Exa Contribution to DPW-6 using a Lattice-Boltzmann Method

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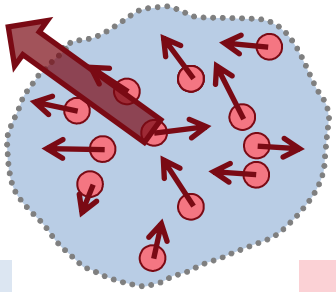
Numerical Method
Lattice Boltzmann Method



Classical CFD

Continuum Equations

↓

Discrete Approximation

↓

Numerical Integration

LBM

Discrete Statistical Approximation of Particle Movements

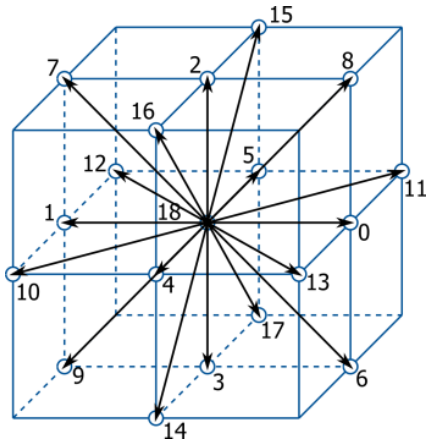
↓

Advection and Collision of Particle Distributions

Results

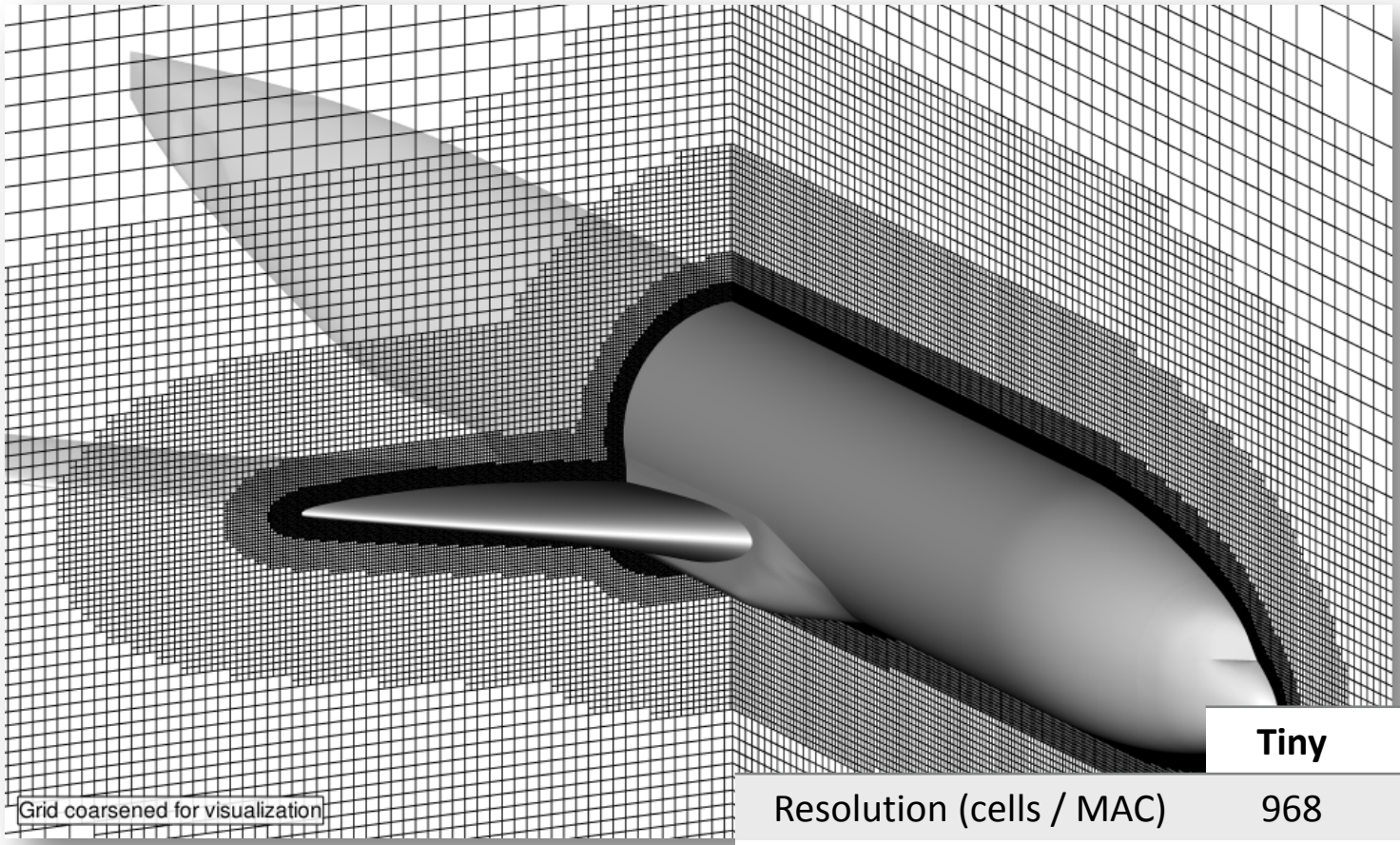
Numerical Method
Lattice Boltzmann Method - Properties

