Experimental Investigation of turbulent swirling jets

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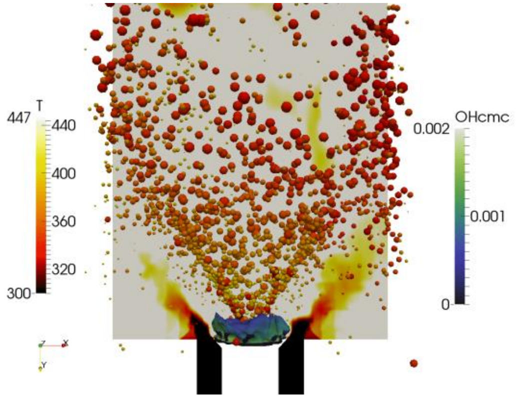
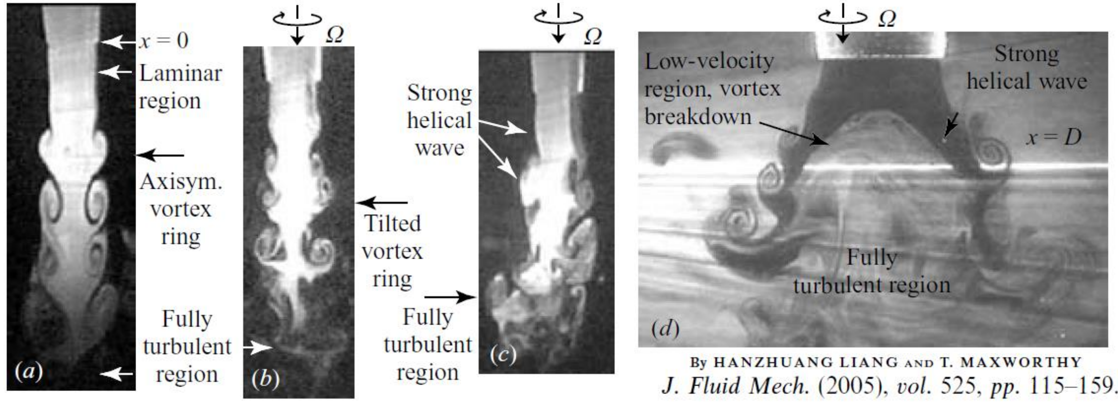
INTRODUCTION

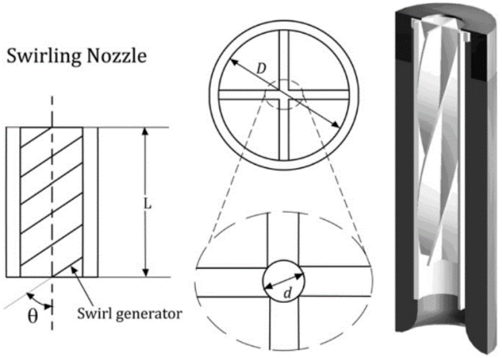




By HANZHUANG LIANG AND T. MAXWORTHY

J. Fluid Mech. (2005), *vol.* 525, *pp.* 115–159.

(a) $S = 0$, (b) $S = 0.44$, (c) $S = 0.80$, (d) $S = 1.03$. $Re = 1000$



Heat transfer enhancement with **swirling jets** (Ianiro & Cardone, Appl Therm Eng, 2012)

J. Fluid Mech. (1998), *vol.* 376, *pp.* 183–219. Printed in the United Kingdom 183
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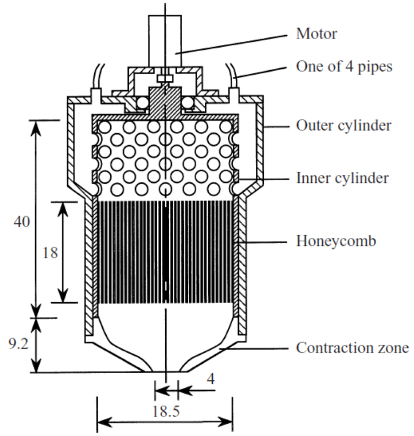
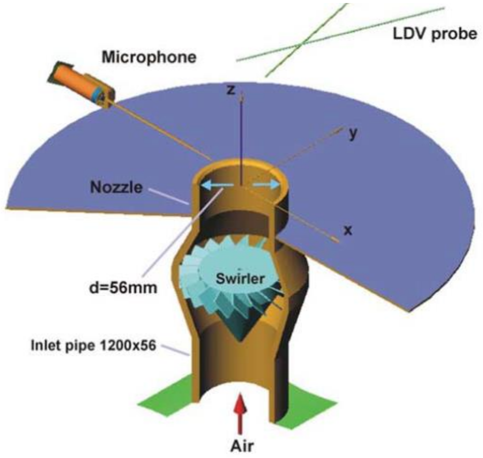
Experimental study of vortex breakdown in swirling jets

