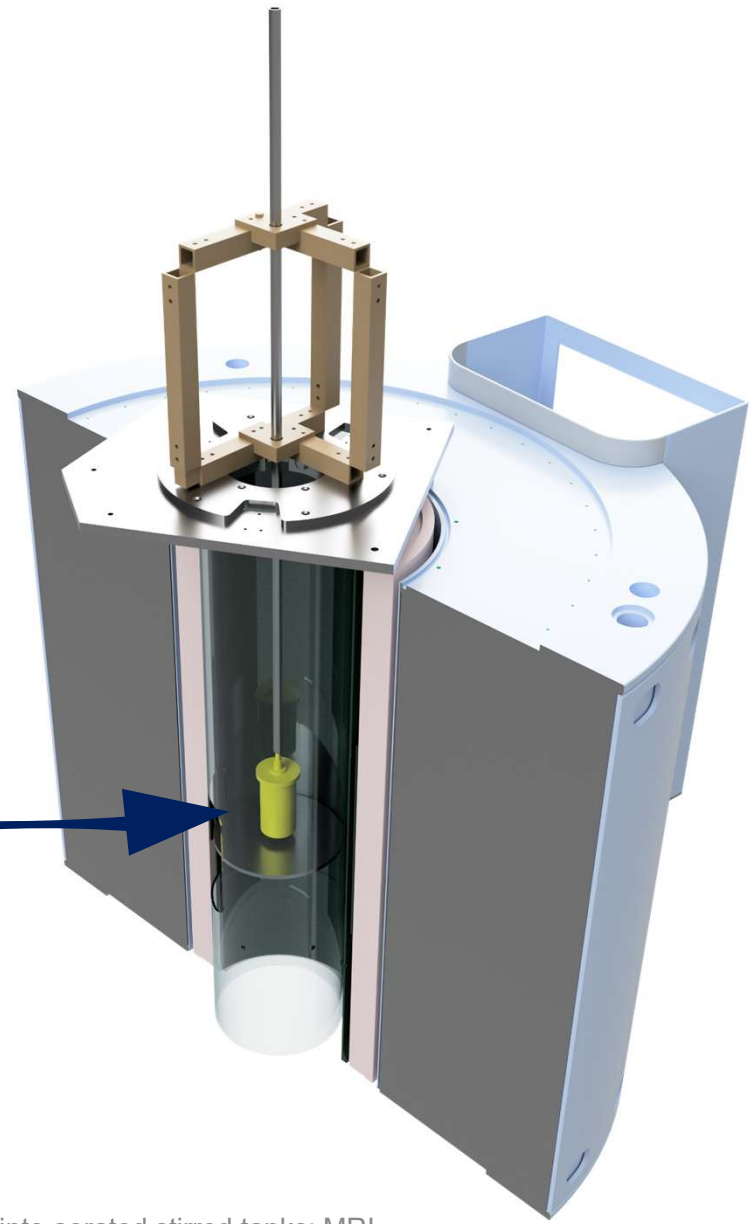
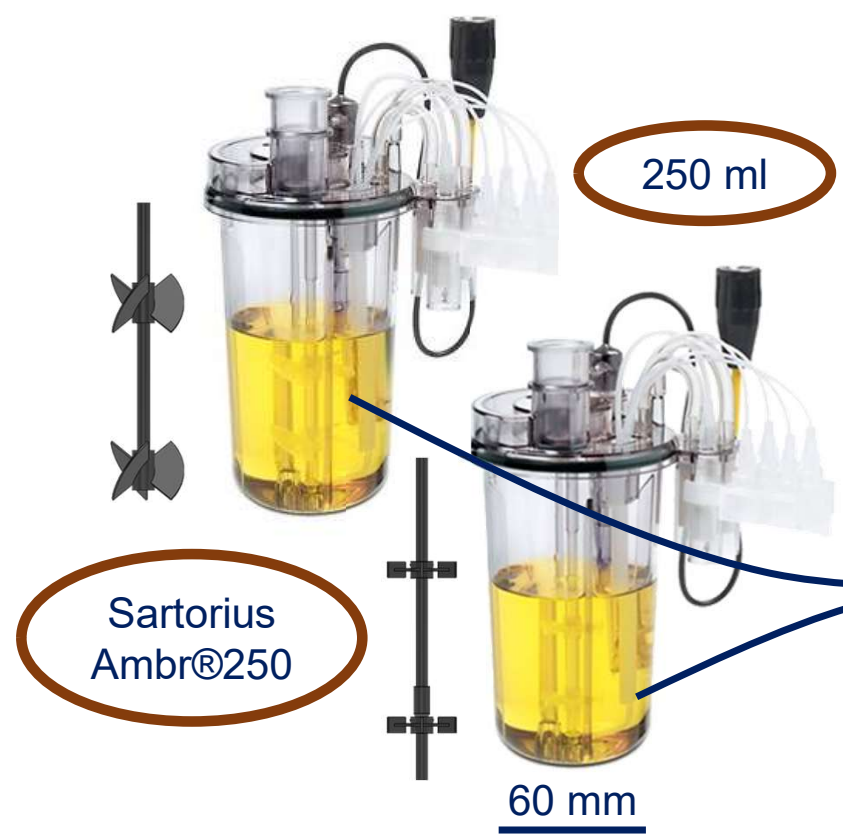
Material  
contrast



