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Models for active drag reduction

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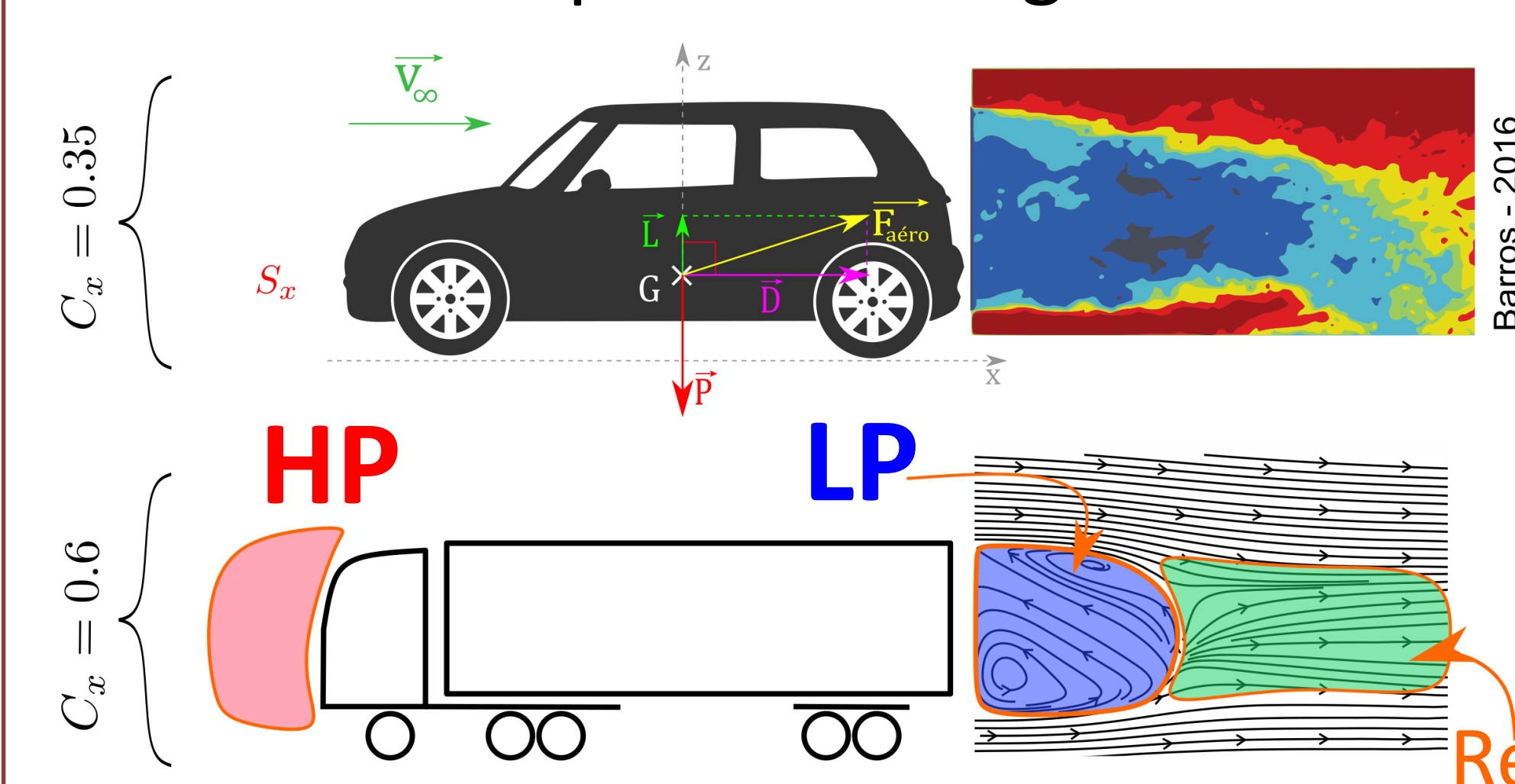
