Comparison of numerical and experimental C_p on a 4:1 rectangular cylinder

A. Guissart, T. Andrianne, G. Dimitriadis and V.E. Terrapon

Department of Aerospace and Mechanical Engineering
University of Liège

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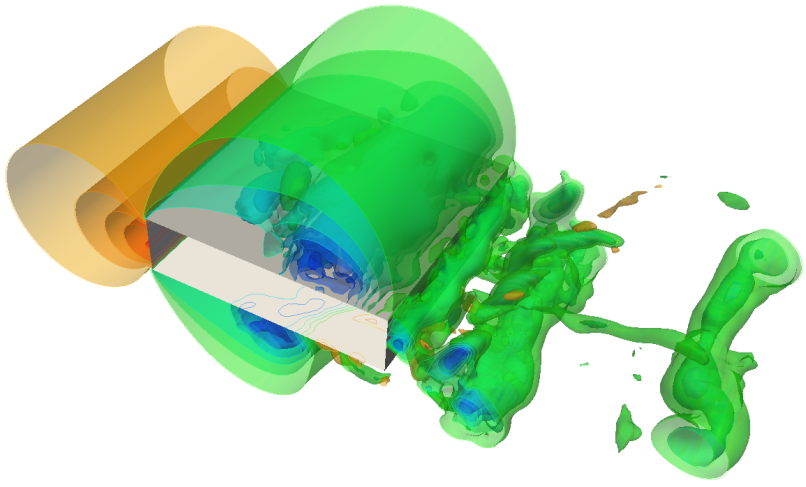
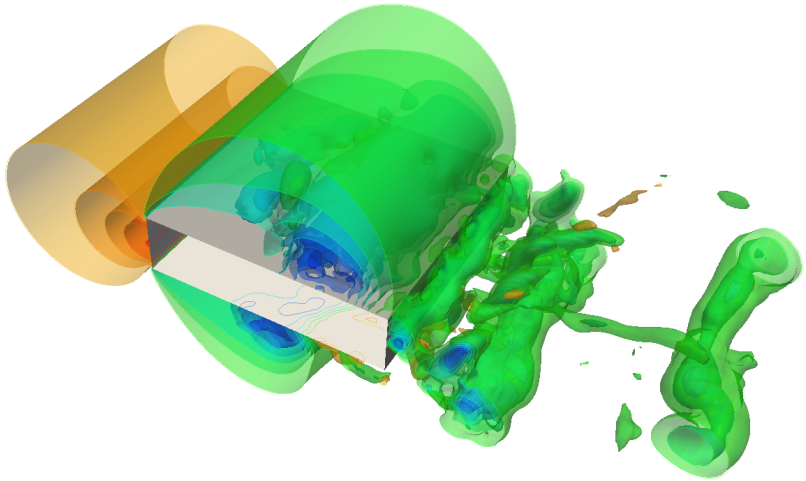


Context

- flow around
  a 4:1 rectangular cylinder
- numerical and experimental studies
- moderate Re and different α



Context

- flow around
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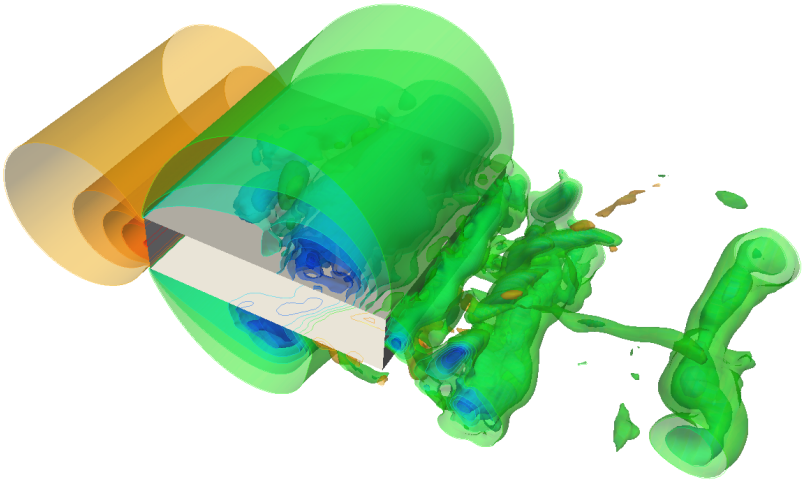
Objectives

- determine the effects of α on the flow features and the aerodynamic loads
- assess the capability of URANS and DDES to provide an accurate estimation of the flow and the aerodynamic loads

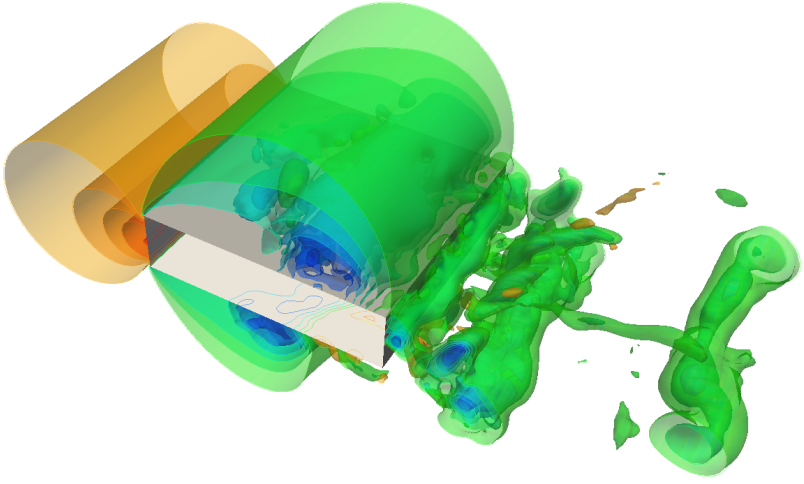
Methodology

Methodology



Flow studied through EXP and CFD

Methodology



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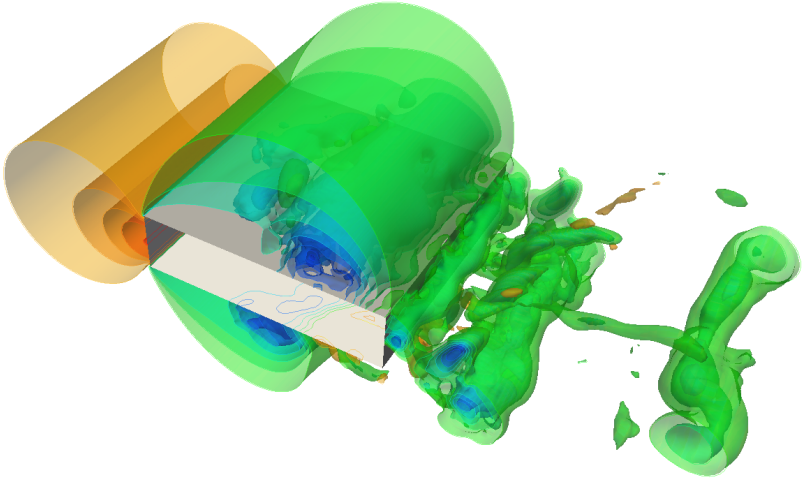

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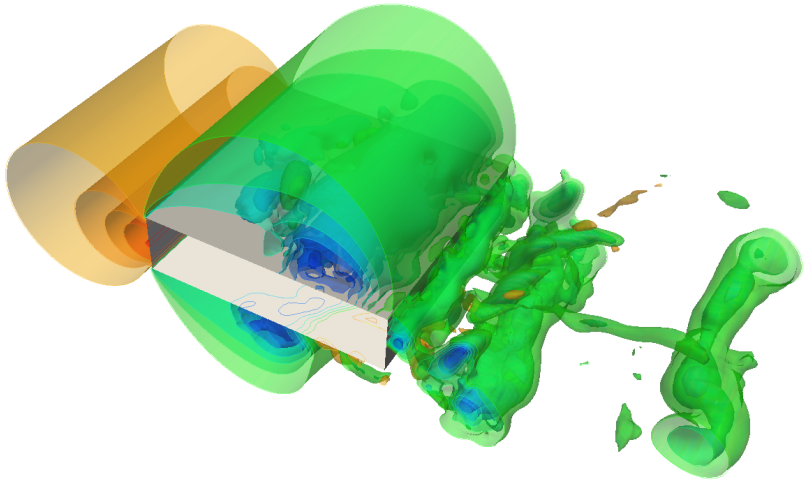

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Comparison of EXP and CFD results

- **statistics on C_p, c_l, c_d, c_m and St**
- **dynamic mode decomposition (DMD) on unsteady C_p**

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- DMD[a] = decomposition in single frequency spatial modes

$$\mathbf{V}_1^N(\mathbf{x}, t) = \sum_{k=1}^{K} \underbrace{q_k^{DMD}}_{\text{amplitude}} \underbrace{\phi_k^{DMD}}_{\substack{\text{spatial}\\ \text{mode}}} \underbrace{\exp\left(\lambda_k^{DMD}\mathbf{t}\right)}_{\substack{\text{time}\\ \text{evolution}}} \quad \text{with} \quad \mathbf{V}_1^N = \left[C_p\, c_l\, c_d\, c_m\right]^T$$

[a] "Dynamic mode decomposition of numerical and experimental data" by Schmid (2010)

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- DMD is used to reconstruct an approximation of the results

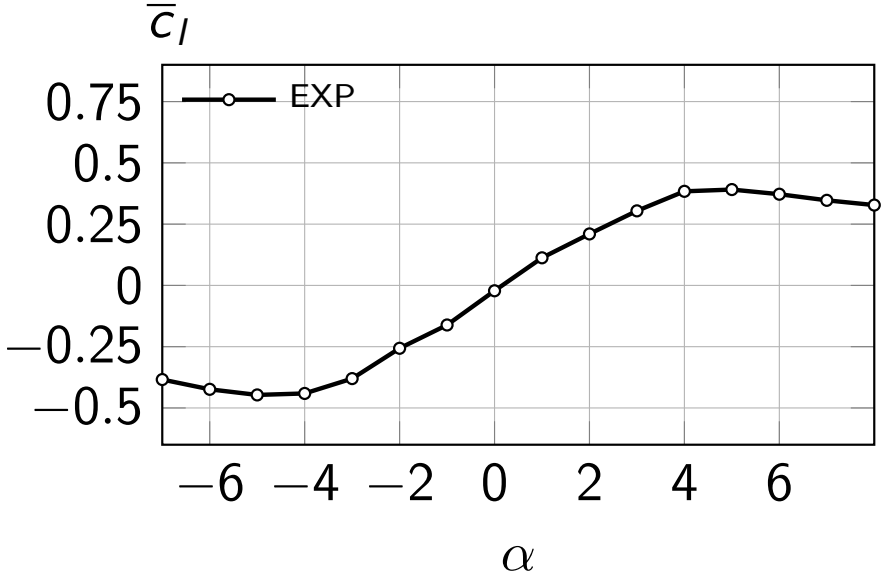
$$\widehat{\mathbf{V}}_1^N = \sum_{k^{\text{th}}\text{selected mode}} q_k^{DMD}\phi_k^{DMD}\exp\left(\Im\left(\lambda_k^{DMD}\right)\mathbf{t}\right)$$

- selected modes correspond to the mean of $\mathbf{V}_1^N$ and the mode associated to the shedding frequency

[a] "Dynamic mode decomposition of numerical and experimental data" by Schmid (2010)

Results

Results: mean load coefficients and St



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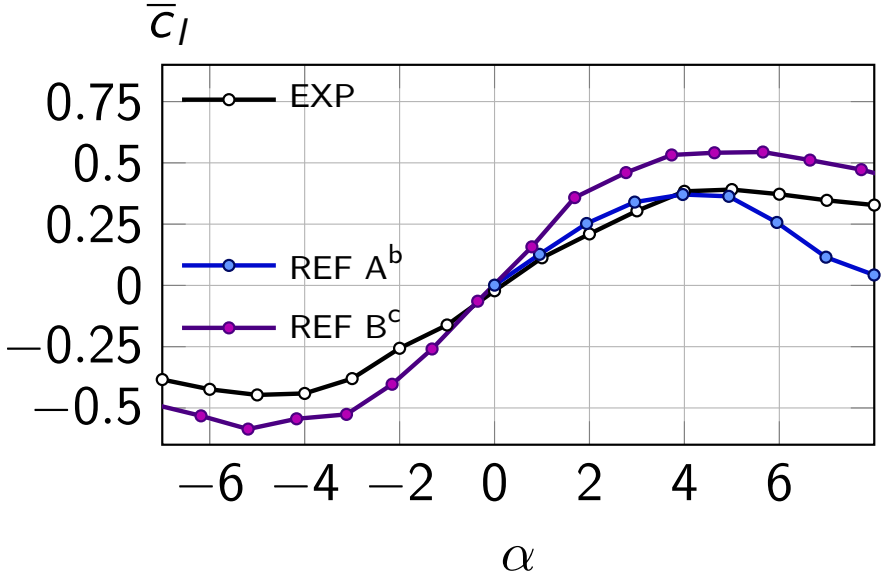

[b] "Aeroelastic instability of rectangular cylinders in a heaving mode" by Washizu et al. (1978)

[c] "Torsional flutter of rectangular prisms" by Nakamura and Mizota (1975)

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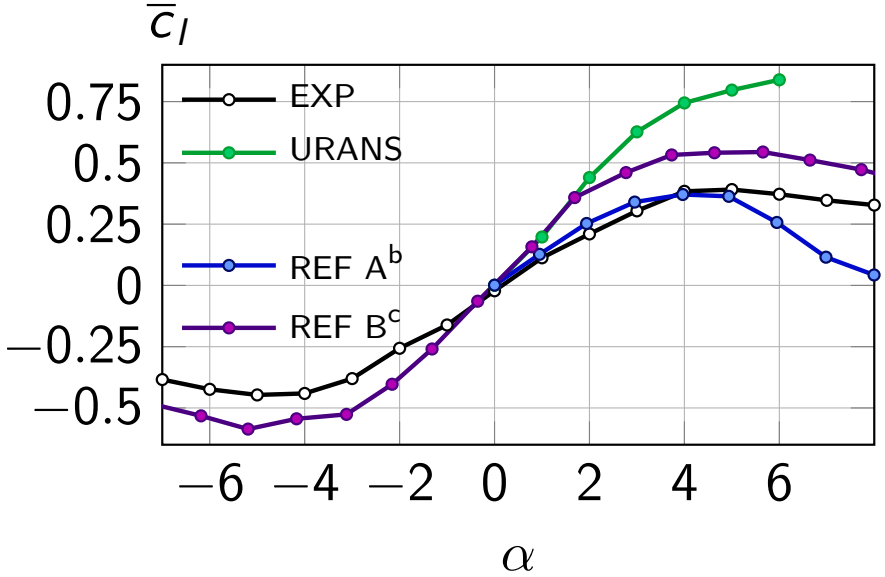

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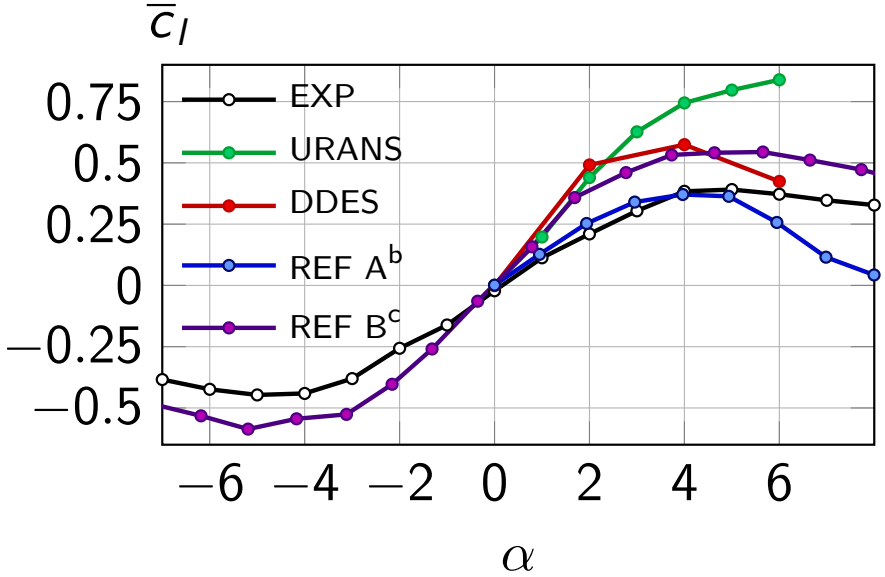