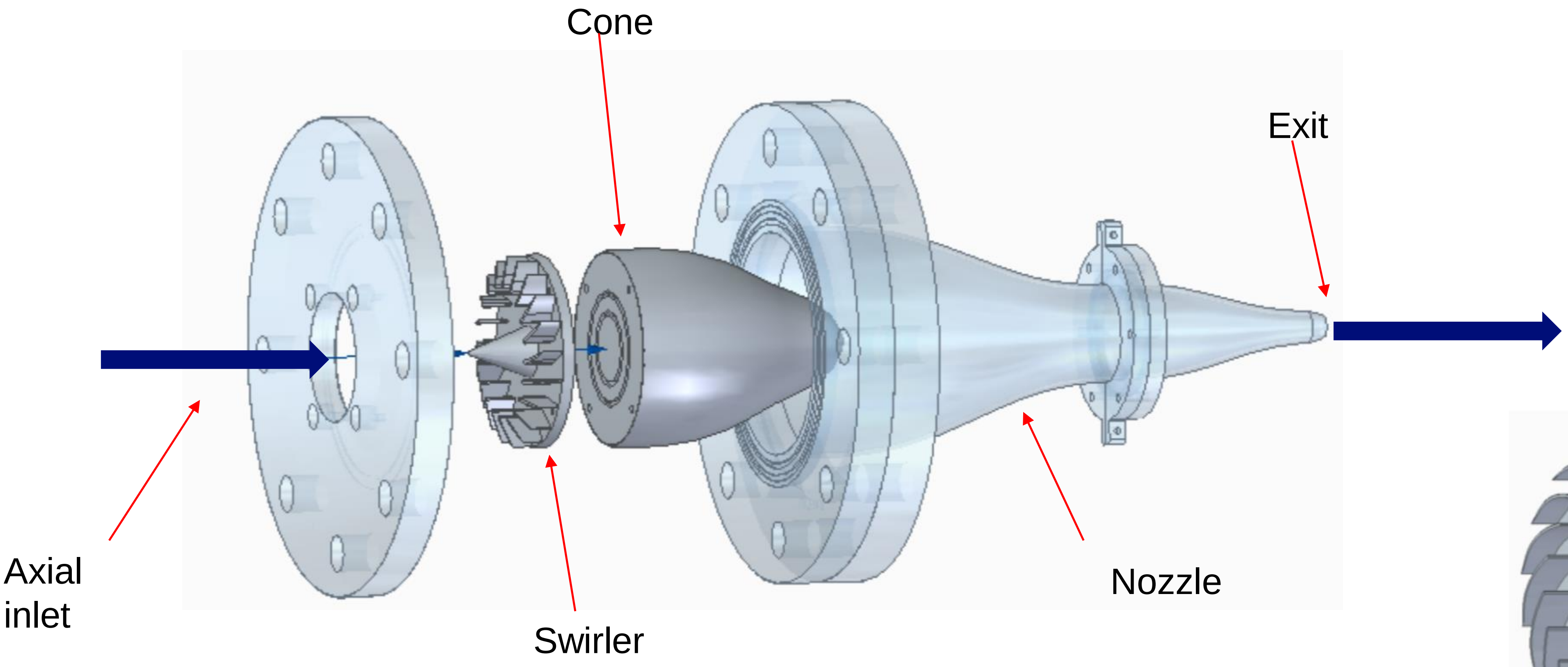
By PAUL BILLANT[1,2], JEAN-MARC CHOMAZ[1] AND PATRICK HUERRE[1]