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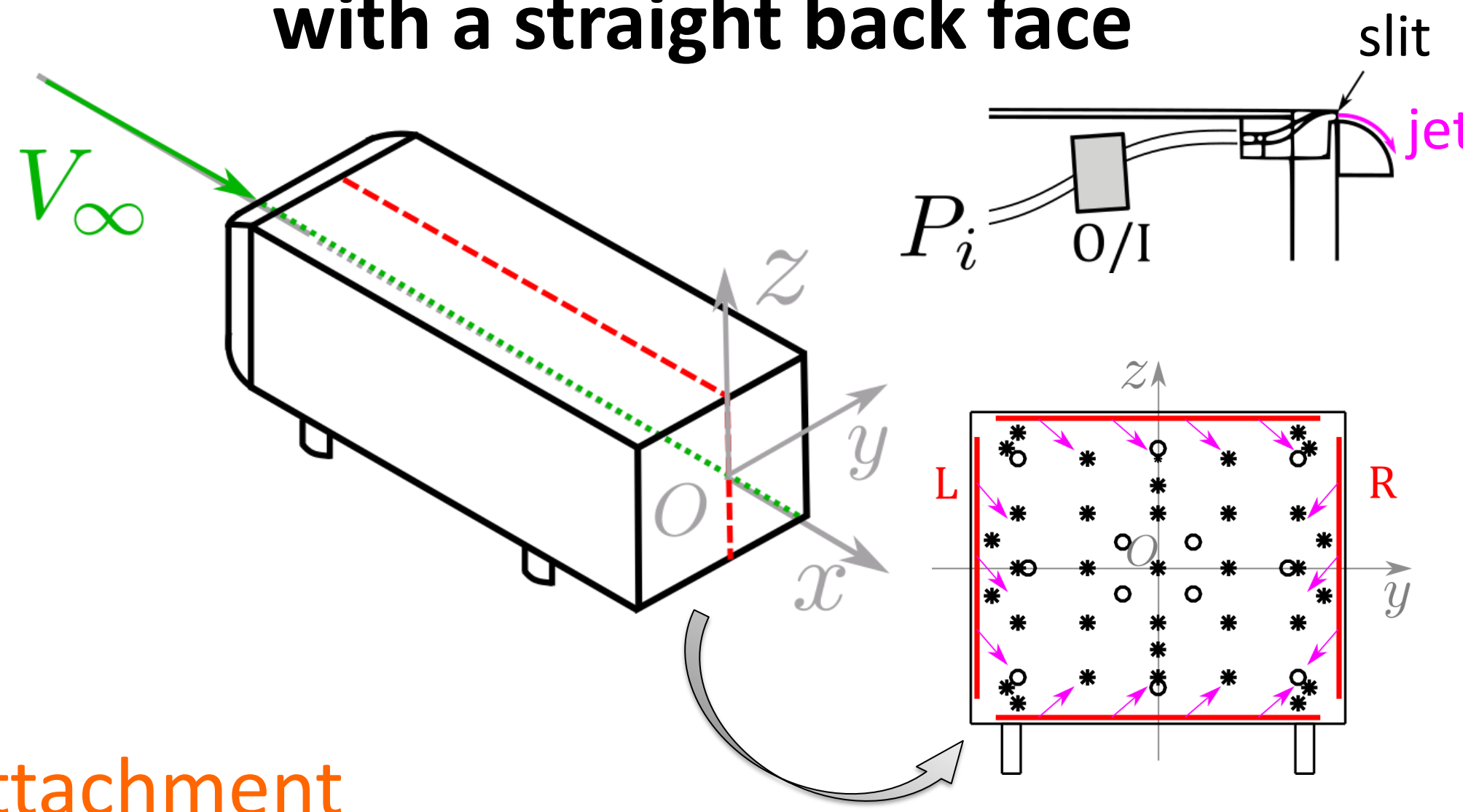
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Development of control law strategies for drag reduction of ground vehicles

