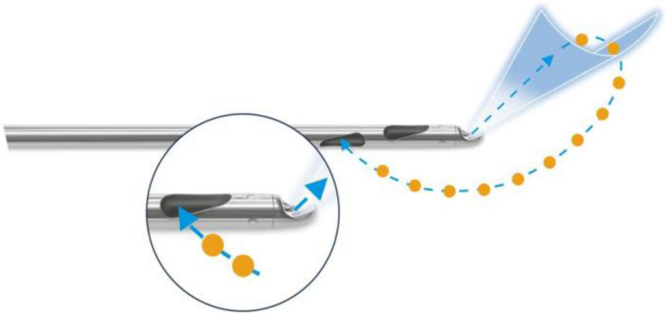
Christoph Drobek*, Robert Mau, Hermann Seitz

Tomographic Particle Image Velocimetry of a water-jet for low volume harvesting of fat tissue for regenerative medicine

BMT 2015, Lübeck, *16.09.2015*

Water-assisted liposuction (WAL)



- WAL: injection of saline+lidocaine+adrenaline through cannula, reflected over baffle

  → simultaneous aspiration of the fat tissue (fat and stem cells) very gentle

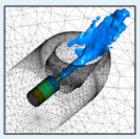
- **project goal:** development of a new WAL device with even gentler aspiration of smaller amounts of fat tissue

  → aspirated fat and stem cells stay vital to be used in regenerative medicine

Comparing CFD simulations and experimental methods

CFD simulations

Injection of water into water

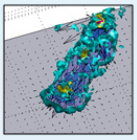


Injection of water into air

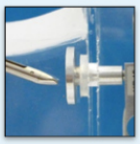
Injection into arbitrary fluids

Experimental investigations:

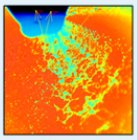
Tomographic PIV measurements (while injecting water into water)



Measurement of acting force of water-jet using force sensor (while injecting water into air)



Shadowgraphic measurements of droplet mass and velocity (while injecting water into air)



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Motivation: Velocity field measurement using PIV

- **Goal:** Identification of the velocity profile (3D3C) during infiltration

  → calculation of momentum and force

- available:

  Micro-Stereo-PIV (LaVision)

- for the project: extension/conversion to **Tomographic PIV**

Working principle of Tomographic PIV

- similar to Stereo-PIV, min. 2 cameras, typical 3-4 cameras
- Volume reconstruction from camera images
- correlation of both reconstructed volumes

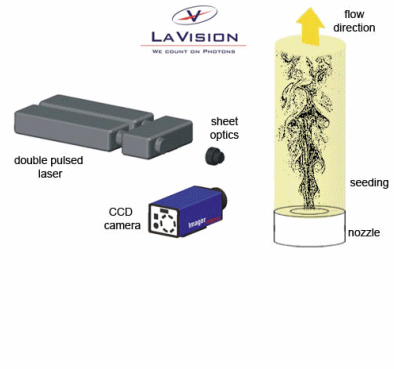

Figure: Working principle of PIV [LaVision]

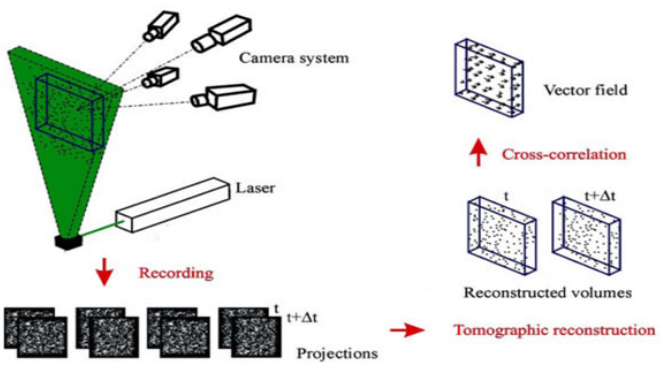

Figure: Working principle of tomographic PIV [Raffel et al.: Particle Image Velocimetry]