- Discretization
  - *Inherently unsteady*
  - *Limited set of discrete particle velocities*
- Turbulence Modelling
  - *Compute coherent, anisotropic structures*
  - *Model universal, isotropic structures*
  - *Two equation k-ε model (extended RNG)*
- Grid Approach
  - *Automatic Cartesian grid generation*
  - *Wall function*
- New Transonic Capability



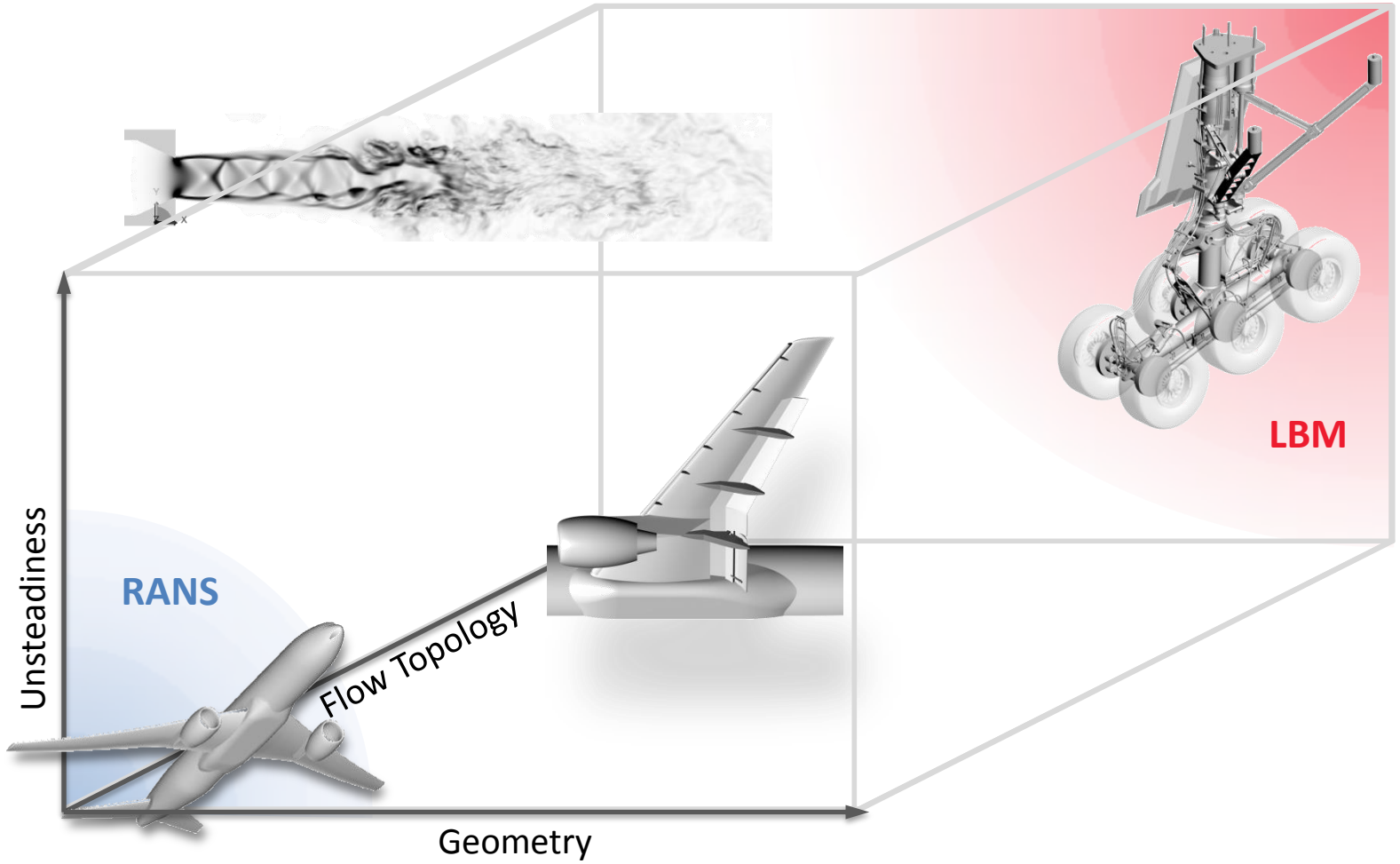
Schematic view only, not representative of transonic LBM model