Flow

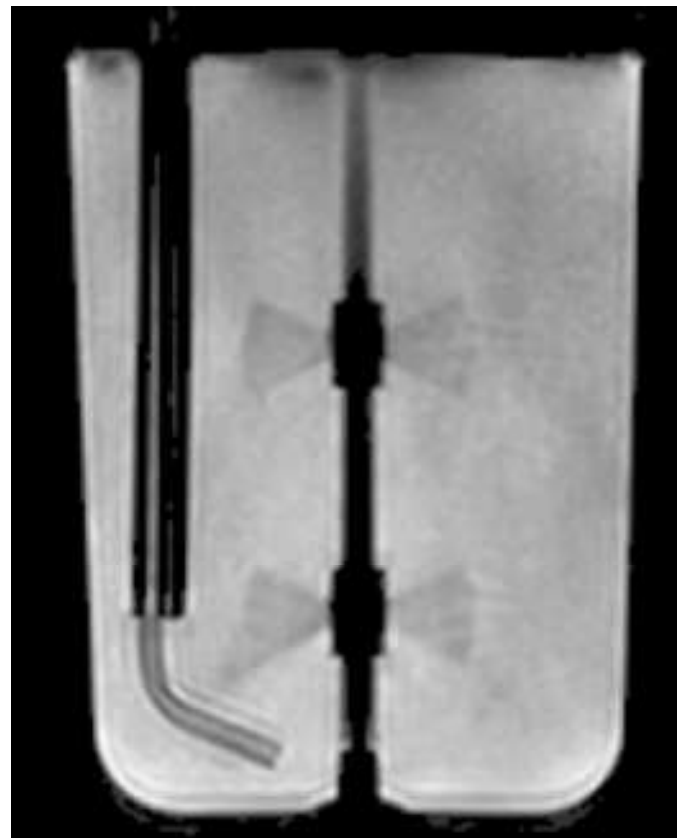
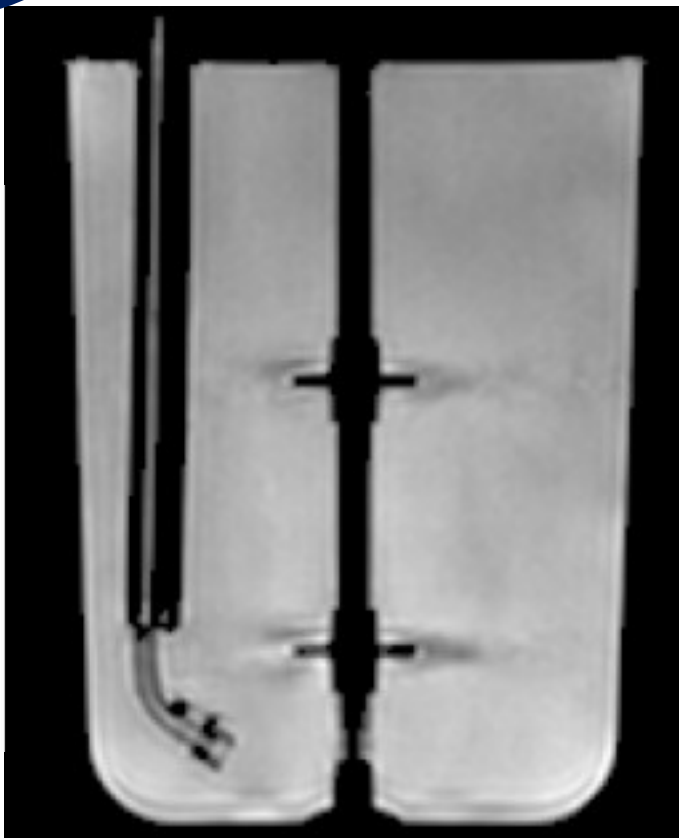
Gas content

Experimental  
setup

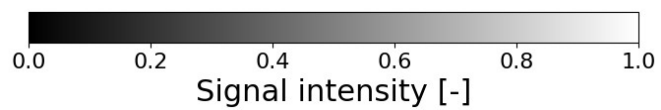


Material  
contrast

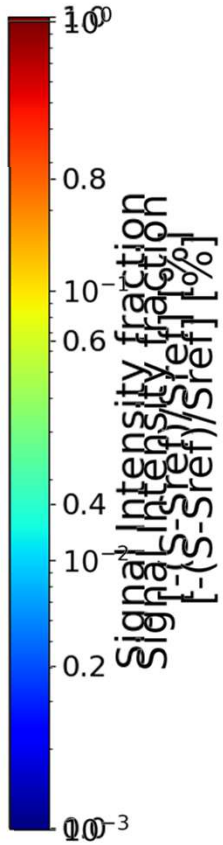
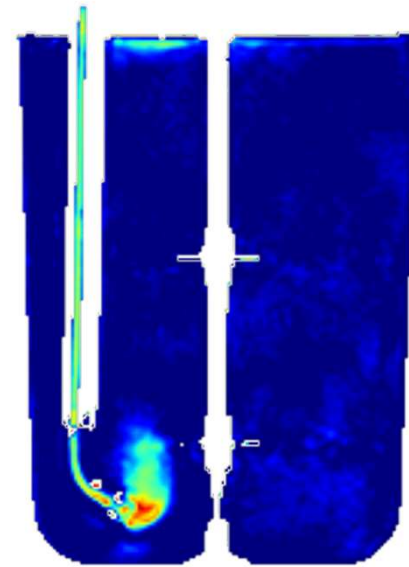
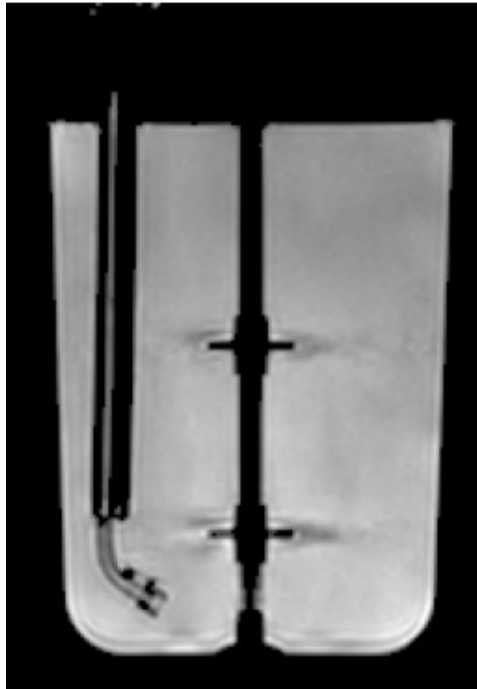
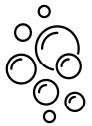
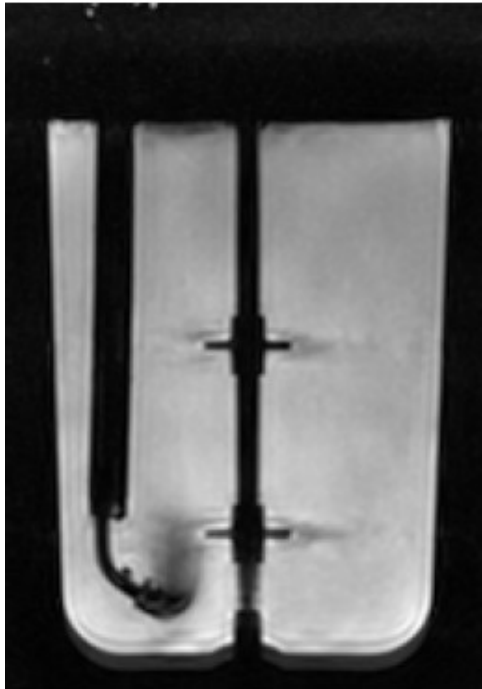
350 rpm