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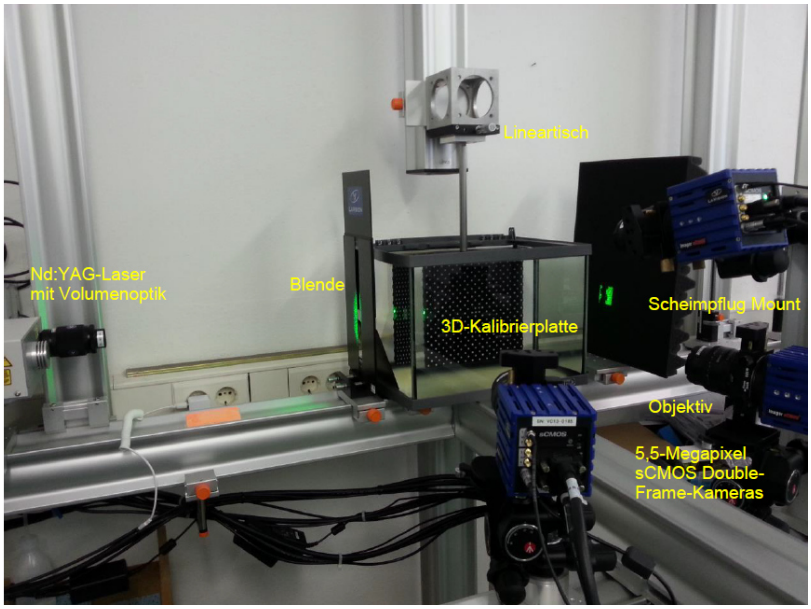
Setup I: Tomo-PIV system (LaVision, Göttingen)

double-pulse laser
- Nd:YAG, 532nm
- frequency: 20Hz
- pulse energy: 50mJ

illumination volume
- divergent
- thickness: 20mm

double-frame cameras
- 3x Imager sCMOS
- 25fps @ 5,5MPixel
- Scheimpflug mounts

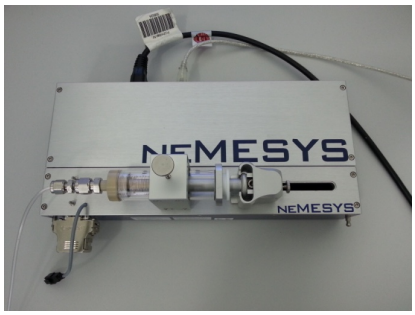


Setup II: pump, cannula

- Human Med WAL devices: injection uses a disposable piston pump
  → volume flow transient
  → piston pump „keeps“ seeding particles

Establishment of method: constant volume flow desirable

- Use of low pressure syringe pump Cetoni NEMESYS 290N (max. 50ml/min)
  + f_{laser} only 20 Hz (only 4-5 images during injection)
  + no trigger for PIV system necessary
  + easier to compare to CFD simulations

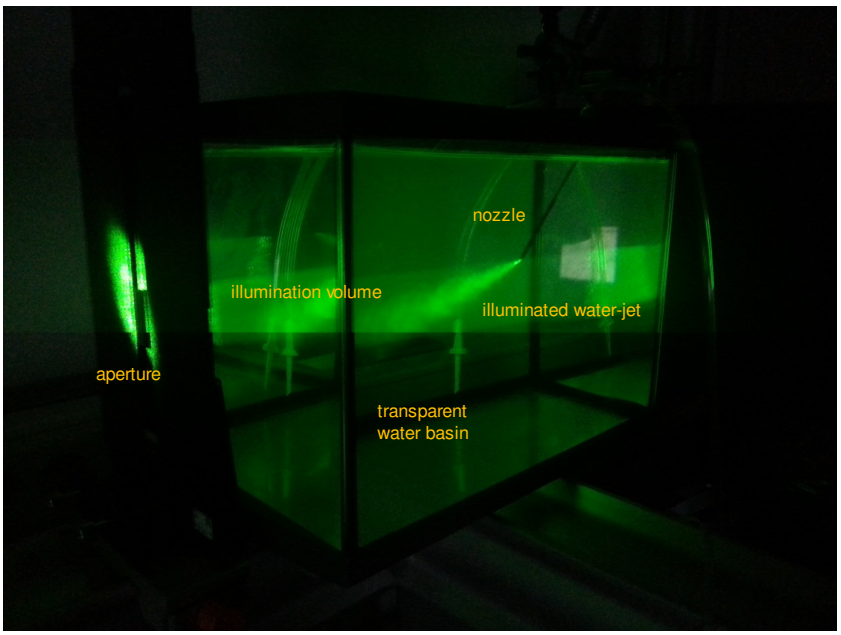


Further setup:

