

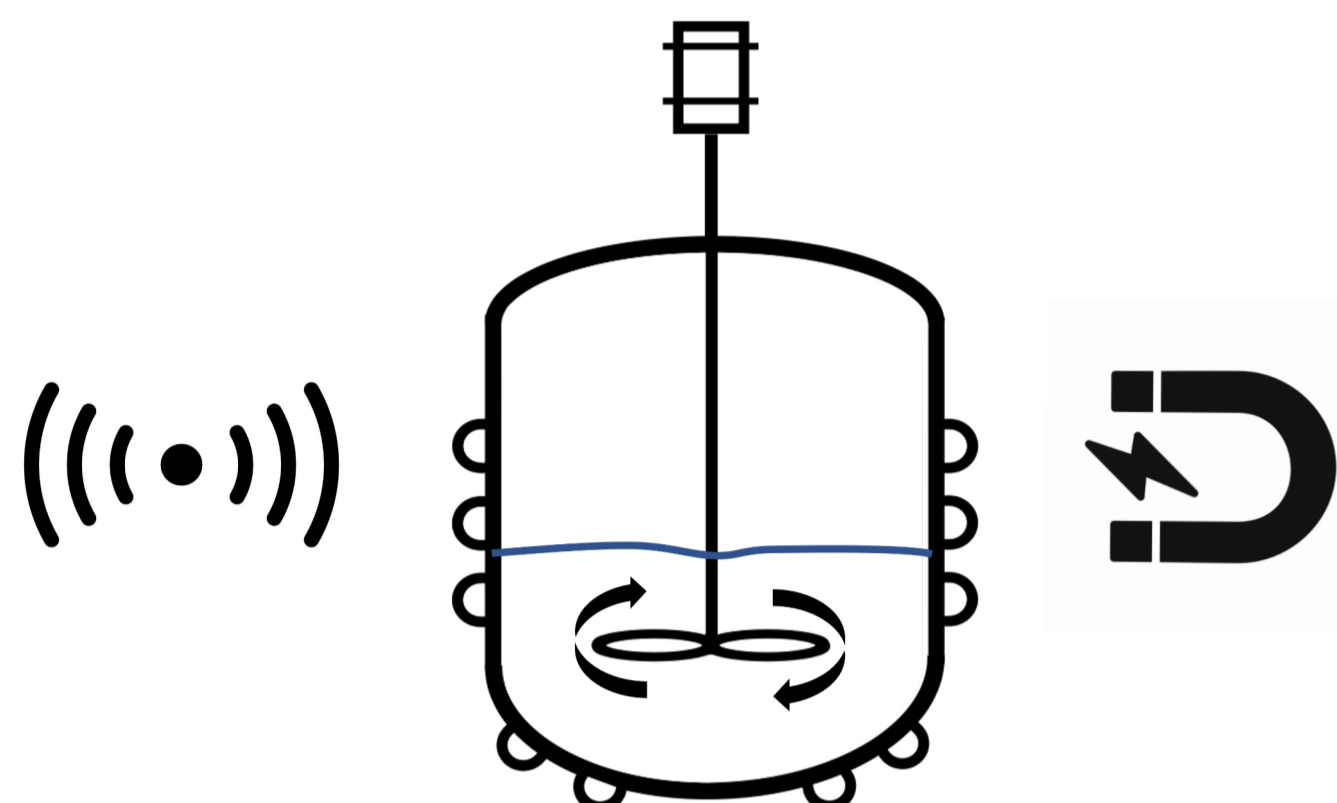
Advancements in Application of a 3T Vertical MRI System for Analysing Hydrodynamics in Stirred Tank Reactors

T. Lenczyk^a, S. Benders^a, A. Penn^a

^aInstitute of Process Imaging, Hamburg University of Technology

Opportunity for MRI

MRI allows insights in complex hydrodynamic structures like stirred tank reactors (STRs), which are not yet completely understood. The lack of three dimensional data of STRs is hindering up-scaling and optimisation of (bio-)chemical processes [1].



Vertical MRI System featuring multi-purpose platform

The vertical design of a MRI allows direct drive of a columnar STR in its original orientation. We built a platform for mounting a wide range of STRs with an OD up to 400 mm and height up to 1000 mm.

