Critical issue for EXP and CFD: CAD to 3D printing

H. Magnes, S. Marragou, M. Vilespy, T. Schuller

H2 Week, Thursday 29, 2024

Critical issue for EXP and CFD: CAD to 3D printing ….. and other details

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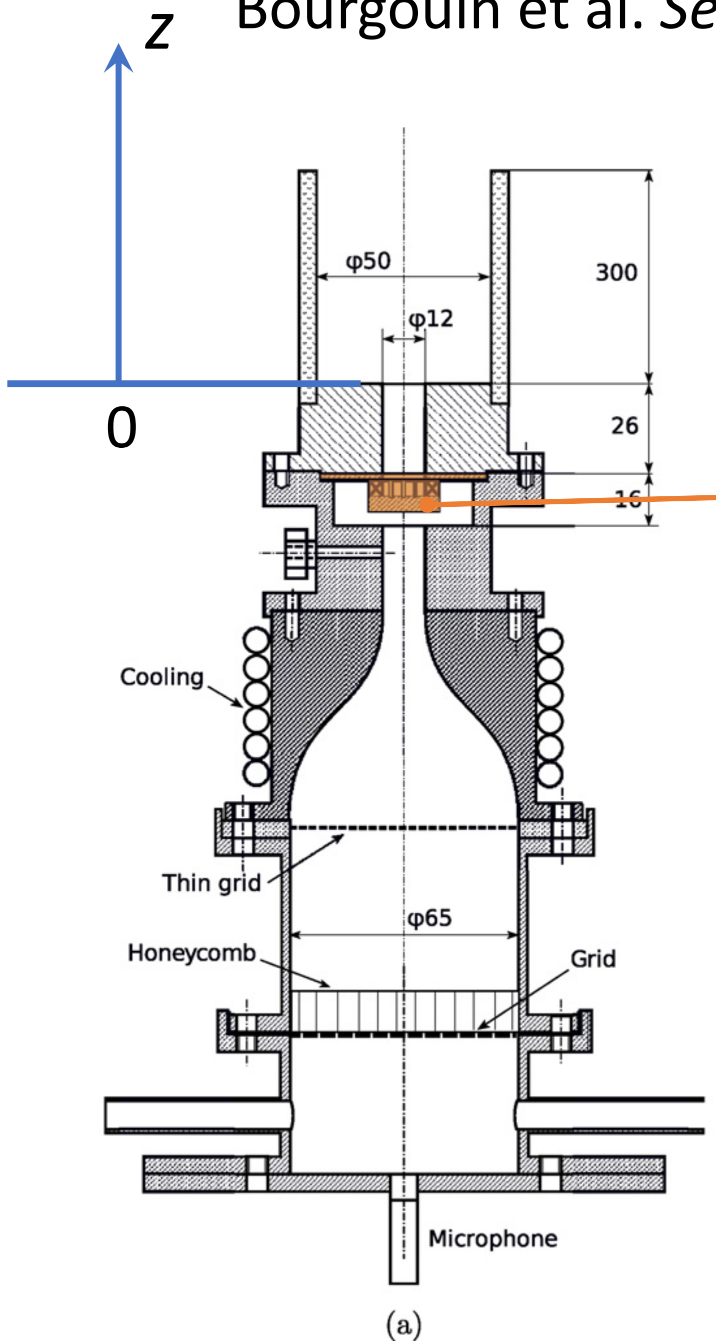
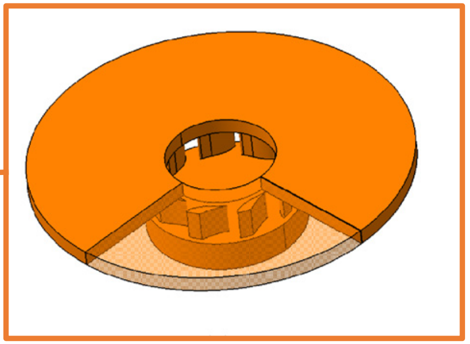
H2 Week, Thursday 29, 2024

3D printing, 10 years ago

Bourgouin et al. *Sensitivity of swirling flows to small changes in the swirler geometry*
C. R. Mecanique 341 (2013) 211–219



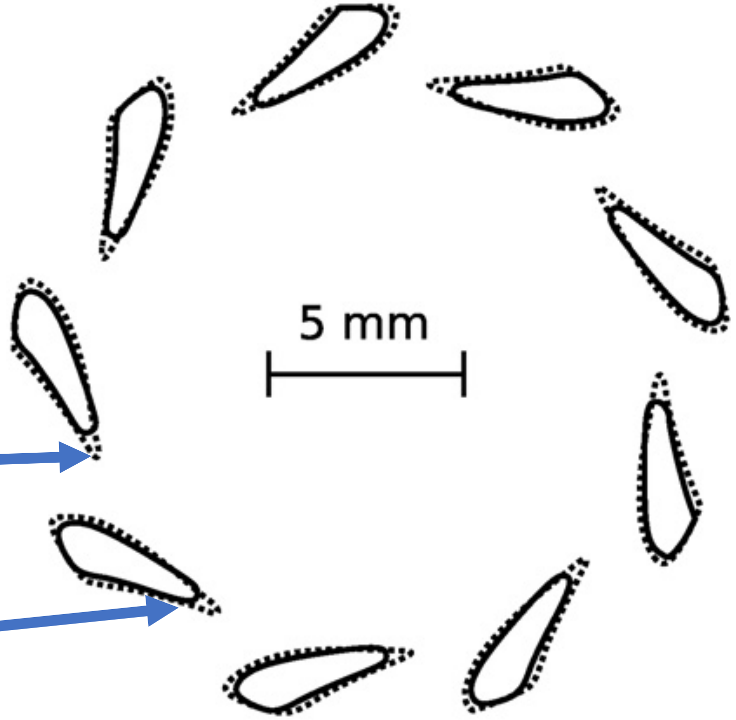
Radial swirler: 3D printed plastic material



Transverse cut

Dashed lines
Desired shape

Full line
Printed swirler



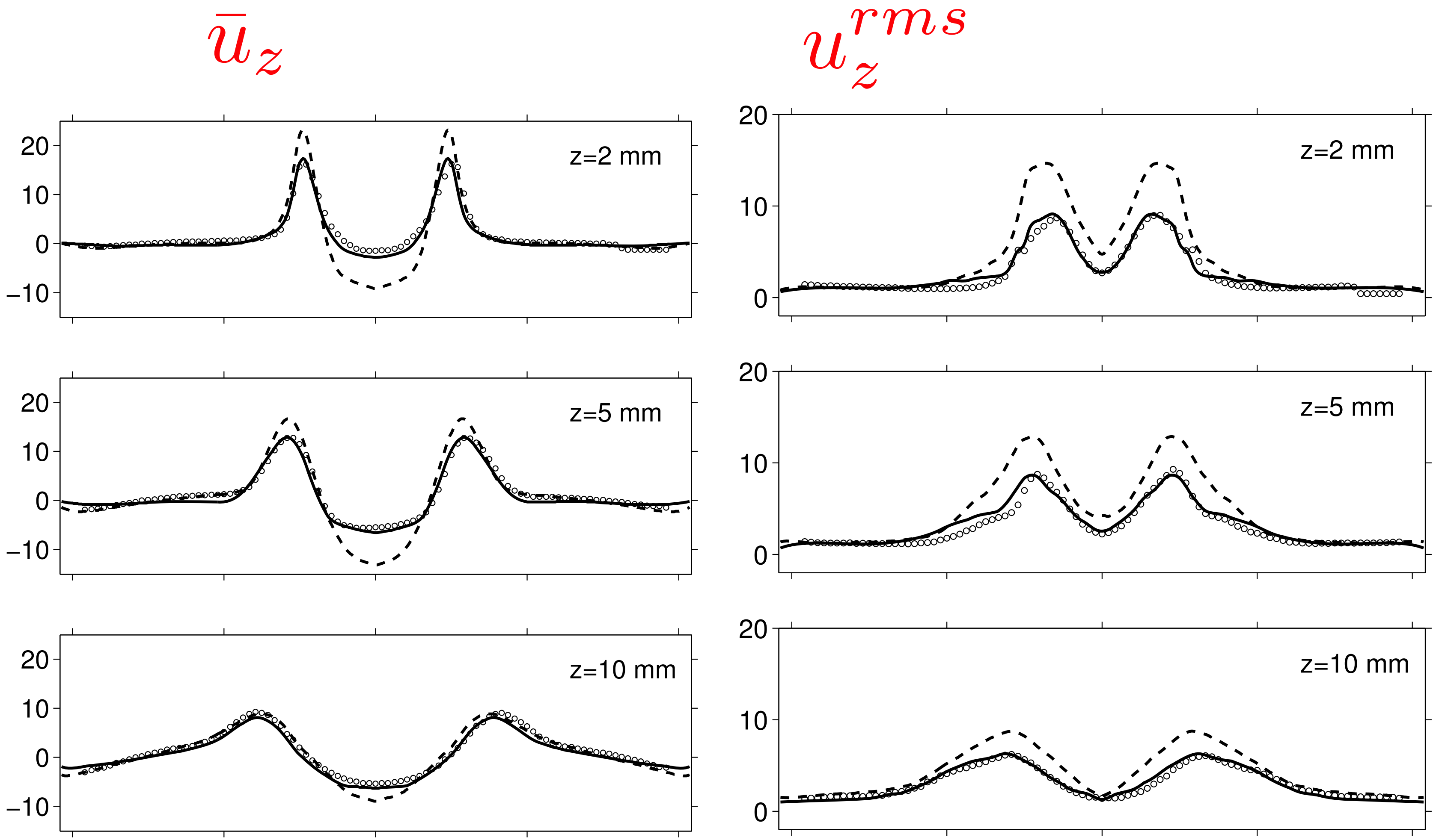
Large difference at the swirler trailing edge