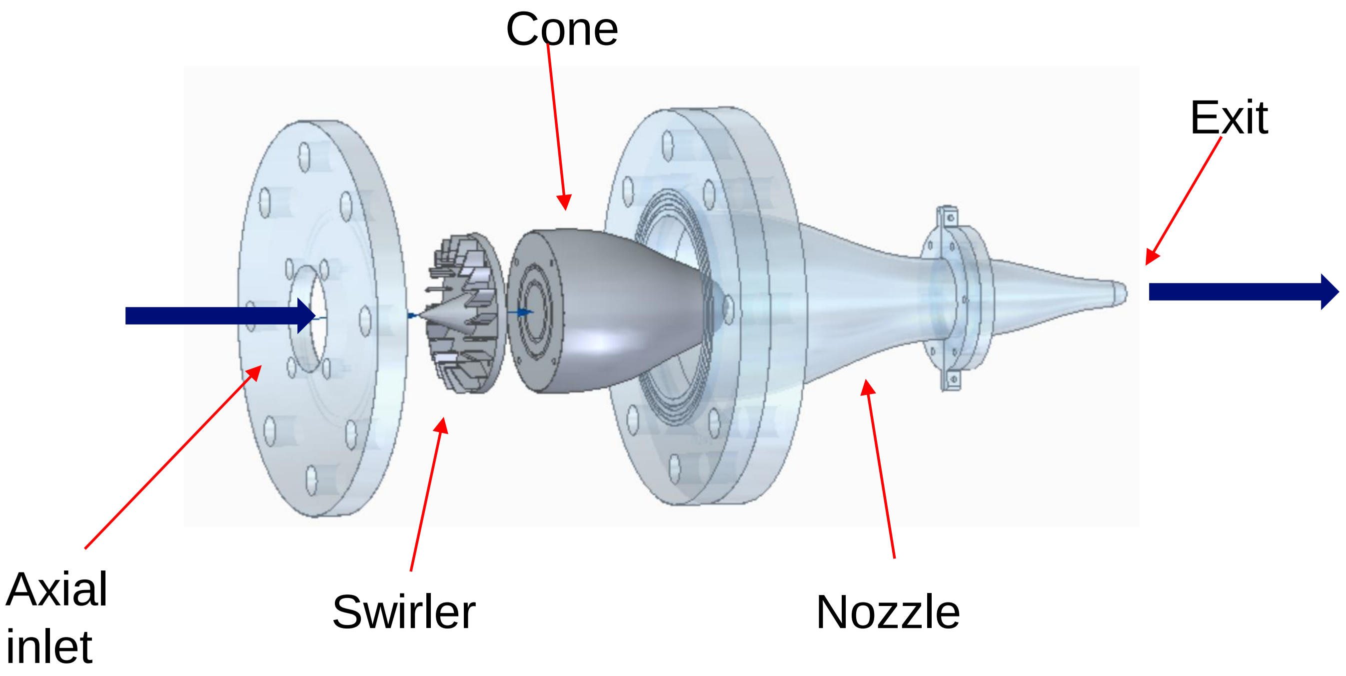


Cala et al. EiF 2006

GEOMETRICAL DESIGN: CONCEPT



GEOMETRICAL DESIGN



Advantage:
- Simplicity

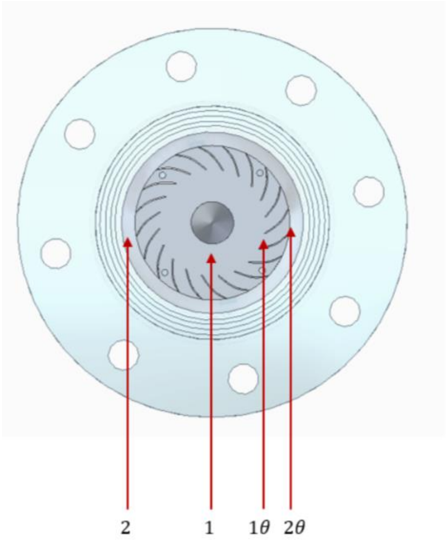
Disadvantage:
- Less control on effective swirl number

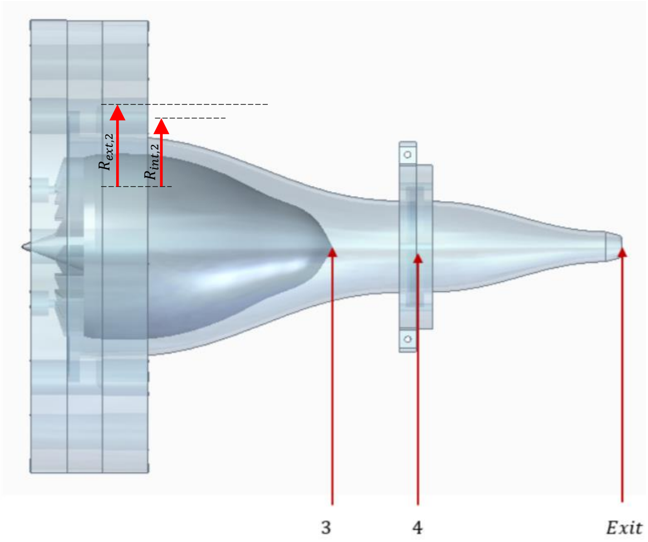
$$S = \frac{G_\theta}{D/_2\, G_x}$$

GEOMETRICAL DESIGN

Assumption:

- **Conservation of momentum**





$$G_\theta = 2\pi\rho \int_0^R U_x U_\theta r^2 dr$$

$$G_x = 2\pi\rho \int_0^R {U_x}^2 r dr$$

$\Rightarrow$

$$G_\theta \rightarrow U_{x,2}\, U_{\theta,2} \frac{{R_{ext,2}}^3 - {R_{int,2}}^3}{3}$$

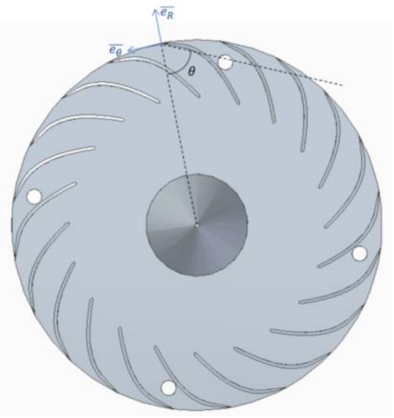
$$G_x \rightarrow {U_{x,exit}}^2 \frac{{R_{exit}}^2}{2}$$

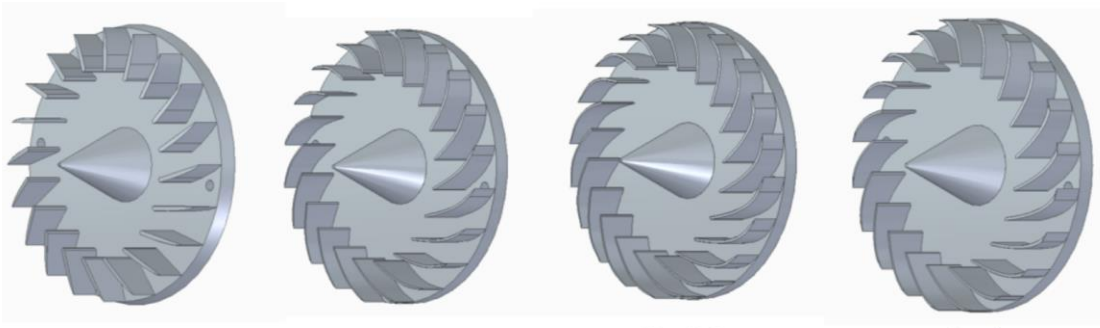
GEOMETRICAL DESIGN

$$S = \frac{G_\theta}{{}^{D}\!/_{2}\, G_x} = \frac{2}{3} \frac{U_{x,2} U_{\theta,2}}{{U_{x,exit}}^2} \frac{{R_{ext,2}}^3 - {R_{int,2}}^3}{{R_{exit}}^3}$$