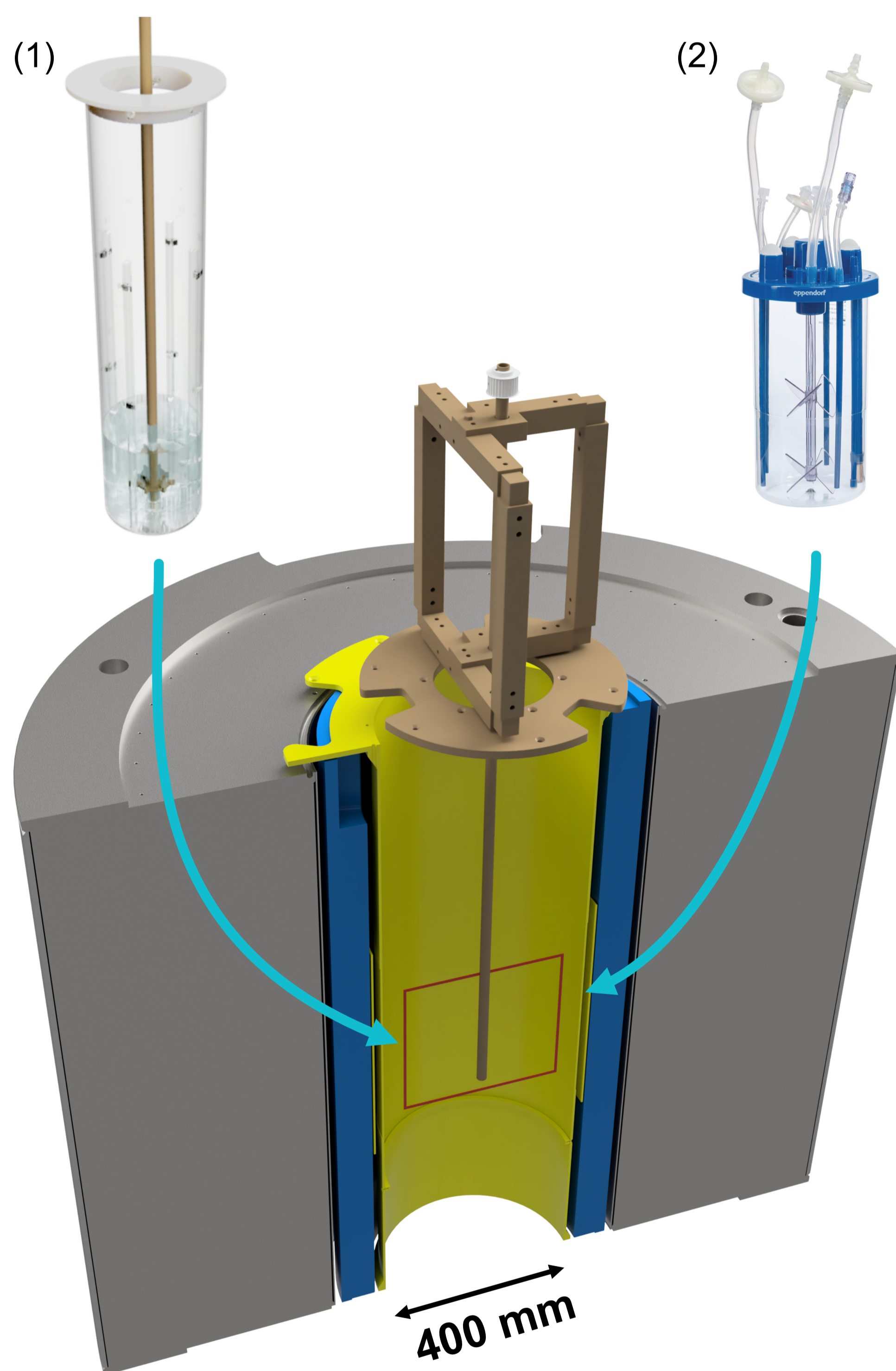


Figure 1. Rendering of custom-built STR (1) for maximum size and a commercial BioBlu© 1c Single-Use Bioreactor (2) by Eppendorf [2].