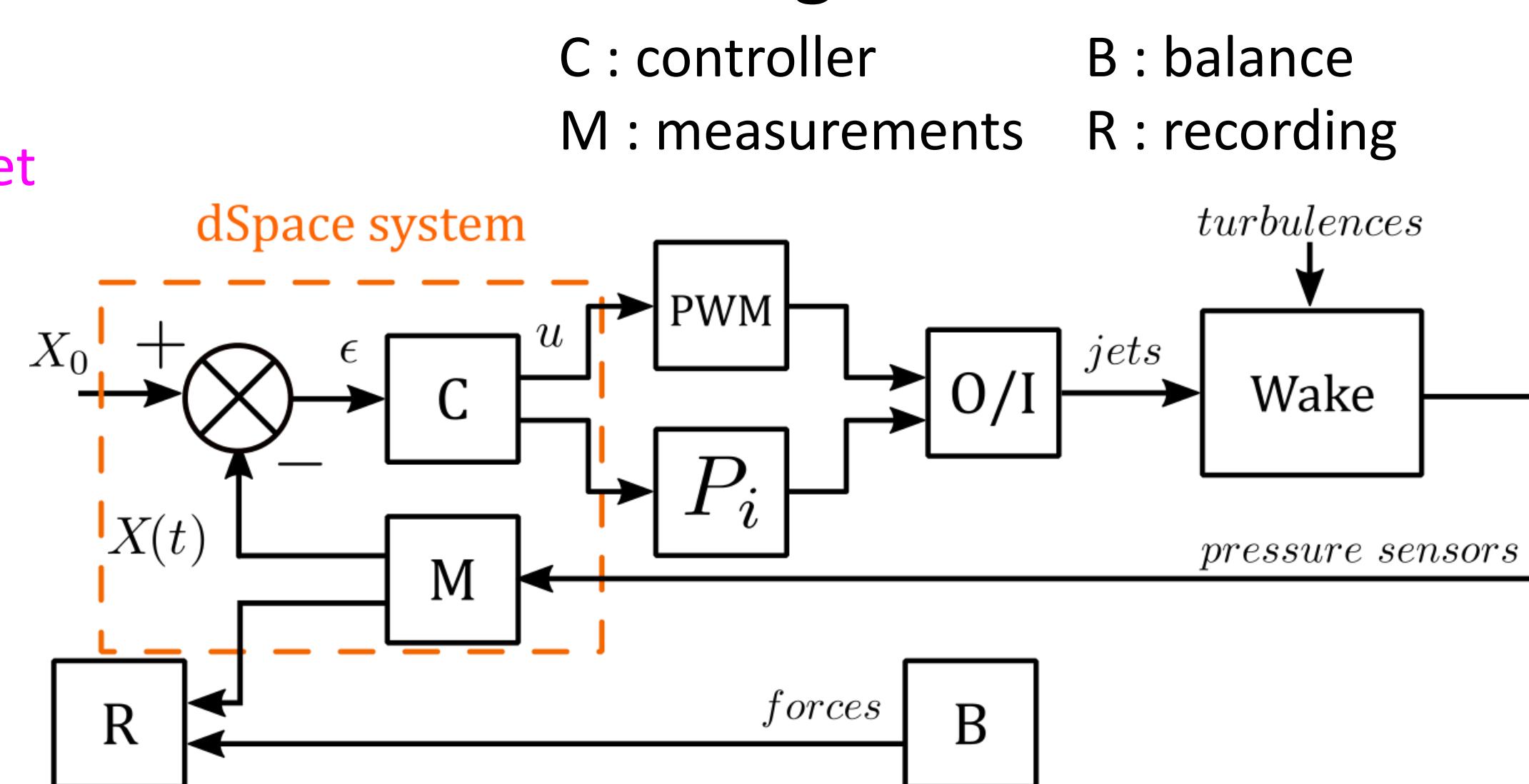
> 30% of the total aero-dynamic drag comes from pressure drag