⇩ **MASS CONSERVATION**

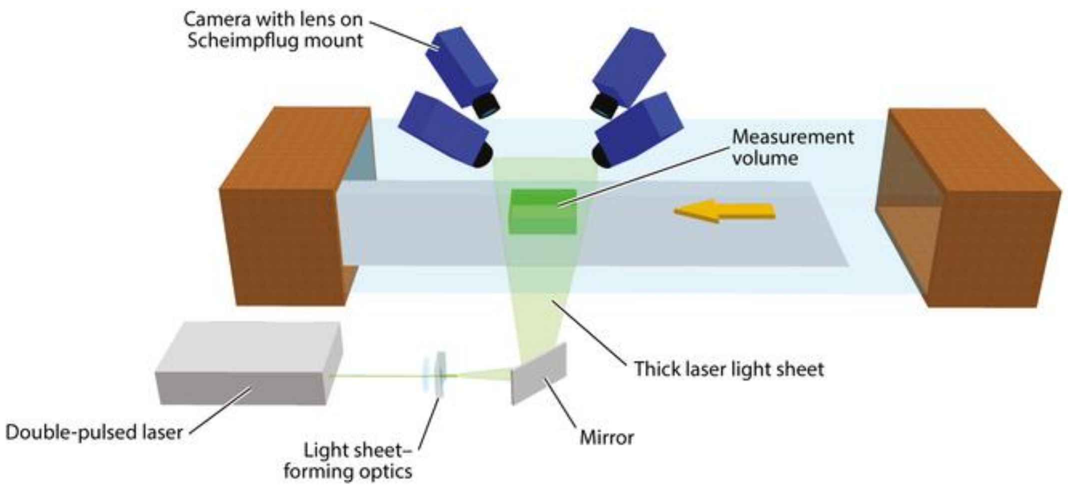
$$S = \frac{{A_{exit}}^2}{A_2\, A_{2,\theta}} \frac{{R_{ext,2}}^3 - {R_{int,2}}^3}{{R_{exit}}^3} \frac{2 \tan\theta}{3}$$