60 mm



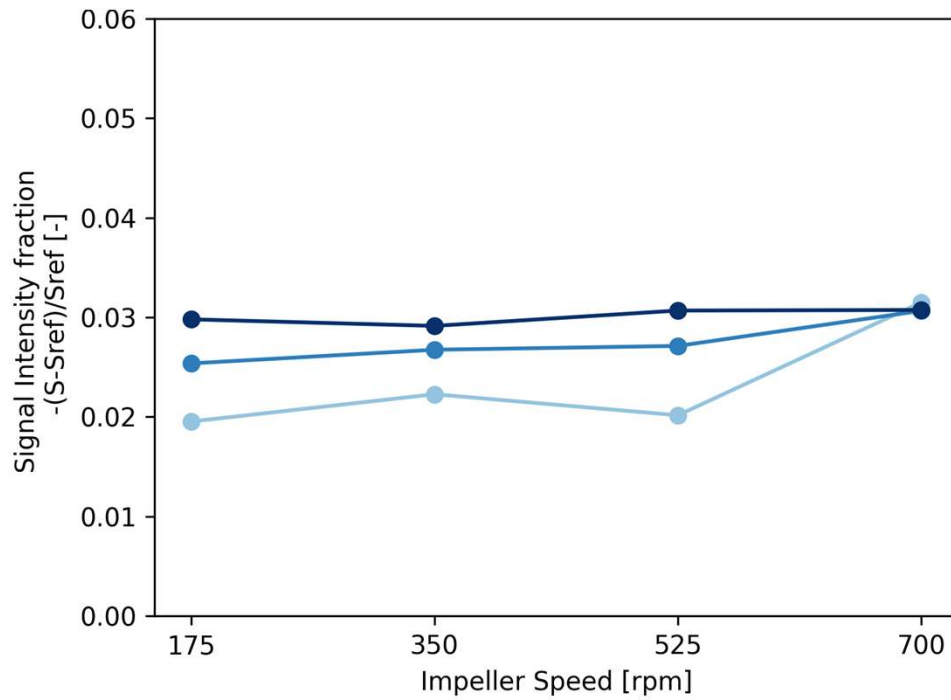
Gas  
content



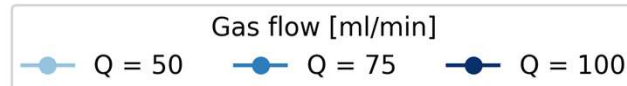
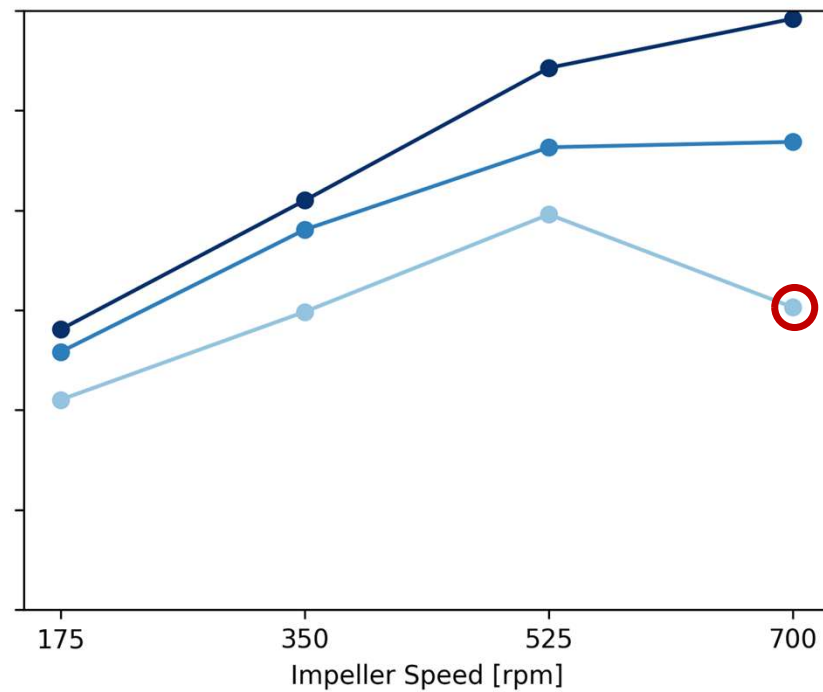
# Gas content



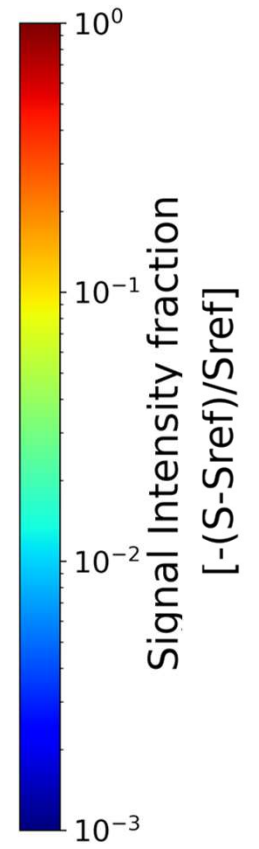
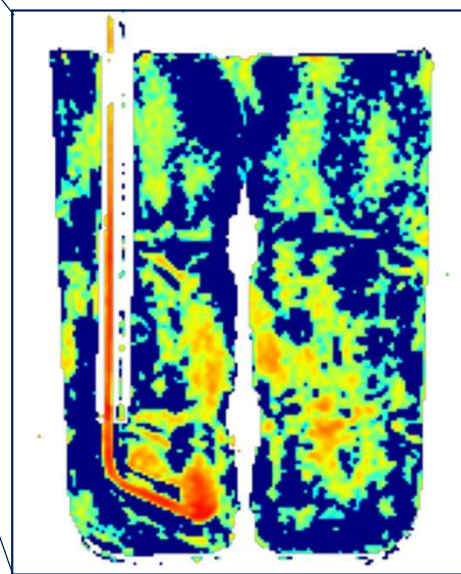
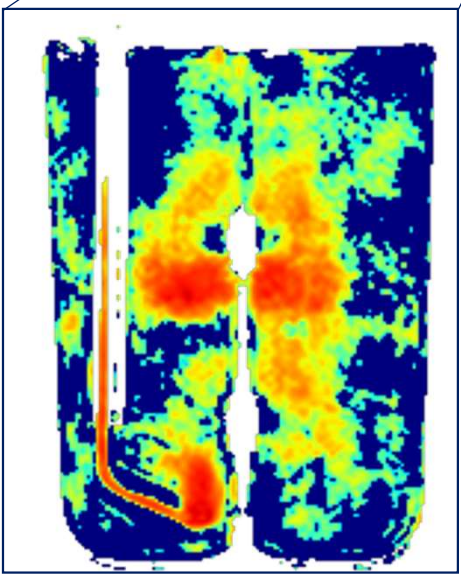
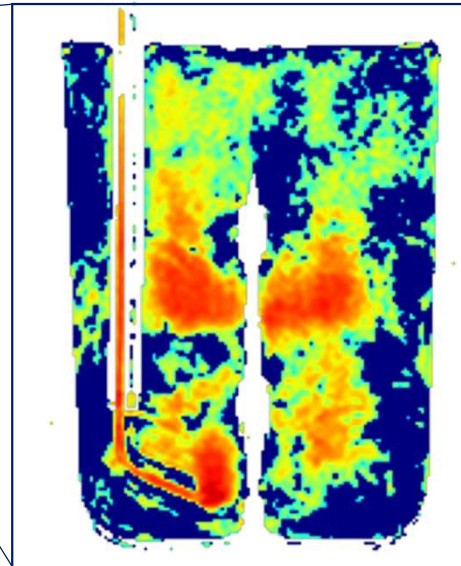
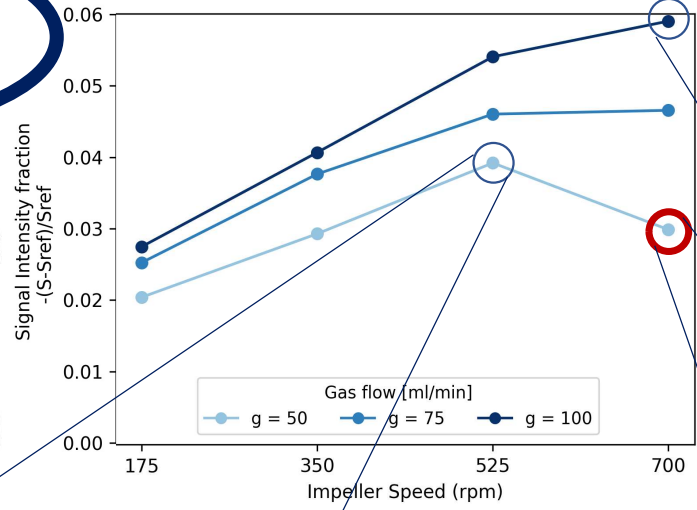
### Rushton