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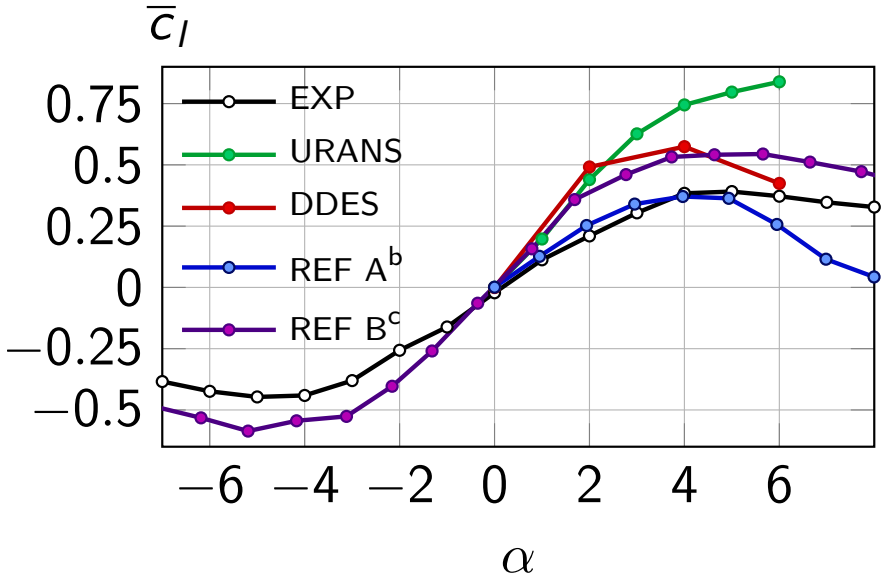

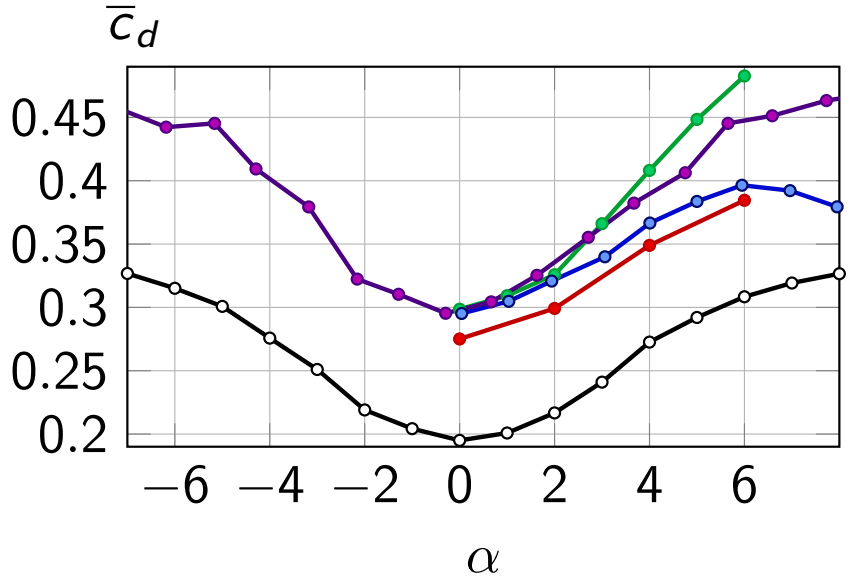

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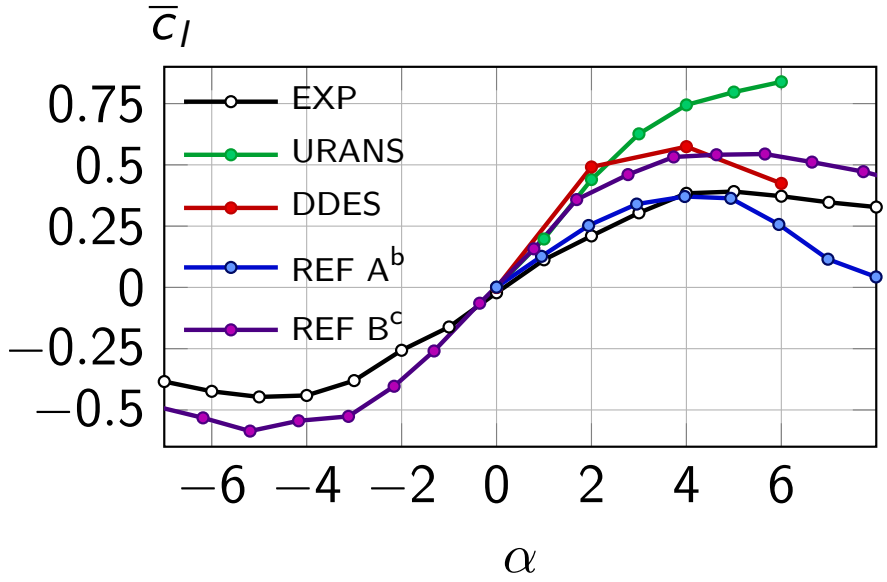

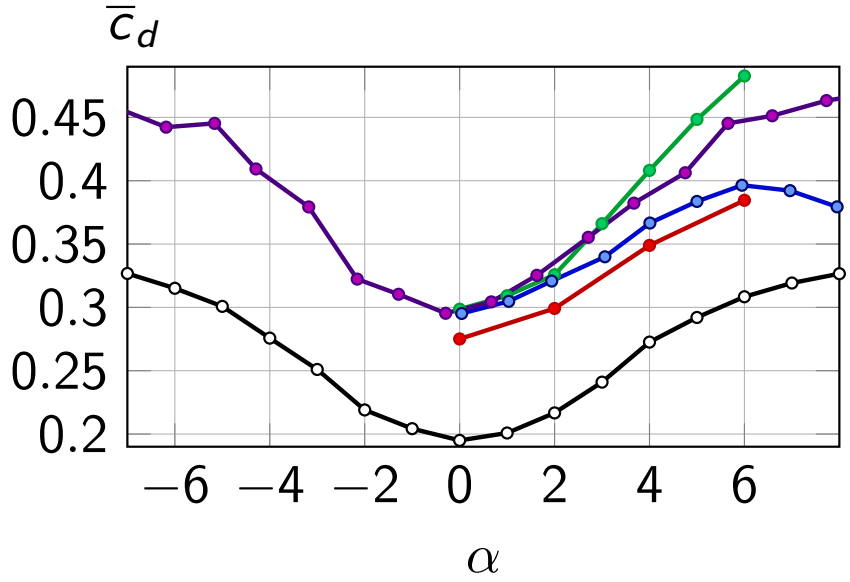

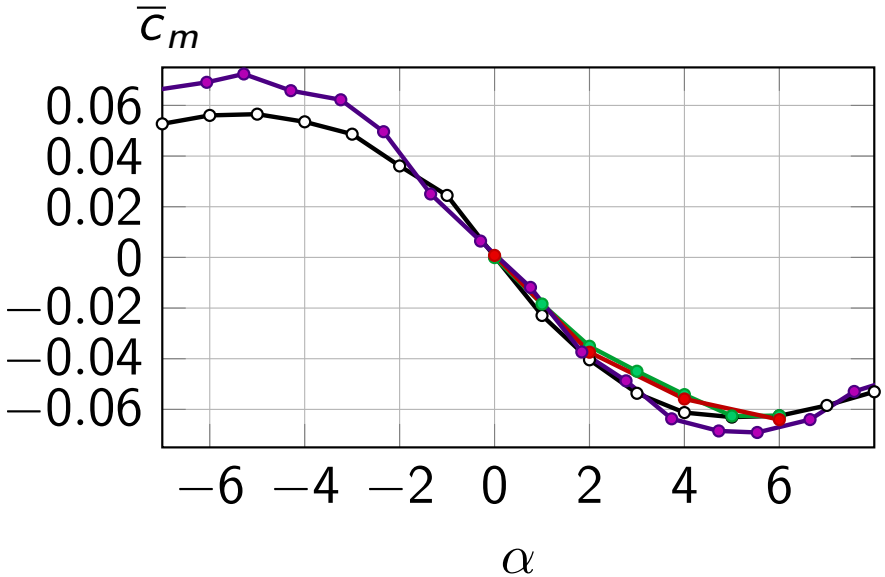

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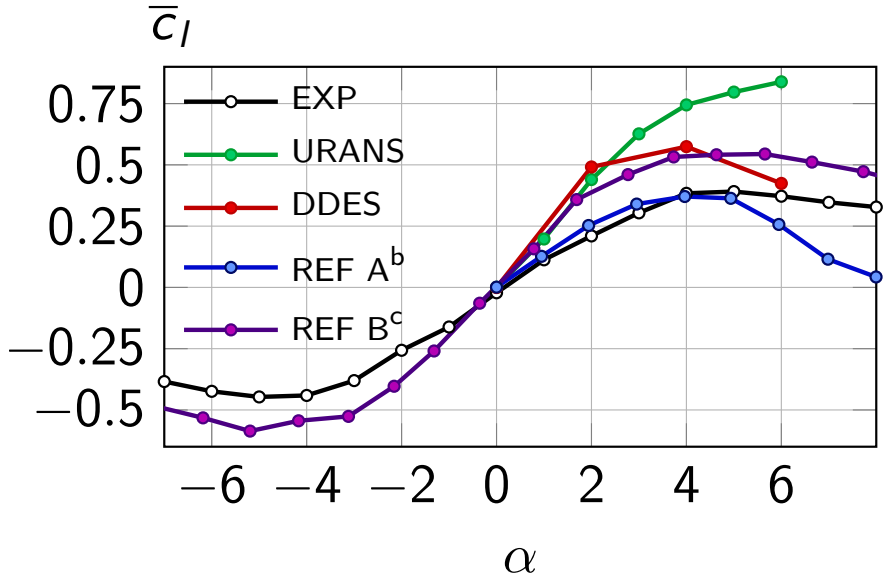

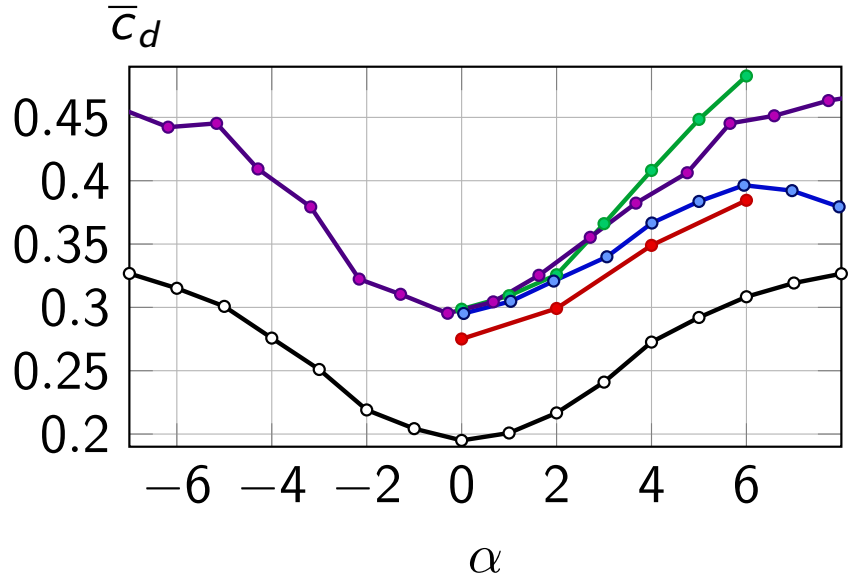

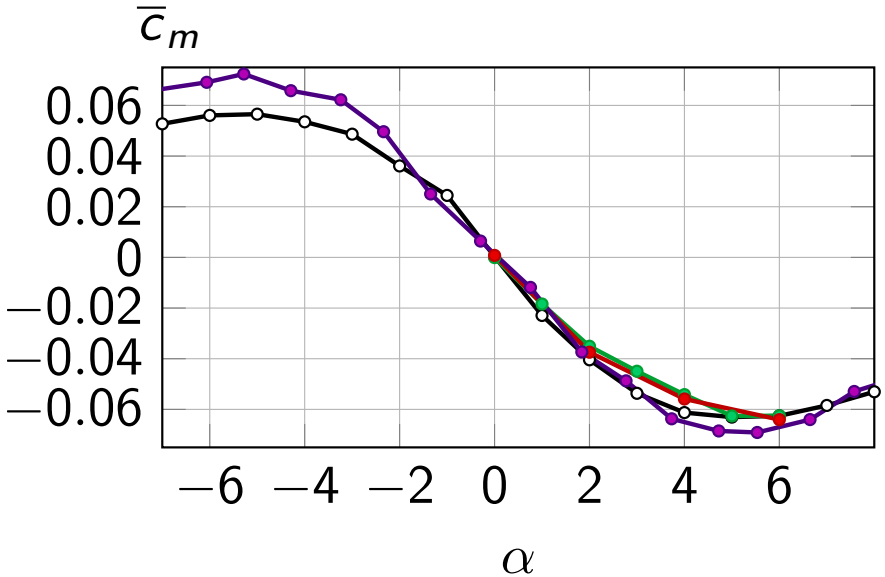

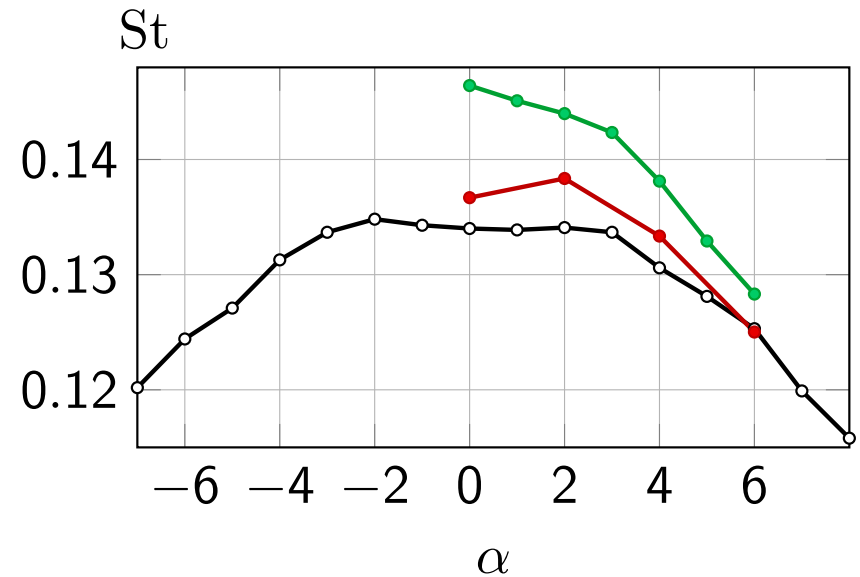

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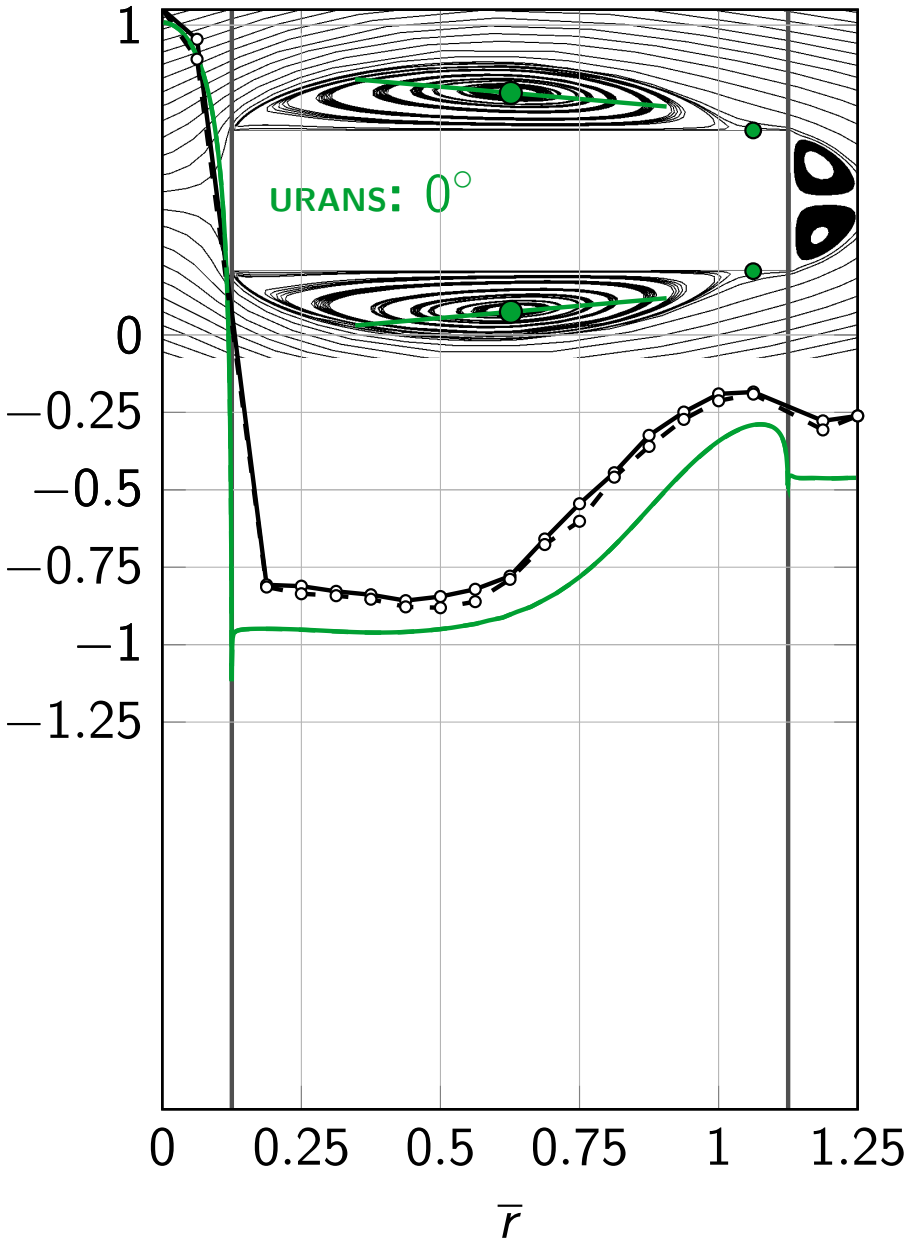