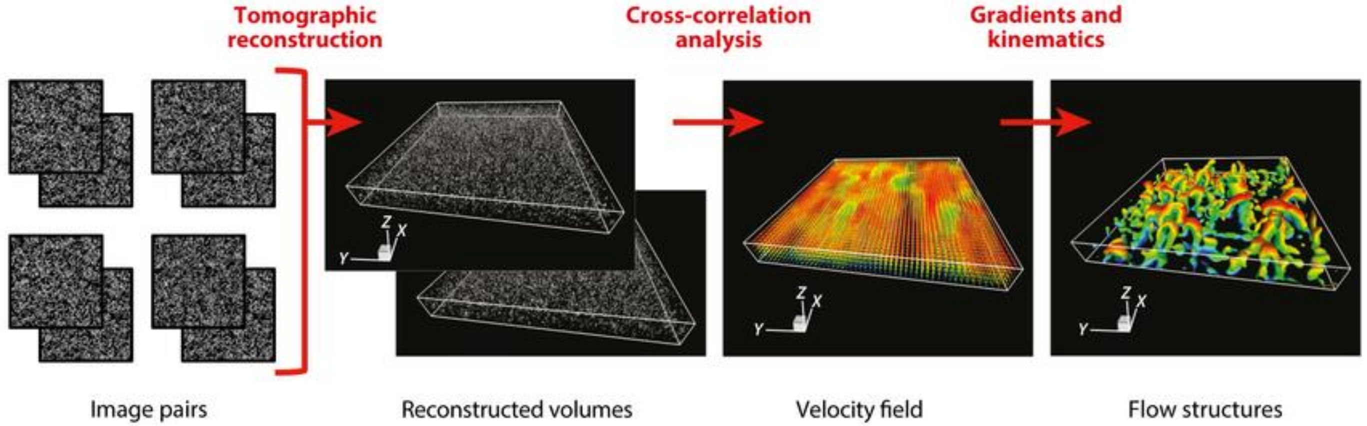




$S = 0.1$ $S = 0.4$ $S = 0.8$ $S = 1$

EXPERIMENTAL SETUP

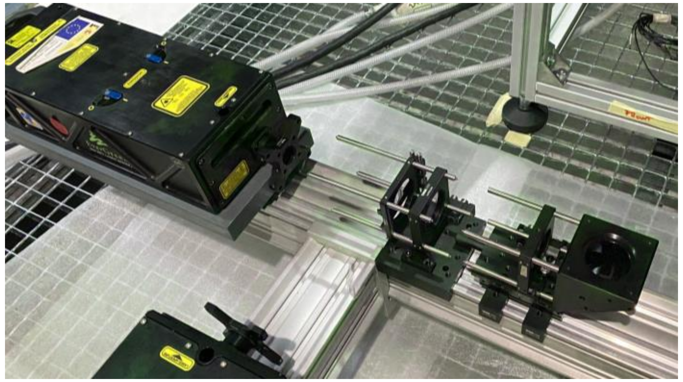




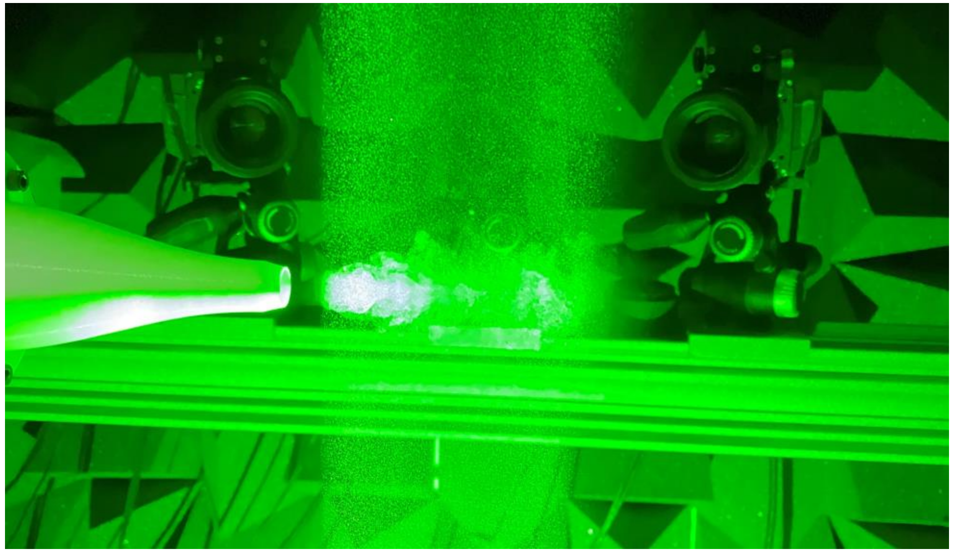
Westerweel J, et al. 2013.
Annu. Rev. Fluid Mech. 45:409–36