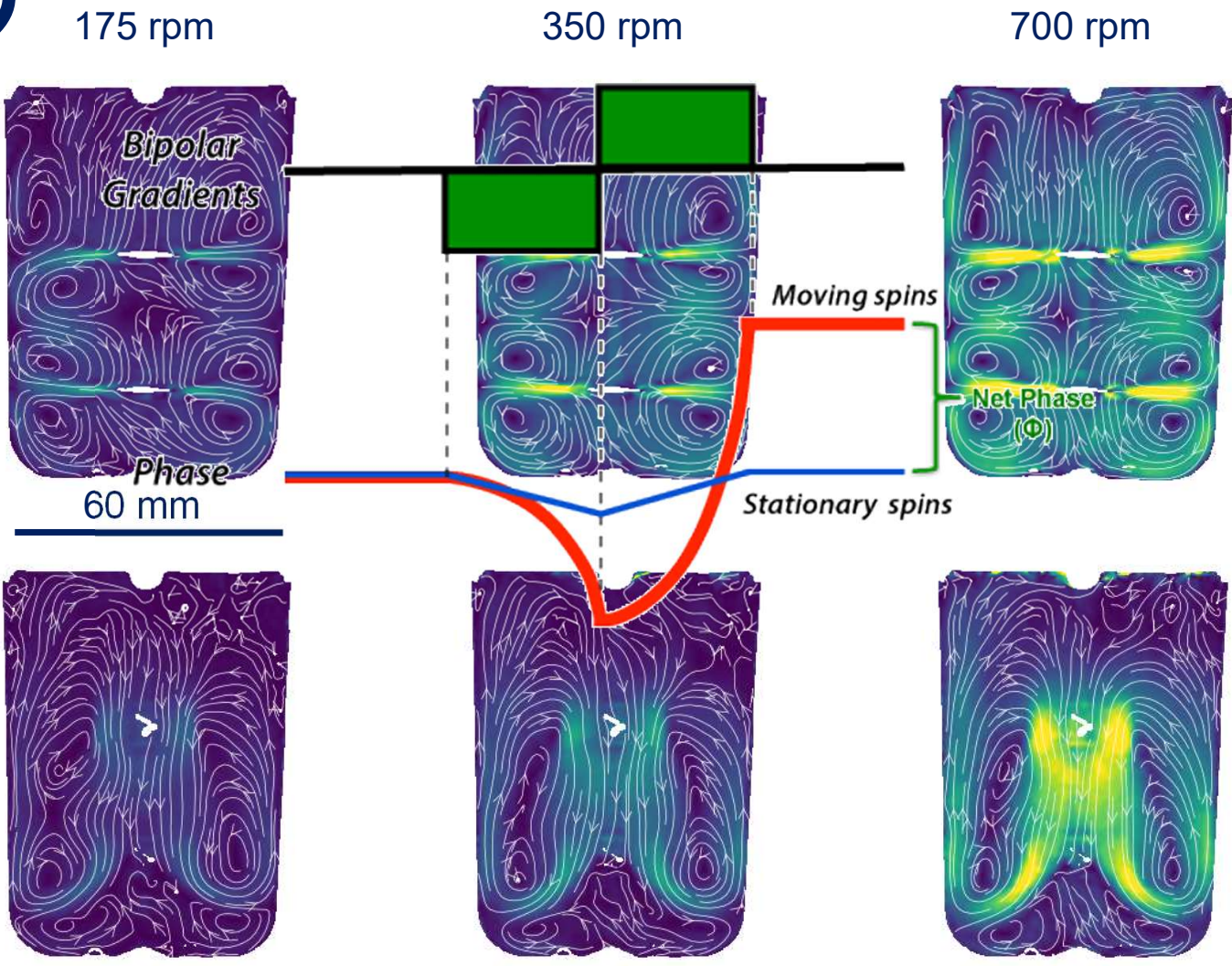
### Pitched-blade



Gas  
content



Flow

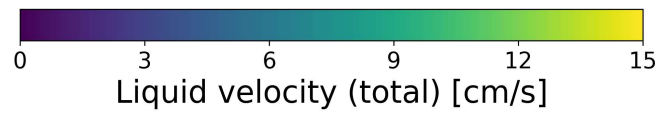


Flow

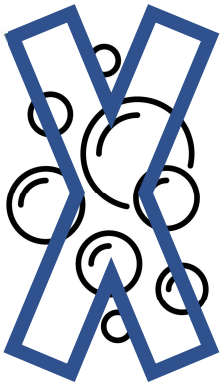


60 mm

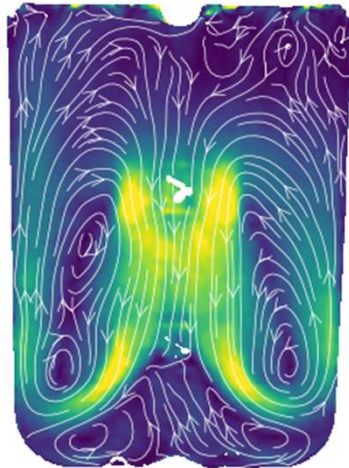
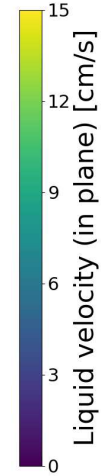
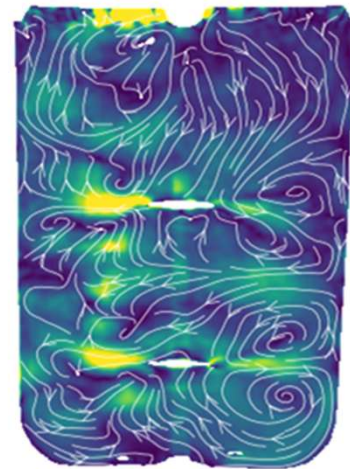
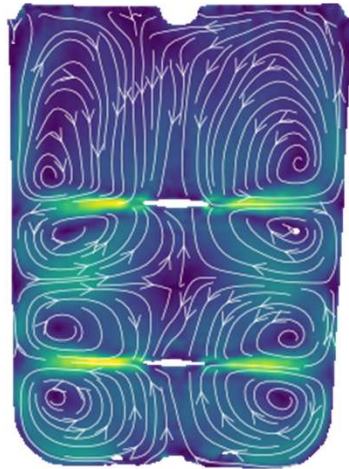
350 rpm



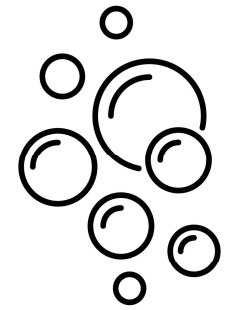
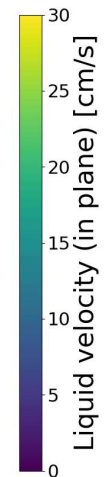
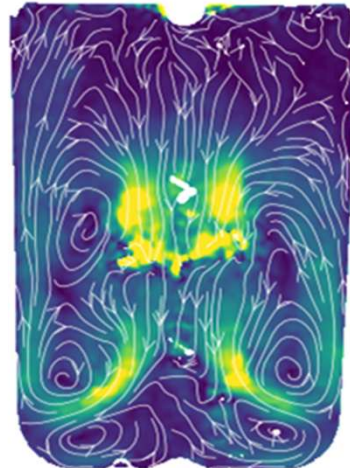
Flow



0 ml/min



700 rpm

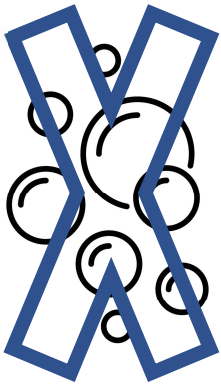


100 ml/min