Consequences on velocity profiles at burner outlet

o o o PIV

- - - - - Simulations with the geometry of the initially desired swirler design

______ Simulations with the geometry that was printed



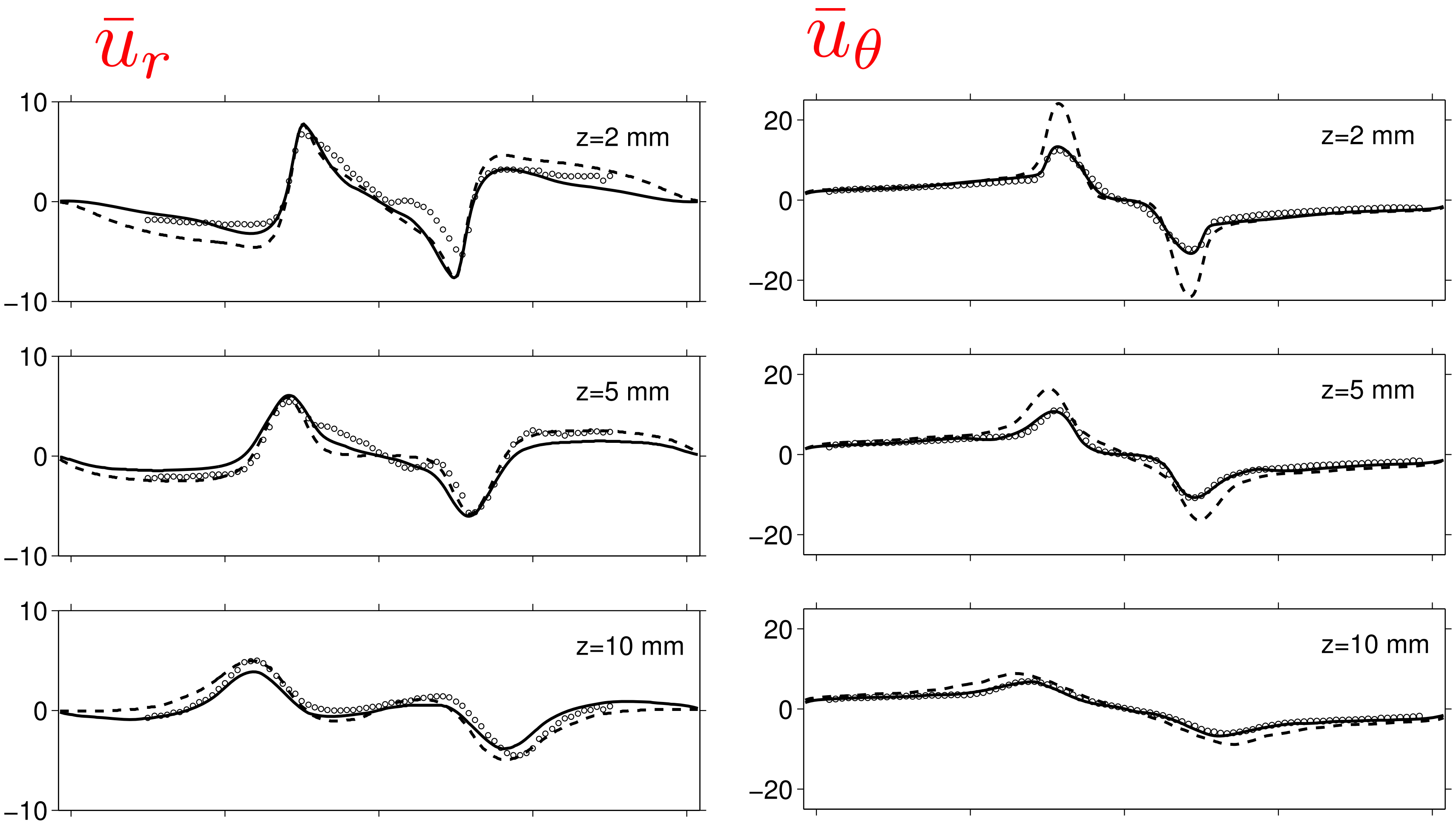
Ub= 9.88 m/s, Re_D=7900

Consequences on velocity profiles at burner outlet

o o o PIV

- - - - - Simulations with the geometry of the initially desired swirler design

______ Simulations with the geometry that was printed



Velocity field inside the radial swirler

Desired geometry

Printed geometry

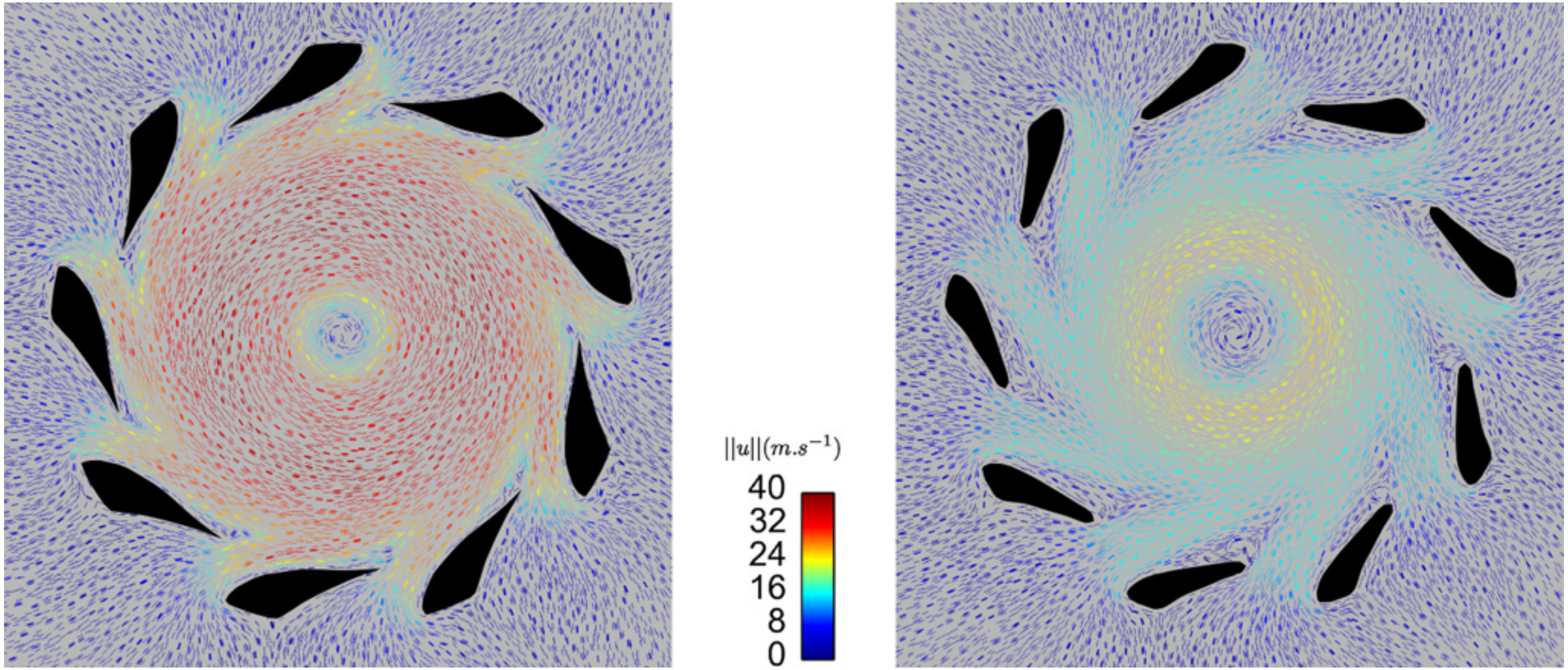
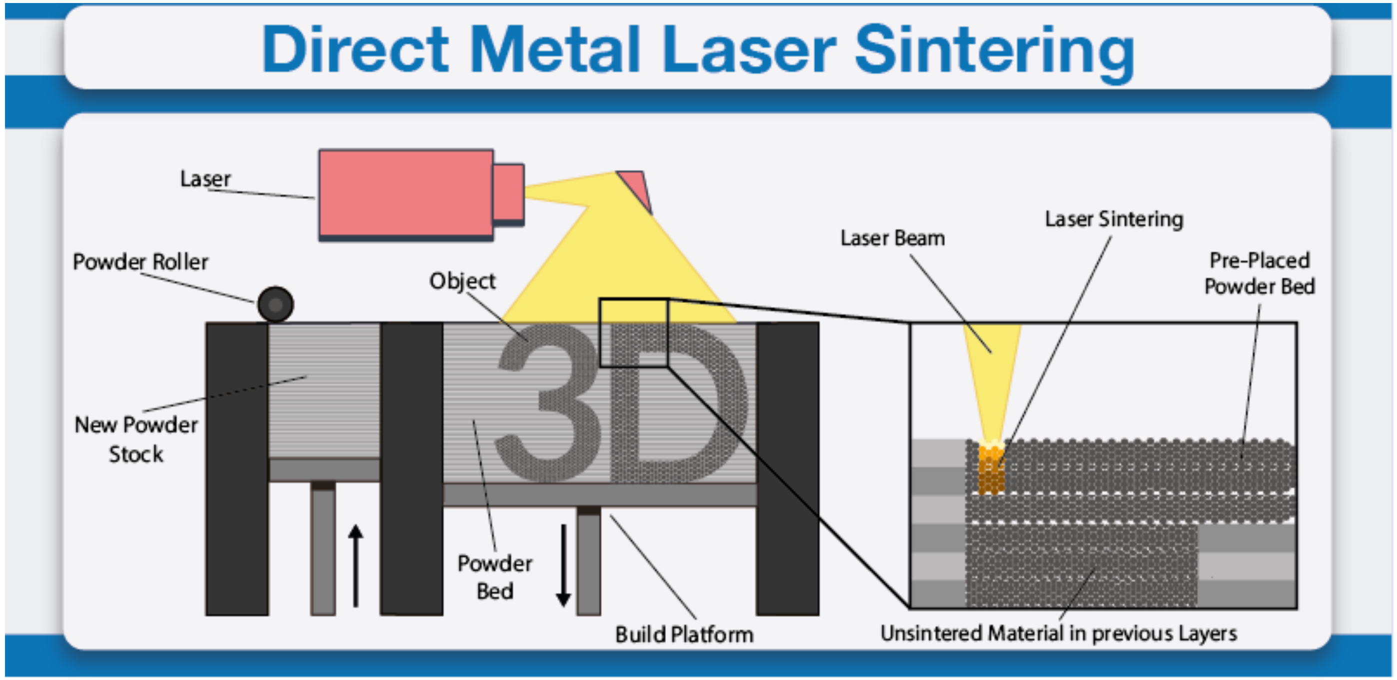


Fig. 5. Velocity field, colored by the velocity magnitude, in a section at the middle of the swirler height (2 mm) for swirler 1 (left) and swirler 2 (right).

3D printing, today

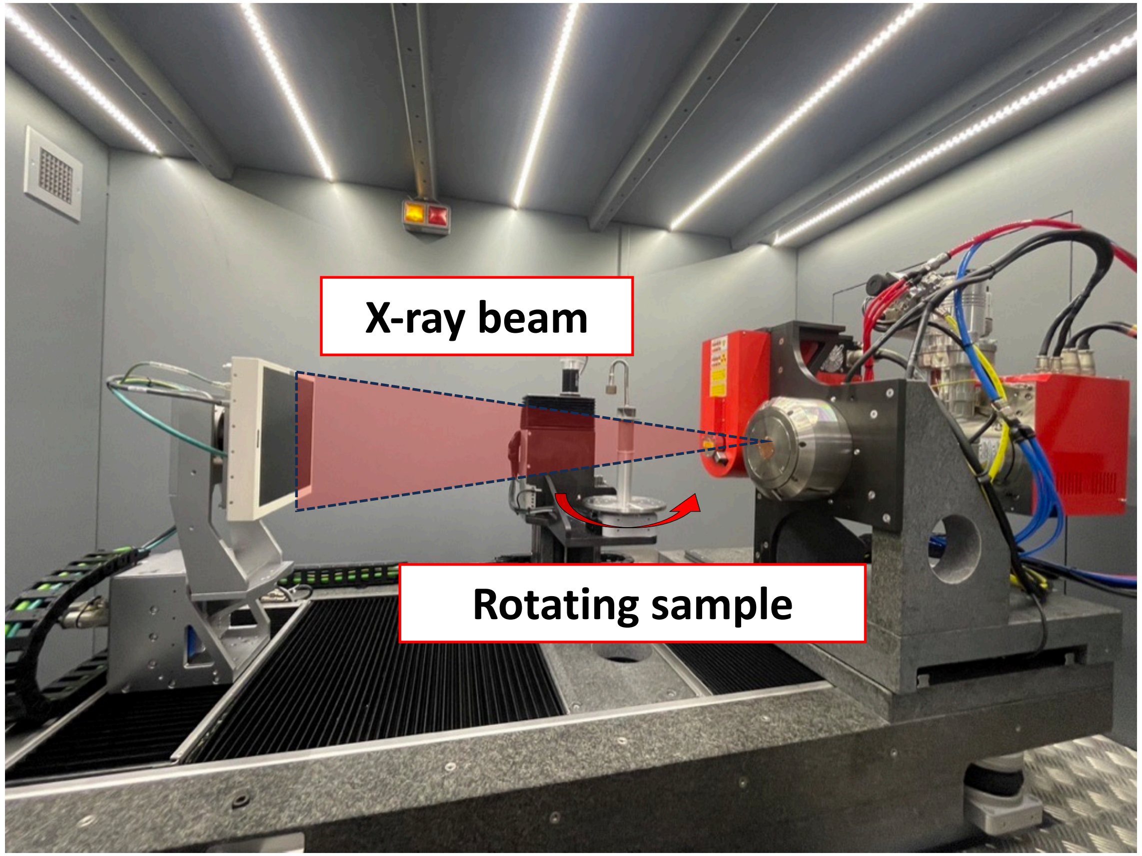
MSHI – 3D printing

3D printing via Direct Metal Laser Sintering (DMLS) in Inconel 718
No thermal treatment
Polishing by sandblasting



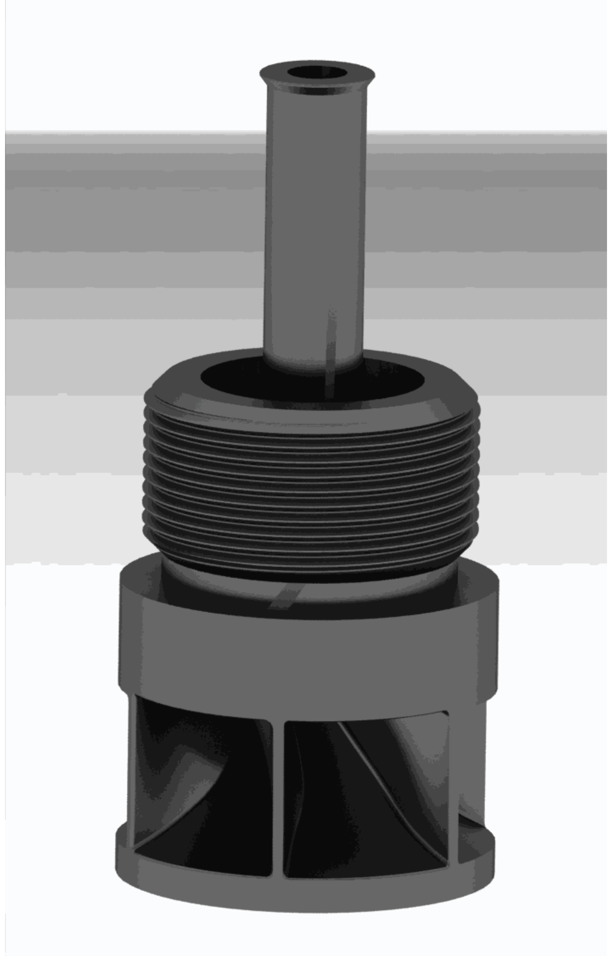
1. What is the precision with respect to drawing?
2. What about reproducibility?