EXPERIMENTAL SETUP

LASER & OPTICS



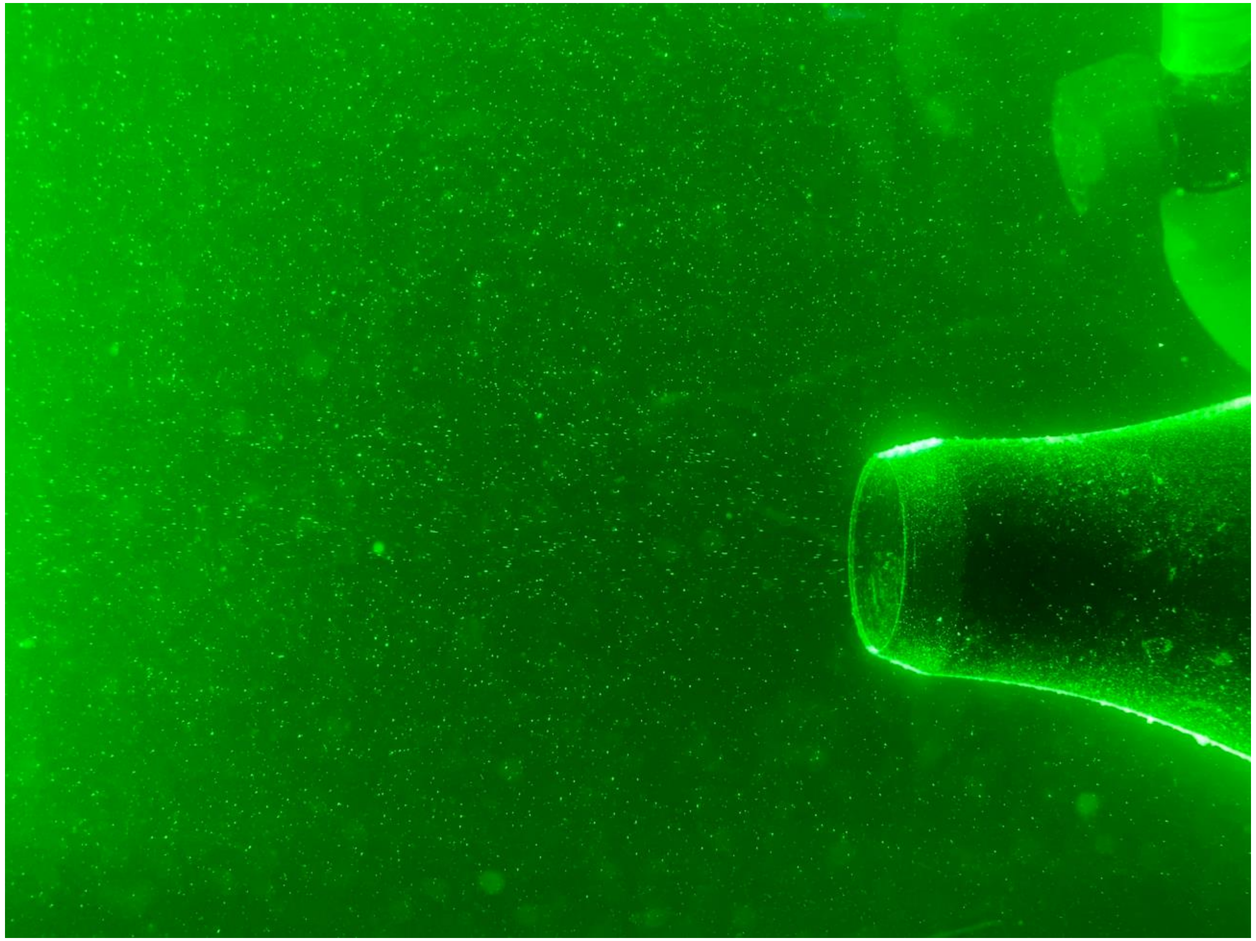
CAMERAS



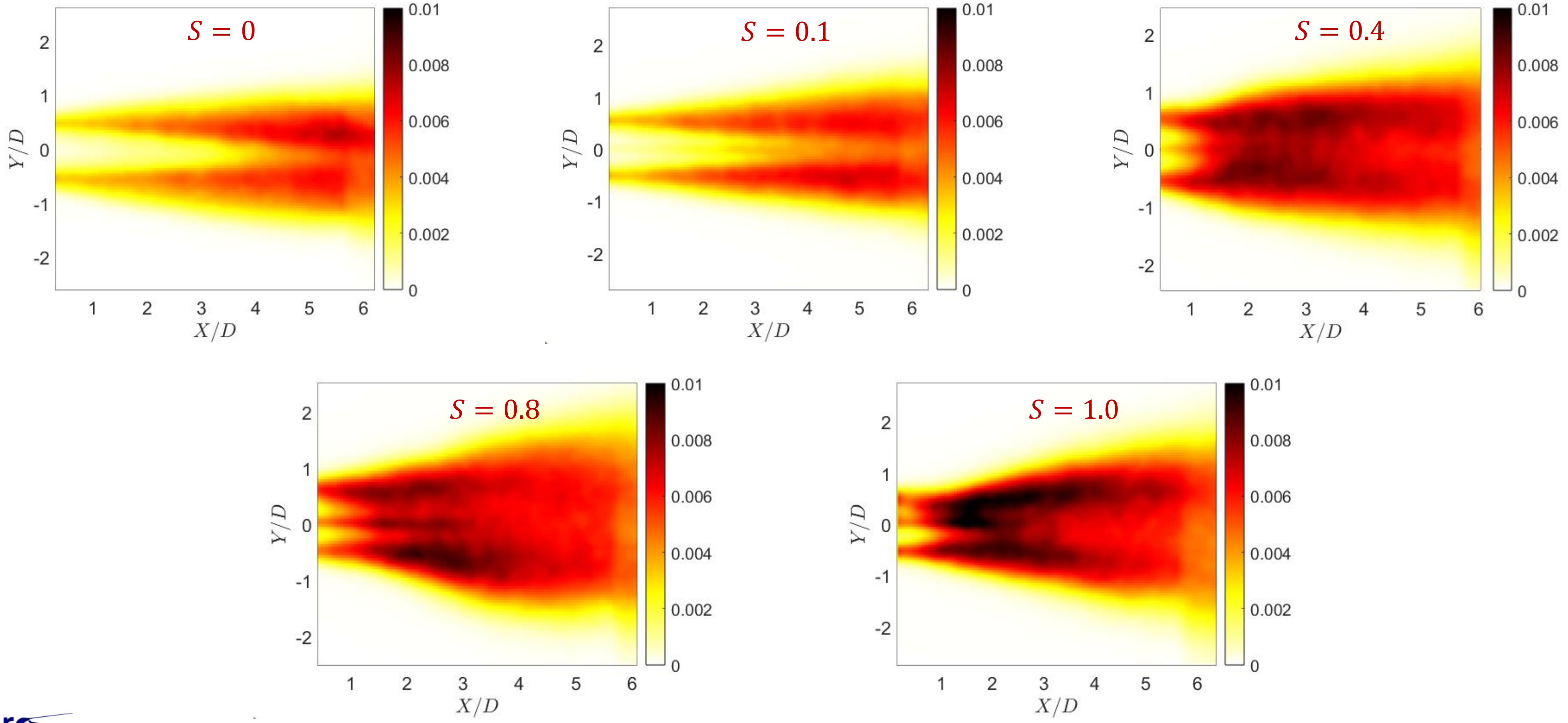
THIN TOMO PIV

$D = 1cm$
$Re = 35000$
$\dot{m} = 5\frac{g}{s}$
$V = 6.40 \times 5.75 \times 0.50\ D$