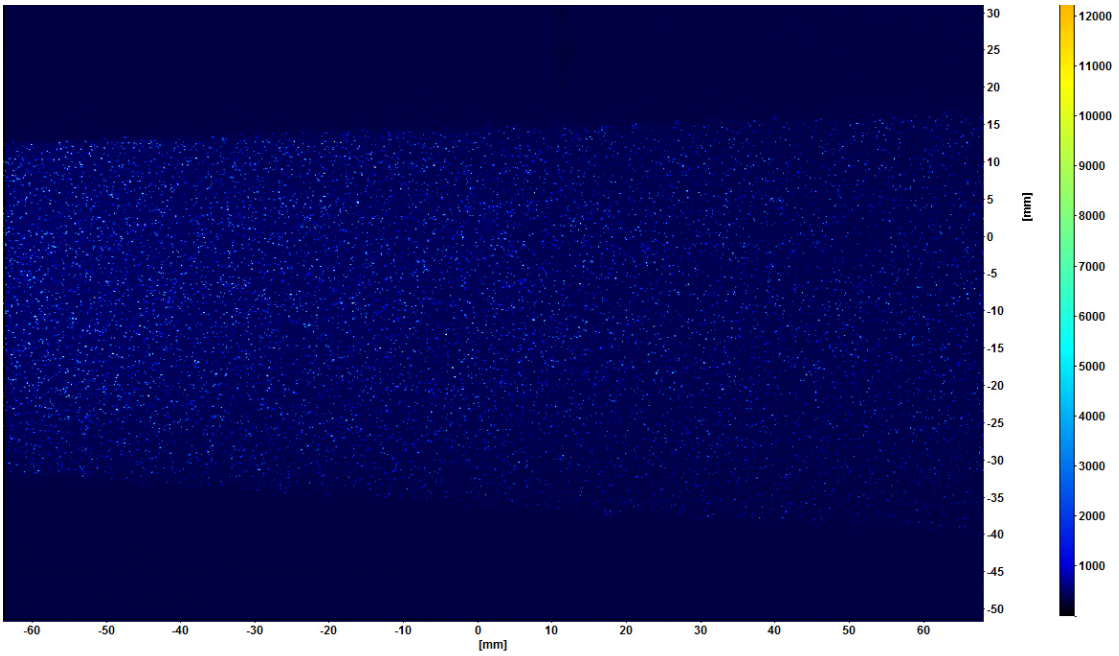
- 25ml syringe (borosilicate glass), up to 7 bar
- Swagelock fittings, d_a=3mm-silicone hose to nozzle
- Biofill-applikator d=3,5mm; transparent water basin

Measurements

- volume flow 50ml/min
- time between pulses dt=5ms
- seeding: 10µm glass hollow spheres
- Laser power 40%
- attentuator 4,0 / 10



Results: Tomo-PIV 50ml/min (raw images)