Numerical Method
Computational Mesh

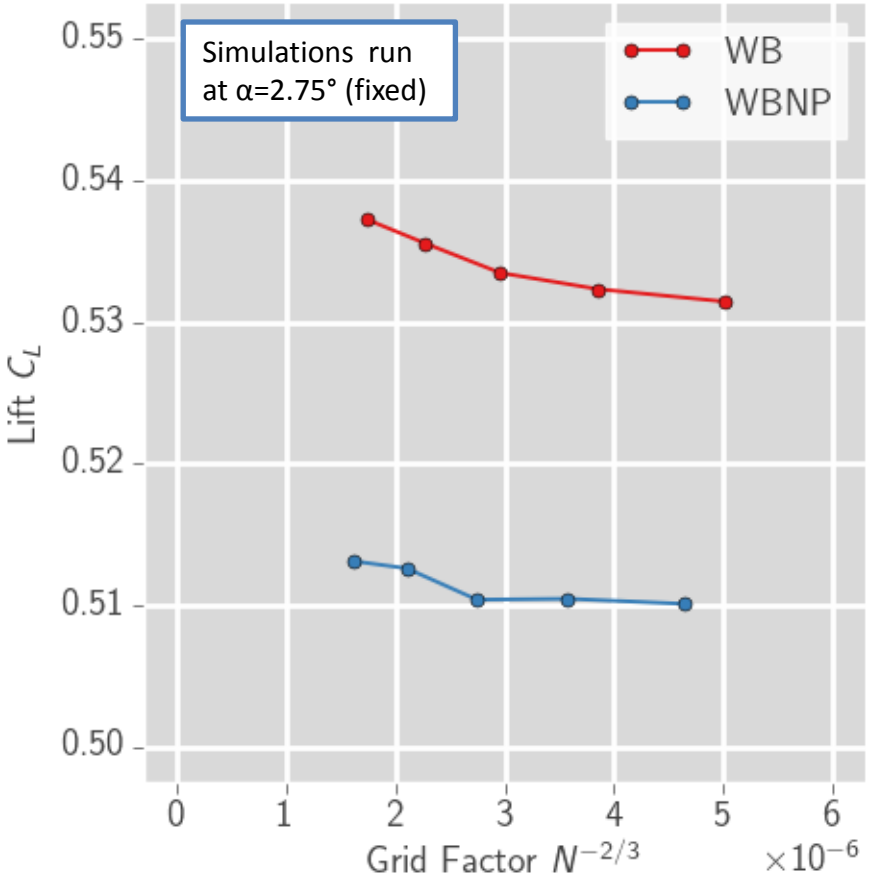


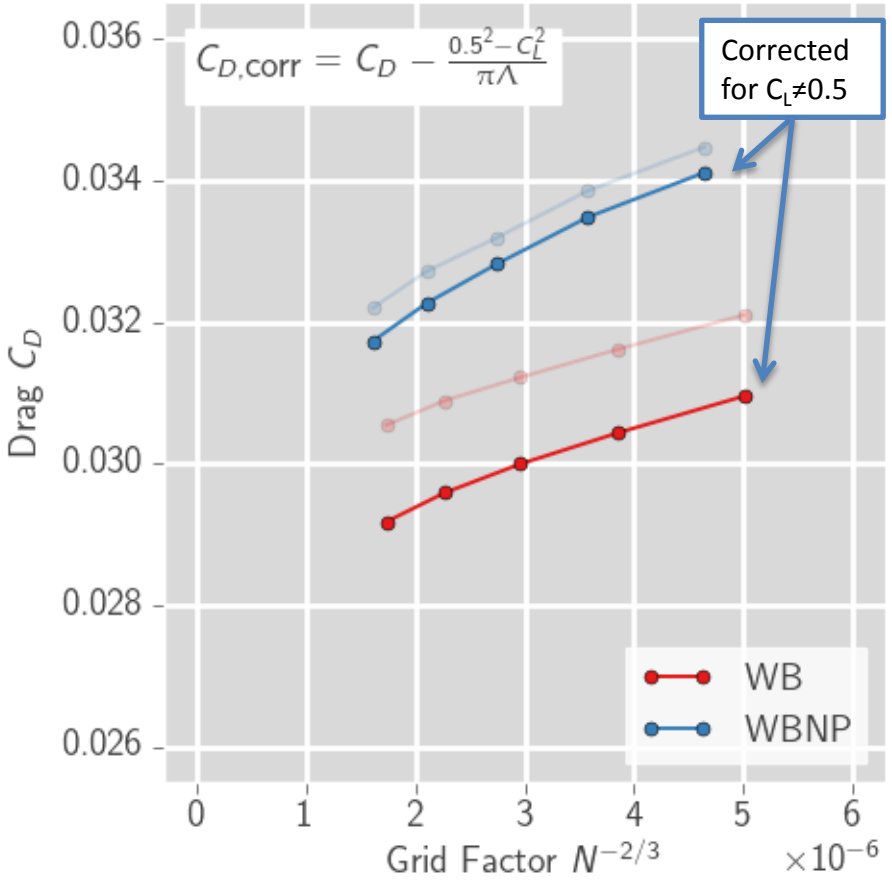
	Tiny	Medium	X-Fine
Resolution (cells / MAC)	968	1280	1693
Voxels [10^6]	89	196	438