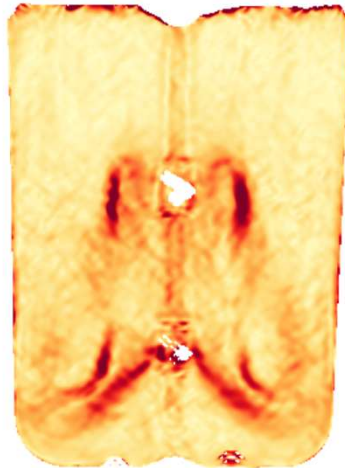
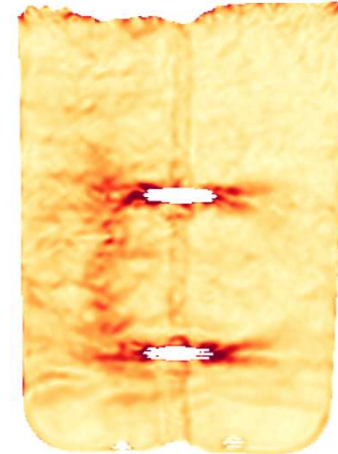
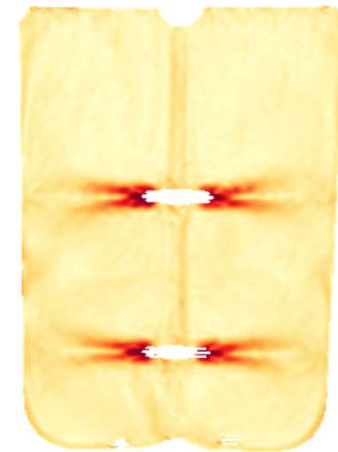
Flow  
Shear rate

$$\dot{\gamma} = \sqrt{2 \left( \left( \frac{du_x}{dx} \right)^2 + \left( \frac{du_y}{dy} \right)^2 + \left( \frac{du_z}{dz} \right)^2 \right) + \left( \frac{du_x}{dy} + \frac{du_y}{dx} \right)^2 + \left( \frac{du_x}{dz} + \frac{du_z}{dx} \right)^2 + \left( \frac{du_y}{dz} + \frac{du_z}{dy} \right)^2}$$

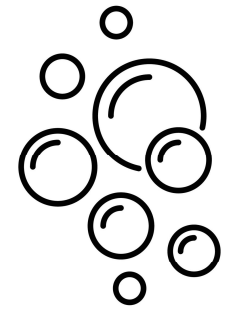
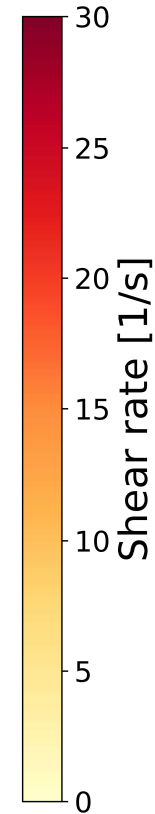
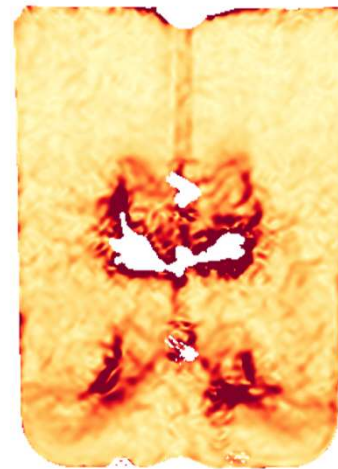
Bird et al. (1960)