Blue: Gradient coil; Yellow: Tx/Rx Body coil; Red: Field-of-view (FOV)

MRI parameters

Fluid	Copper sulfate solution
Type of scan	Phase-contrast
Velocity encoding	5 – 20 cm/s (Adapted to RPM)
Spatial res.	2 x 2 x 10 mm ³
Temporal res.	2 s
Number of signal avg.	10
STR (1)	
Receiver	Tx/Rx body coil
FOV	220 x 120 x 10 mm ³
STR (2)	
Receiver	Custom-built 15-channel Rx array
FOV	150 x 200 x 10 mm ³

High resolution three-dimensional velocity measurements of columnar STRs

Velocity maps effectively visualise flow patterns in STRs. Figure 2 (a) with STR (1) shows Taylor vortices, common with radial impellers. The horizontal slice in Figure 2 (b) presents the influence of baffles on the circulating flow.

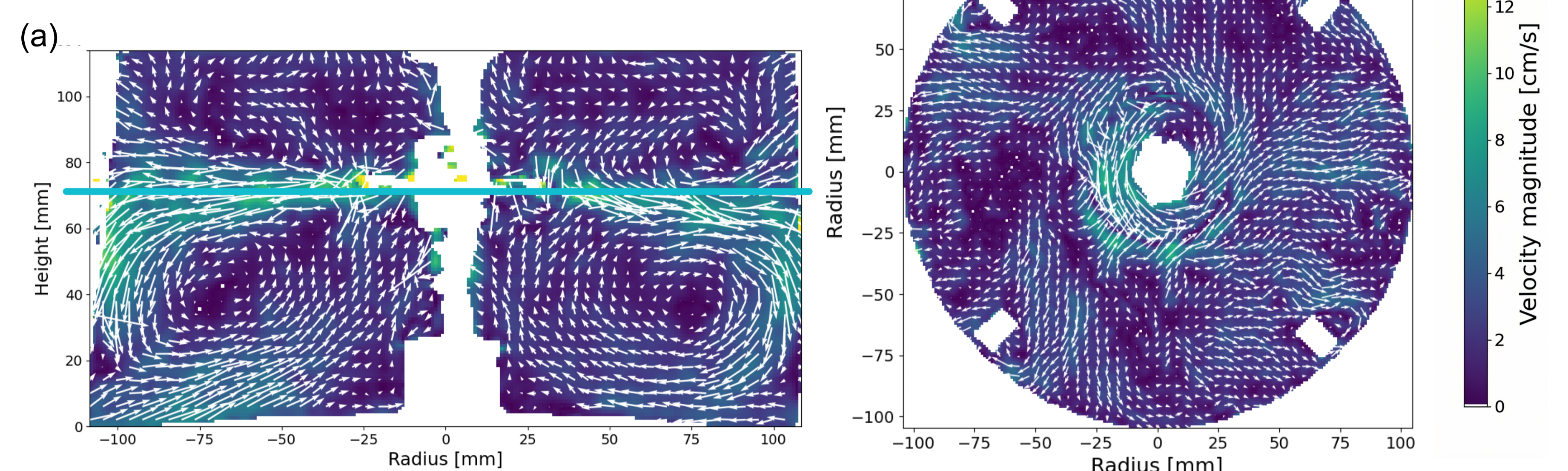


Figure 2. Velocity maps in a vertical (a) and horizontal (b) slice of STR (1) with a rotational speed of 60 RPM. For visibility reasons only every 4th vector is shown.

Figure 3 (a) shows a vertical velocity map of STR (2). The two pitched-blade impellers form four symmetrical vortices. The three horizontal slices in Figure 3 (b) - (d) illustrate how internals such as sensors and spargers affect flow. The plots in Figure 3 (e) and (f) show velocity component averages at 5 to 70 RPM.