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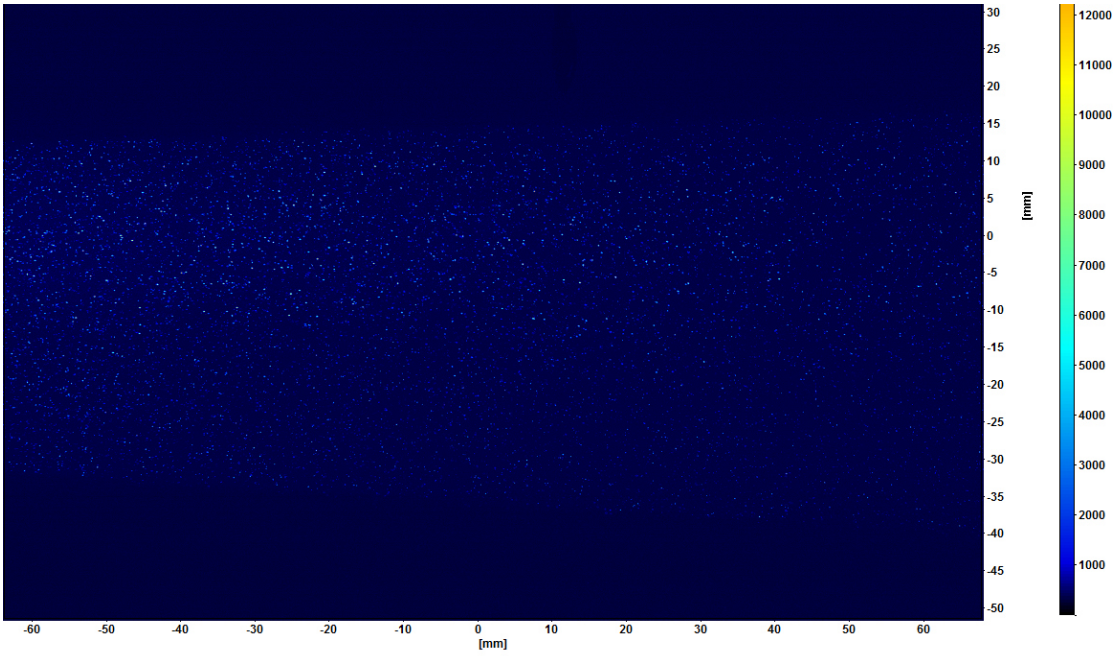
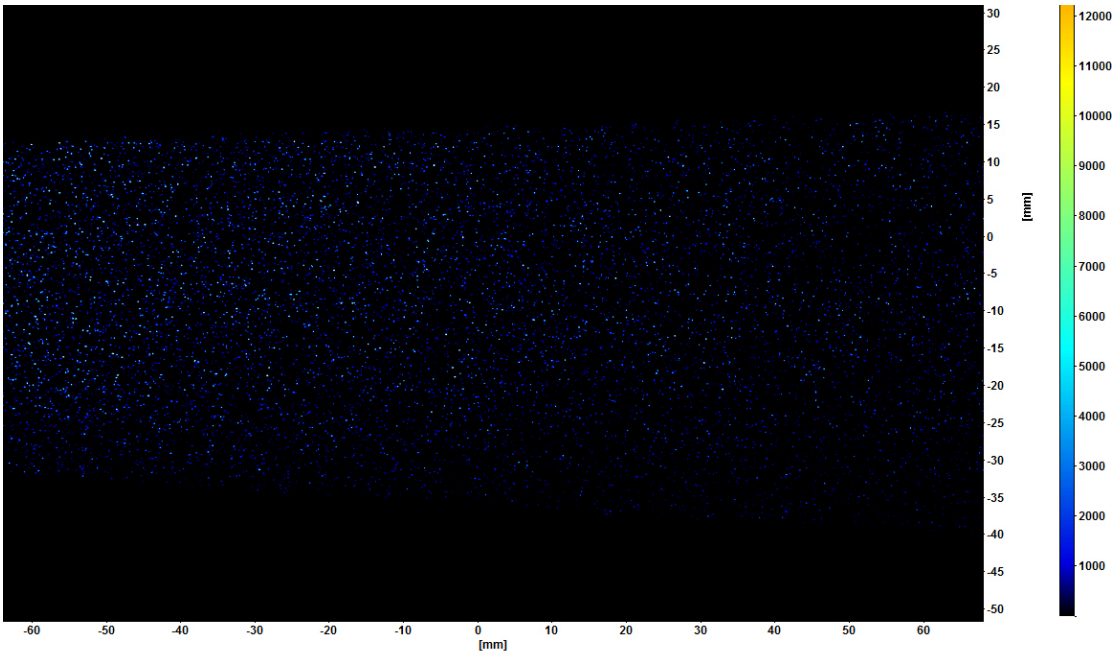


Results: Tomo-PIV 50ml/min (image preprocessing)