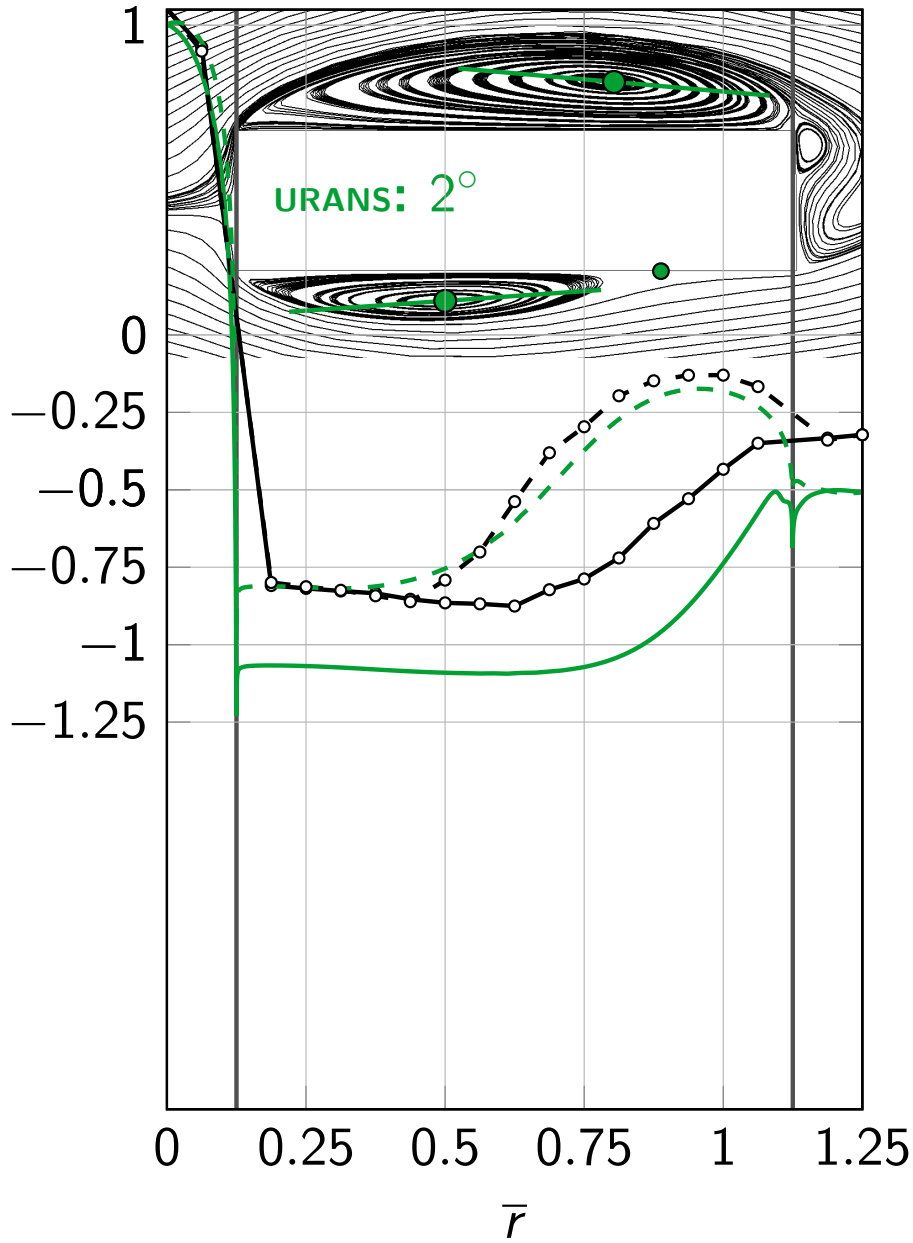

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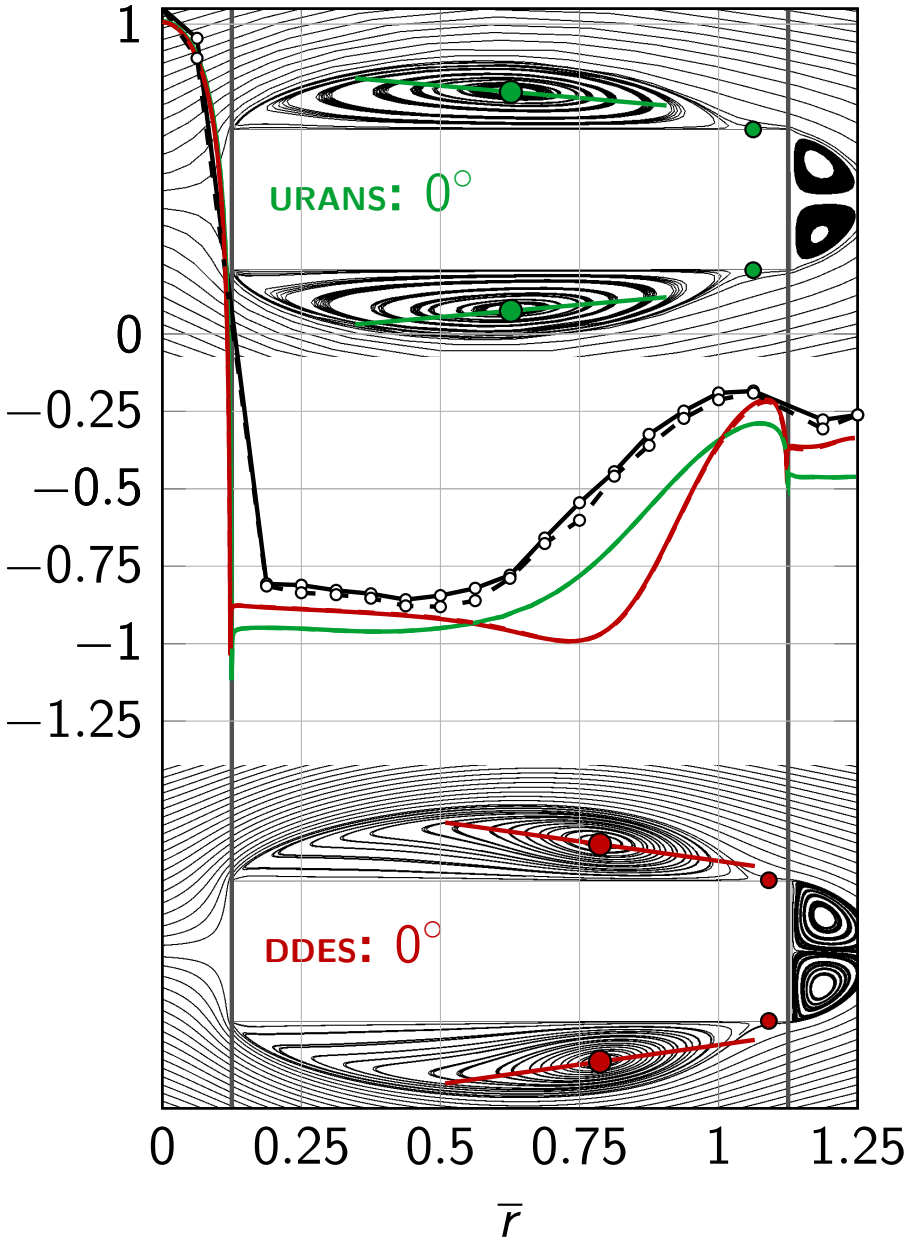

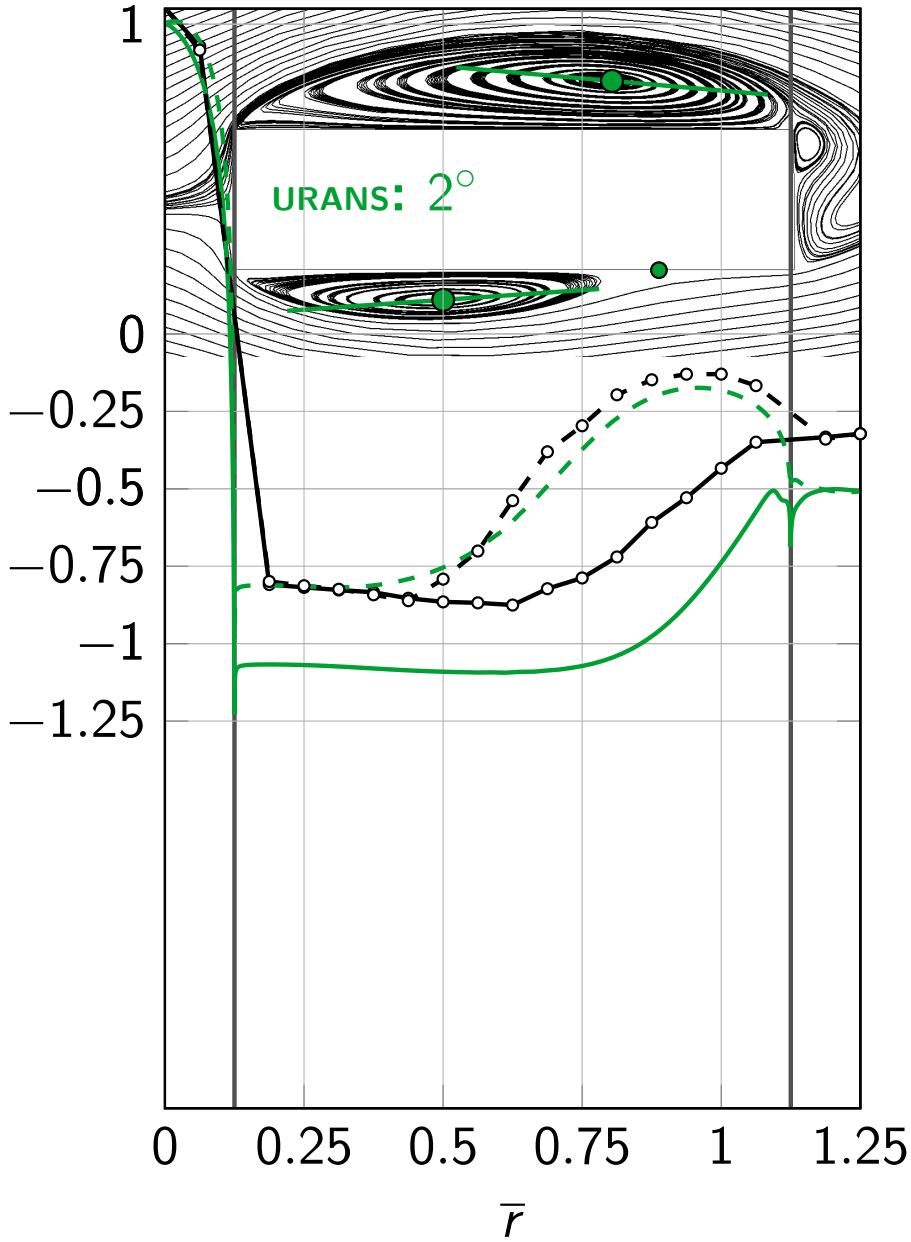

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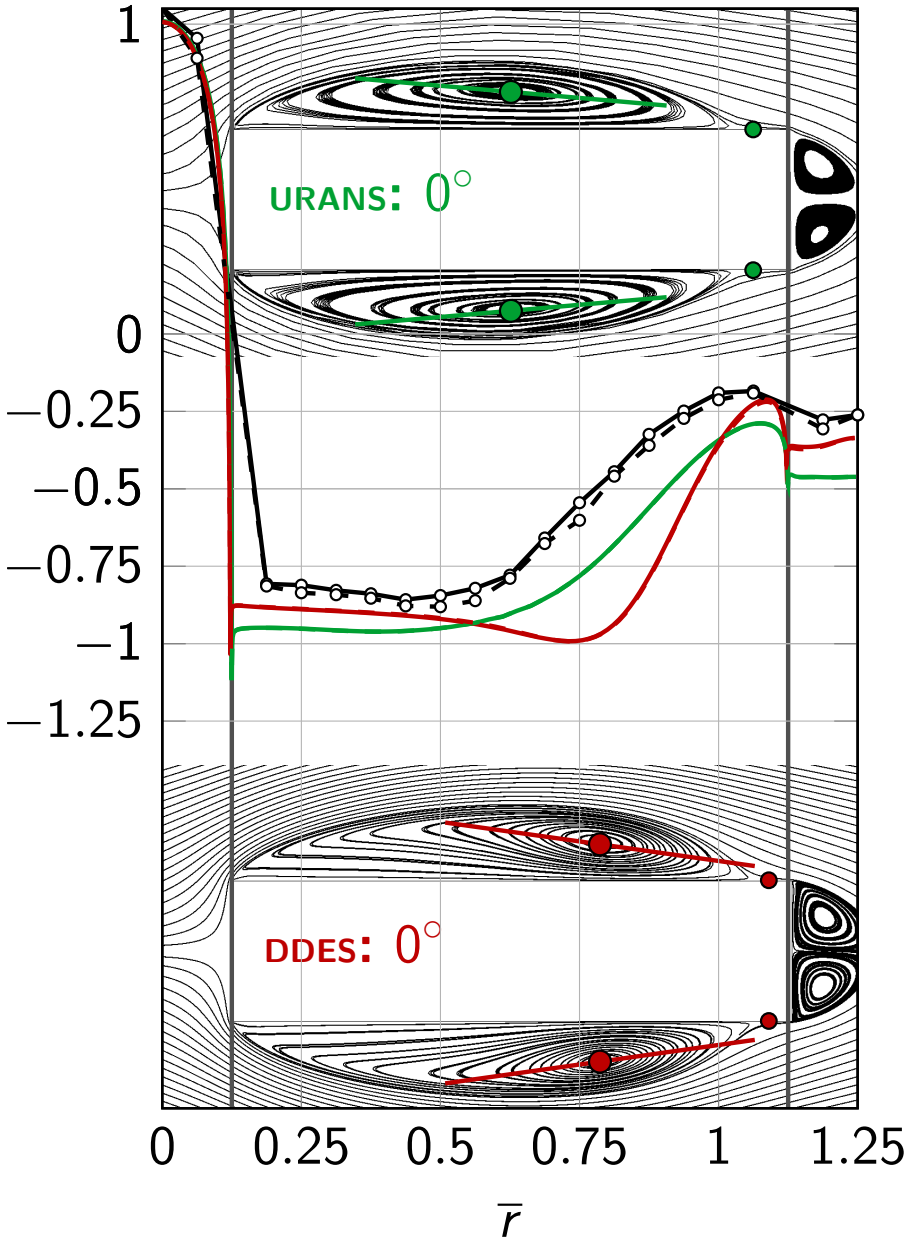