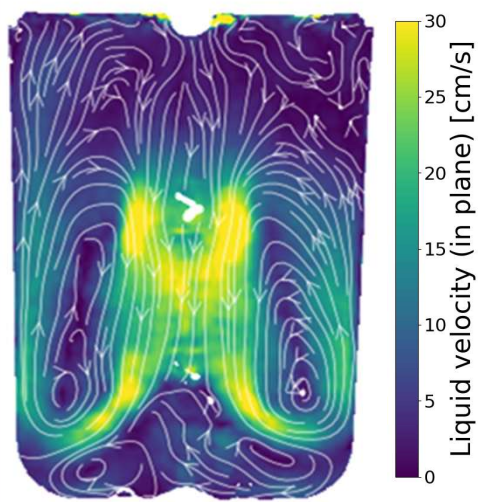
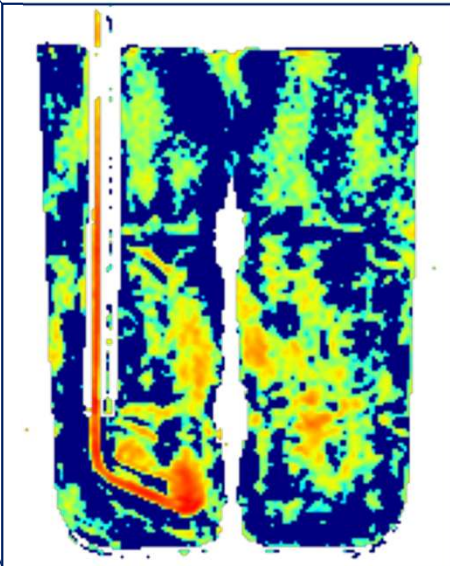
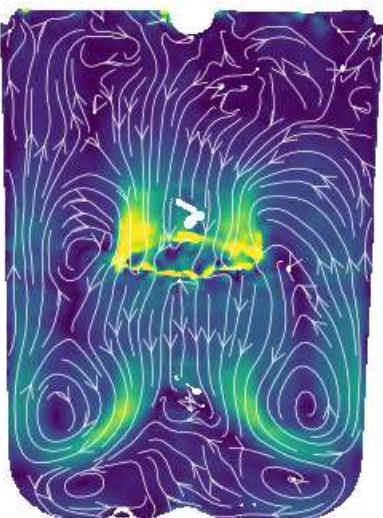
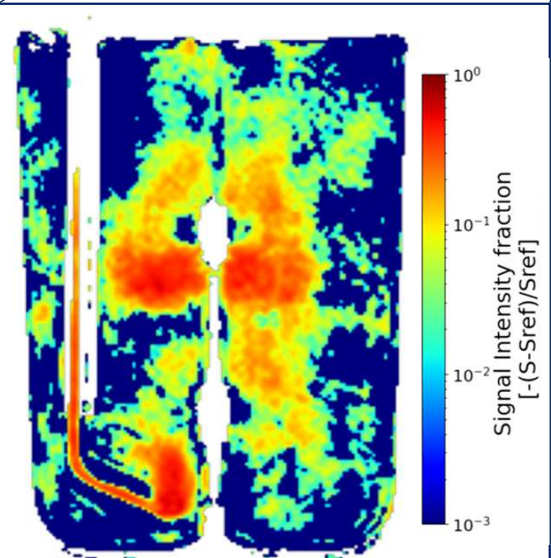
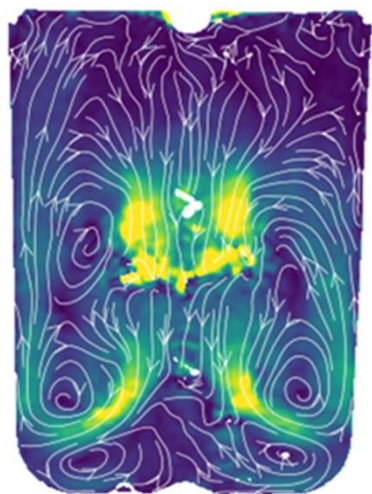
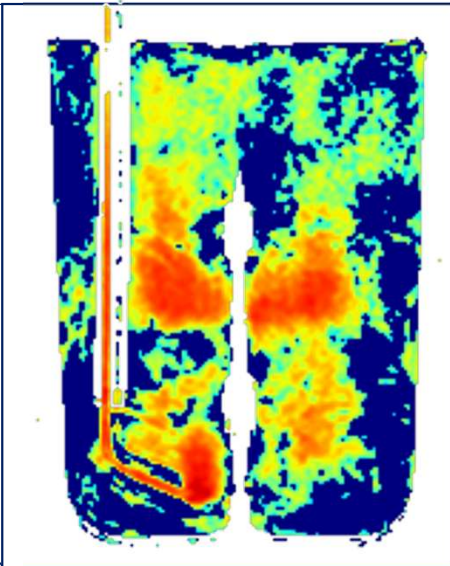
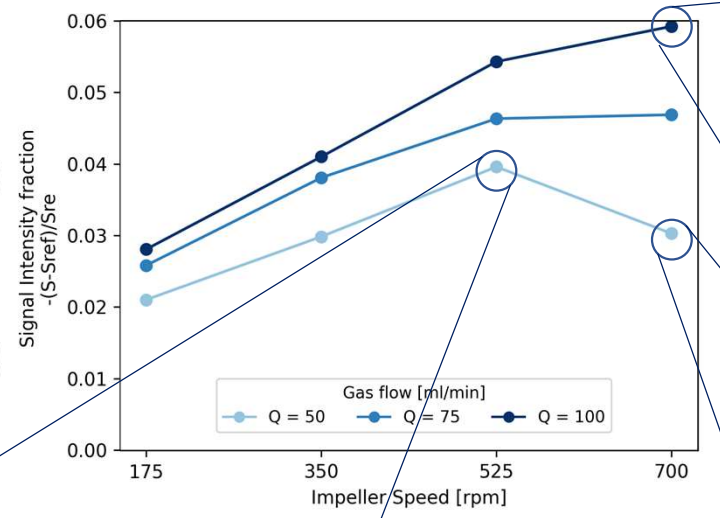
0 ml/min