IMFT X-ray tomograph

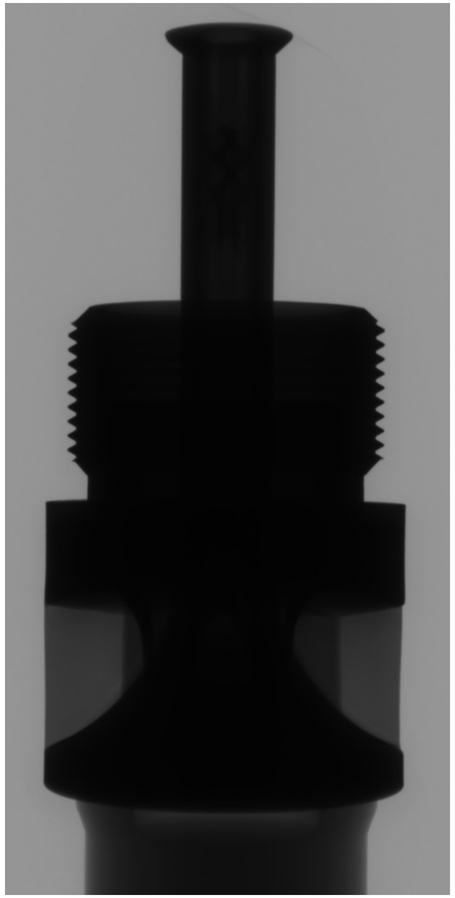


Tomographic X-ray process

Rotating sample



X-ray absorption by matter



Slice reconstruction

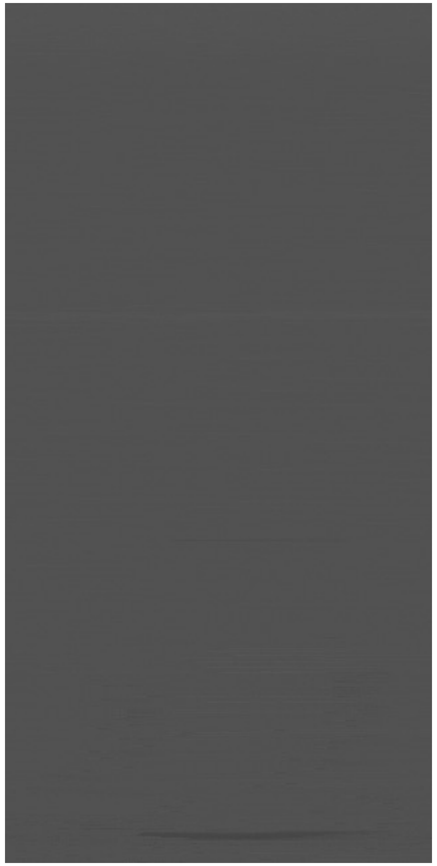
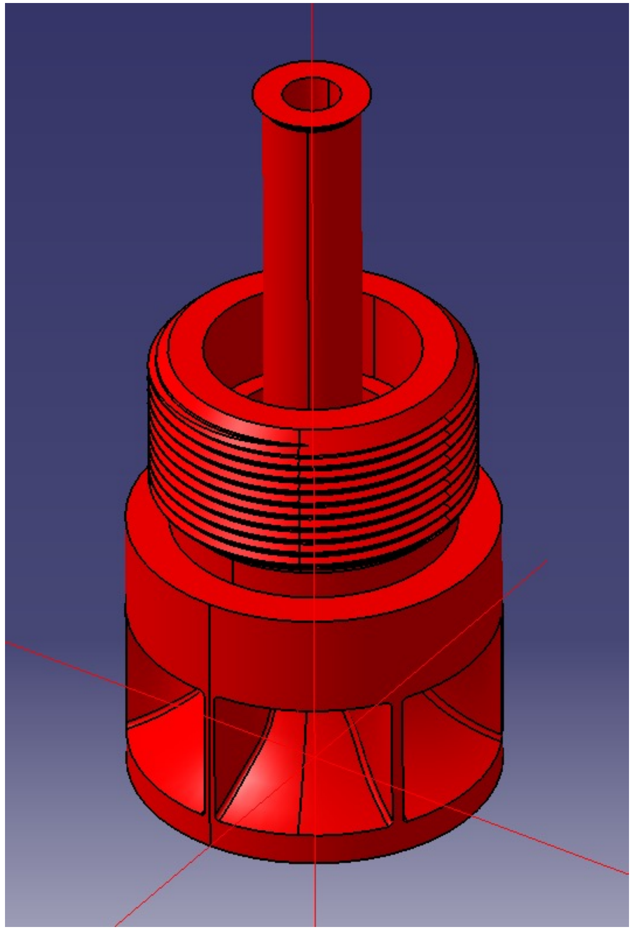


Image post-processing

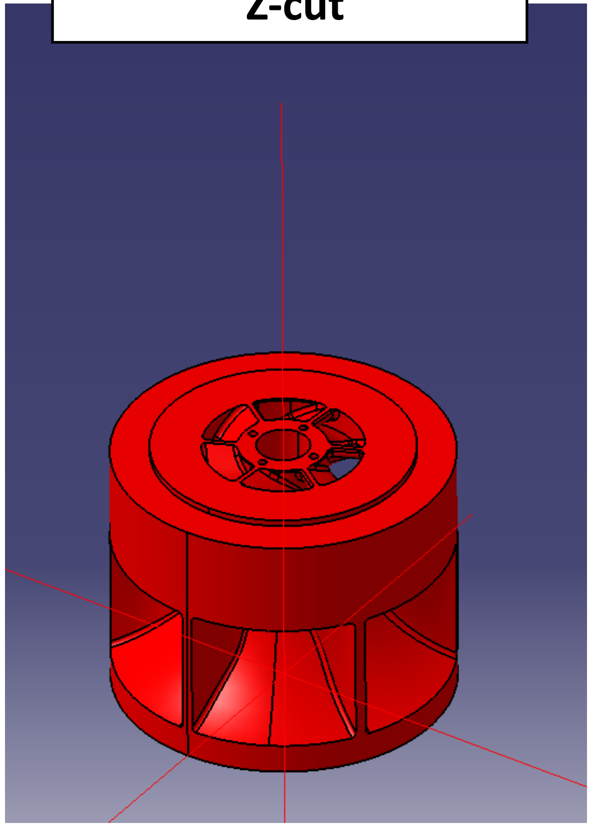
1. Selection of relevant cut planes.

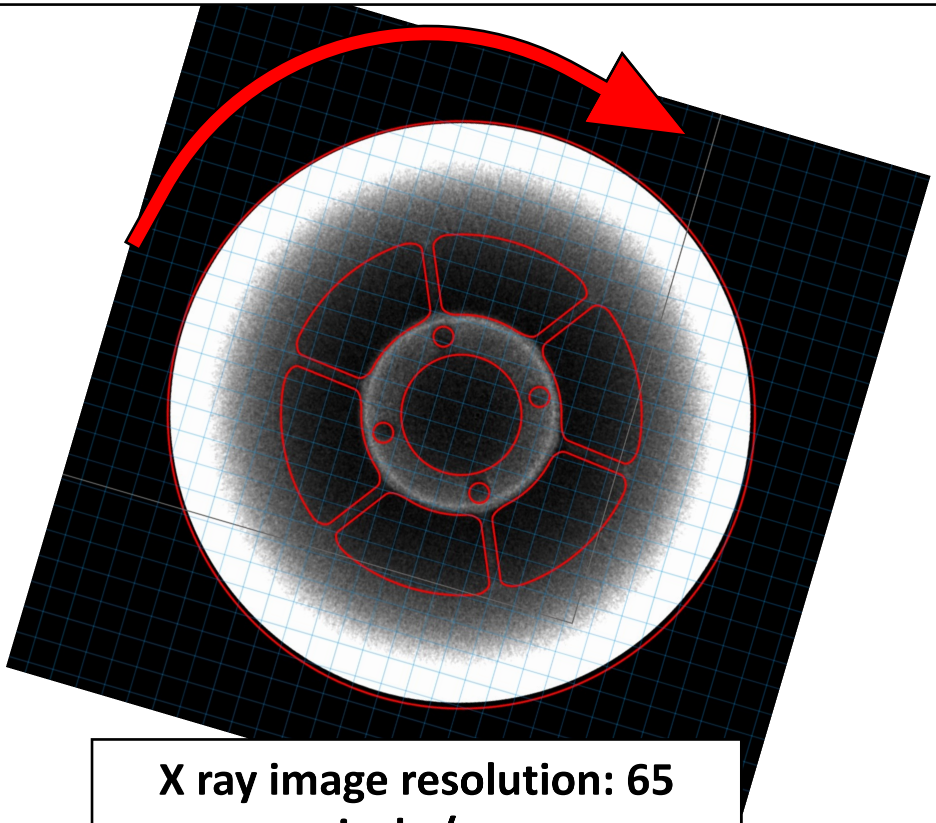
2. Overlay of X-ray images and CAD sketch section at identical scales **(Inkscape)**