CPUh [10^3]	2.8	7.2	31
Wallclock on 360 cores [h]	8.1	21	45

Numerical Method
Application of LBM vs RANS



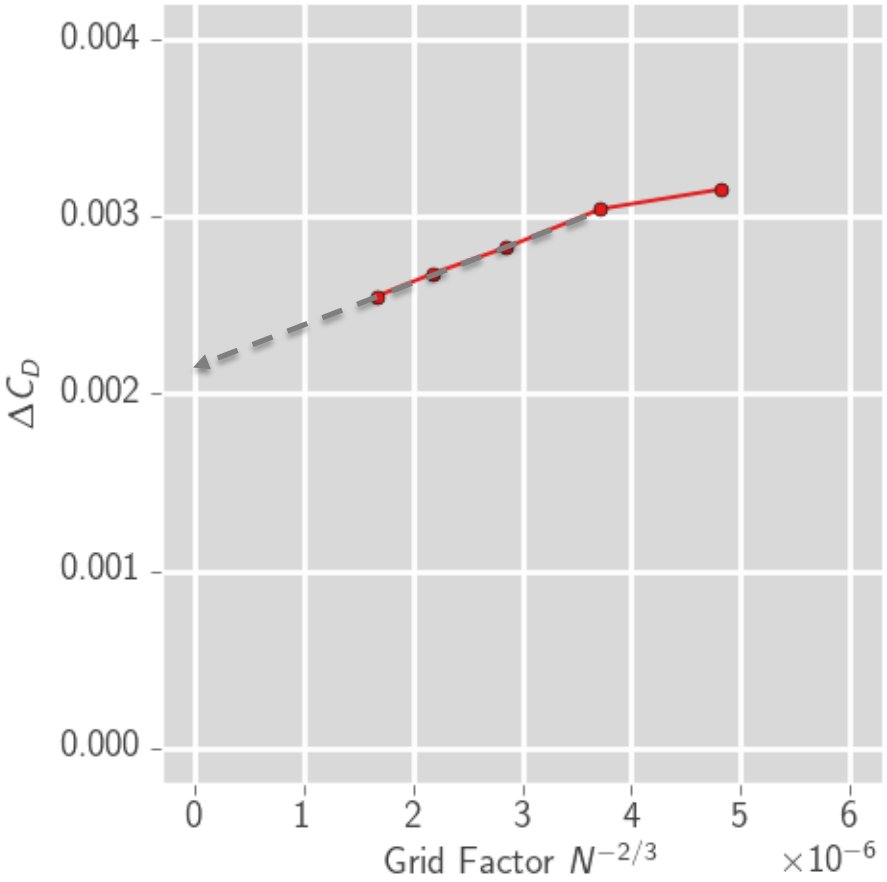
Exa DPW-6 Results
Case 2 Grid Convergence – Forces