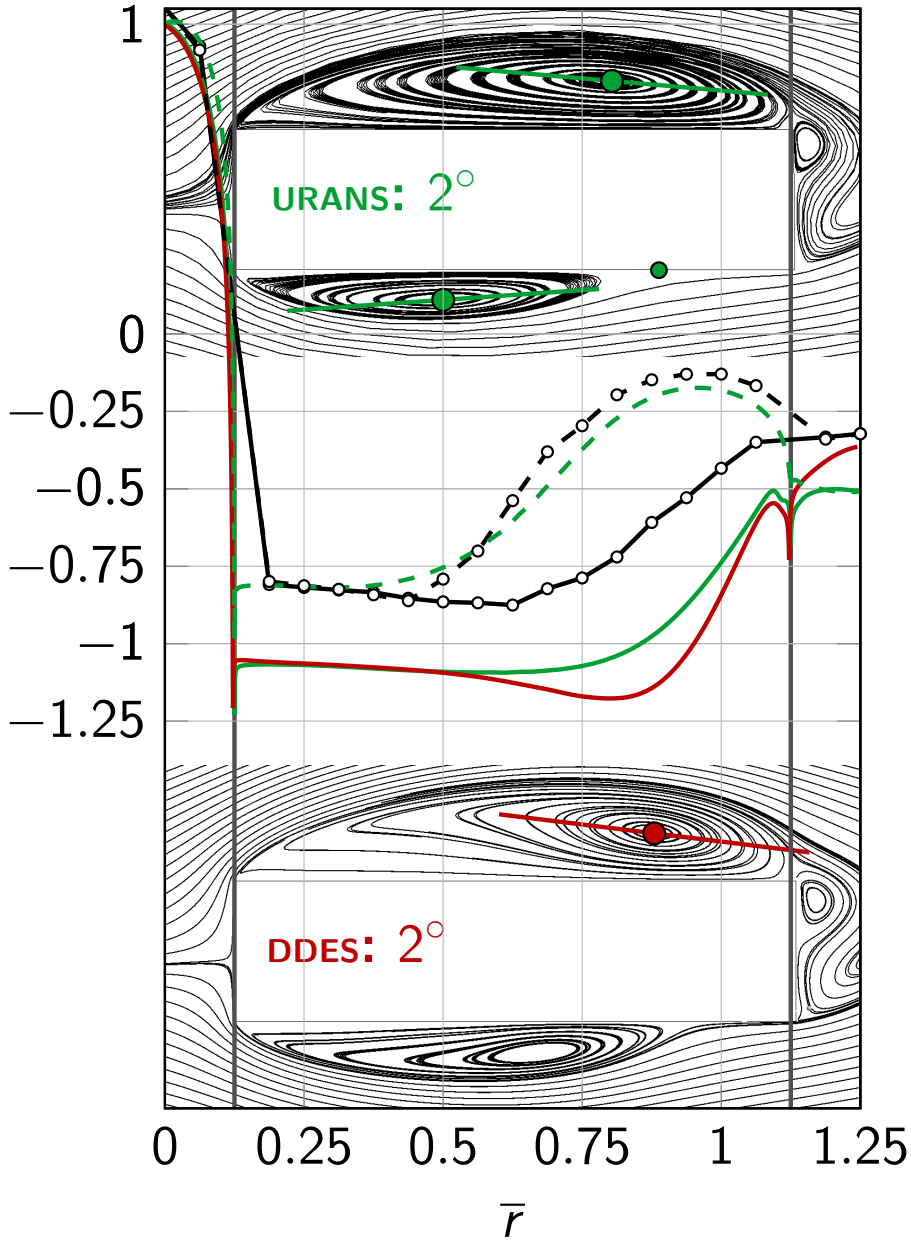

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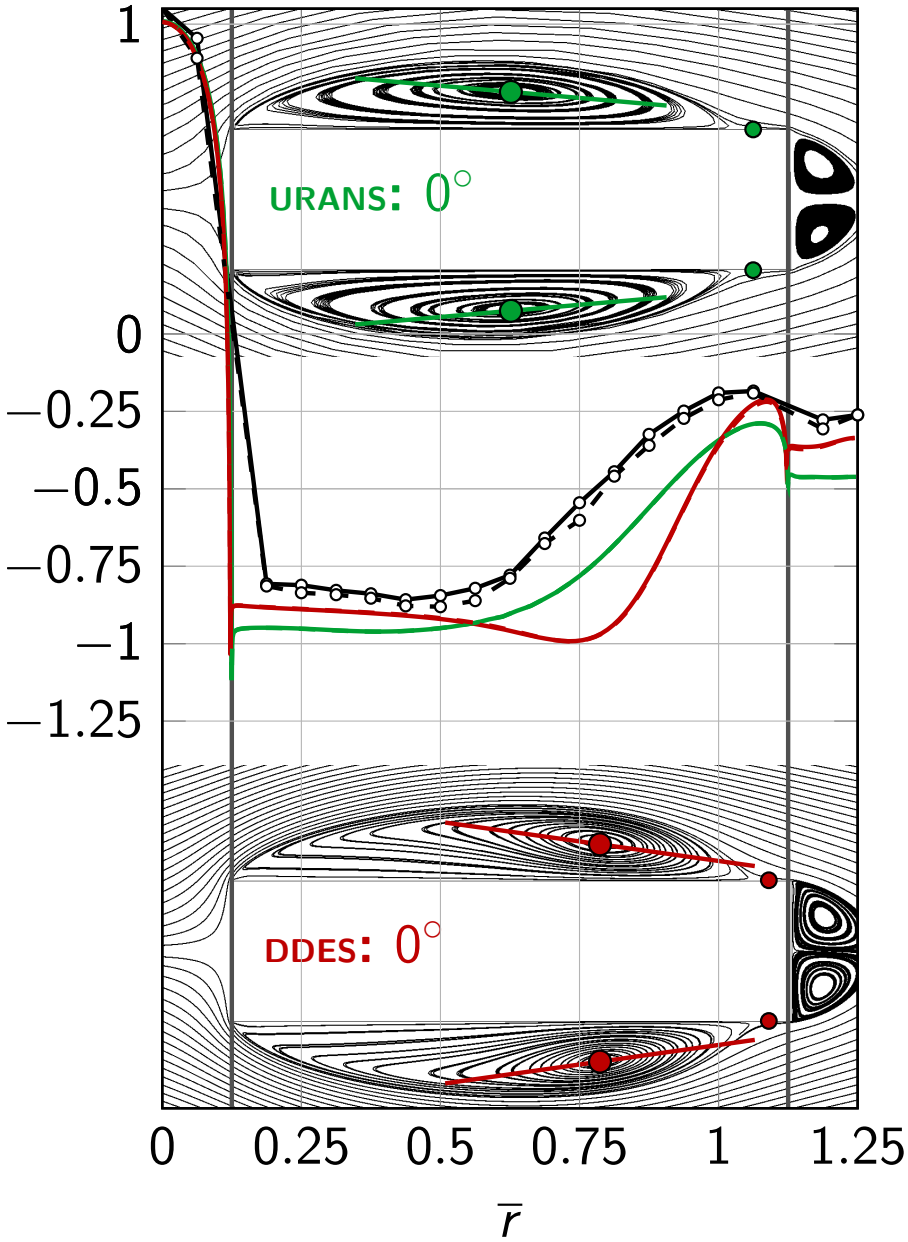
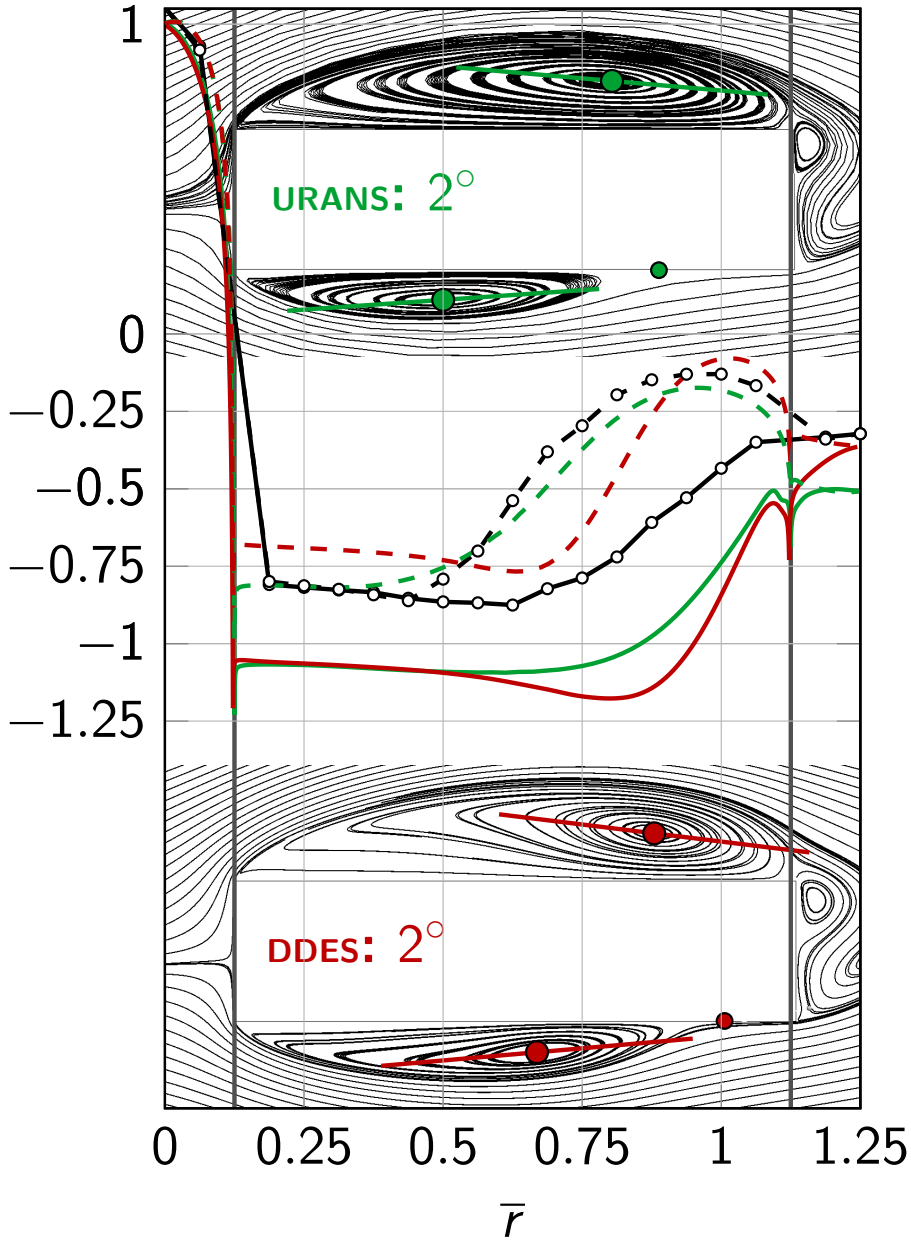
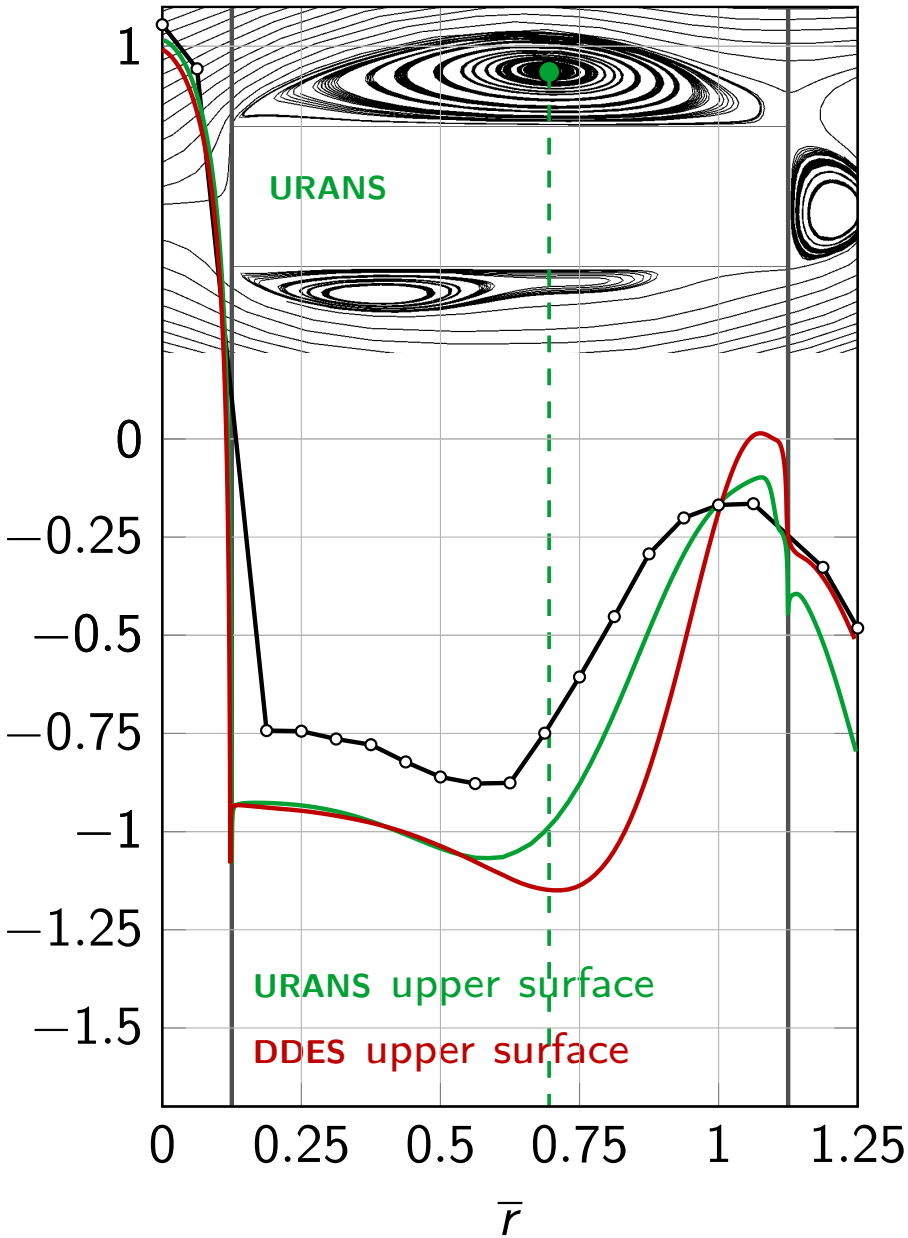
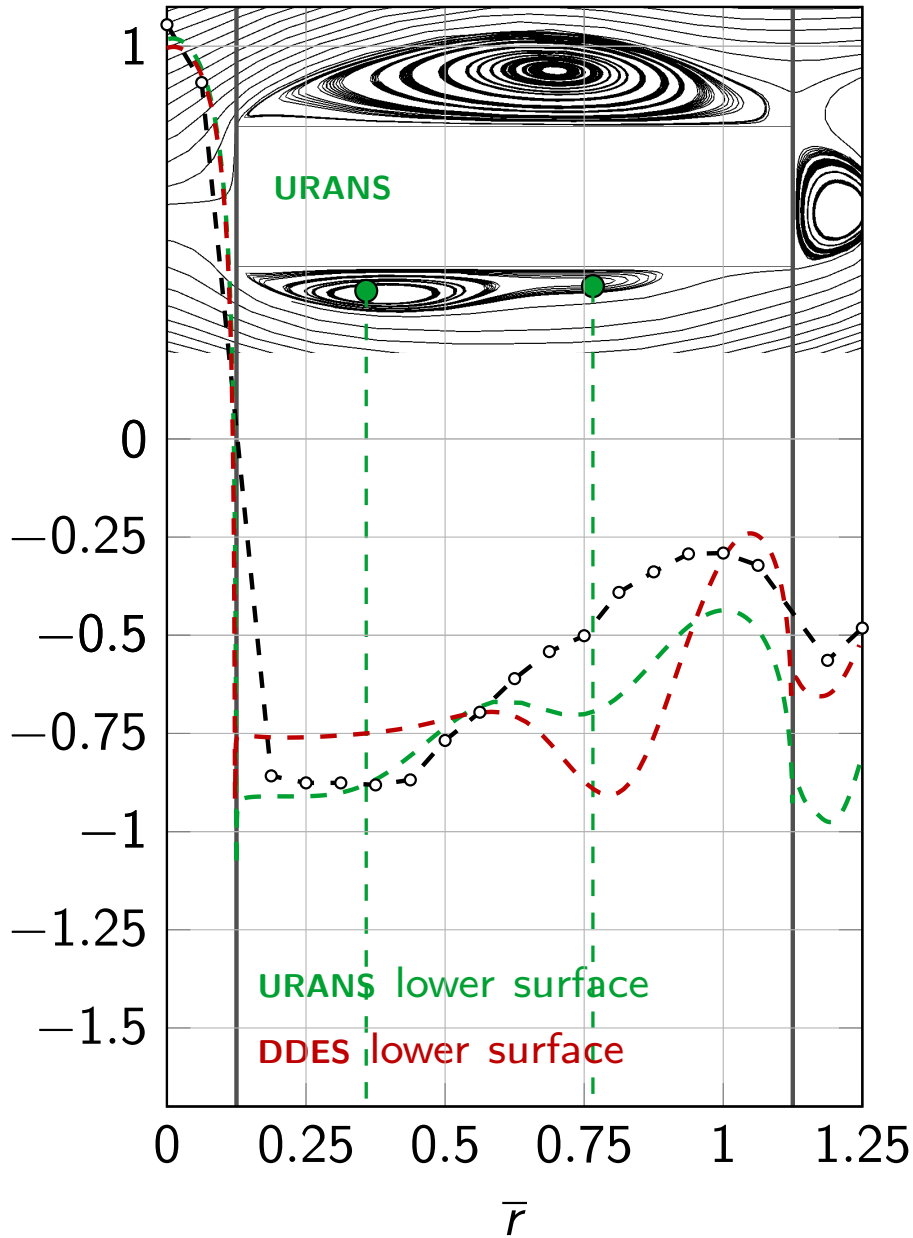