3. **Orientation of the Z-cut: X-ray vs. CAD**



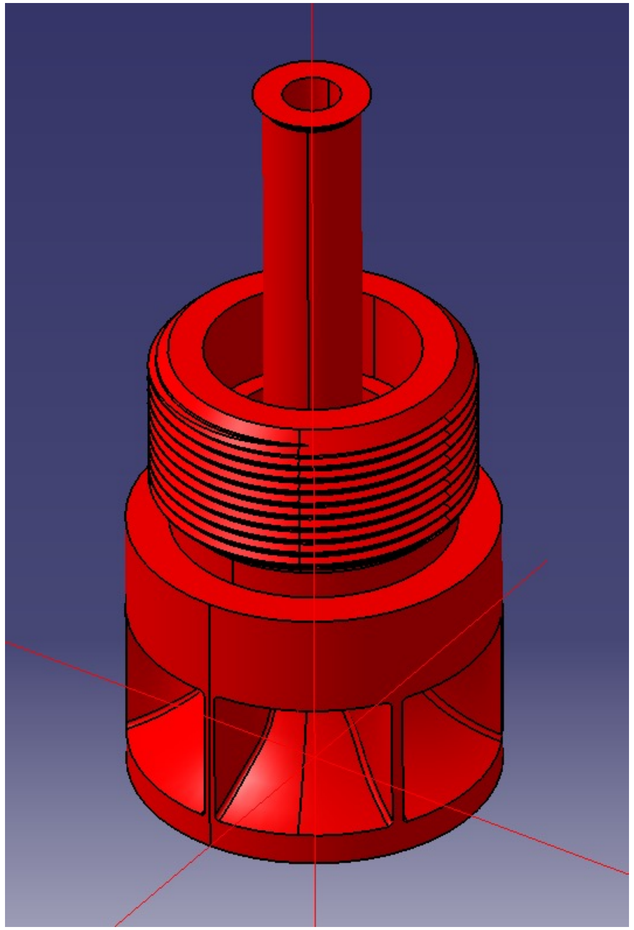
Z-cut



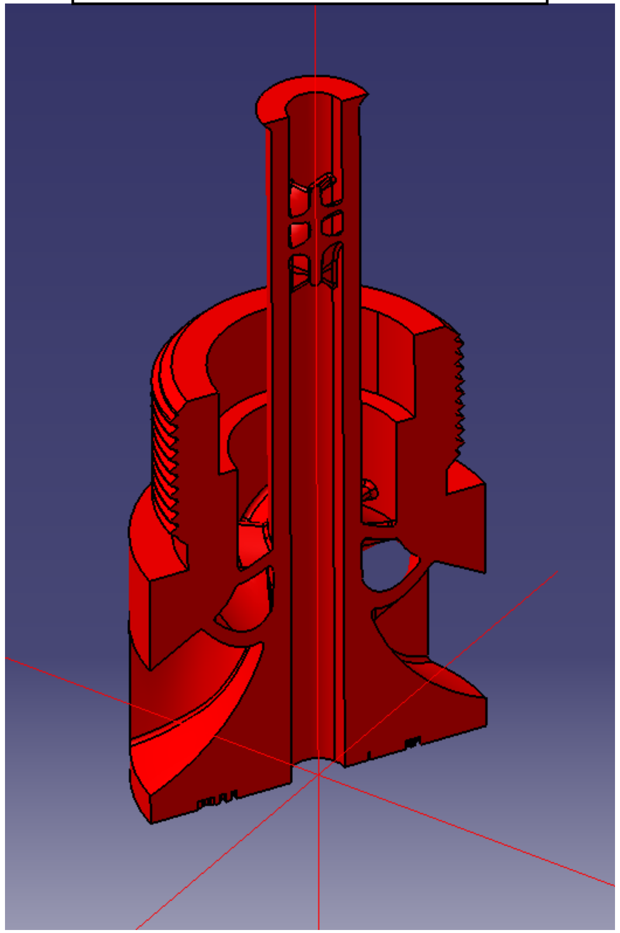


X ray image resolution: 65 pixels /um

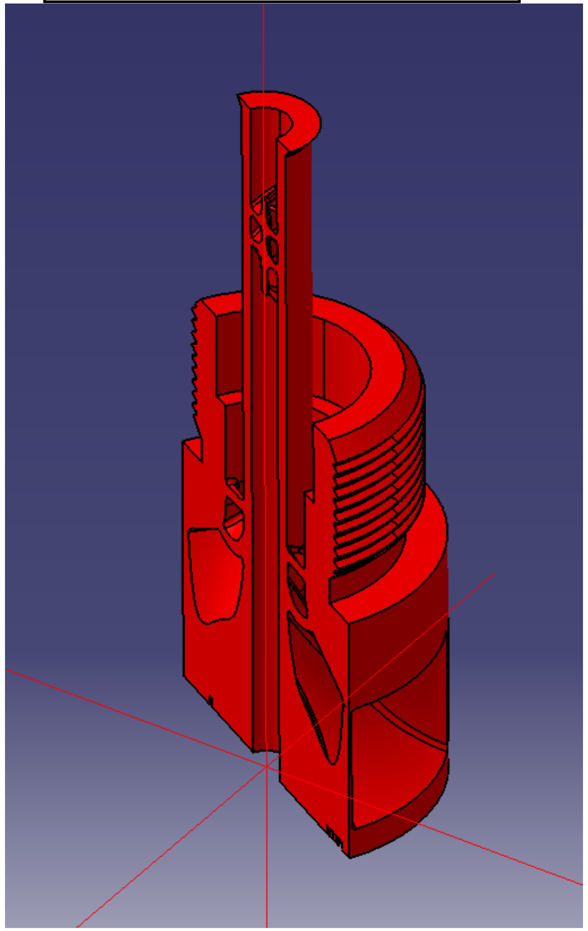
Image post-processing

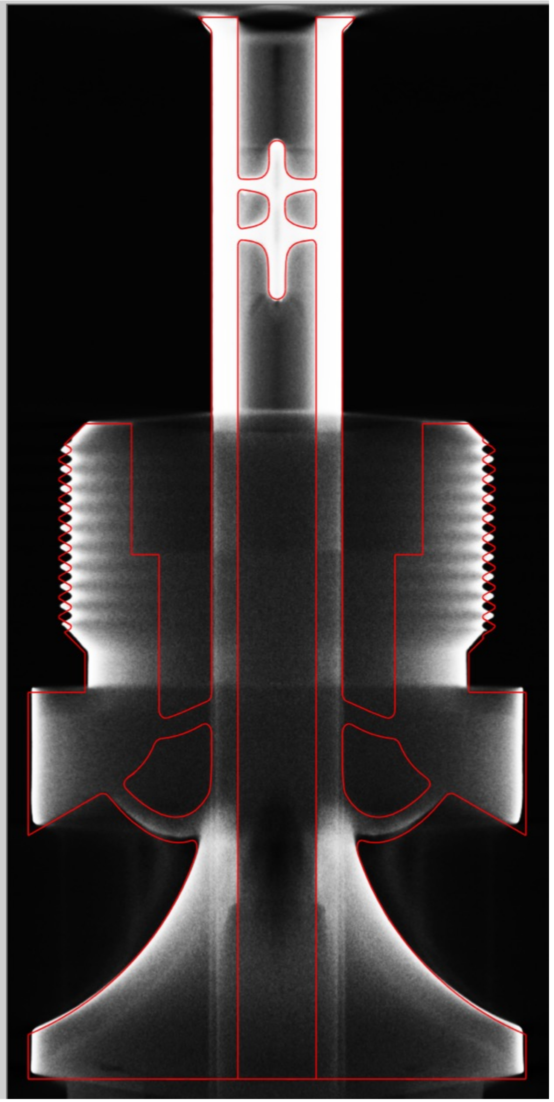


X cut

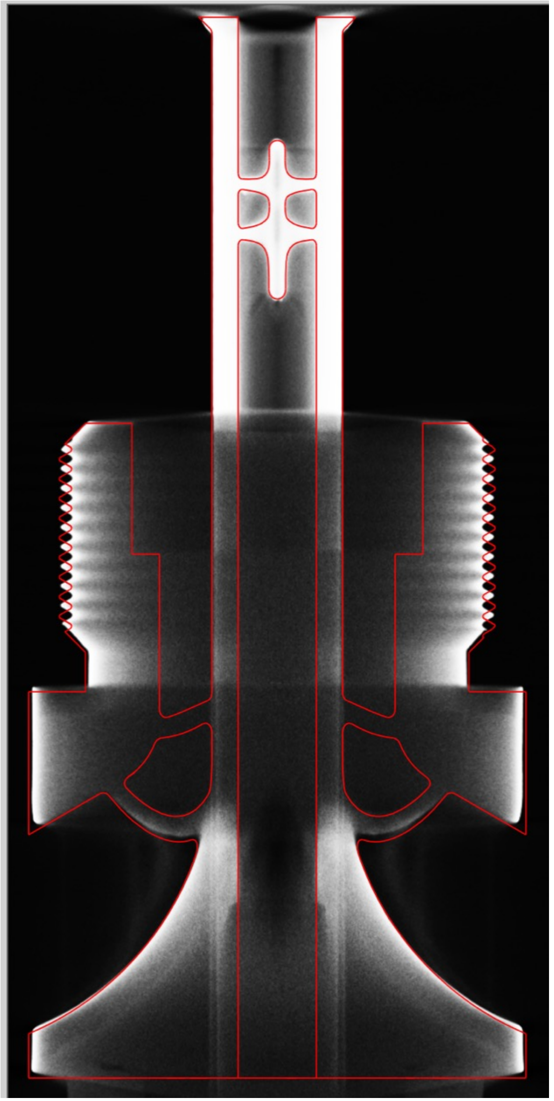


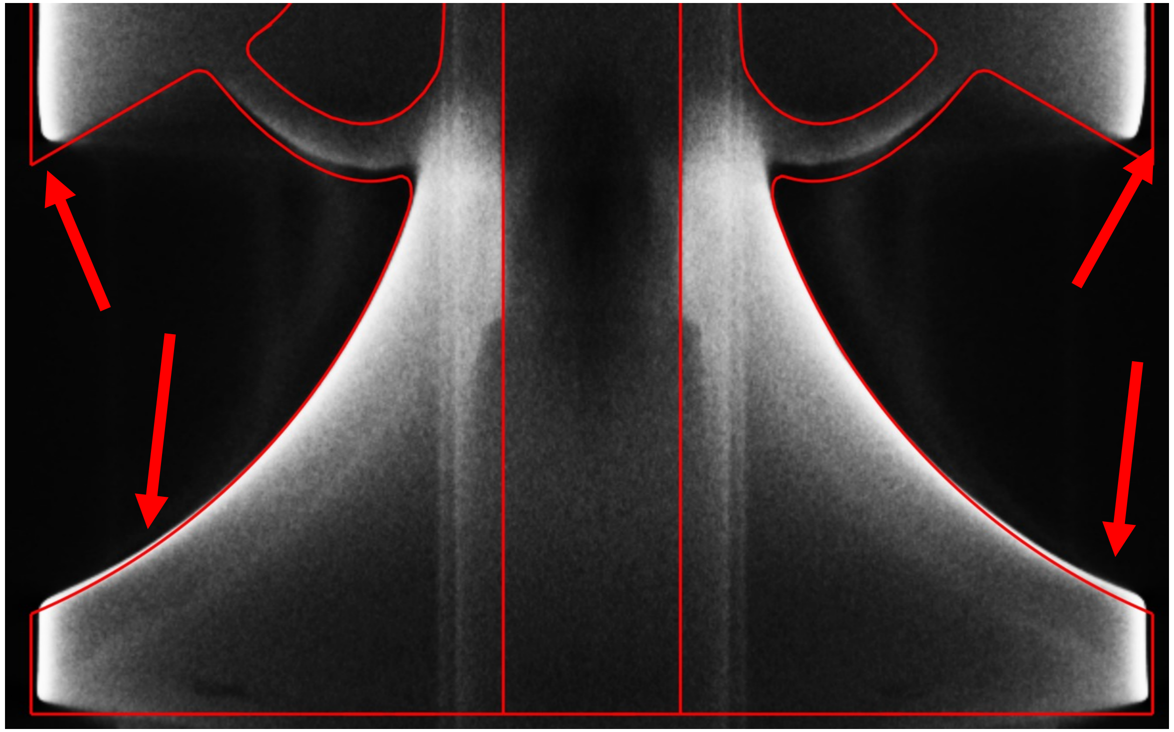
Y cut





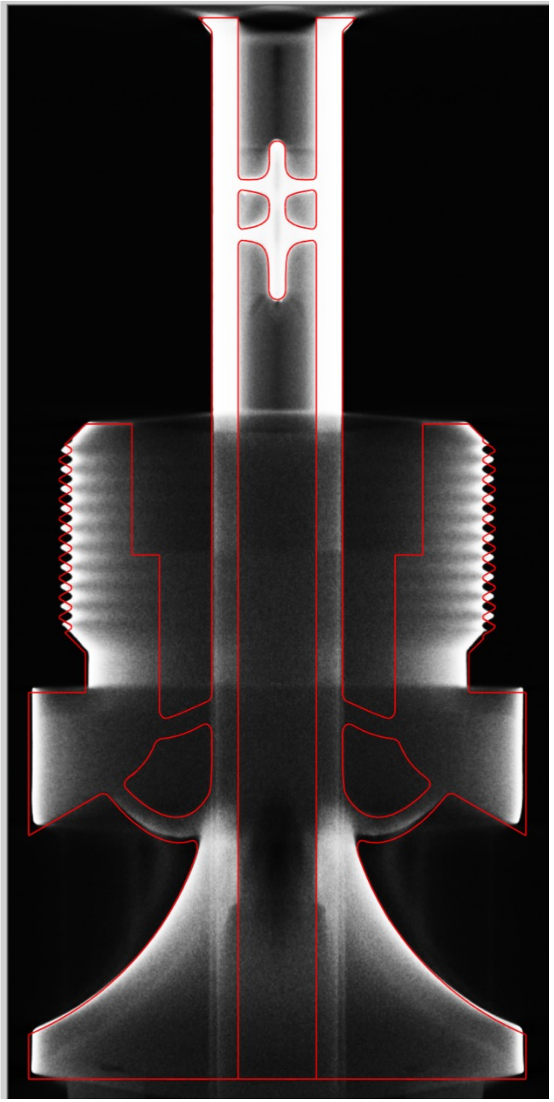
Comparison between CAD and printed swirler

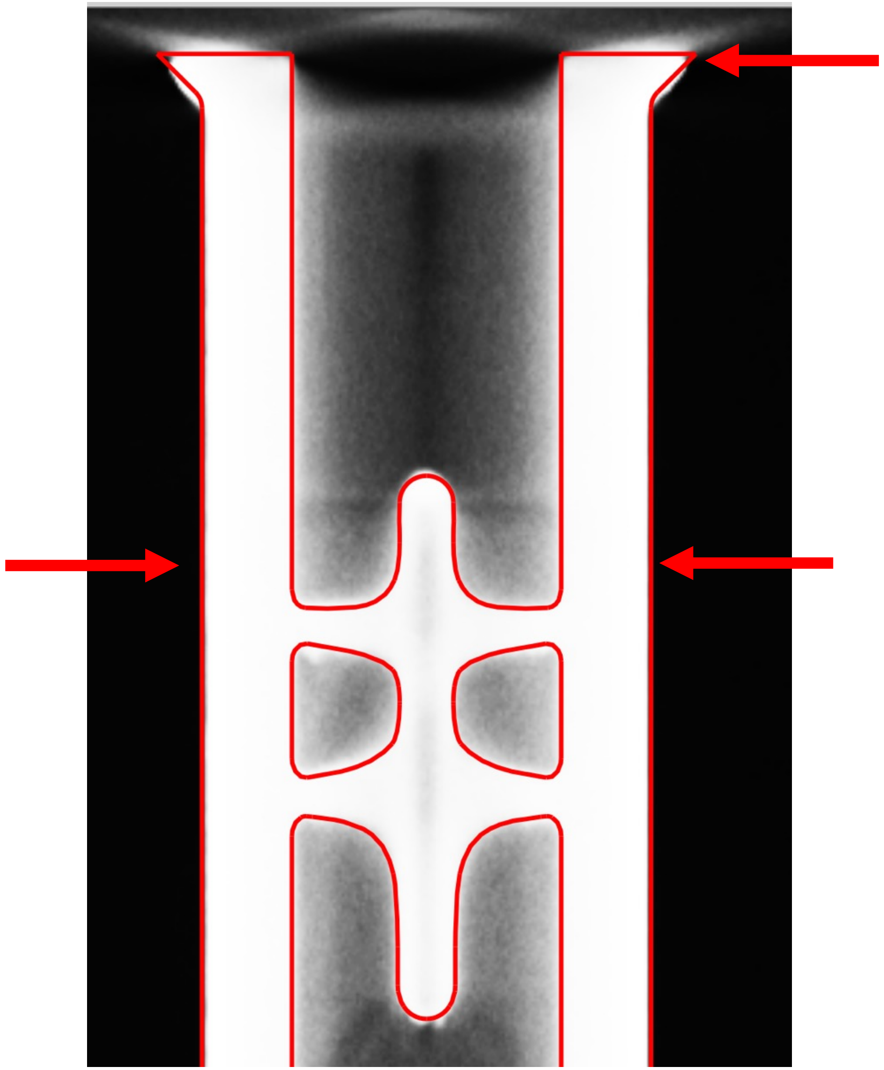




- Difference in air inlet channel profile: approximately 0.4 mm.
- Poor quality of the printing for sharp angles of the air inlet channel (support is required for printing in these areas)