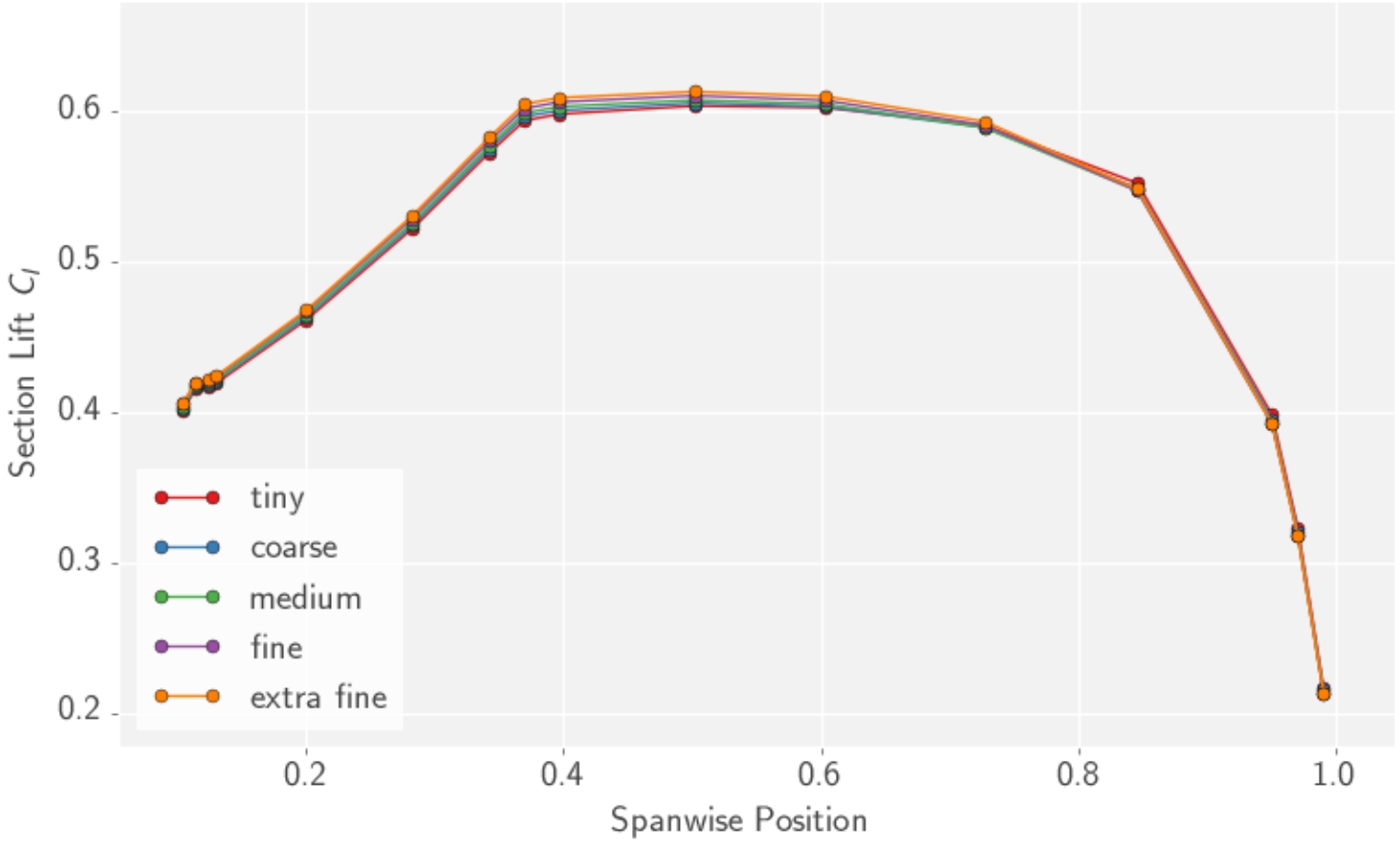


Exa DPW-6 Results
Case 2 Grid Convergence – Drag Difference

Drag increment
WBNP -WB: +23 d.c.
(Extrapolated)