Results: variation of $\widehat{C_p}$ for $\alpha = 2^\circ$





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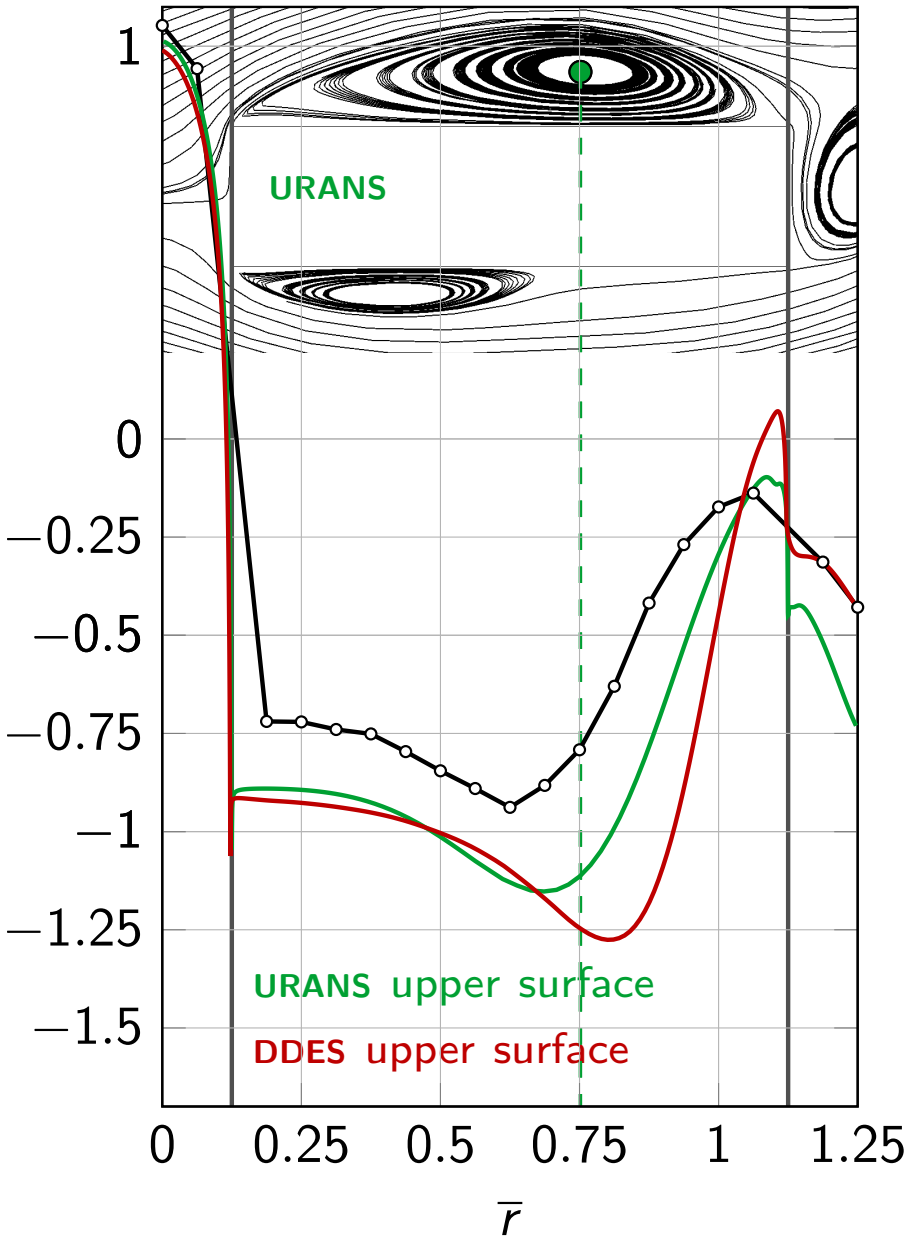

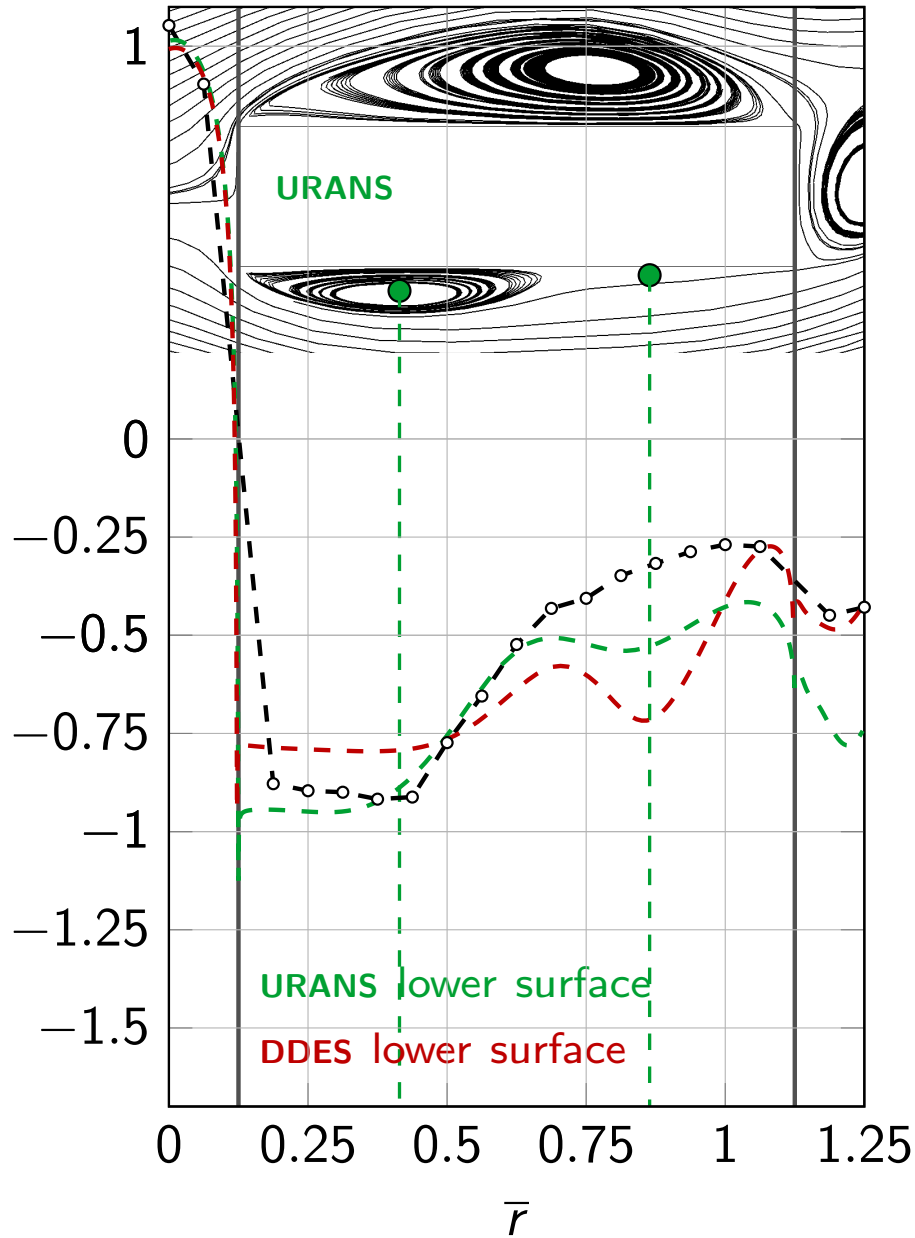

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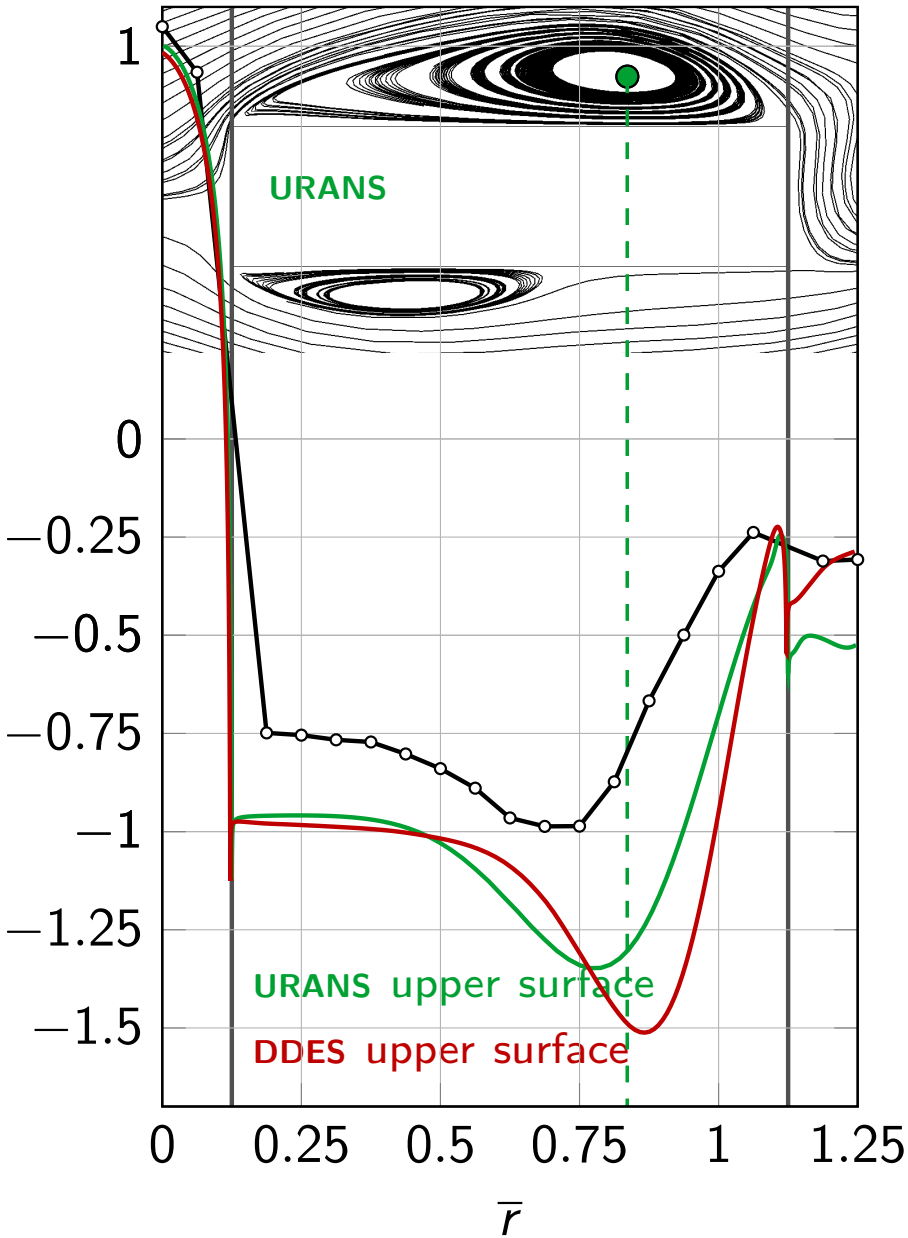