Comparison between CAD and printed swirler

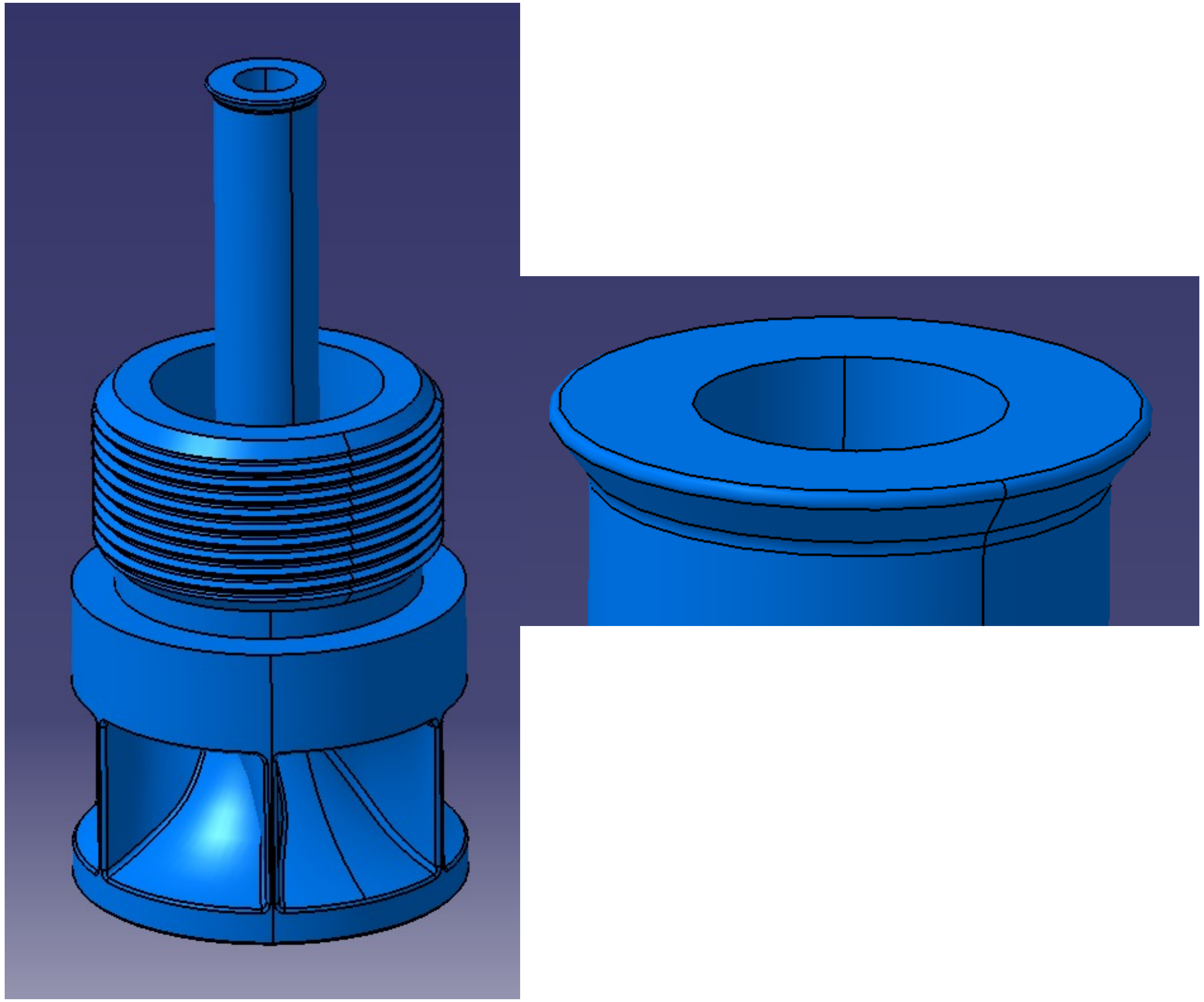


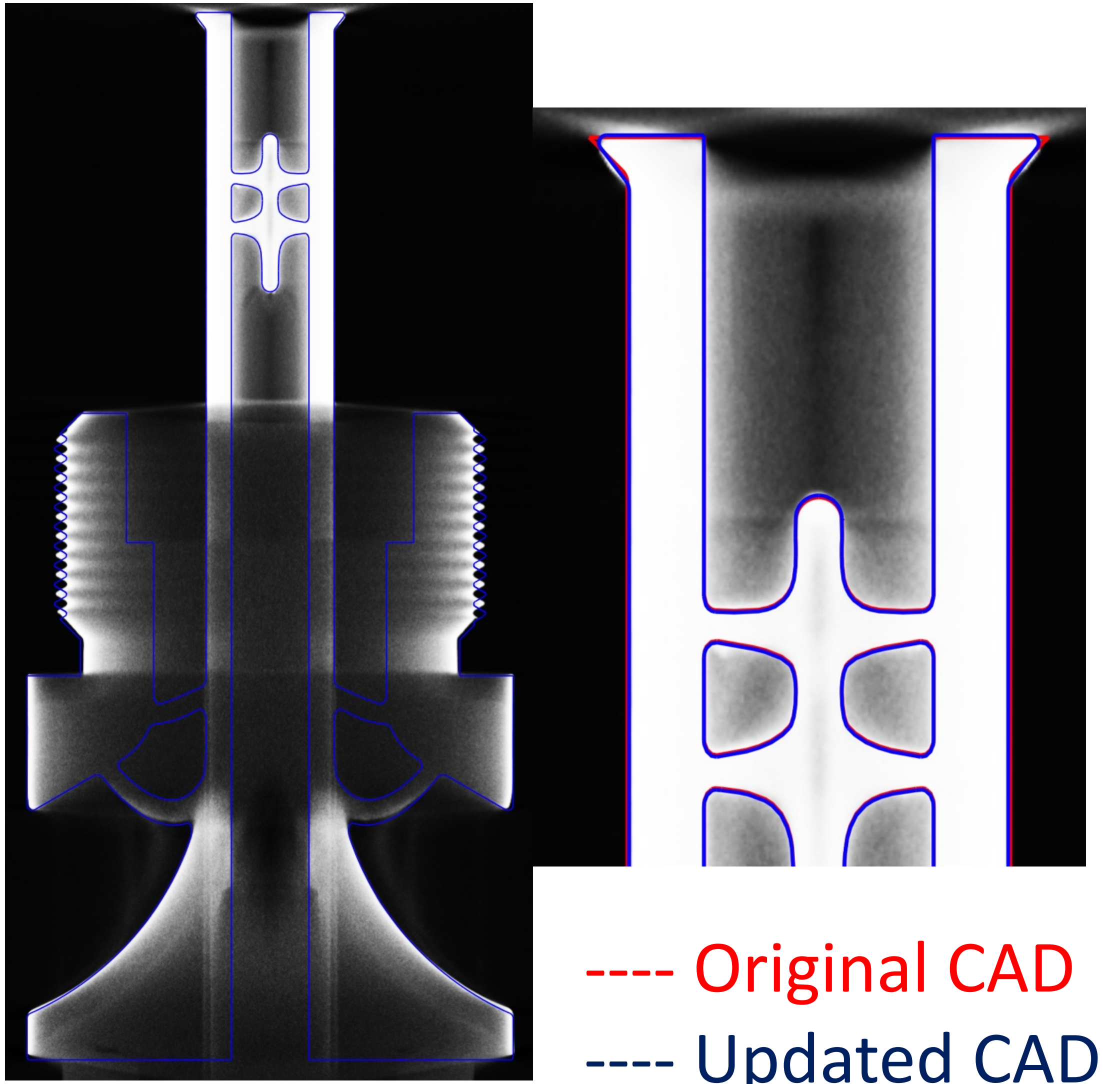


0.4 mm difference in the diameter of the deflector

Difference of 0.1 mm on H2 tube diameter

Updated CAD with respect to X-ray tomography



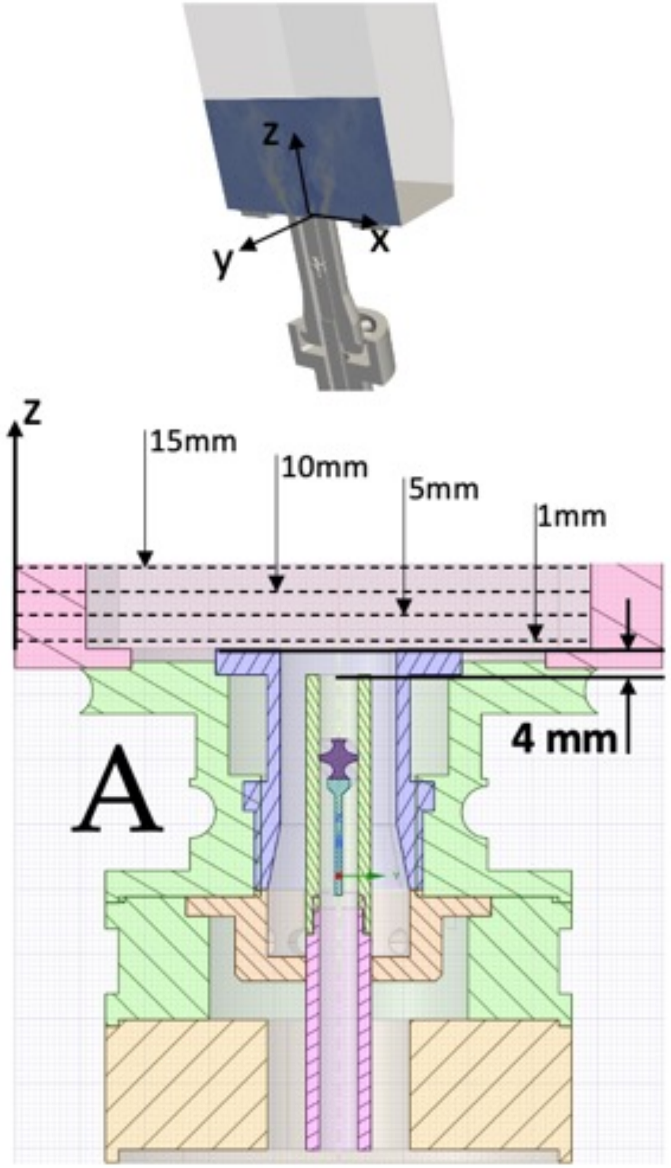


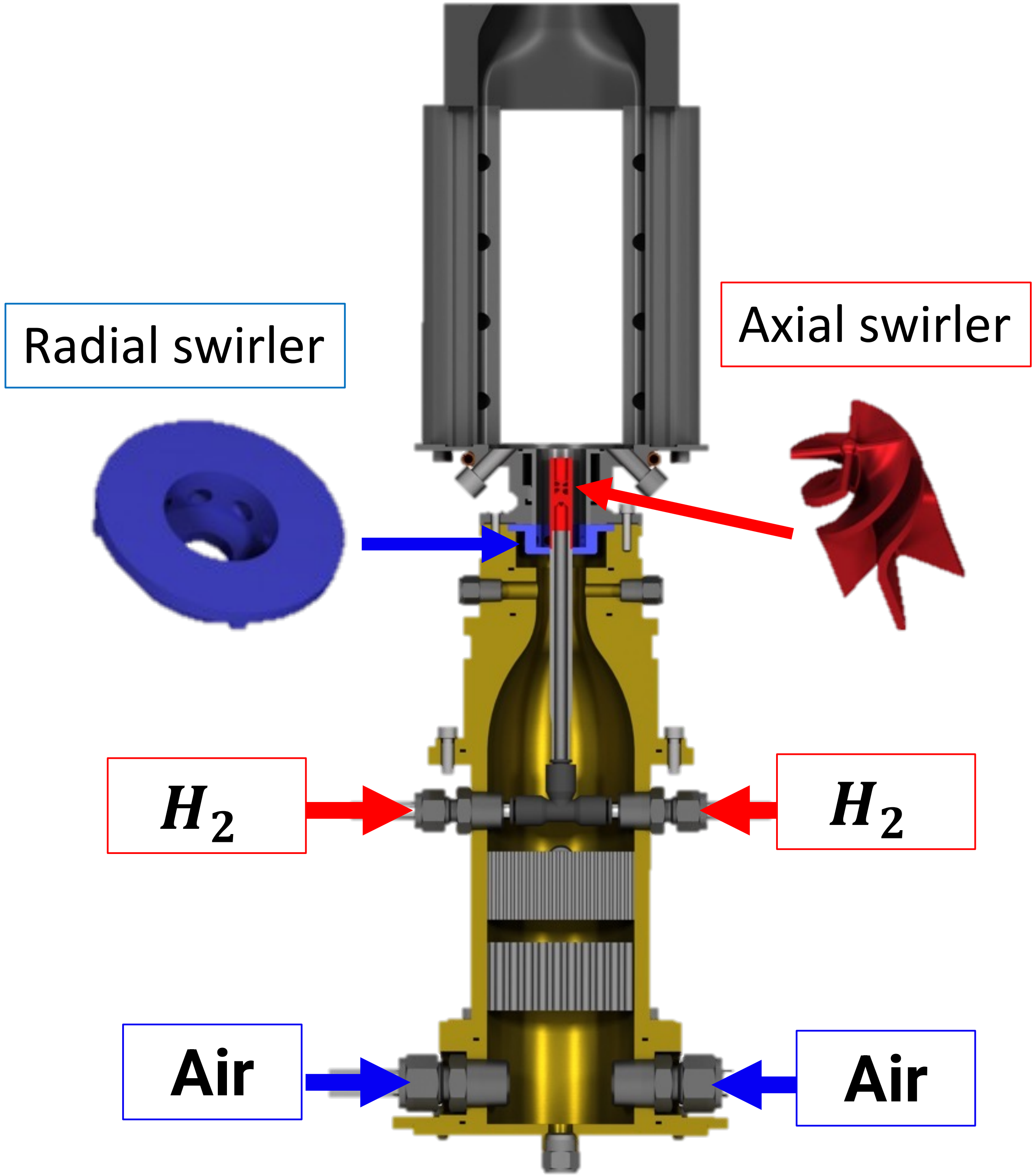
---- Original CAD

---- Updated CAD for CFD

Comparisons between EXP and CFD: an example

HYLON TNF setup

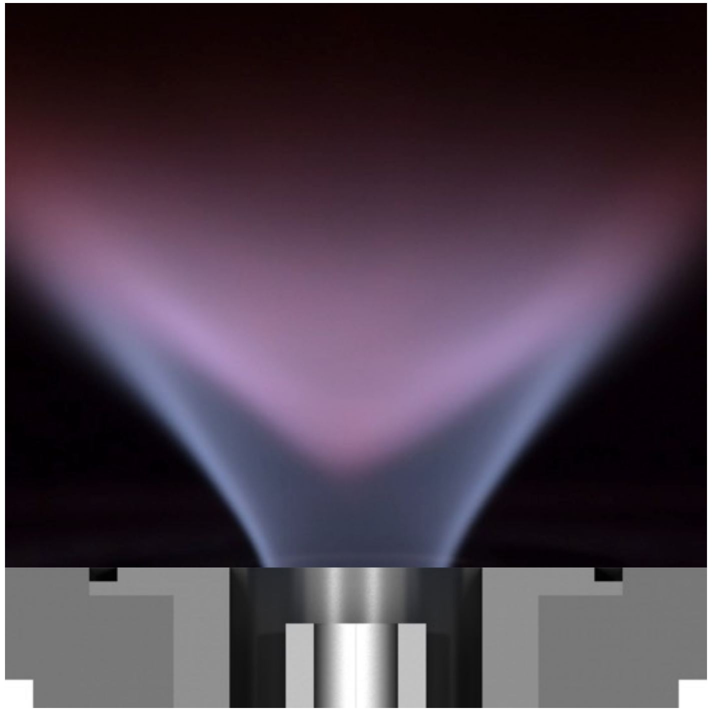




Target flames