700 rpm



100 ml/min

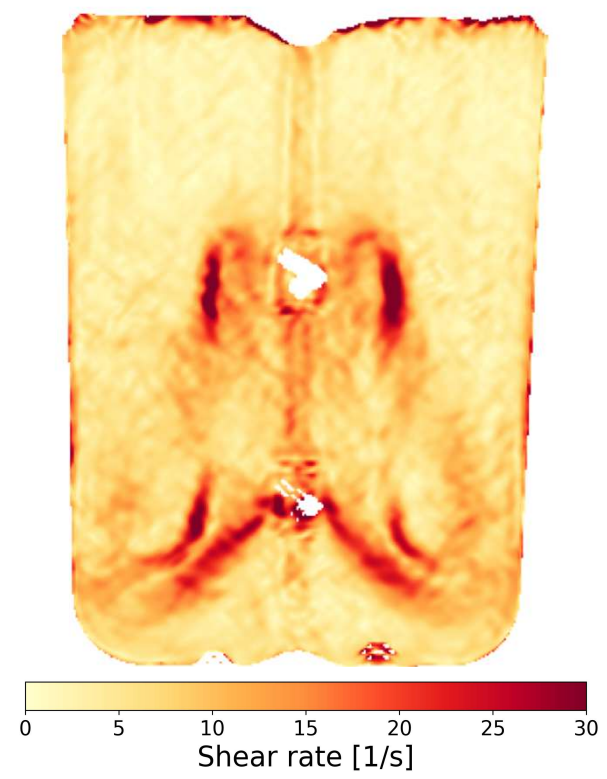
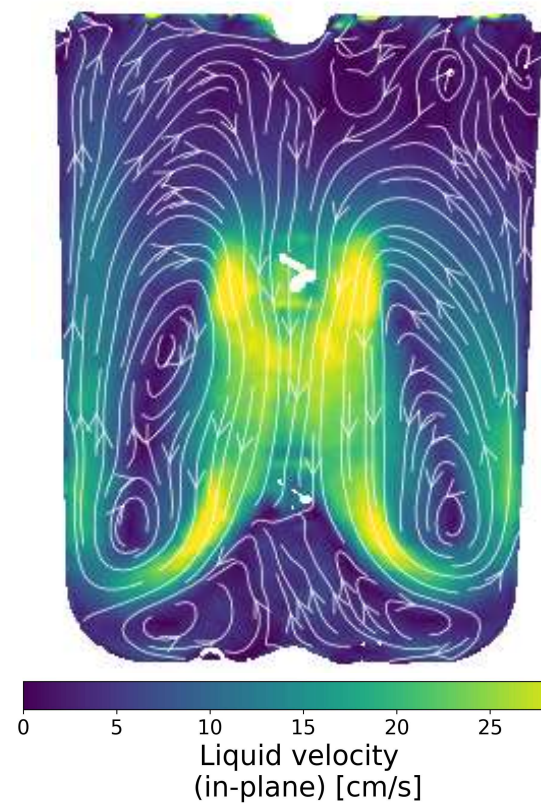
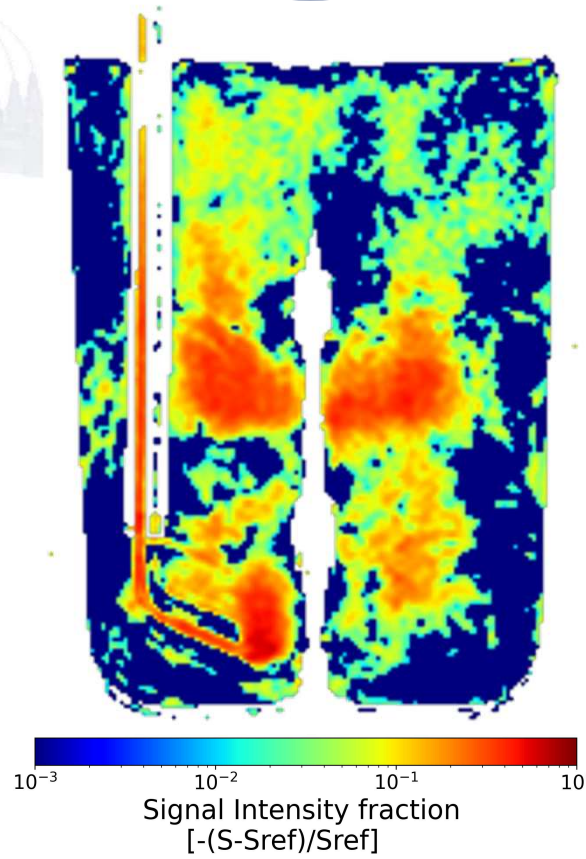


Summary

Gas  
hold-up

Velocity  
distribution

Shear-rate  
distribution



# Outlook

## Verification & Quantification of gas-liquid data

**Advances in Fluid Dynamic Stirred Tank Characterization – Opportunities of using MRI**  
Noah v. Schnitzler, Till Lenczyk, Boris Hübner, Jürgen Fischen, Thomas Wucherplang, Alexander Penn, Michael Schülter

**Motivation and Objective**

- Process characterization at large (200 l) and expansion of size range in process engineering
- Optical setup for process development and early system processControl
- Real-time monitoring of gas-liquid interface
- Use of MR as tomographic measurement technology
- Optical measurement compared to validation-reference measurement of the system in laboratory-scale experiment
- Validation of opaque media

**Ambrico Geometry**

**MRI Setup**

- Installation of vertical size (10 cm) in thickness
- Continuous measurement for 3 min with each measurement point
- Reference to large diameter correlates with gas interface

**Optical Setup**

- Non-contact with backlight
- Reference to large diameter correlates with gas interface

**Data Distribution Measurements**

**MRI**

**Optical**

**Observations**

- Real-time differences in MR and optical measurement data in the different experimental runs
- Overall lower gas probability in MRI
- MR can be used to analyze gas flow in bioreactors
- ROI selection essential
- Opaque media analysis possible
- Further validation needed

**Outlook**

- MR measurements of large reactor
- Real-time monitoring of gas-liquid interface
- Validation of opaque media
- Further validation needed

**TUHH Hamburg University of Technology**

**Boehringer Ingelheim**

**IPI Institute of Process Imaging**

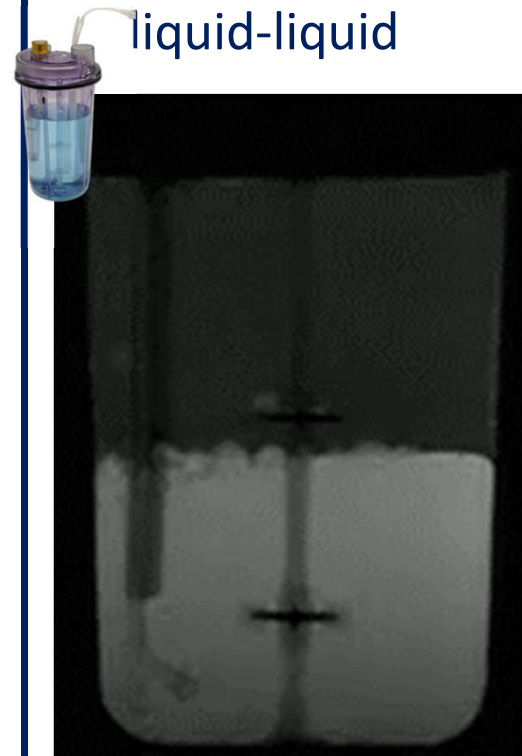


Noah v. Schnitzler

### P42: Advances in Fluid Dynamic Stirred Tank Characterization – Opportunities of using MRI

28/04/2026

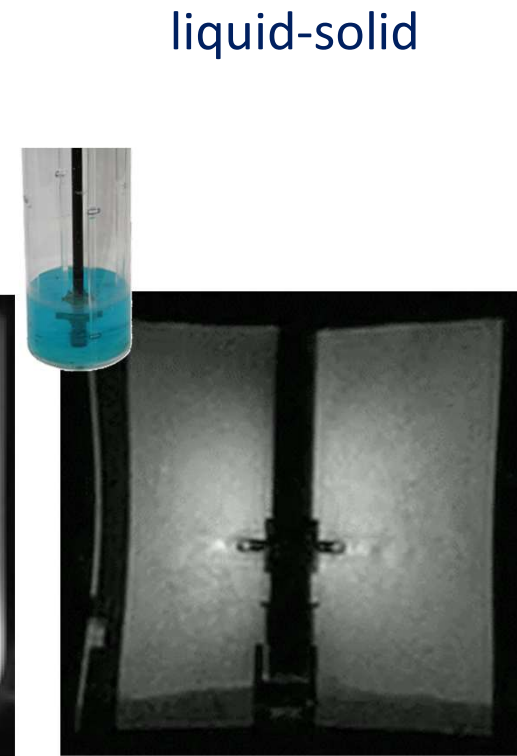
## Investigation of other complex fluid dynamic systems