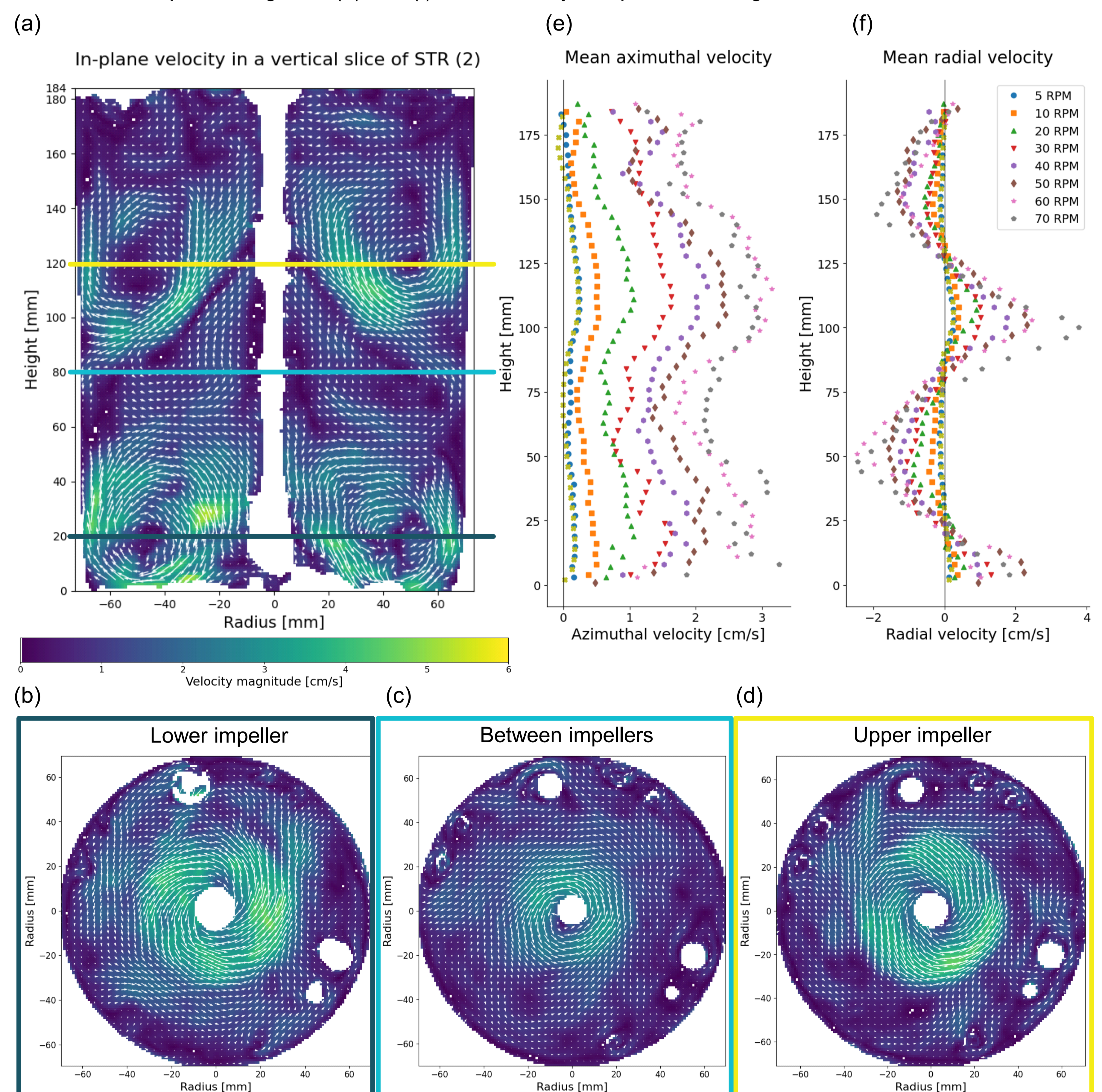


Figure 3. Velocity maps in a vertical (a) and horizontal (b-d) slices of STR (2) with 60 RPM. For visibility reasons only every 3rd vector is shown. (f) and (g) show averaged velocity components over height.

Outlook

Our first study of STRs in the unique vertical 3T MRI system shows its ability to measure flow in relevant systems in (bio-)chemical engineering. Scan parameter optimisation and improved data reconstruction will provide more insights, e.g. shear-rates and dead zones. Synchronising scans with the rotation will allow investigating the area around the impeller in more detail. We will broaden the field of application by adding particles, installing gas spargers and investigate non-Newtonian fluids.

References

- [1] Stitt, H., Chemical Engineering Journal (2002), 47-60
- [2] <https://www.eppendorf.com/de-de/Produkte/Bioprosesstechnik/Einweg-Bioreaktoren/BioBLUc-Single-Use-Bioreactors-p-PF-157954>