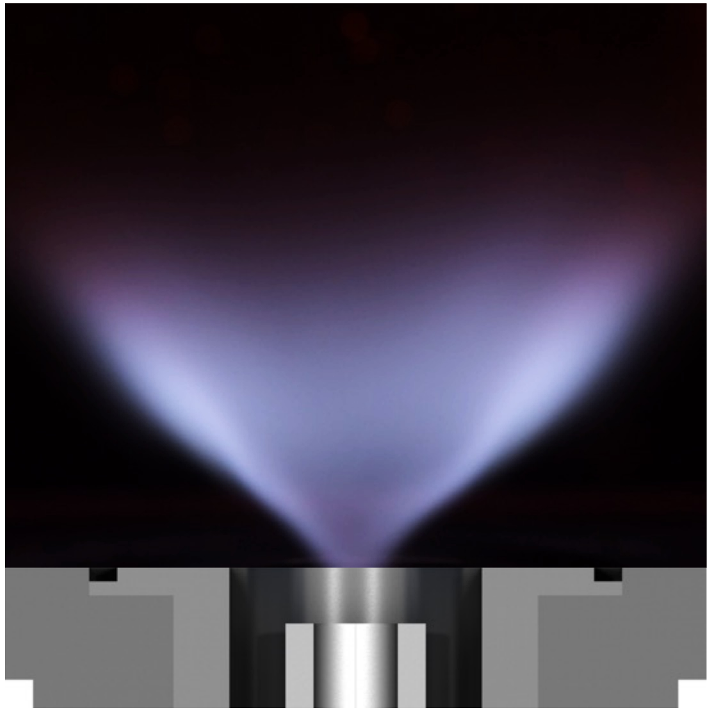
FLAME A (Anchored)

$$U_{air} = 12\, m/s$$
$$U_{H_2} = 14\, m/s$$
$$P = 3.8\, kW \;\; - \phi = 0.45$$



FLAME L (Lifted)

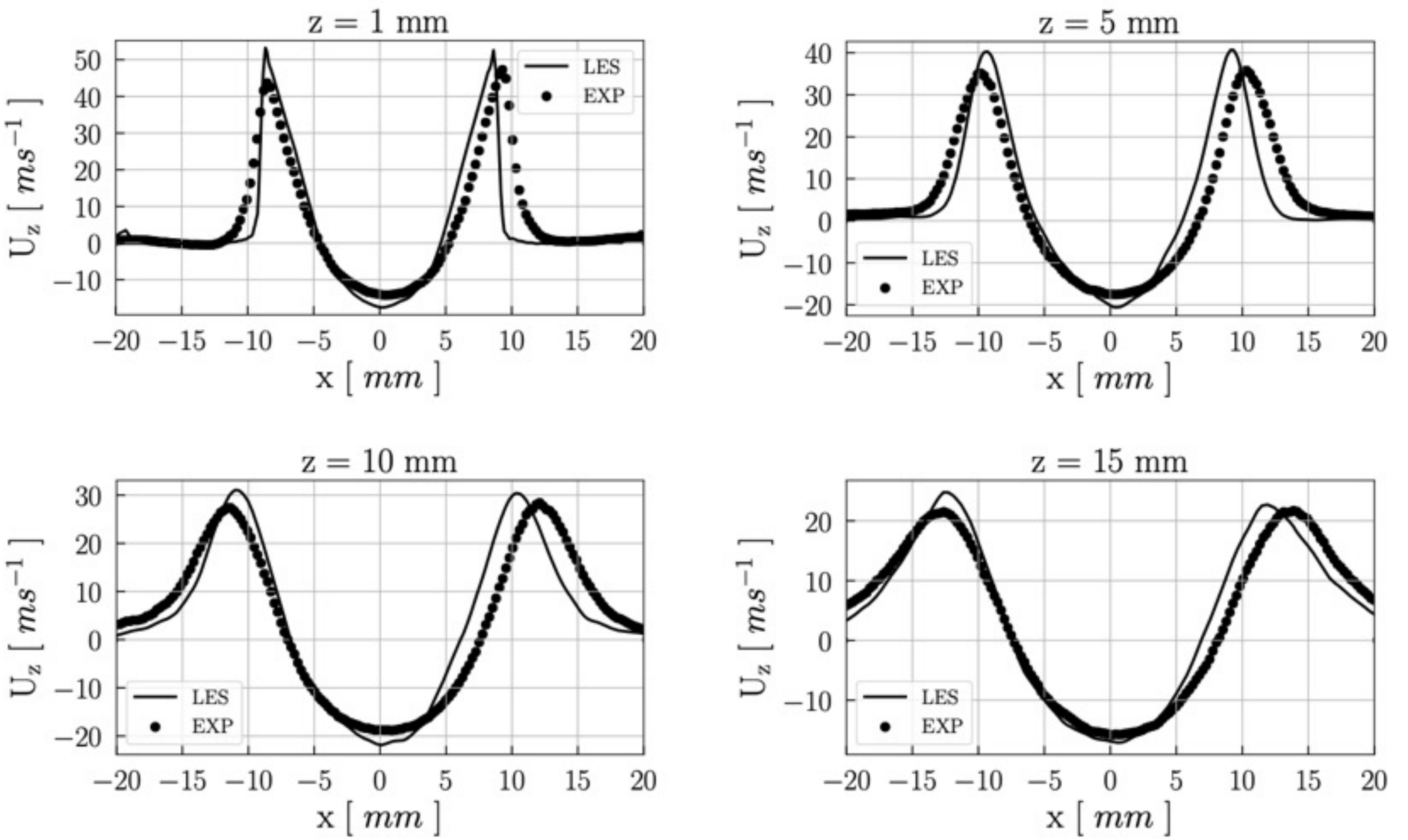
$$U_{air} = 29\, m/s$$
$$U_{H_2} = 35\, m/s$$
$$P = 9.5\, kW \;\; - \phi = 0.45$$



Initial PIV – LES comparisons Marragou / Aniello

Flame L

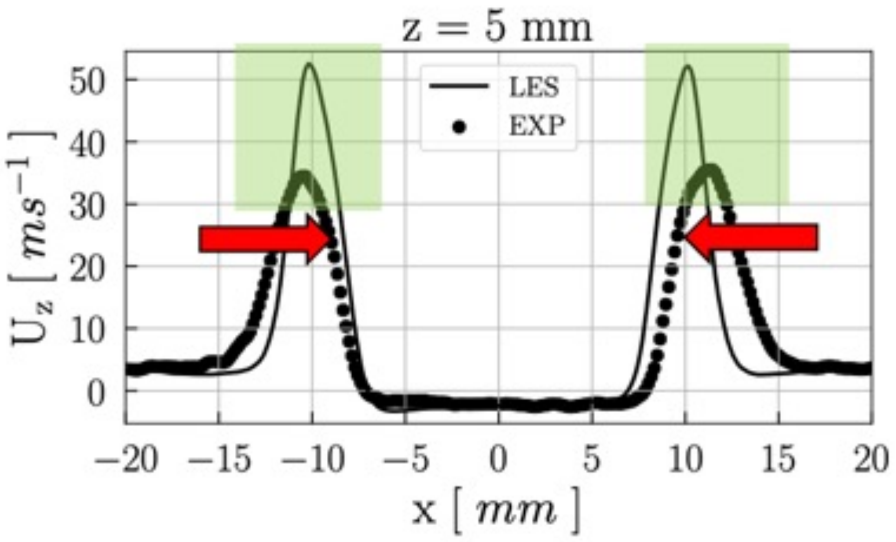
Cold flow

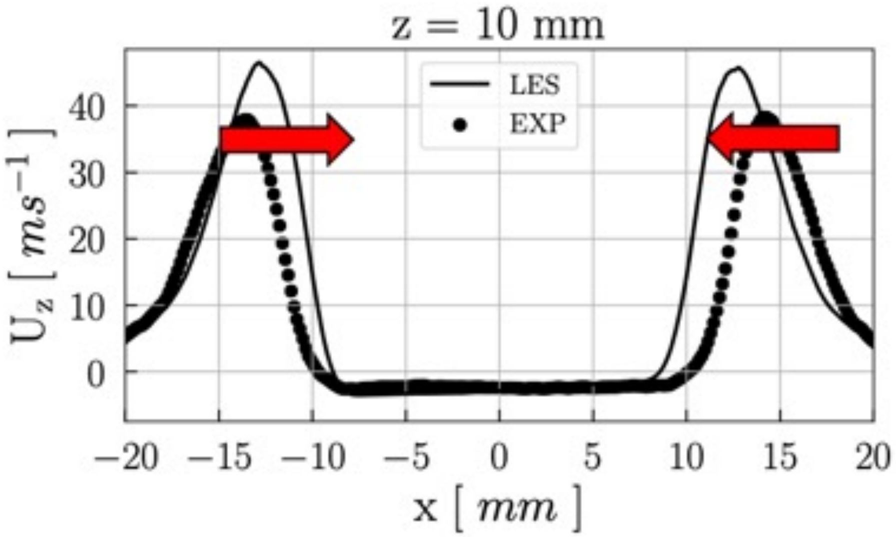


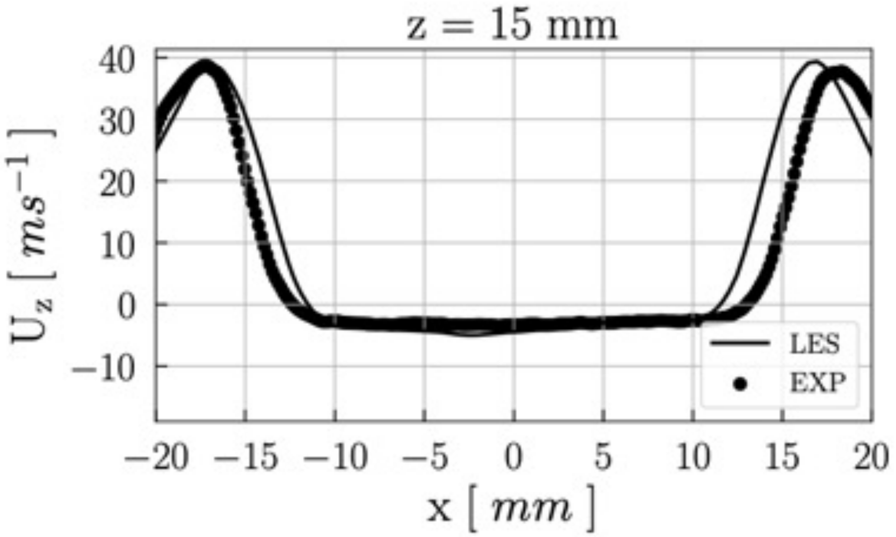
Initial PIV – LES comparisons Marragou / Aniello