Experimental Ahmed body mock-up with a straight back face



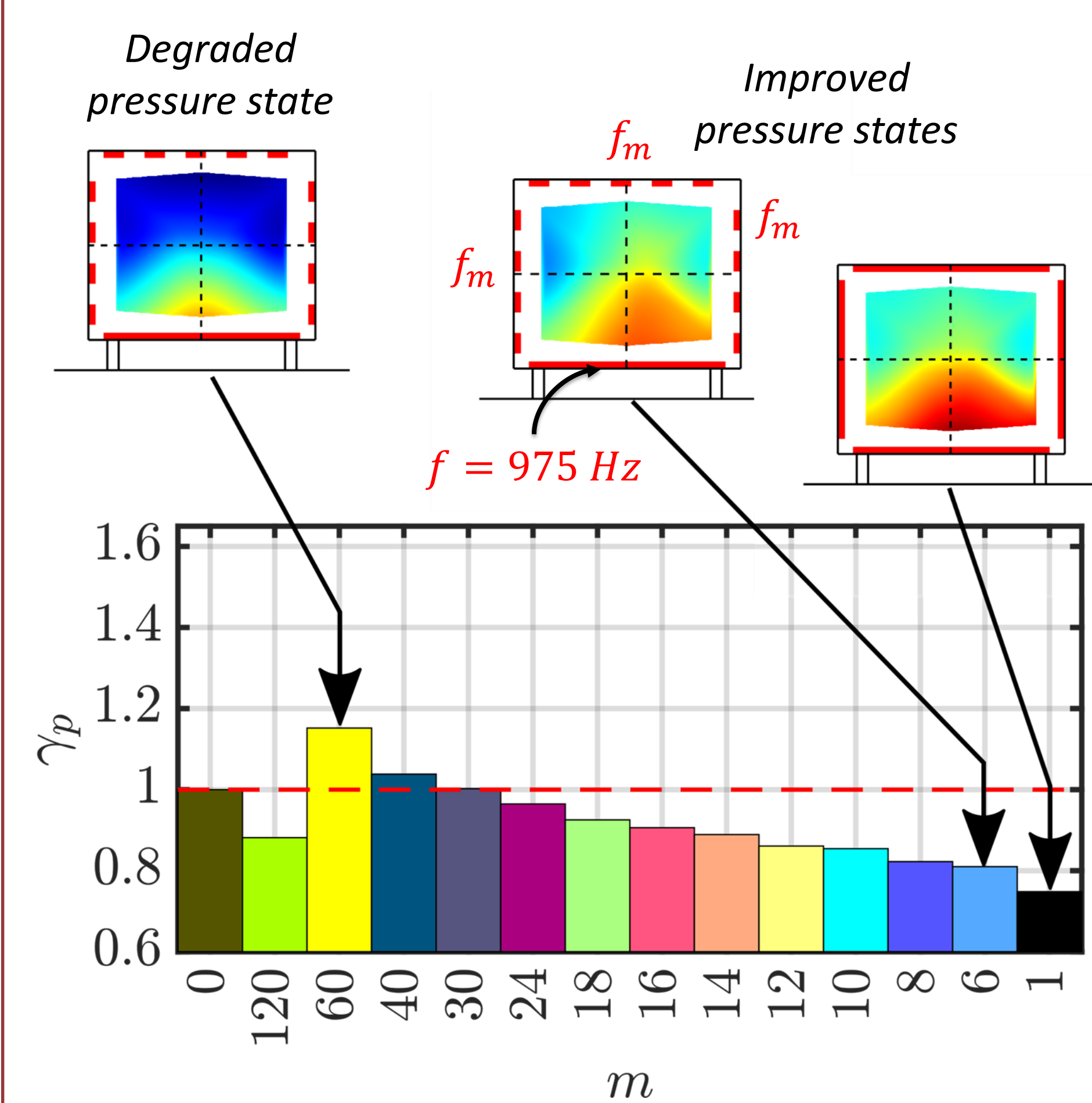
Control diagram :



Developed pressure drag mitigation control laws

Open-loop modulation strategy :

\bar{C}_p = mean pressure loss coefficient ;
 γ_p = ratio of pressure loss relatively to the uncontrolled value