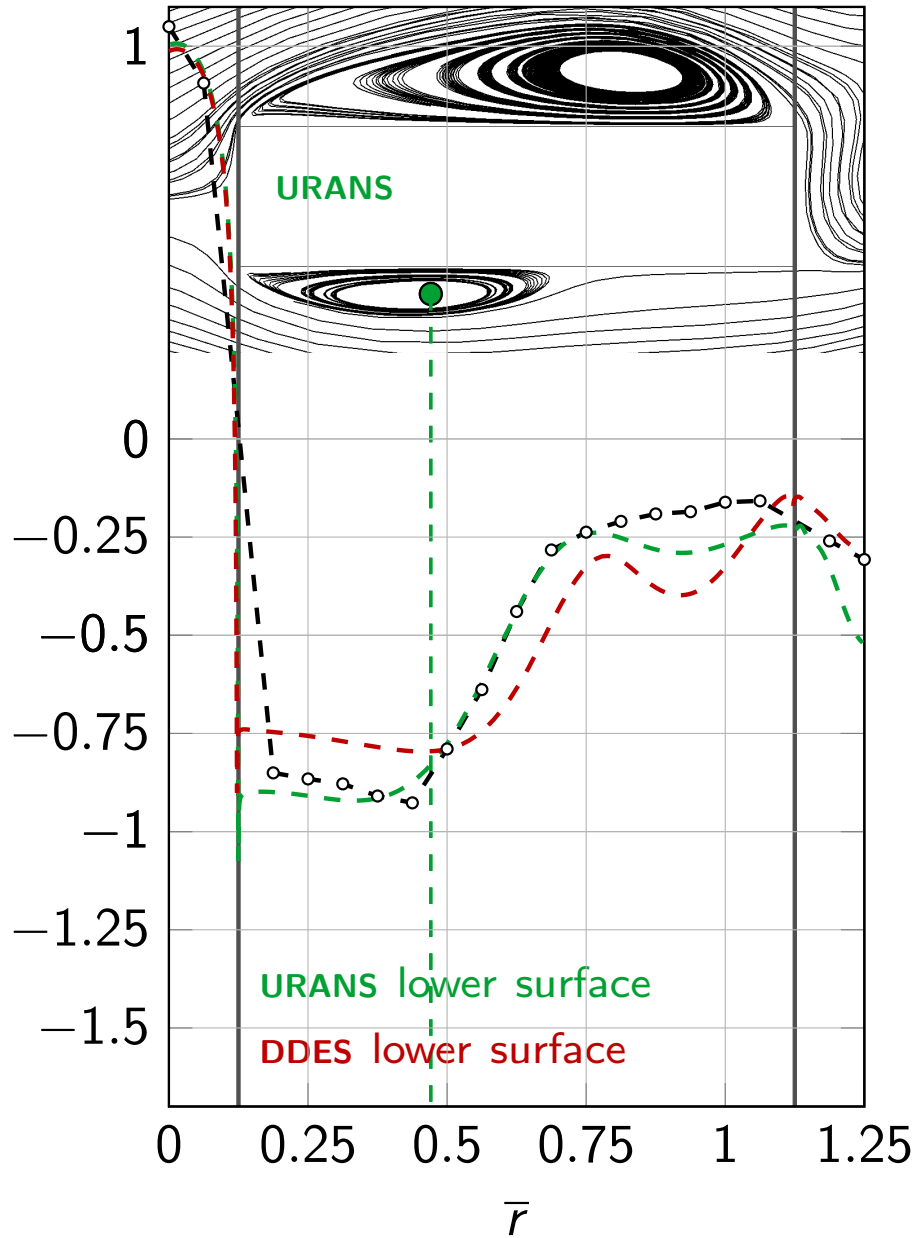

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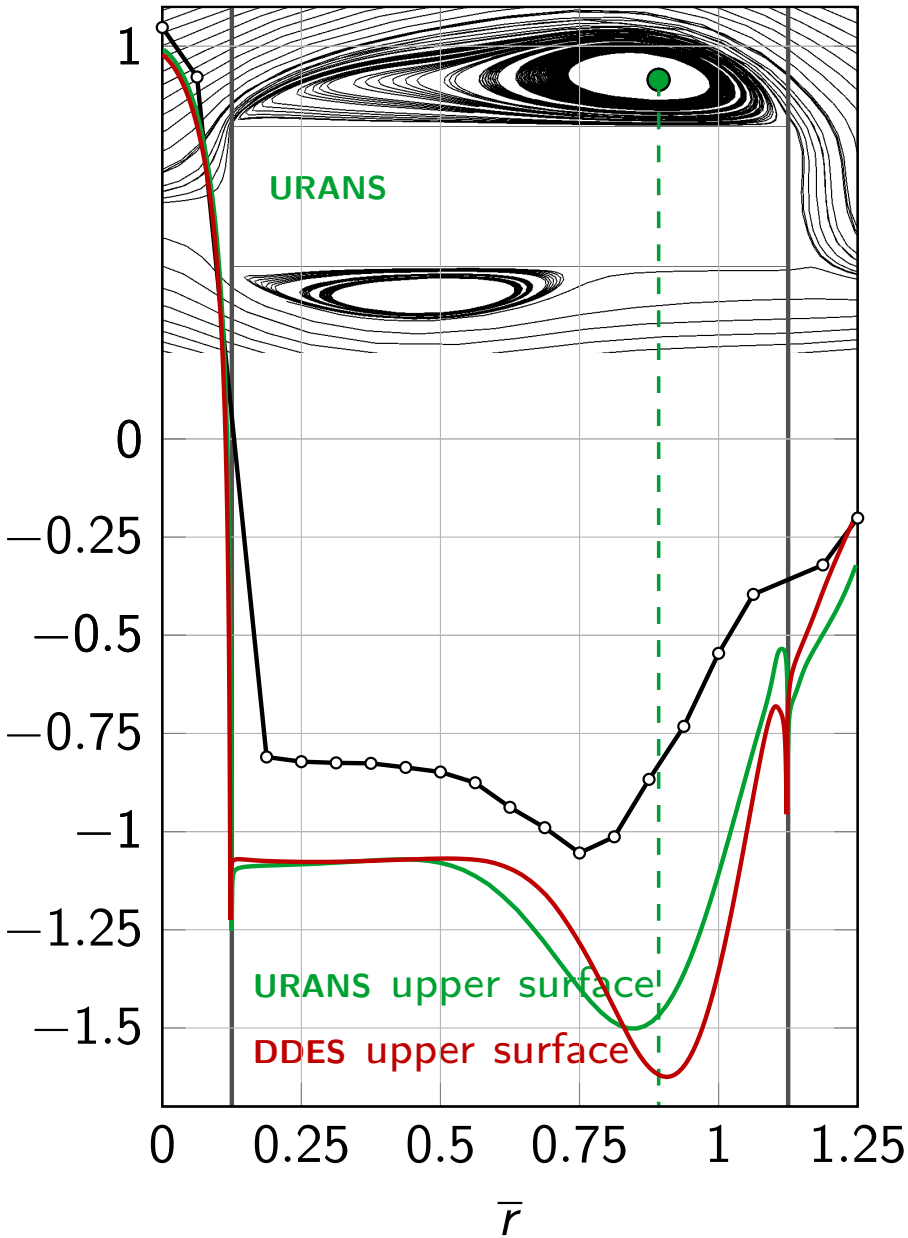

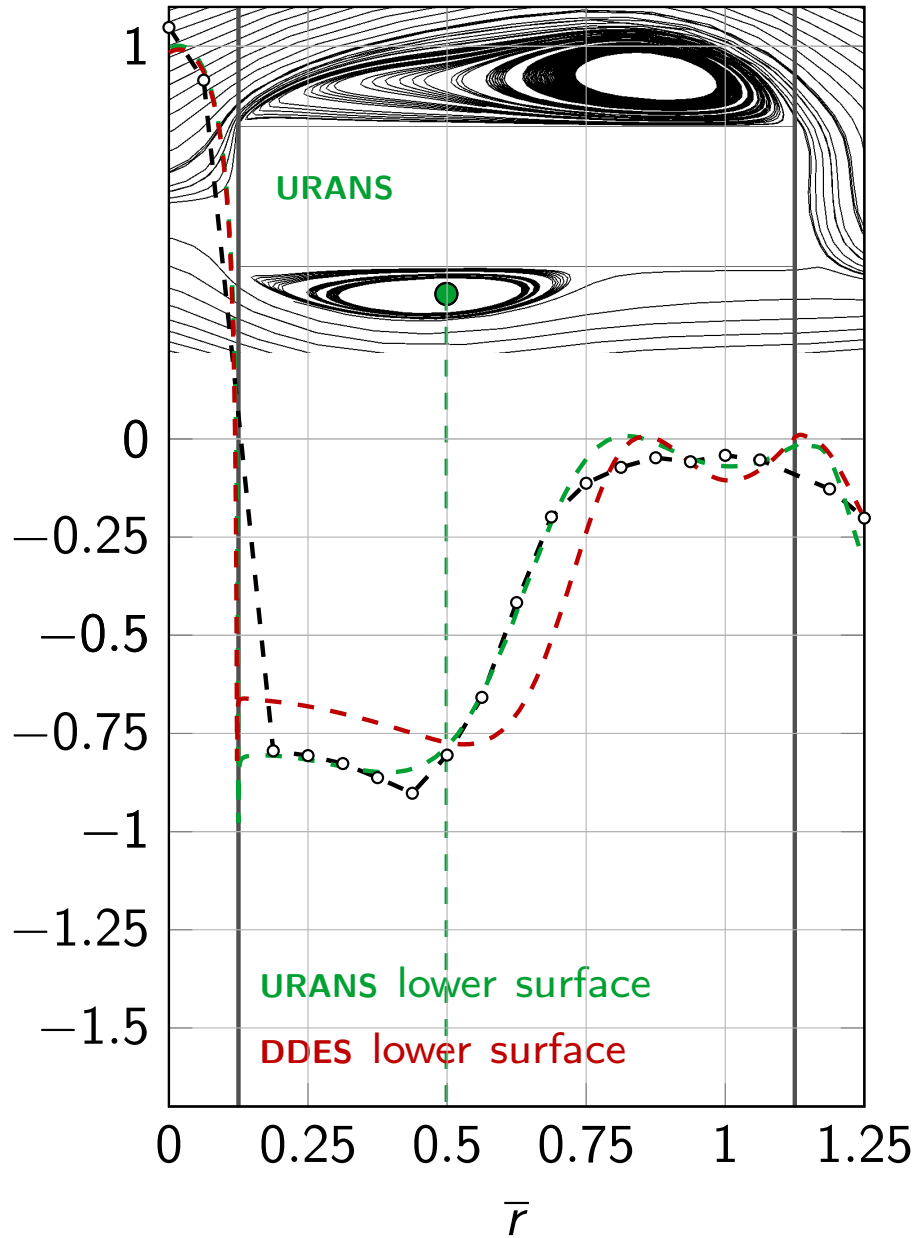

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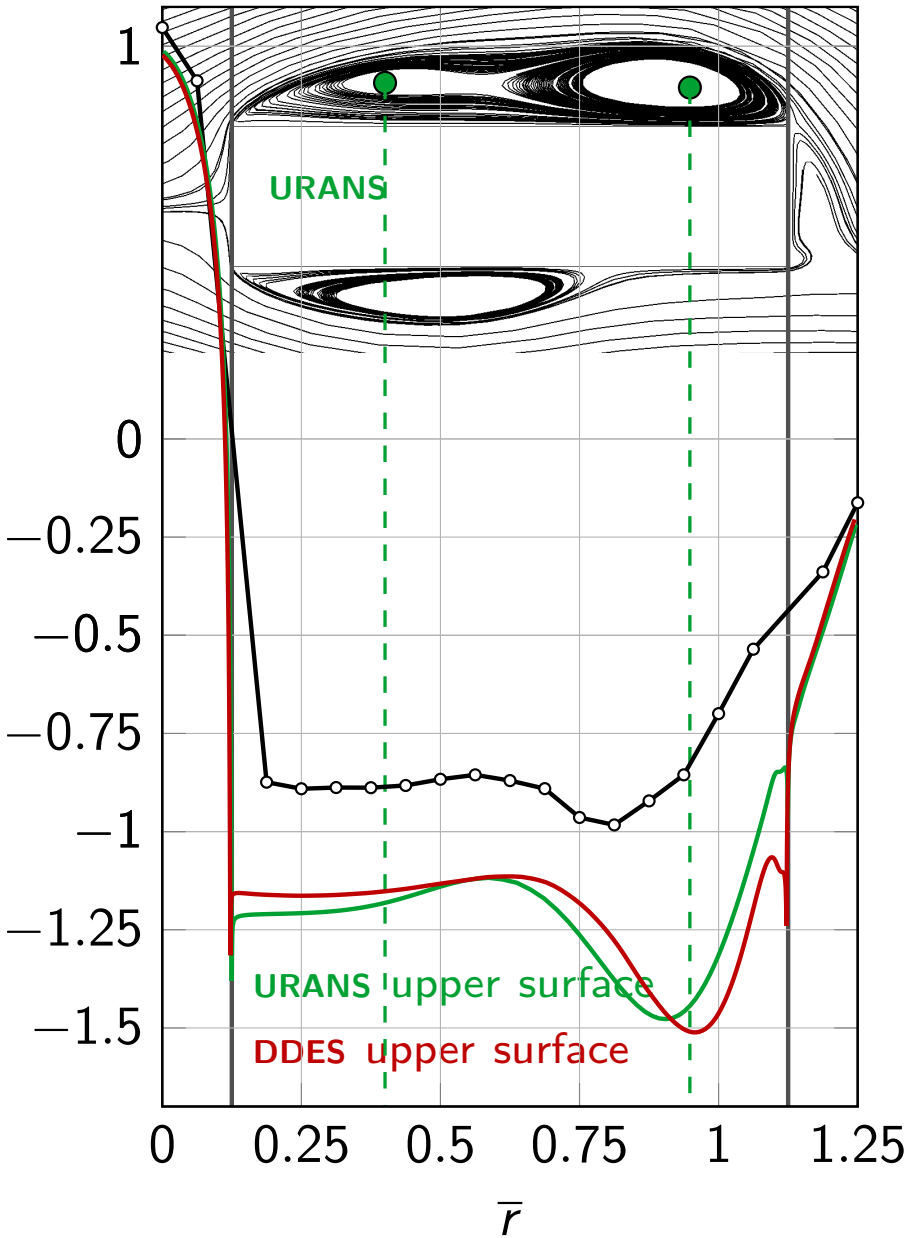

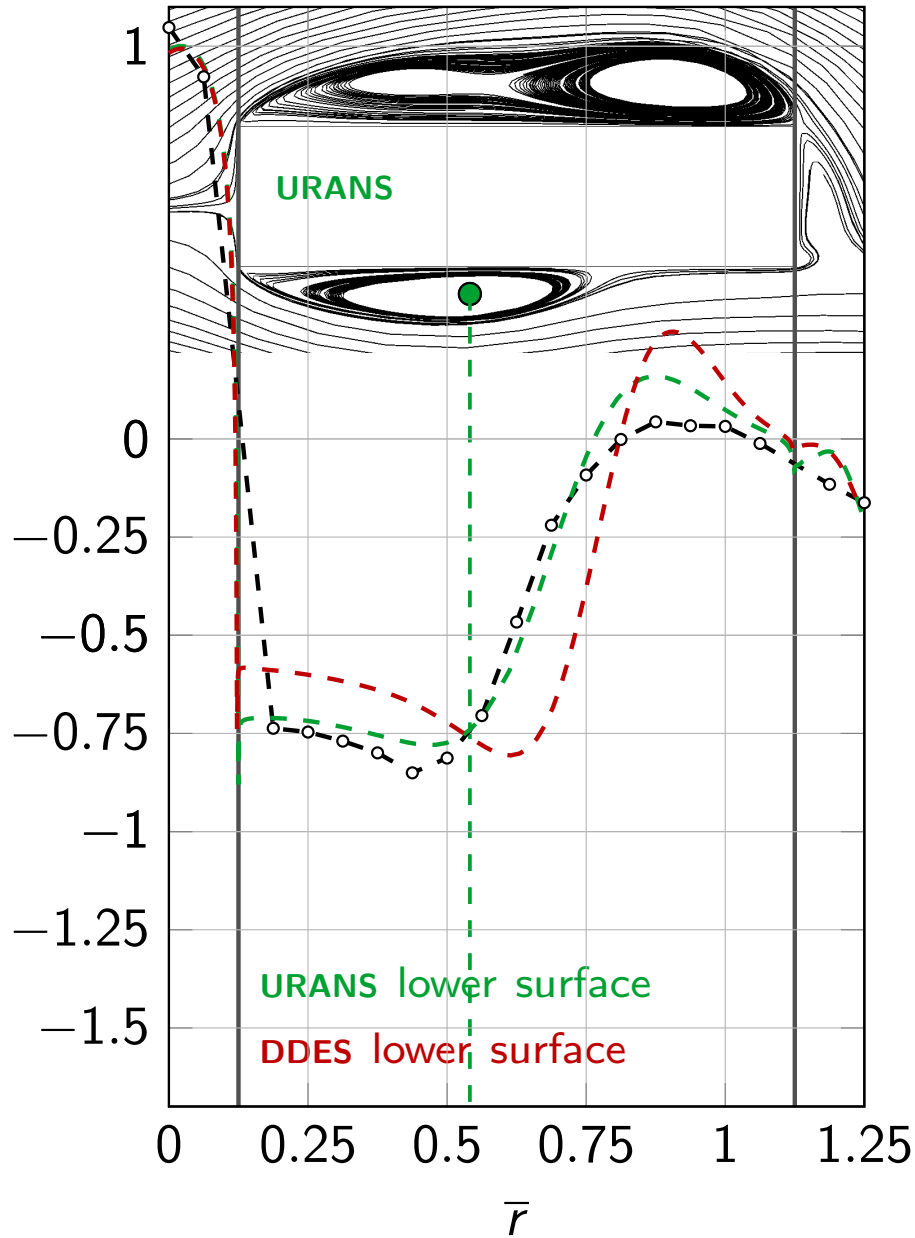

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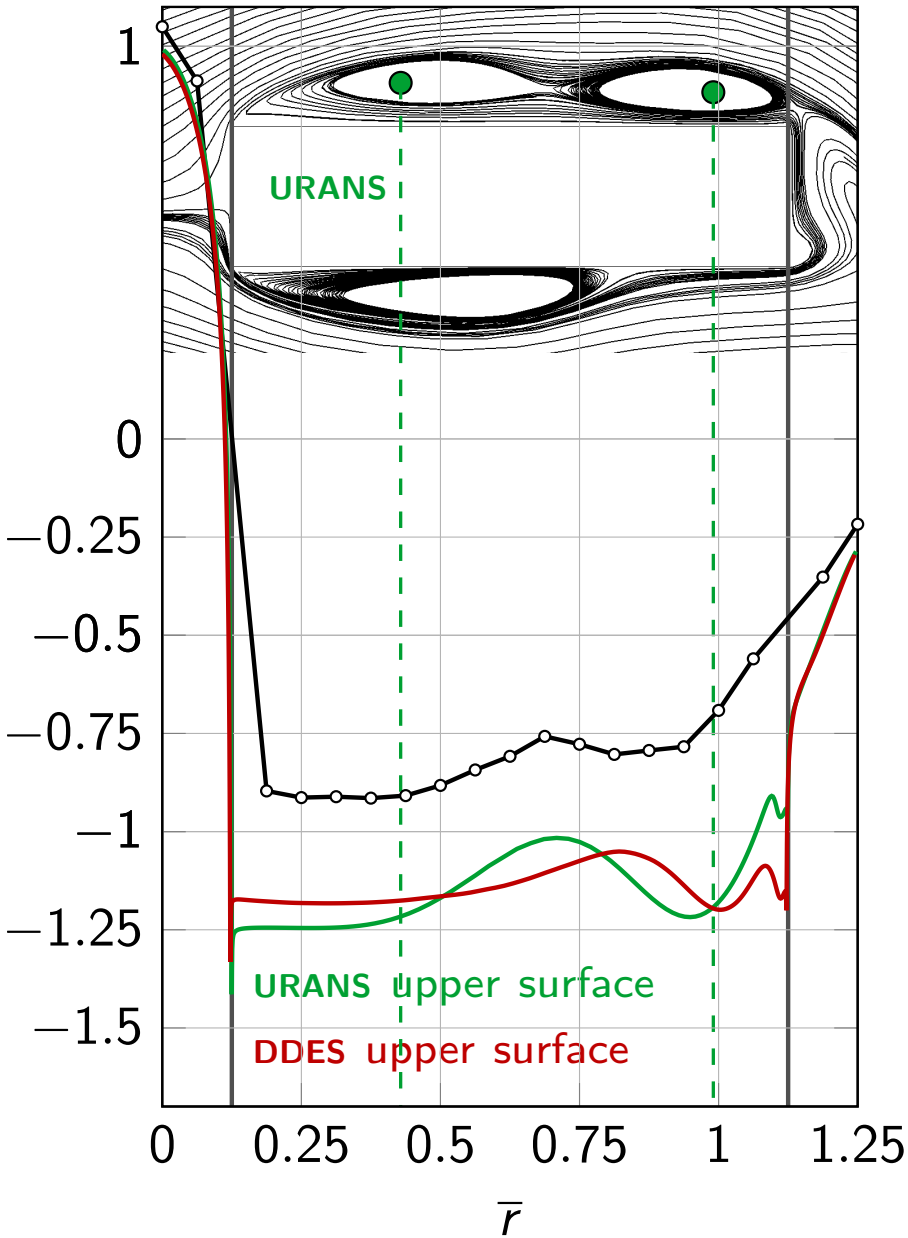