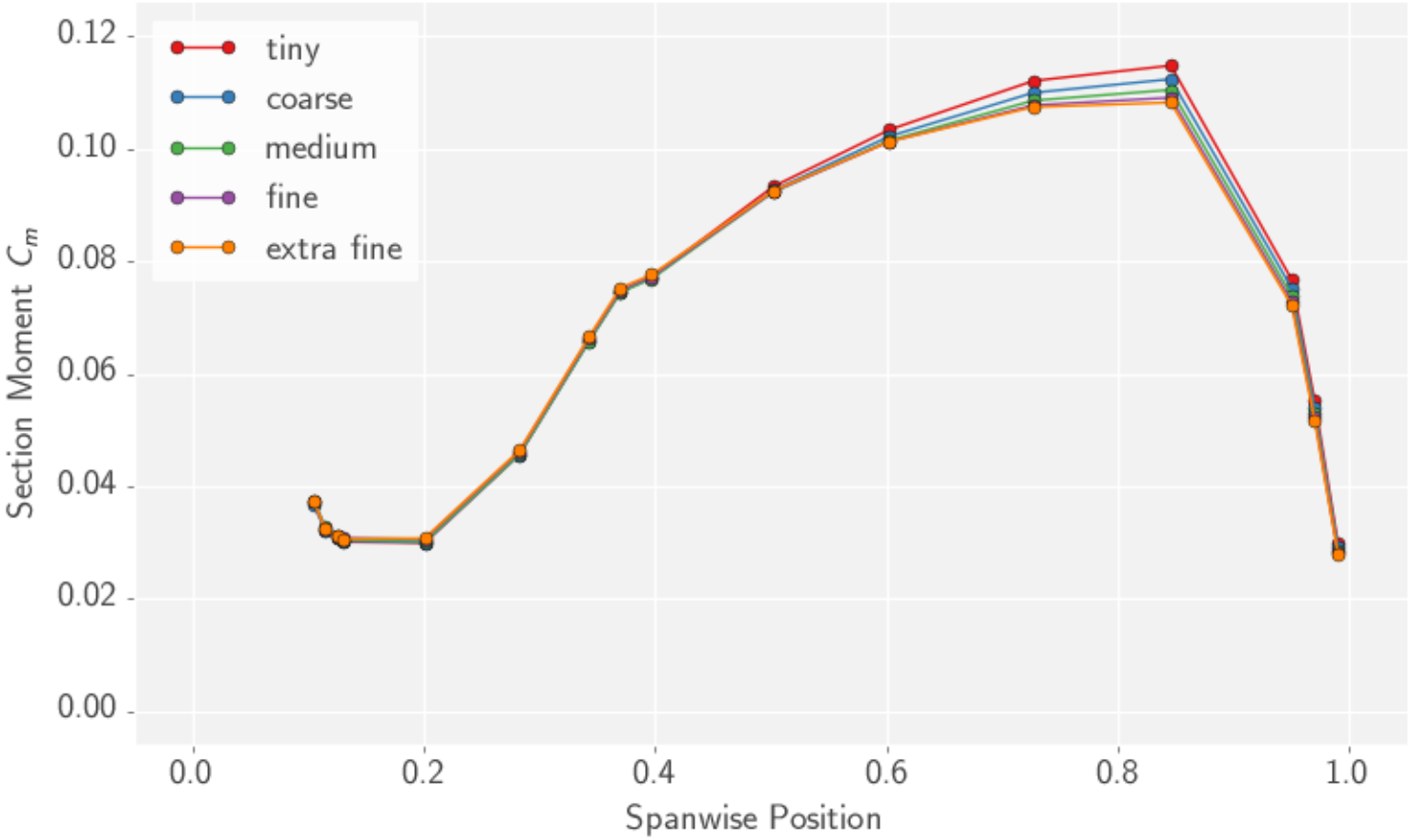


Exa DPW-6 Results
Case 2 Grid