SWIRLING JETS IN WATER

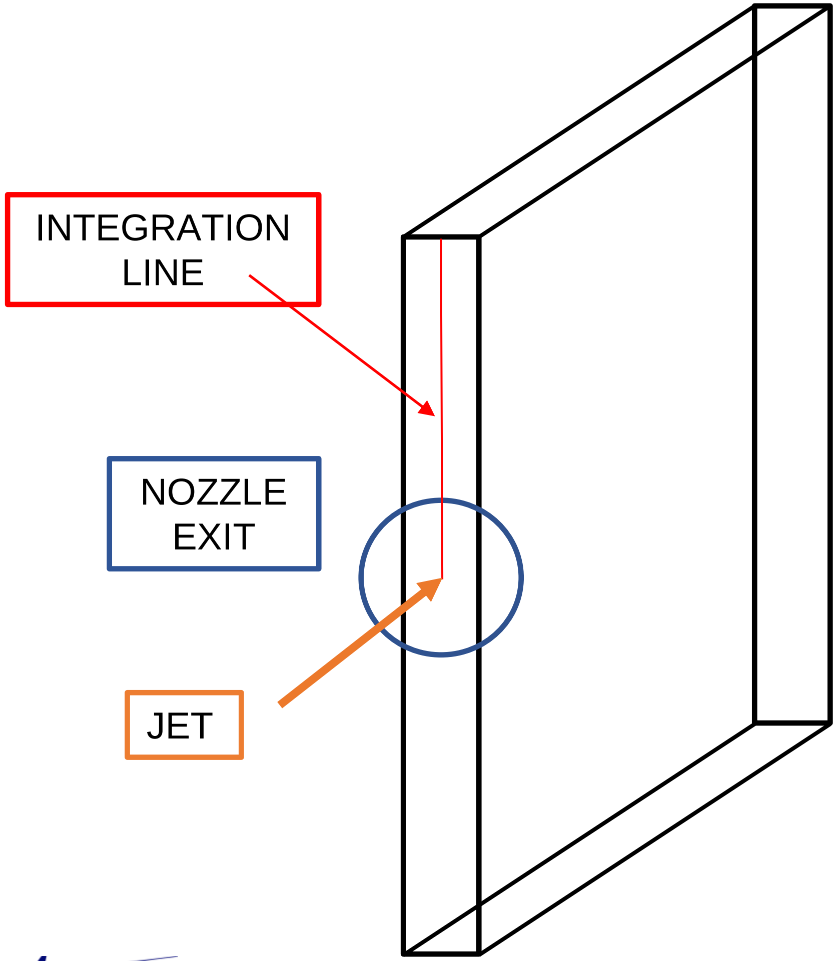


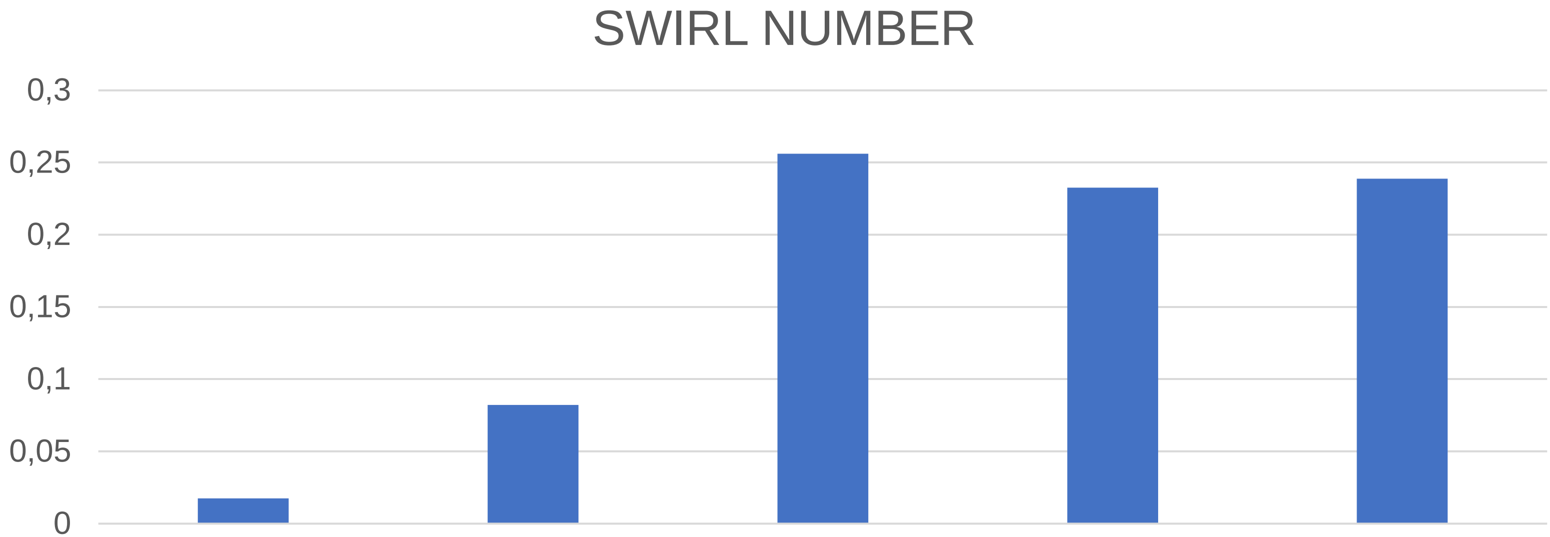
PIV RESULTS: TURBULENT KINETIC ENERGY



PIV RESULTS

$$S = \frac{2}{D}\frac{\int_0^\infty U_x U_\theta r^2 dr}{\int_0^\infty ({U_x}^2 - {U_\theta}^2/_2) r dr}$$