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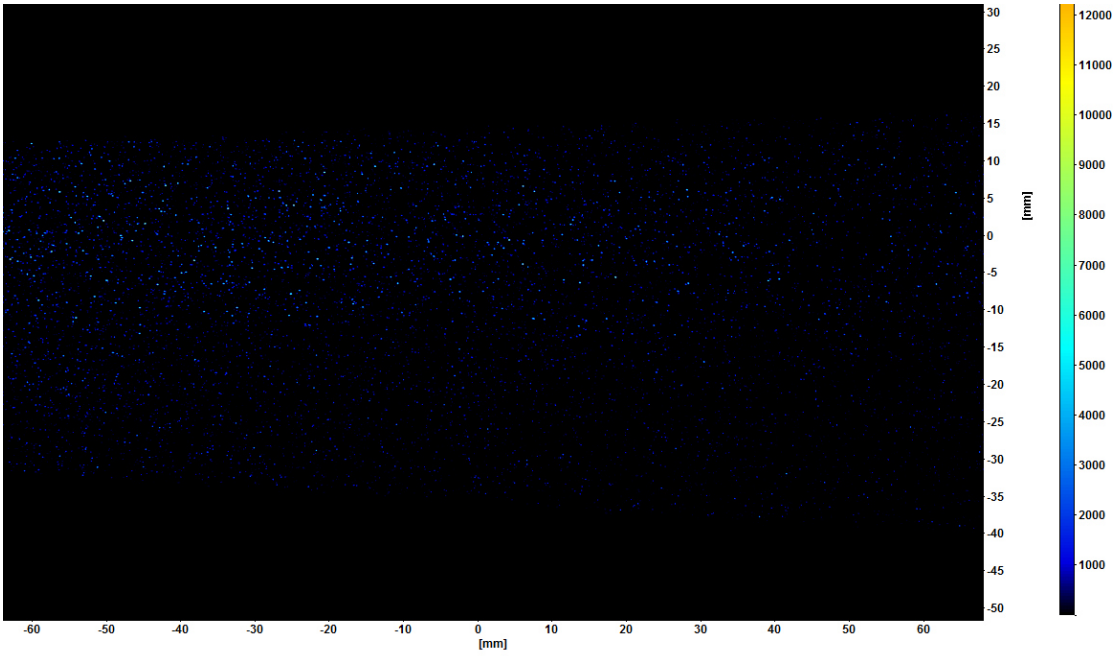
Results: Tomo-PIV 50ml/min (image preprocessing)

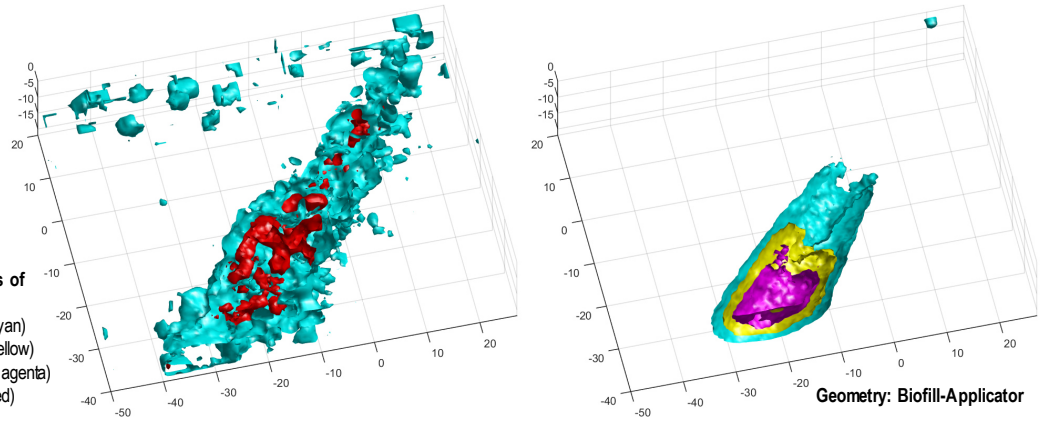


Results: Tomo-PIV 50ml/min – isosurfaces of velocity

- Image series of 200 double images
- Image Preprocessing, Fast MART Reconstruction, Direct Correlation

Left: single image

Right: average of 200 images



isosurfaces of velocity:
0,06 m/s (cyan)
0,09 m/s (yellow)
0,12 m/s (magenta)
0,18 m/s (red)

Geometry: Biofill-Applicator

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Results: CFD simulation 50ml/min

Mesh

- 1,2 Mio. cells (tet, prism)

Models

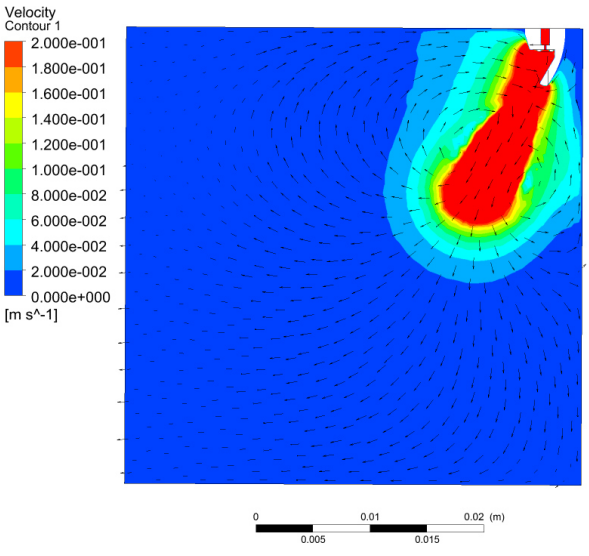
- transient solver
- single phase flow, RANS (SST)
- Injection of water into water