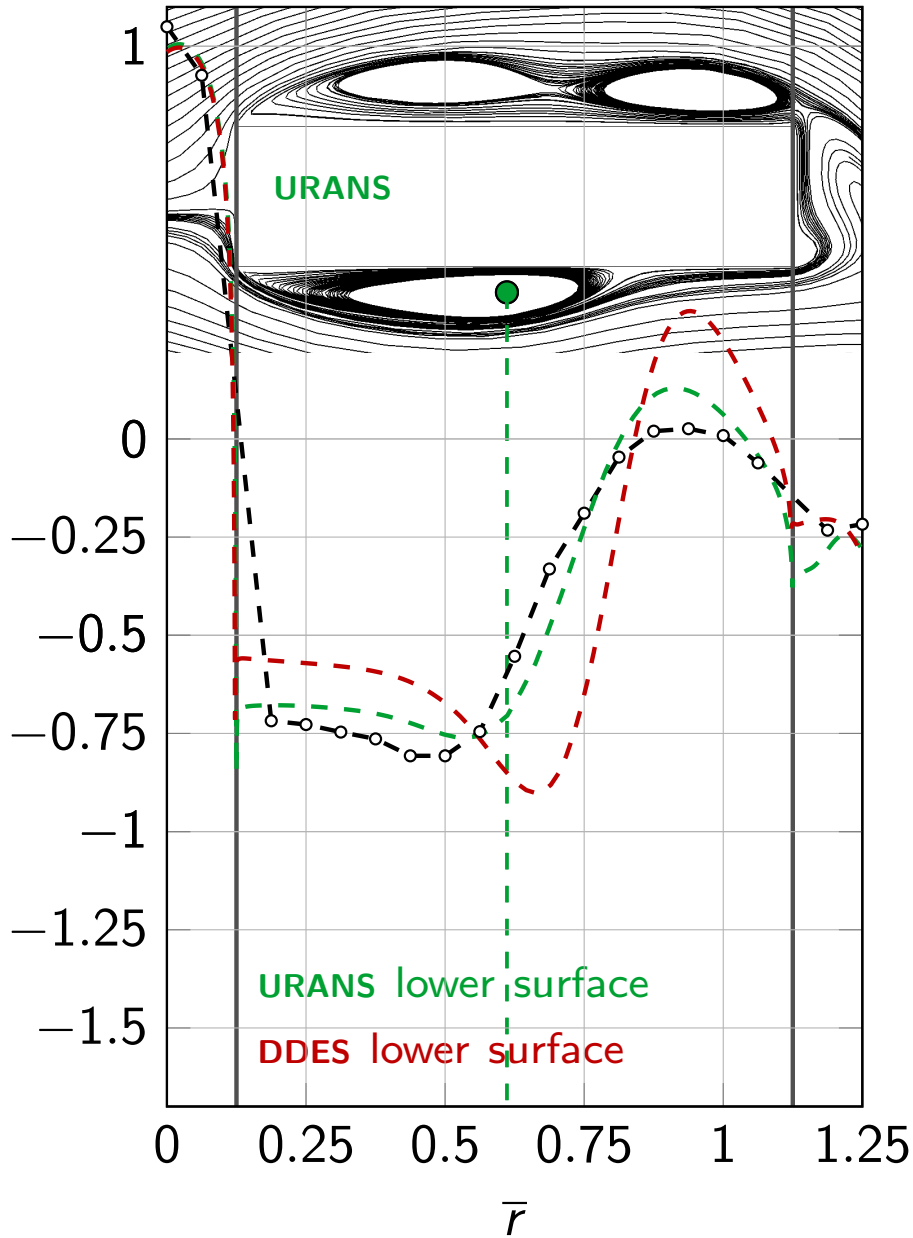

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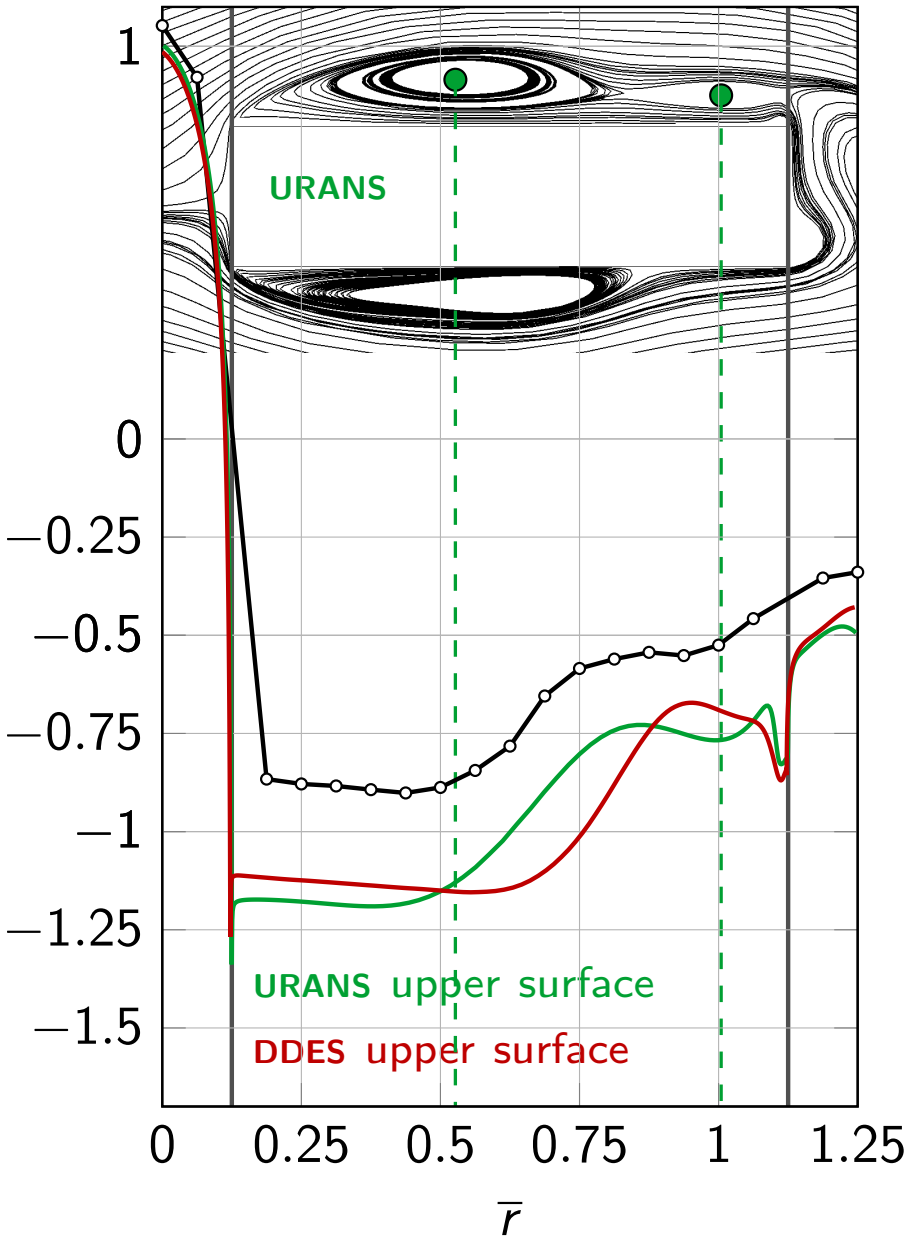
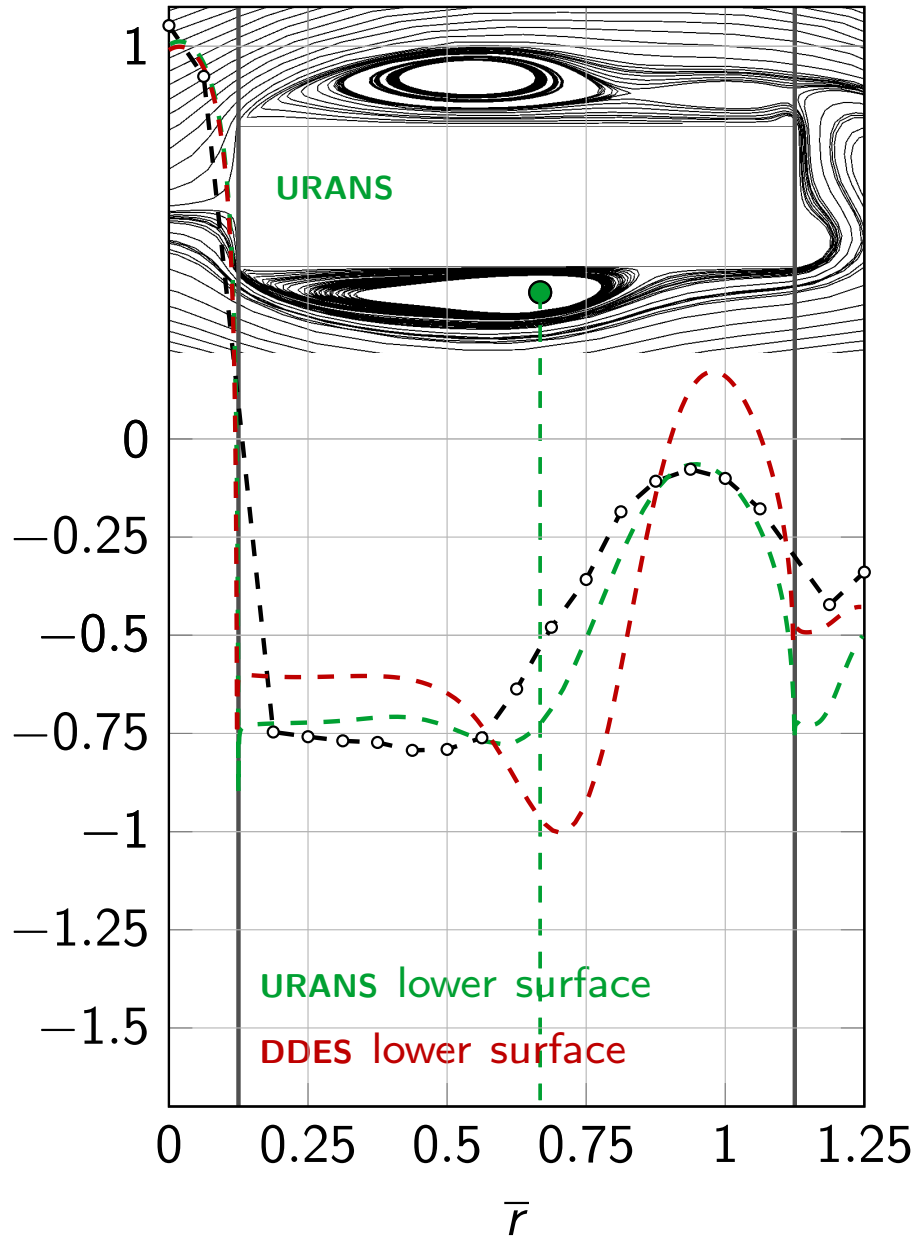
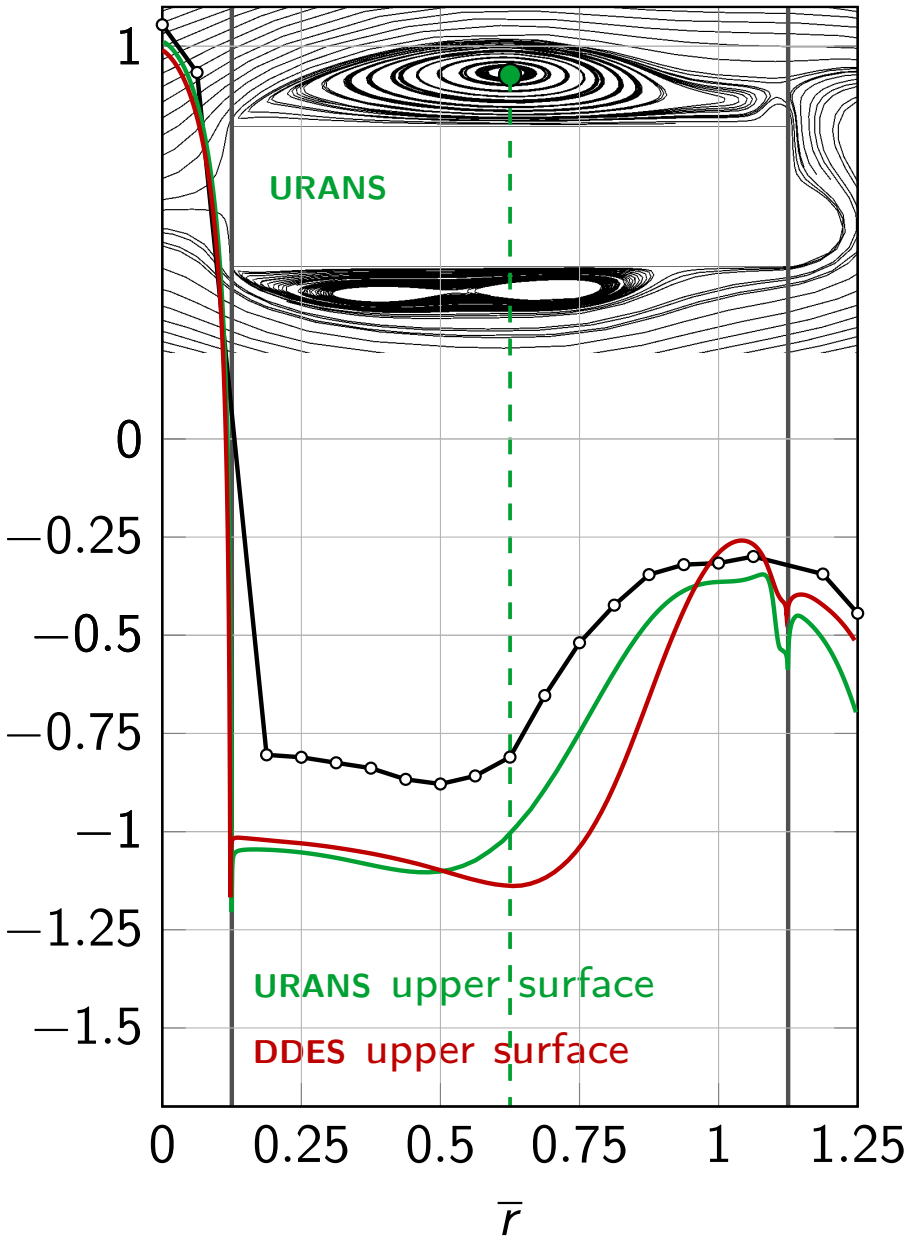
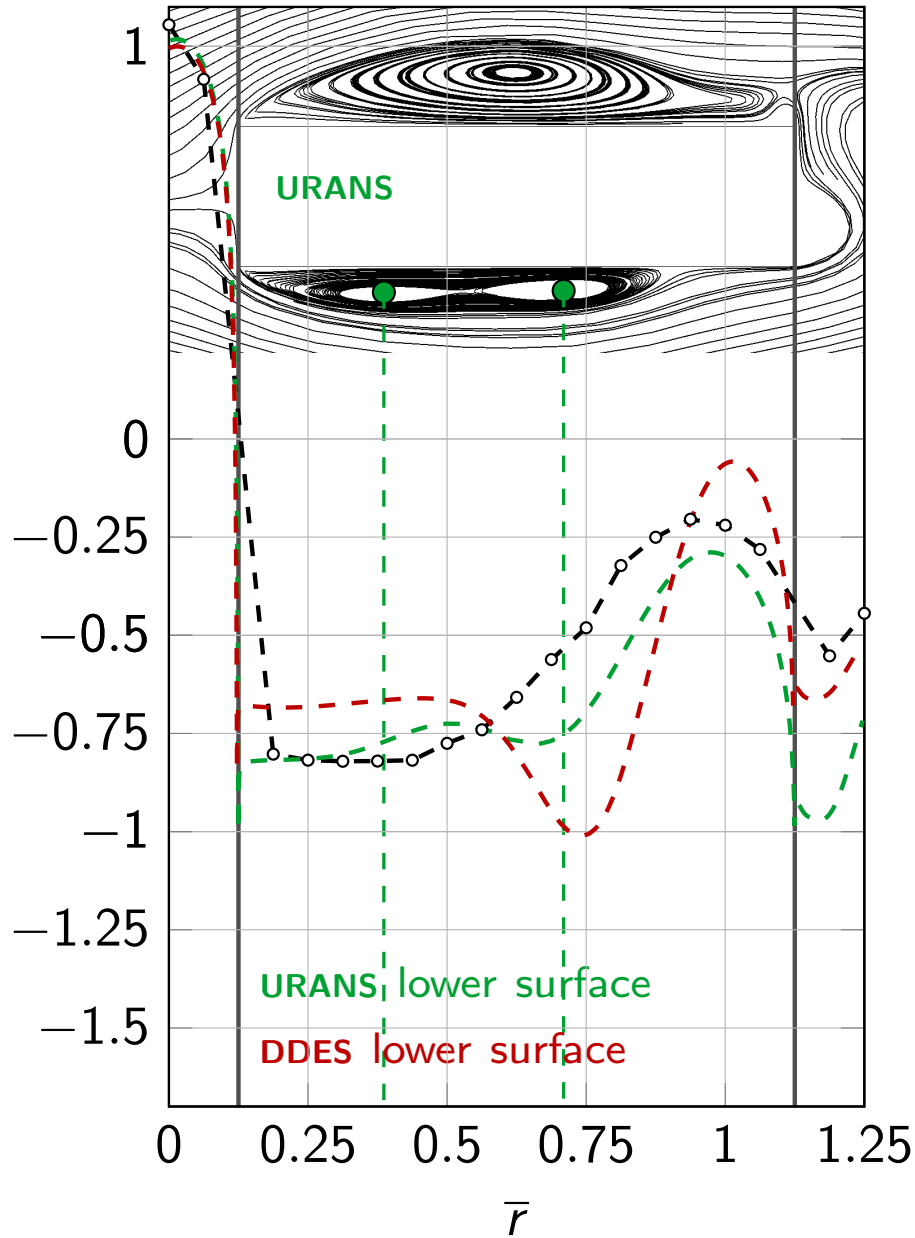