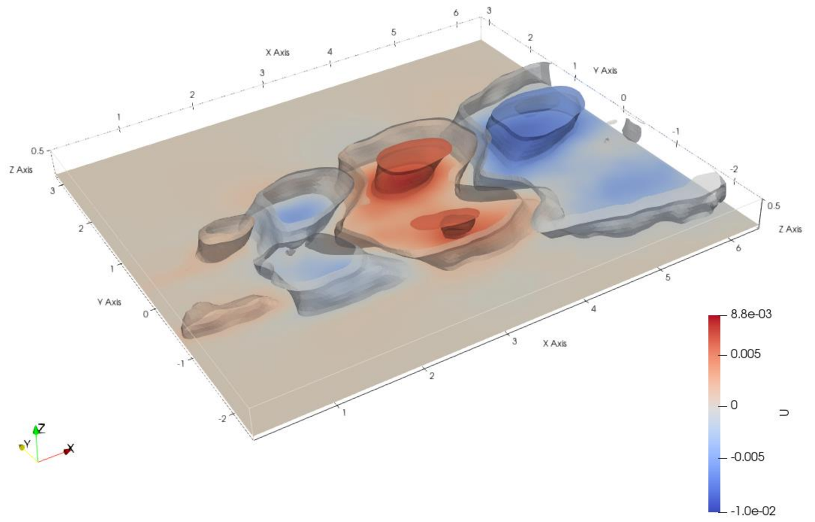




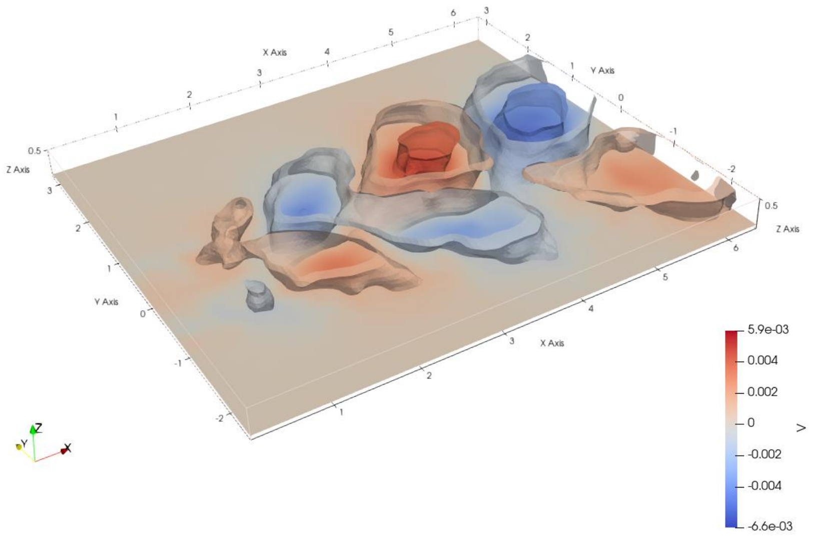
PIV RESULTS: POD MODES – $S = 0.4$

$$[u', v', w'] = \Psi\Sigma\Phi$$

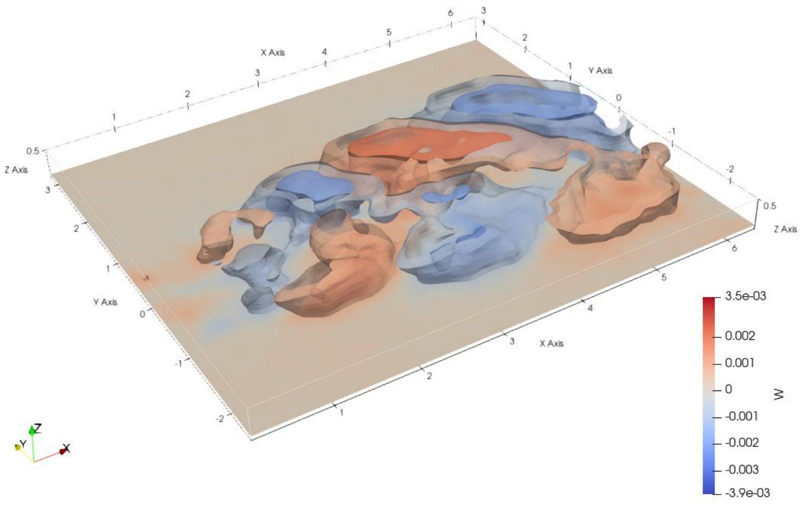
Φ_u



Φ_v



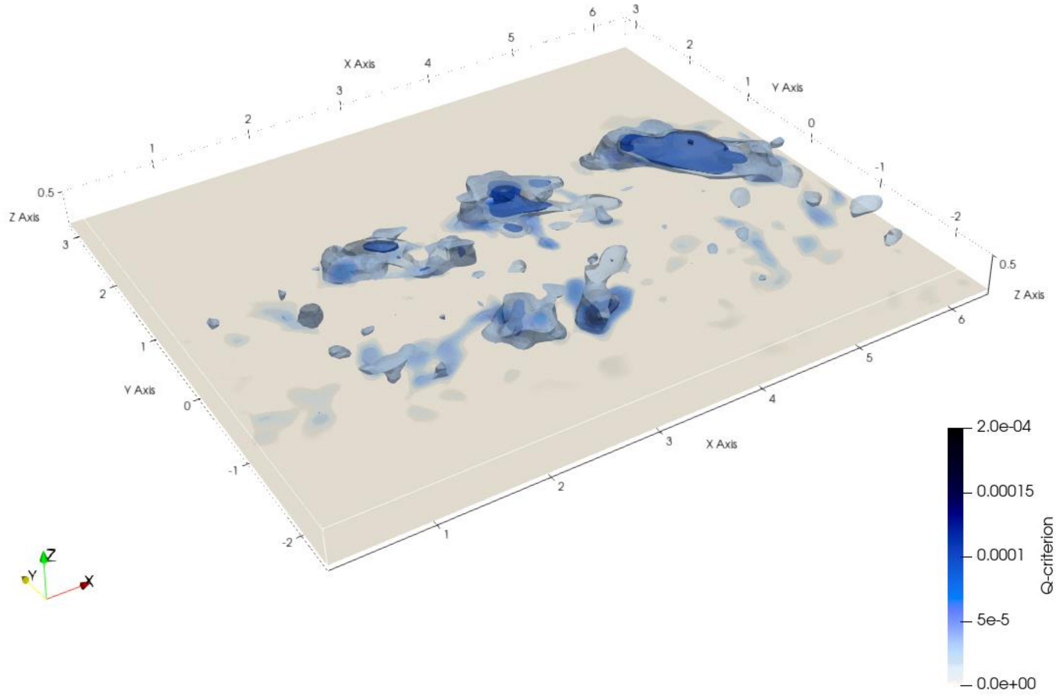
Φ_w



PIV RESULTS: POD MODES – $Q-criterion$

$S = 0.4$

1^{st} POD mode



SUMMARY

- Preliminary assessment of a concept of “geometrical swirl nozzle”
- The method is accurate for low swirl ($S = 0.4$)
- Larger swirl numbers are more difficult to reproduce

FUTURE DEVELOPMENT

- Address Reynolds number effect and nozzle geometry on exit swirl
- Identify empirical scalings for the design of the geometrical swirl nozzle

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