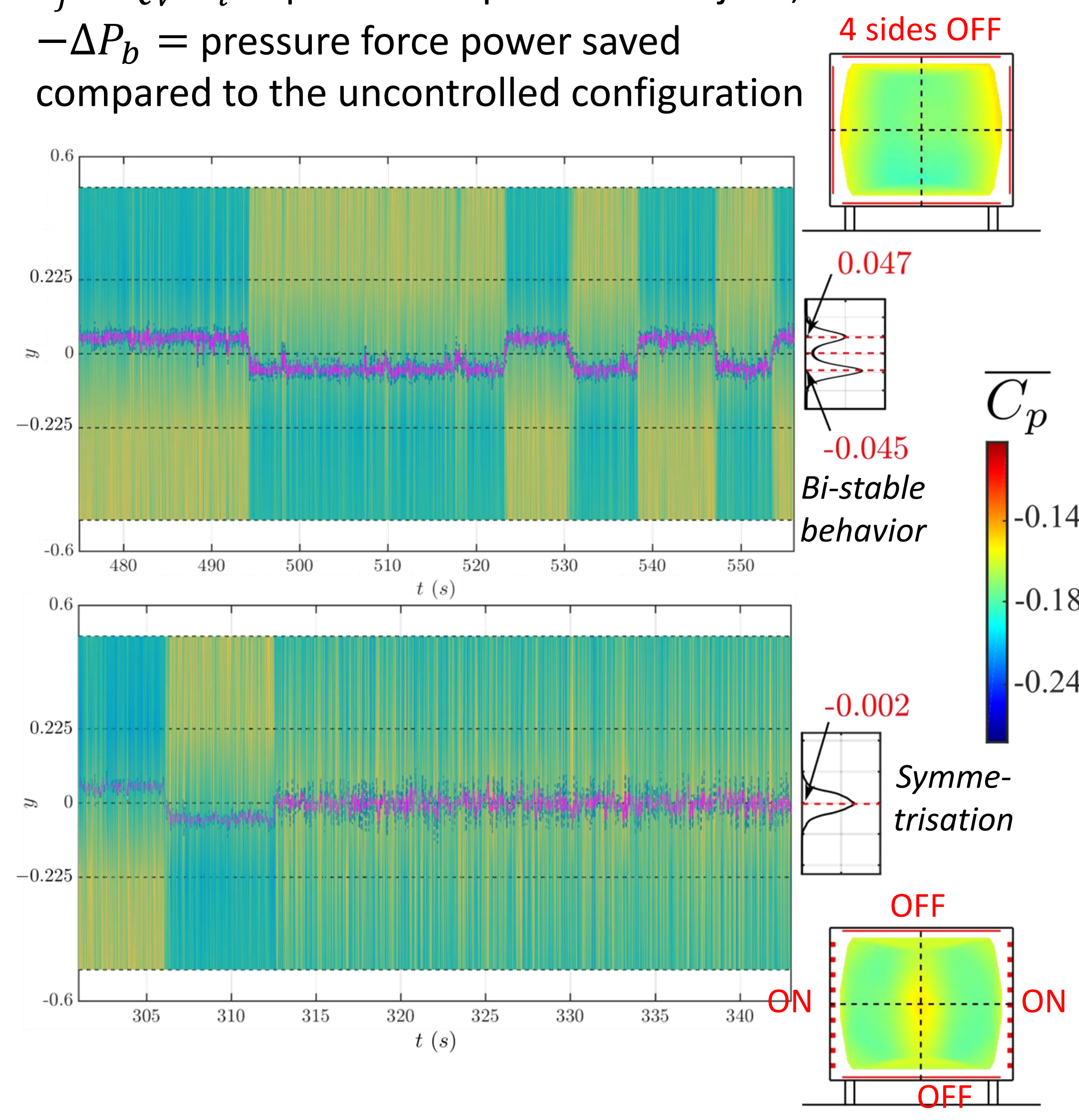


Modulation of the actuation frequency of 3-sides with one side at a fixed frequency

m	$f_m = f/m$	$\Delta\gamma_p$	Q_V (L/min)	η
120	8.13	-11.3%	230	10.9%
6	162.5	-18.9%	222	18.9%
1	975	-24.4%	372	14.5%

Sliding mode closed-loop control of the symmetry of the wake :

$P_j = Q_V \cdot P_i$ = pneumatic power of the jets ;
 $-\Delta P_b$ = pressure force power saved compared to the uncontrolled configuration