Flame L

Hot flow

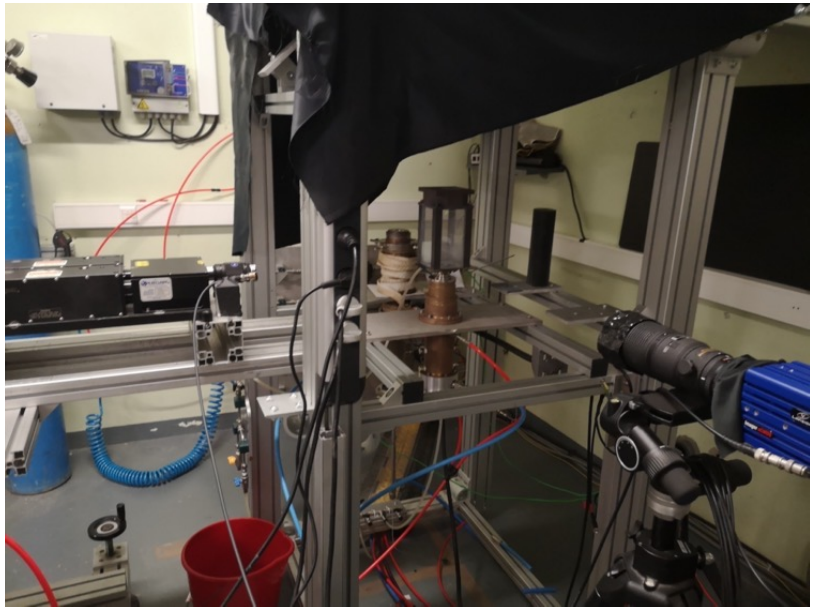


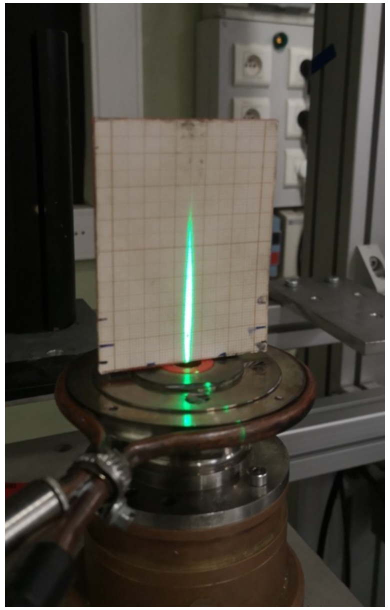


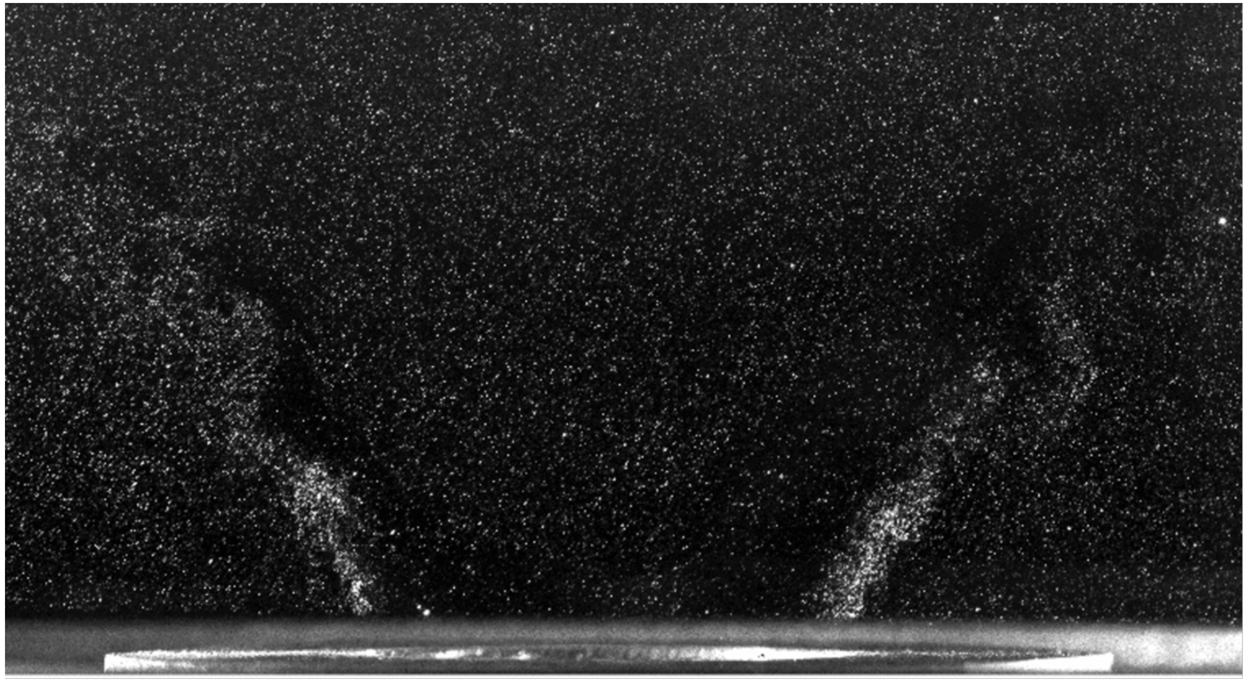


Check list

- Geometry
- Air and fuel mass flowrates
- Leaks
- Air and fuel temperatures
- Geometry
- Laser sheet alignment
- Quality of seeding
- Geometry
- Air and fuel mass flowrates
- PIV parameters: ΔT between laser pulses, interrogation windows
- Laser sheet thickness
- ….







Particle size!

Stokes Number : $S_{tk} = \frac{\tau_p}{\tau_g} = \frac{\rho_p d_p^2}{18\,\mu_g} \frac{u_g}{l_g}$

- $\ll 1$ Particles follows the flow
- $\gg 1$ Balistic particles (insensitive to the small structures of flow)

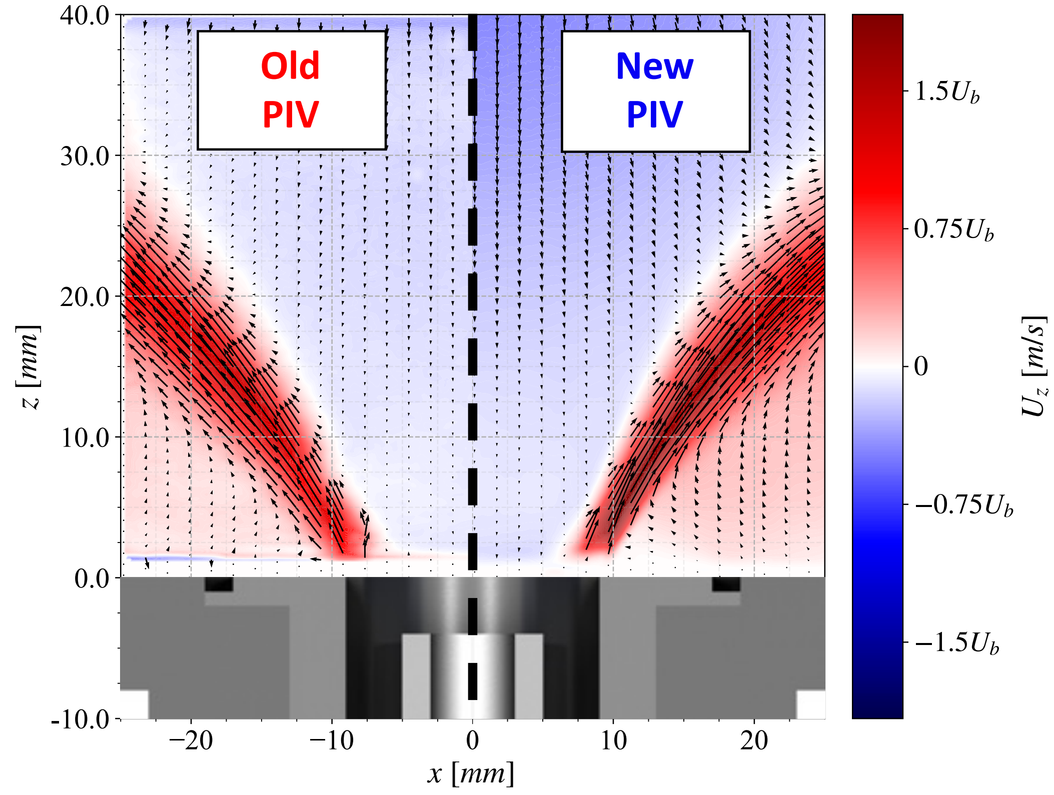
Desired powder

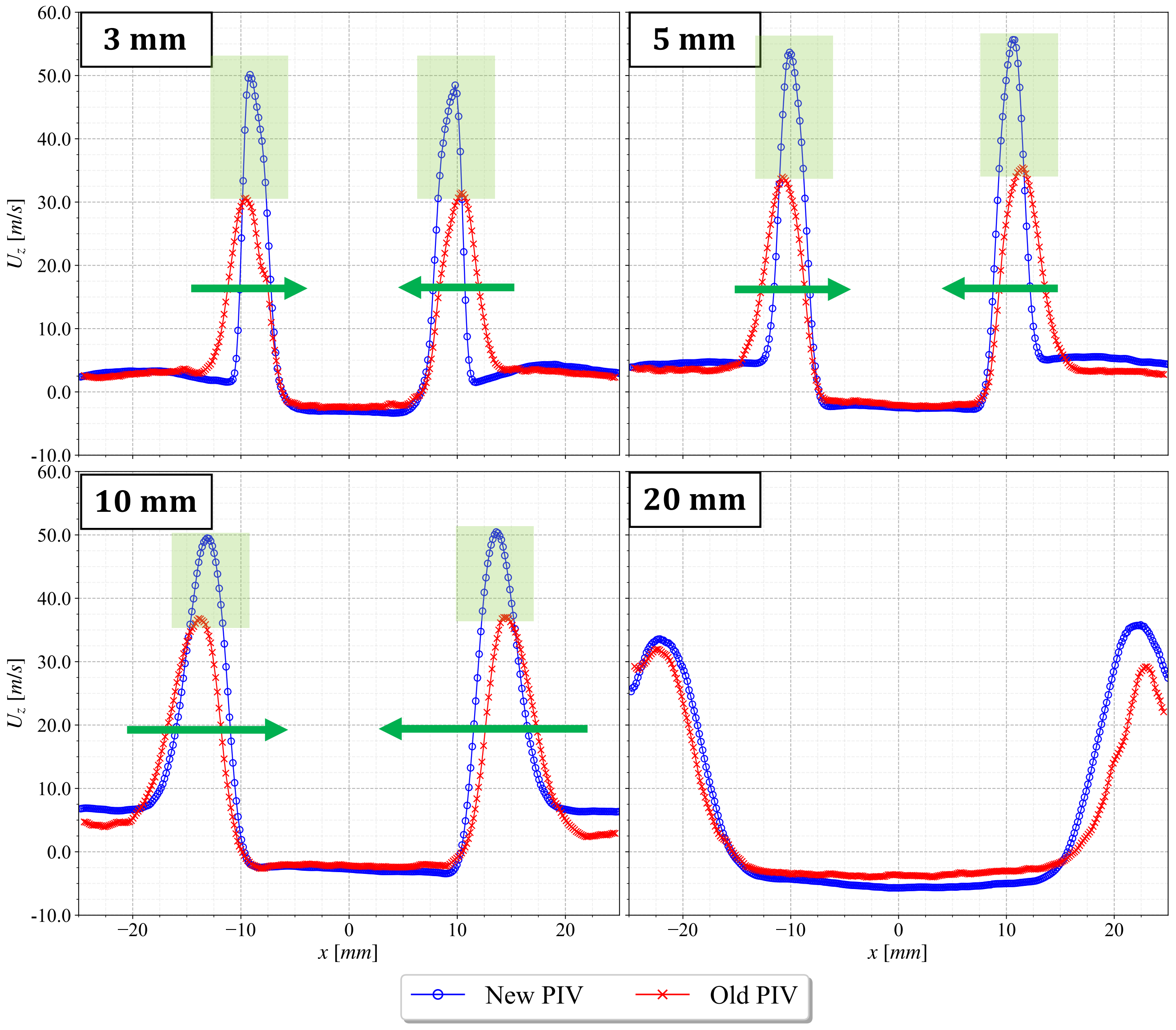
Nom particule	*50361-10, TYPE DX, ALPHA ALUMINA POWDER, 1um*
Densité volumique (g/cm3)	*3,97*
Diamètre (um)	***1***
Tau_p (s)	*1,22E-05*
ug (m/s)	50
lg (mm)	3
Tau_g	6,00E-05
St_k	**0,20**

Final powder

Nom particule	*Dioxyde de zirconium, 96-98 %, extra pur, SLR, Fisher Chemical*
Densité volumique (g/cm3)	*5,85*
Diamètre (um)	***10***
Tau_p (s)	*1,79E-03*
ug (m/s)	50
lg	3
Tau_g	6,00E-05
St_k	**29,872**