Results: variation of $\widehat{C_p}$ for $\alpha = 2^\circ$

$t = 0$





Conclusion

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EXP

- $\overline{c}_l$, $\overline{c}_d$, $\overline{c}_m$ **close to literature**
- **discrepancies in** $\overline{c}_l$ **probably due to** Re **effects**
- **flow dynamics extracted using** DMD

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- **discrepancies in** $\overline{c}_l$ **probably due to** Re **effects**
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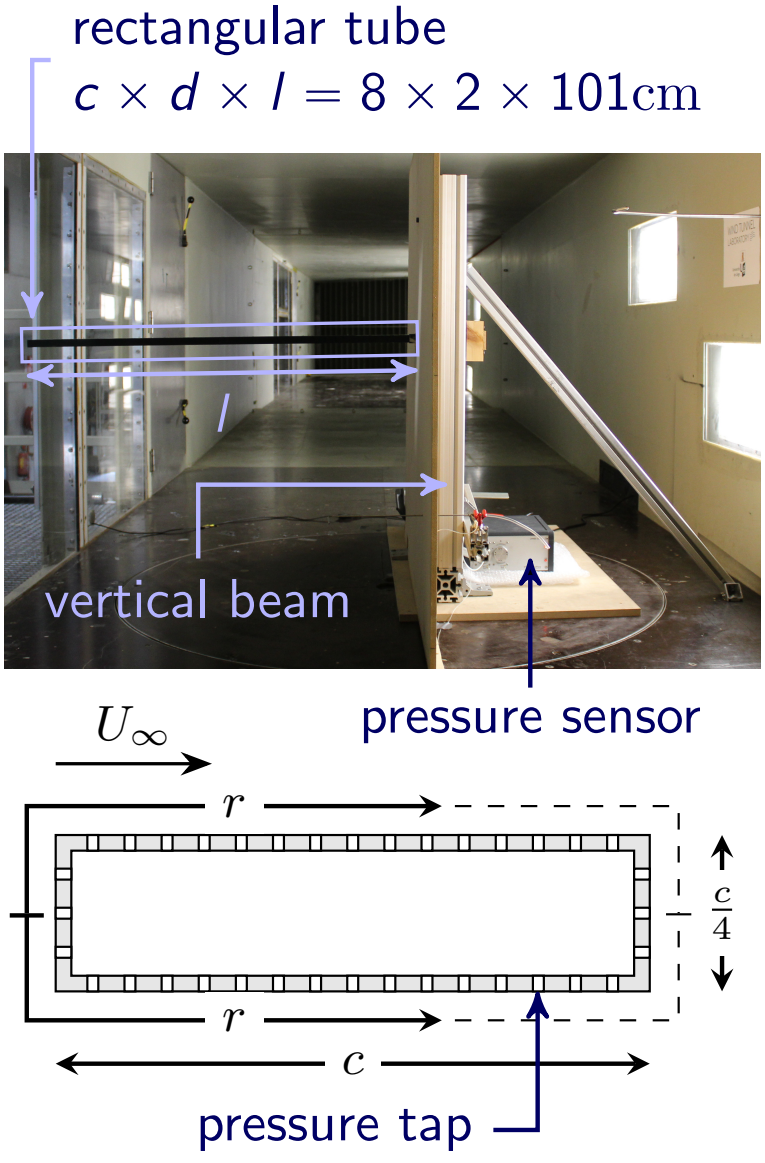
CFD

- **large discrepancies between** ${\overline{c}_l}^{EXP}$ **and** ${\overline{c}_l}^{CFD}$
  $\Rightarrow$ **could be explained by the high sensitivity of the flow**
  $\overline{c}_d$, $\overline{c}_m$ **and** St **are correctly estimated by** CFD
- URANS **performs better than** DDES **to capture mean flow and flow dynamics**
- **only** DDES **is able to estimate the stall angle**

Thanks for your attention!

Additional material

Methodology



Flow studied through EXP

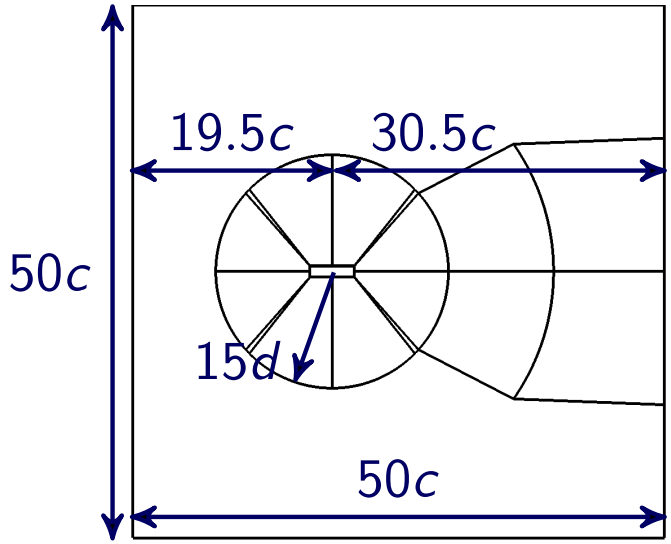
dynamic pressure measurements for different Re and α

- hollow rectangular tube
- 36 pressure taps (15 along c and 3 along d)
- $\mathrm{Re} \in \left[7.8 \times 10^3, 1.9 \times 10^4\right]$

$\Rightarrow$ C_p for $\alpha \in [-7^\circ, 8^\circ]$

$\Rightarrow$ c_l, c_d, c_m computed from C_p
St through Fourier analysis of c_l

Methodology



Flow studied through CFD

2D URANS using $k-\omega$ SST model for different α

3D DDES using SA model for different α

GRID

- unstructured and structured
- dimensions similar to BARC[d]

URANS

- 75 000 cells
- 1 shedding cycle

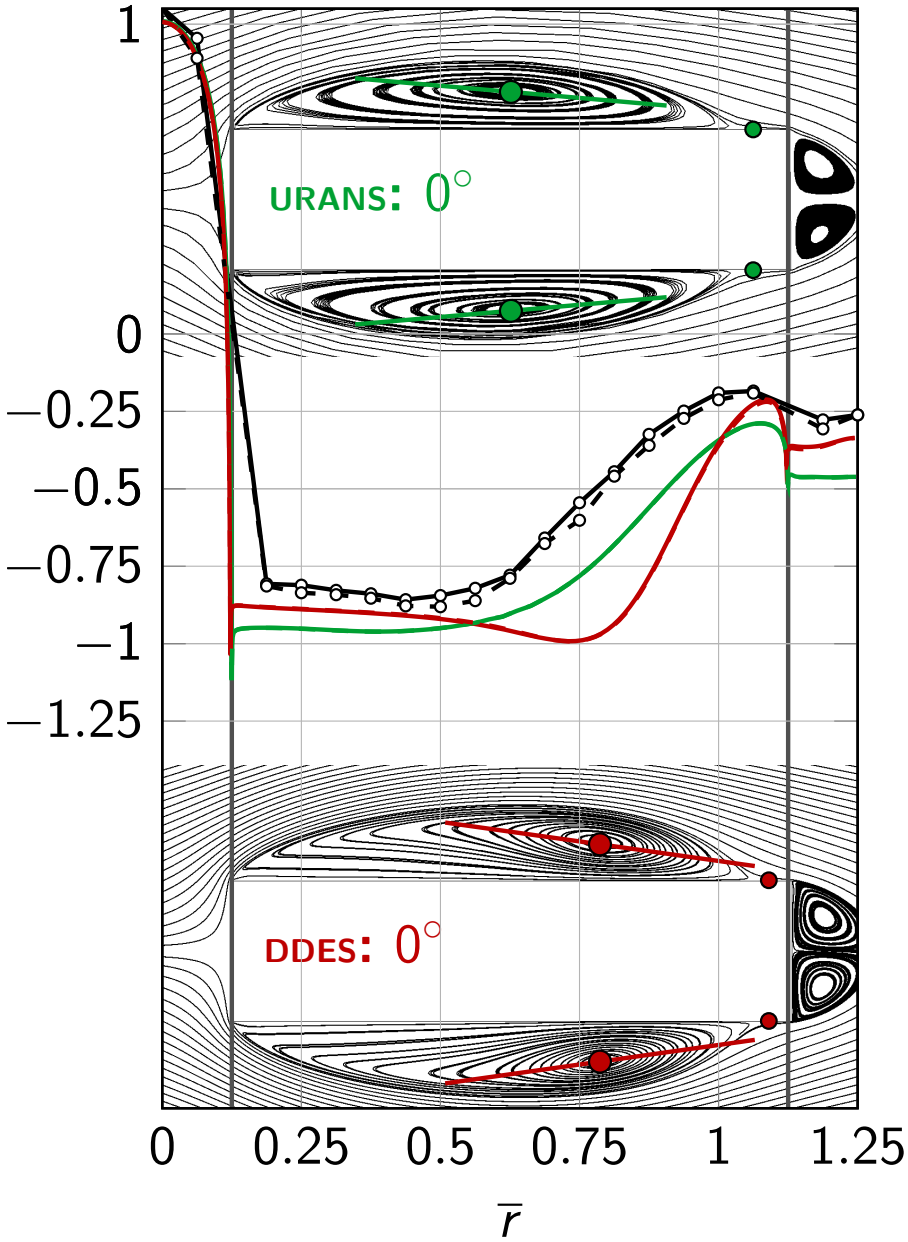
DDES

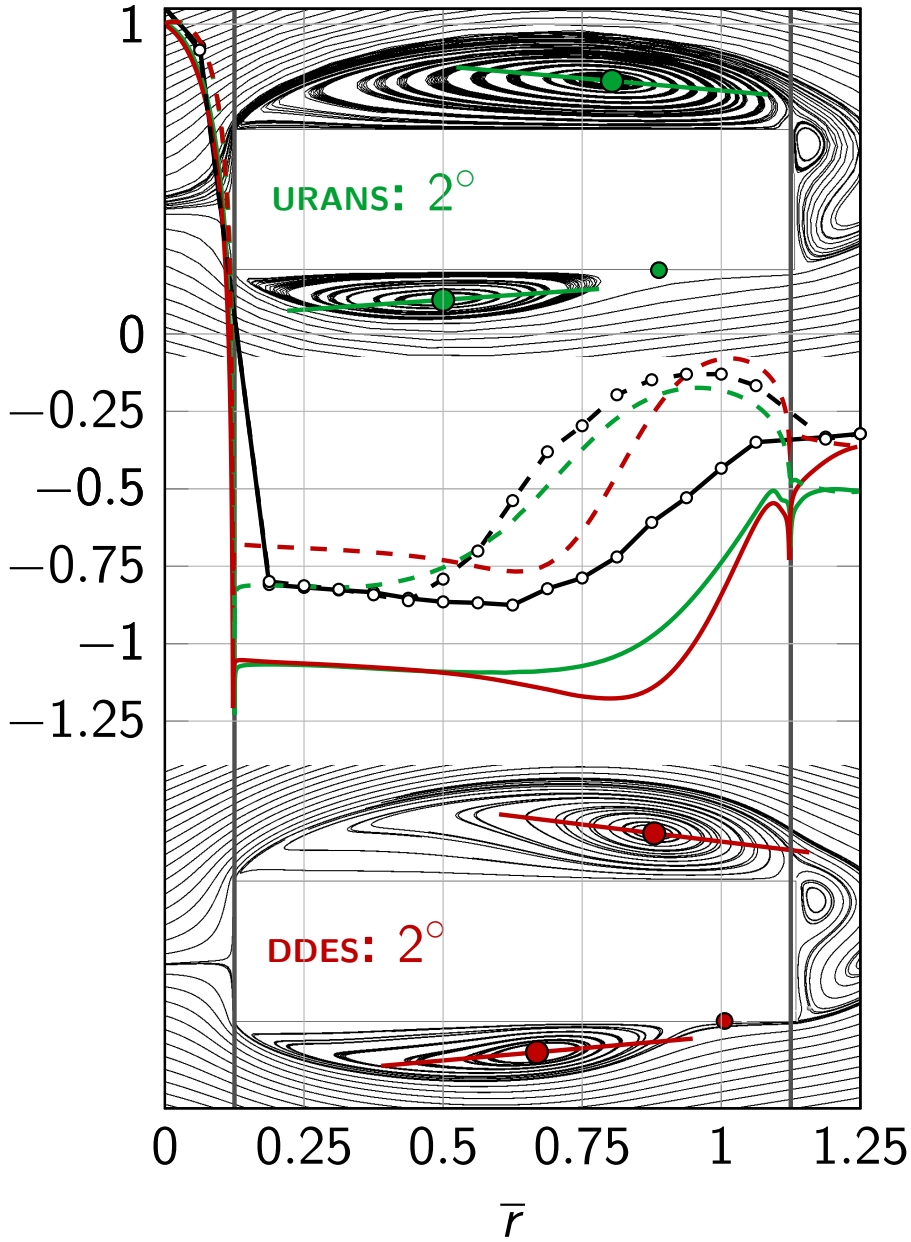
- along z: $1c$ and $\Delta z = {}^{c}/_{64}$
- $\Delta_0 = \Delta z$ in focus region[e] (extends $0.5c$ downstream)
- 8 200 000 cells
- 80 shedding cycles

[d] "BARC: An overview after the first four years of activity" by Bruno, Salvetti, and Ricciardelli (2014)

[e] "Young-Person' s Guide to Detached-Eddy Simulation Grids" by Spalart and Streett (2001)

Results: $\overline{C}_p$





Results: $\overline{C}_p$