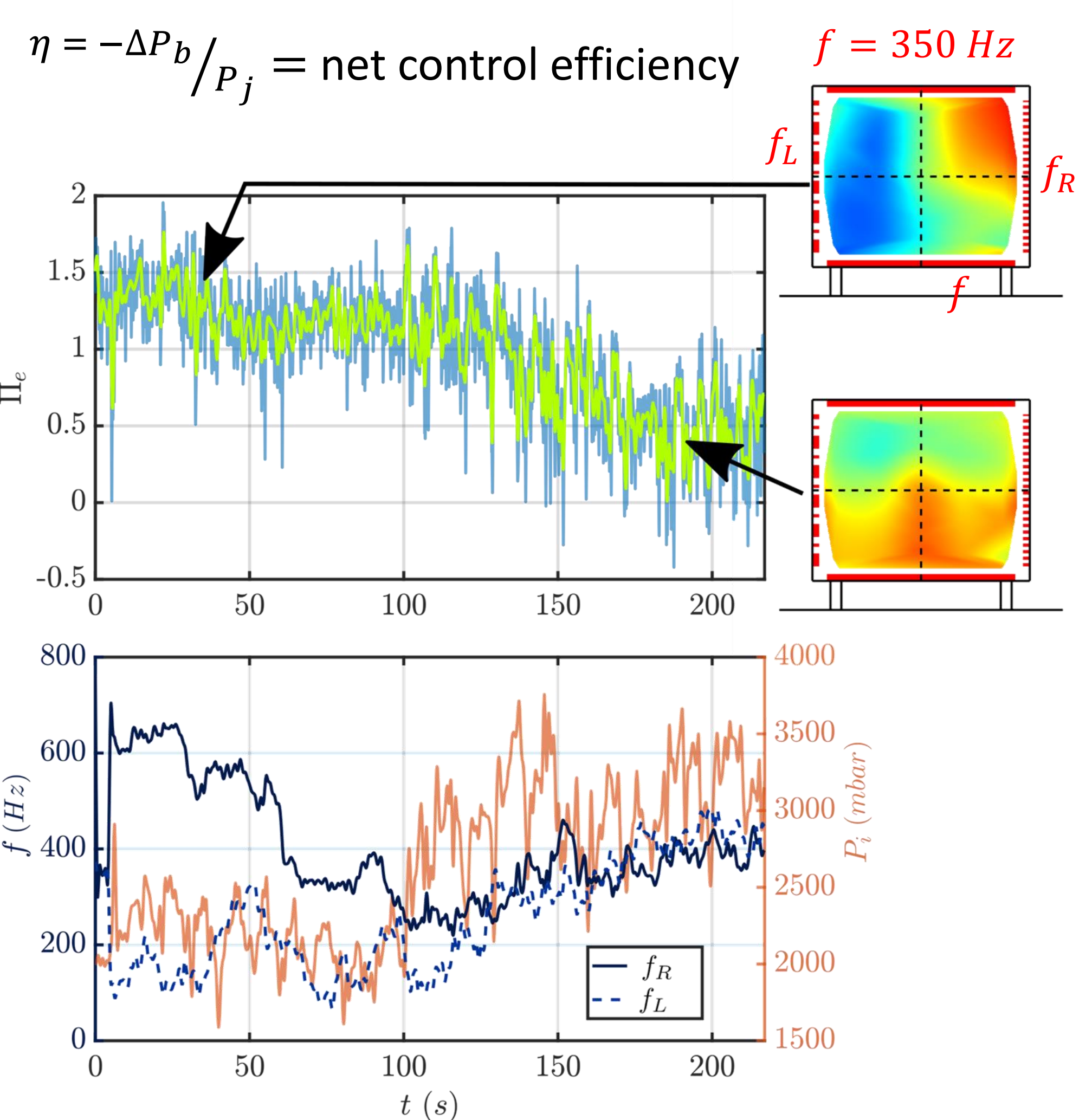


Sliding mode control with time delay compensation by a first order Smith predictor

$\Delta\gamma_p$	Q_V (L/min)	η
-1,92%	≤30	52,8%

Extremum seeking closed-loop control :

Π_e = energetic metric to reduce by adjusting automatically the control parameters ;



3-components extremum seeking strategy :

State	$\Delta\gamma_p$	Q_V (L/min)	η
Initial	-1,62%	312	3,8%
Final	-17,6%	411	22,5%

Conclusions

Validation of different regulation approaches for the drag reduction for a mock-up of a ground vehicle :

- Efficiency improvements found by modulation strategies
- Closed-loop control of the wake symmetry was proved robust, fast and very energetically economical
- Extremum seeking strategies could tackle dynamical issues by finding optimal control parameters for different operating conditions without beforehand open-loop survey studies.

Perspectives

Improvement of the strategies for extremum seeking

- Improving the convergence time of the algorithm
- Extension of the control on a realistic vehicle body shape
- Finalization and tests of models for turbulent flows**
- To obtain observer based control strategies
- To validate the experimented control laws on different kind of actuators and to improve the efficiency of the control

Submitted conference papers

K. Mariette, E. Bideaux, et al., Sliding mode control of the wake symmetry of a bluff Ahmed body, 21st IFAC World Congress, 2020 ;

K. Mariette and Y. Haffner, et al., Large-scale asymmetries of a turbulent wake, 55th 3AF International Conference on Applied Aerodynamics, 2020