Comparison between intial and final PIV



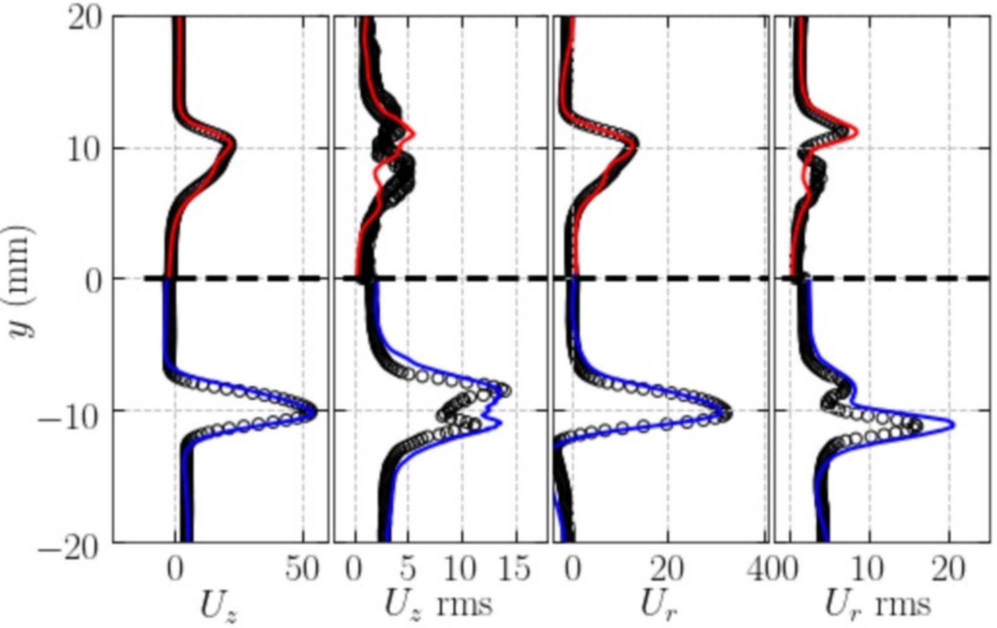


Final PIV vs LES

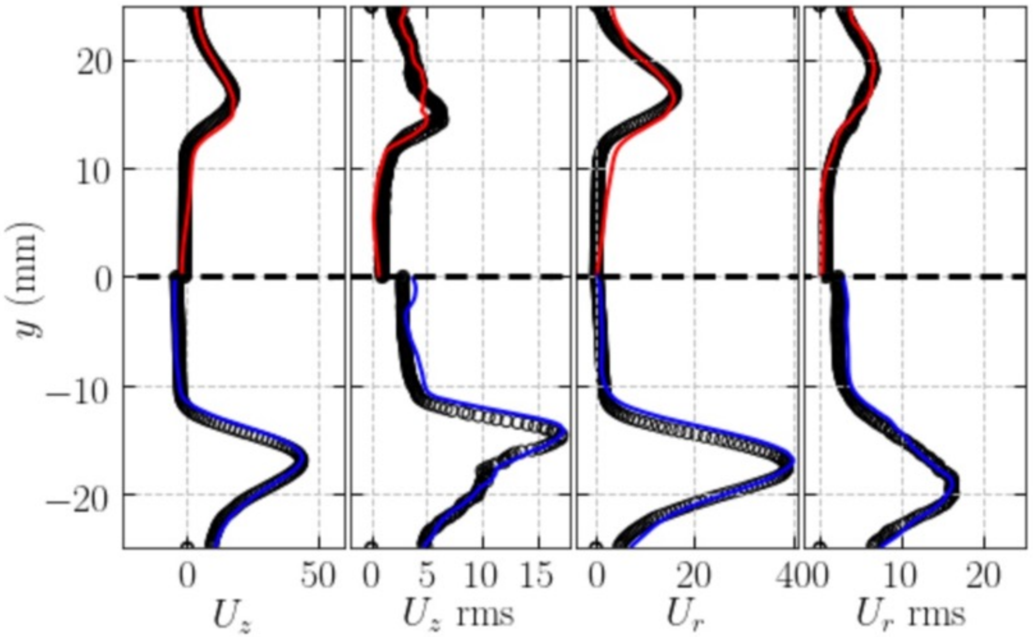
Flame A

Flame L

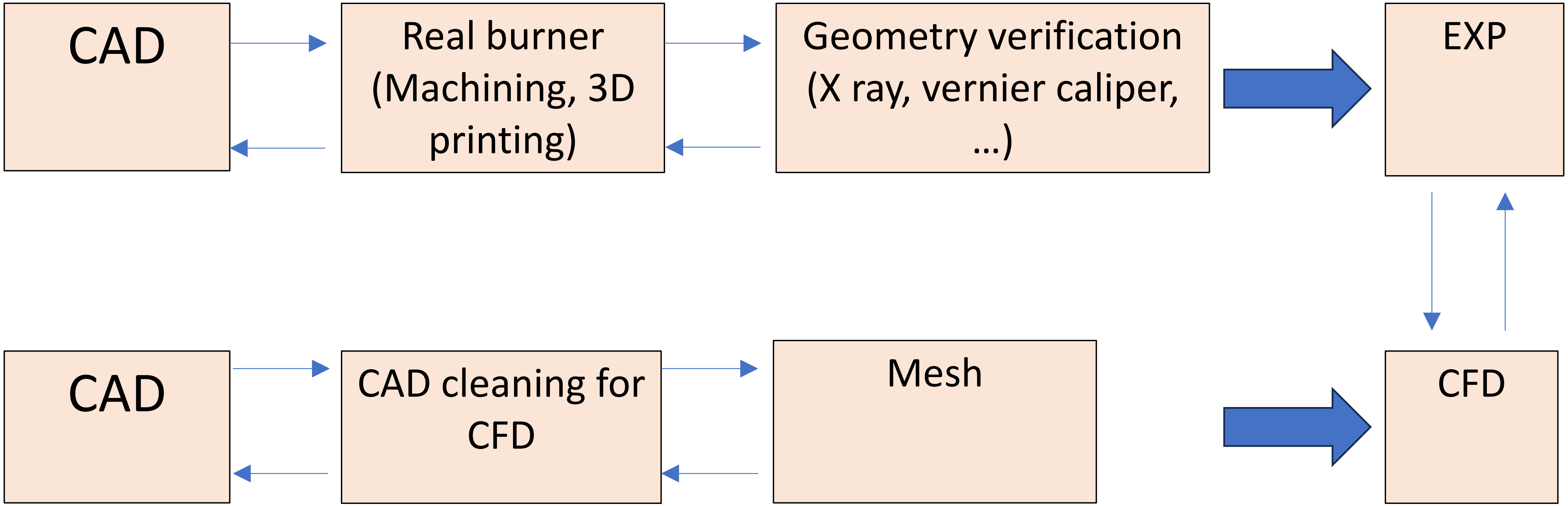
Z = 5 mm



Z = 15 mm

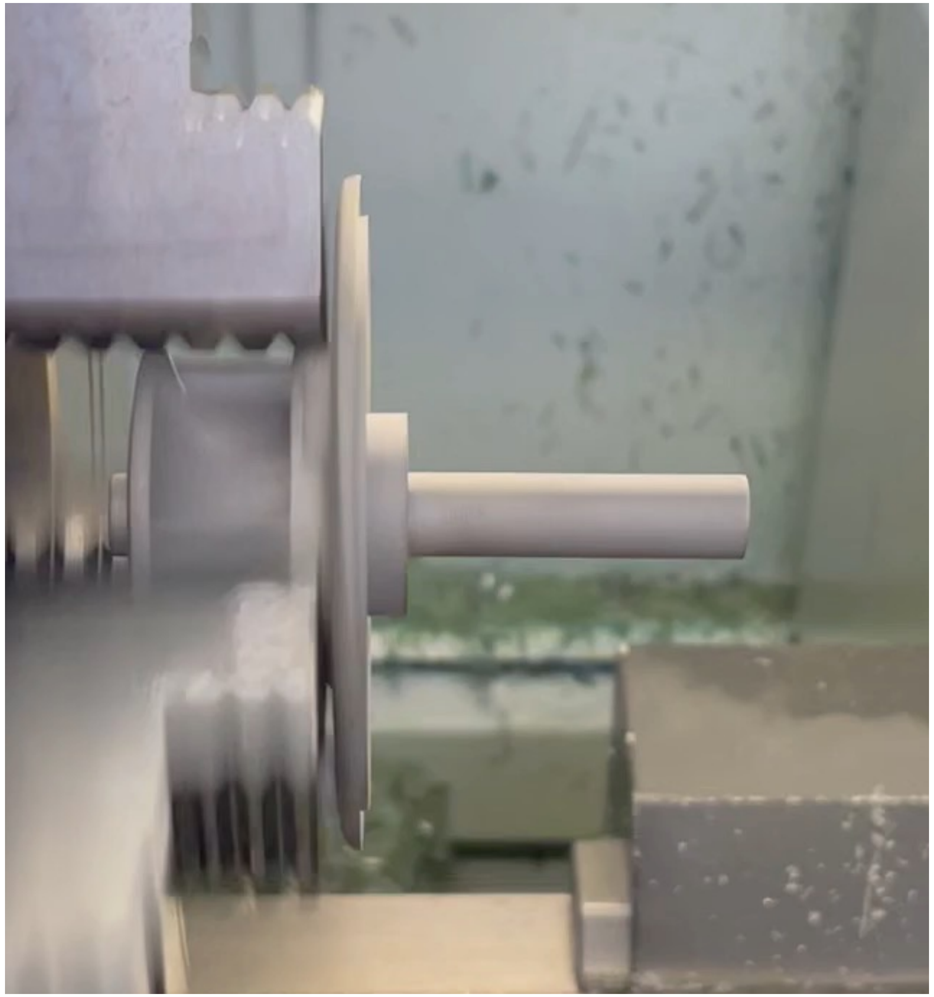


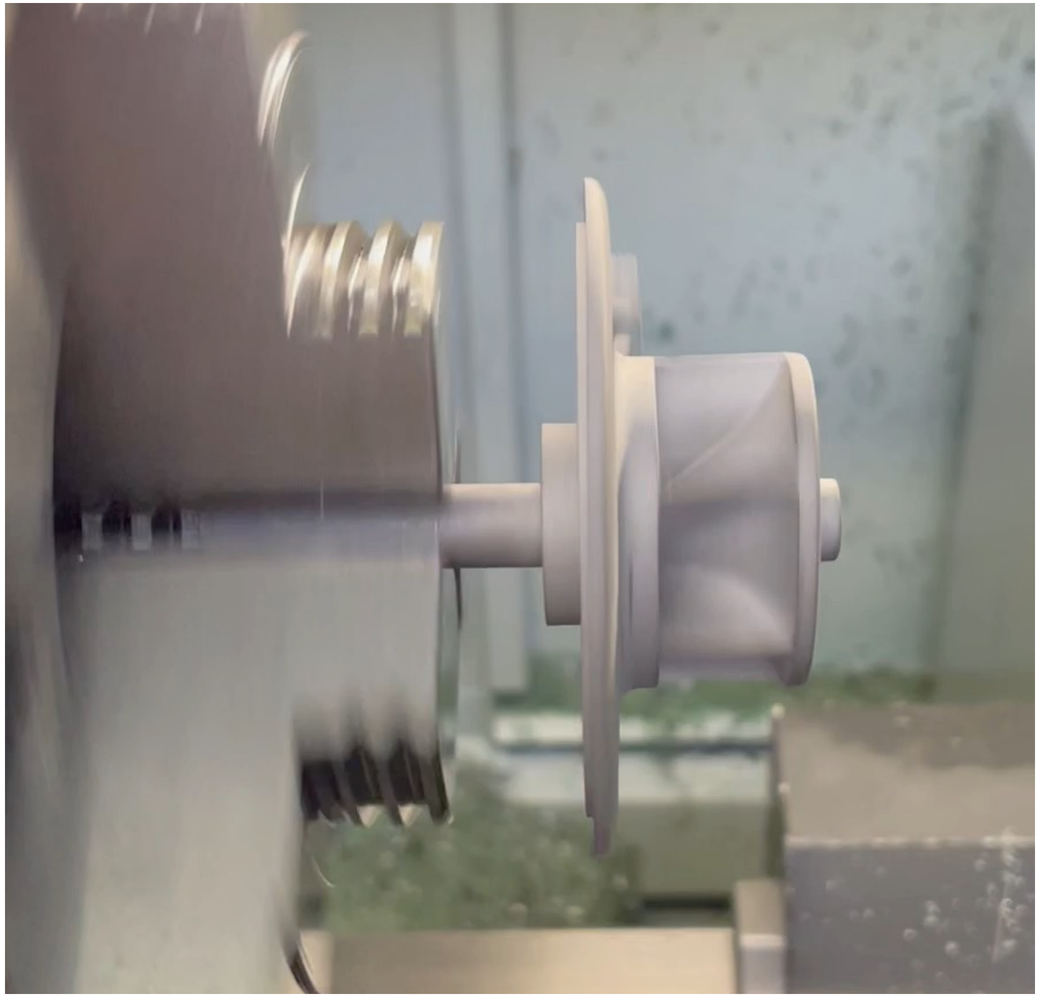
EXP / CFD comparisons: A long chain process



Focal point for database
M. Villespy

Other defects





Impact of spoiler on flame stabilization