Boundary conditions

- inlet: v= 1,65 m/s (=50ml/min)
- outlet: p=0bar

Simulation:

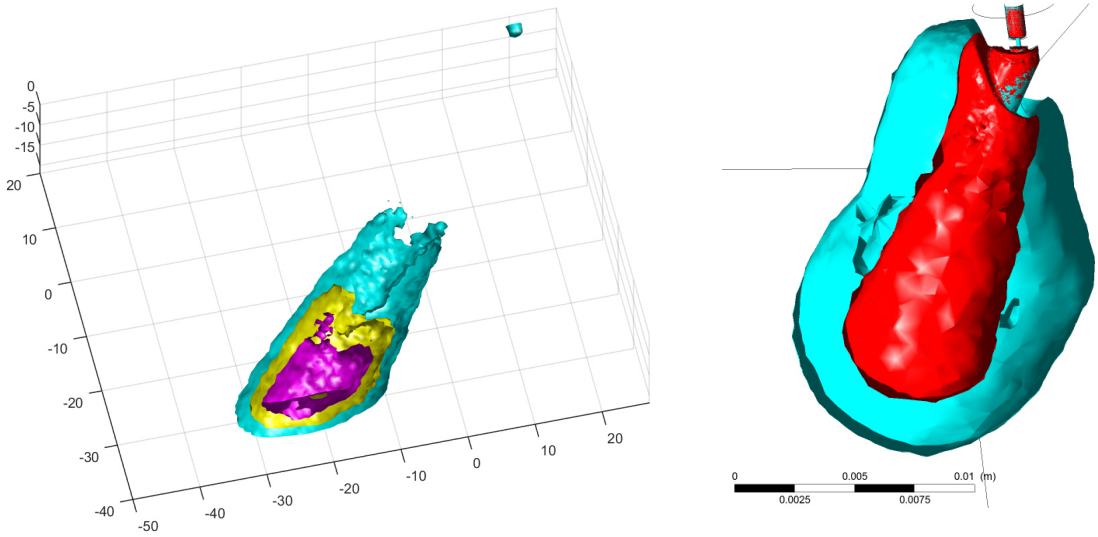
- PRESTO, 1st/2nd order momentum
- Time step size 10^-5s (max. 20it/ts)



Geometry: Biofill-Applicator

CFD simulation & PIV measurement @ 50ml/min

- isosurfaces v=0,06 m/s (cyan) and v=0,18m/s (red)
- Left: PIV (average of 200 images), right: CFD after 2000 time steps



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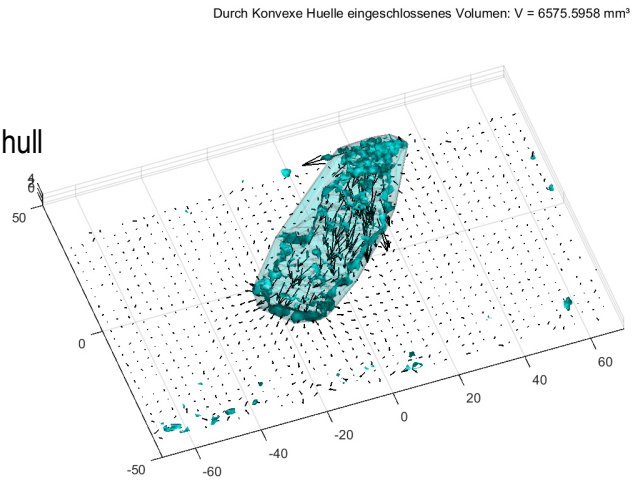
Summary

- neither single PIV images nor average over 200 images match CFD simulation results
  → spray in PIV measurements thinner than spray in CFD simulation
  → less momentum transferred from spray to surrounding water
- probably Tomo-PIV calibration too imprecise (0,01px needed)
- maybe time between pulses (dt) too low or too high
- since spray is transient: resolution of big eddies in simulation using LES instead of RANS

Outlook

- simulation of injection of water into air (using VOF model + Level Set)
  → to compare with available force sensor results
- PIV measurements using Human Med standard piston pump
  → PIV seeding downstream of pump
  → calculation of volume using convex hull



- CFD simulations using volume flow profile of piston pump as inlet boundary condition

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Thank you for your attention!

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Human Med AG, Schwerin

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