60 mm



130 mm



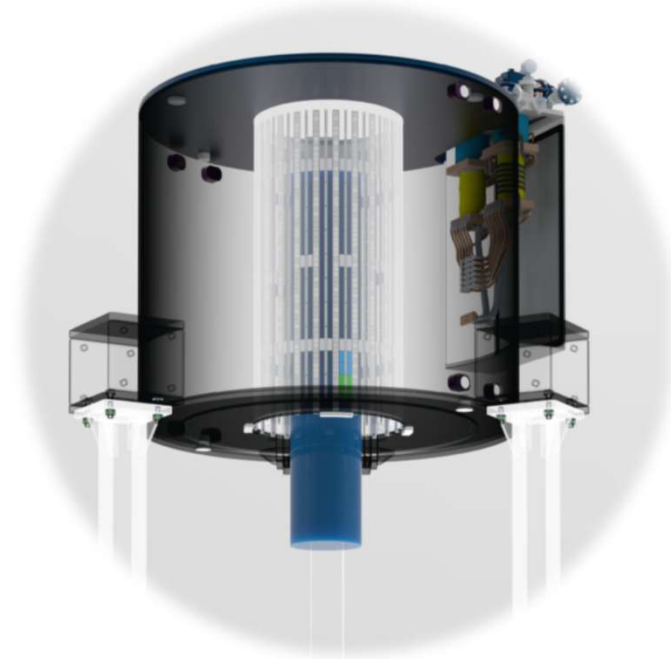
192 mm

Till Lenczyk - A novel view into aerated stirred tanks: MRI

Thank you!



**TUHH**  
Hamburg  
University of  
Technology

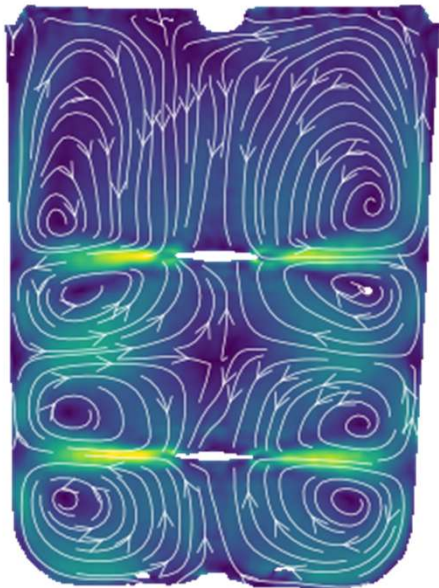


 Institute of  
Process Imaging

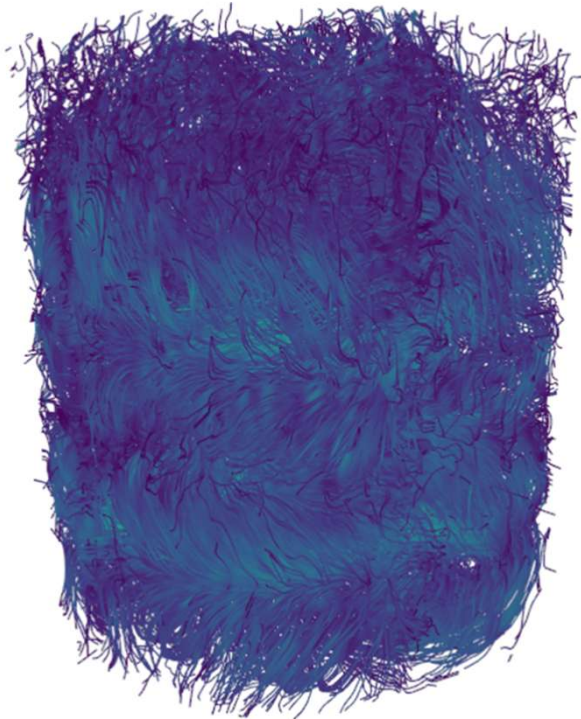


**Contact:**  
Till Lenczyk  
Institute of Process Imaging - V10  
Hamburg University of Technology  
[till.Lenczyk@tuhh.de](mailto:till.Lenczyk@tuhh.de)

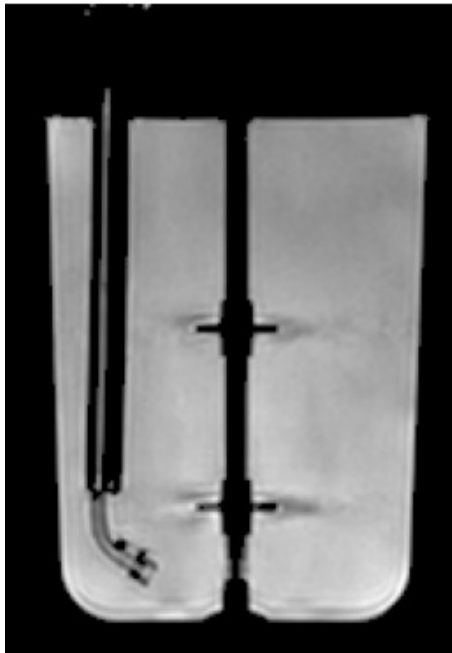




Field-of-view	82 x 110 x 10 mm <sup>3</sup>
Slice thickness	10 mm
Pixel size	1 x 1 mm <sup>2</sup>
Number of averages	20
Total scan duration	100 sec
Field-of-flow	50 cm/s (in all directions)
Echo time	5.8 ms
Repetition time	15 ms
Flip angle	30°



Field-of-view	70 x 70 x 84 mm <sup>3</sup>
Slice thickness	4 mm
Pixel size	1 x 1 mm <sup>2</sup>
Number of averages	8
Total scan duration	710 sec
Field-of-flow	50 cm/s (in all directions)
Echo time	3.2 ms
Repetition time	15 ms
Flip angle	30°



Field-of-view	82 x 110 x 2 mm <sup>3</sup>
Slice thickness	2 mm
Pixel size	0.8 x 0.8 mm <sup>2</sup>
Number of averages	16
Total scan duration	166 sec
Field-of-flow	-
Echo time	2.4 ms
Repetition time	100 ms
Flip angle	90°