Convergence – WB Spanwise Lift

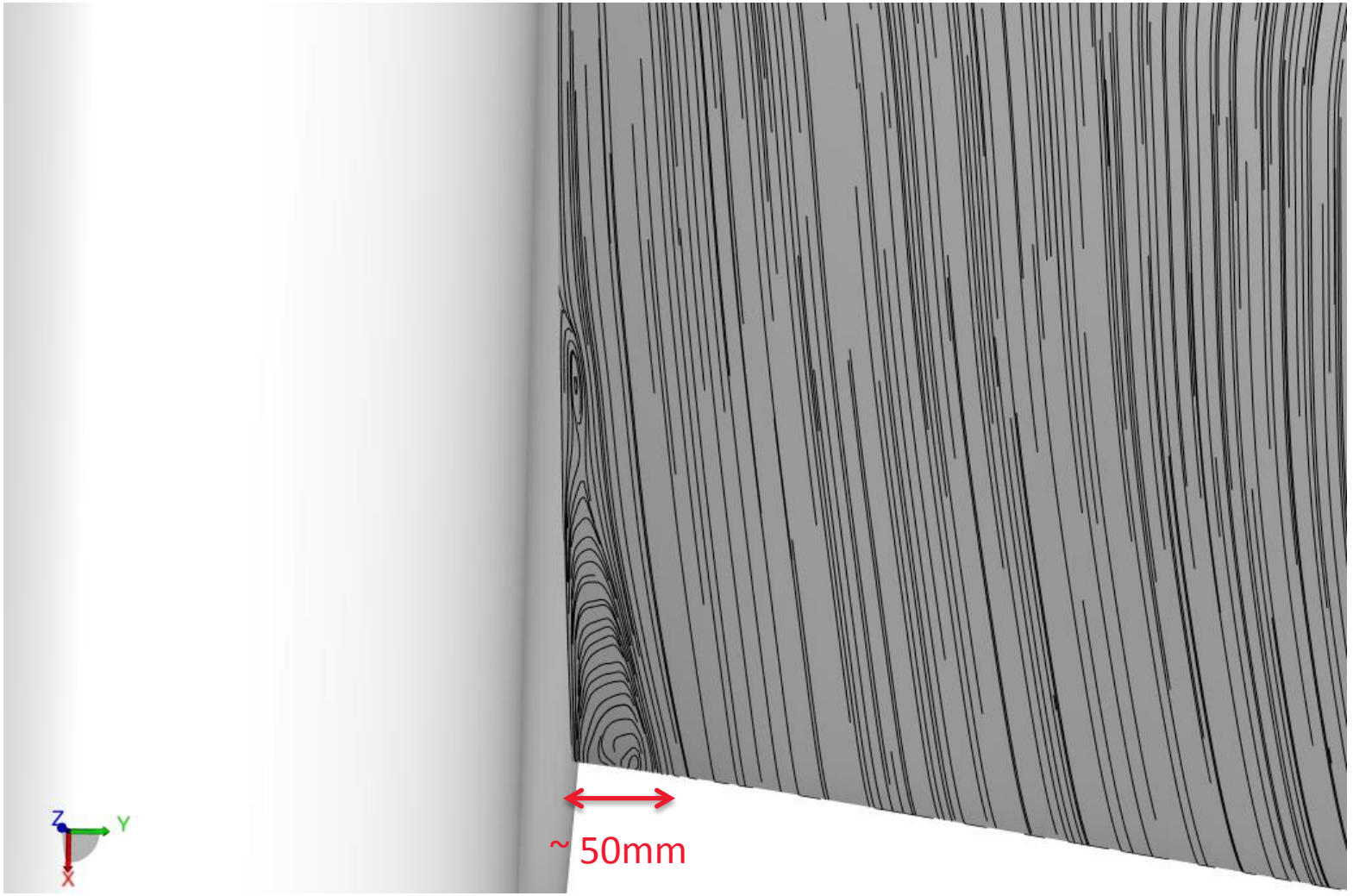


Exa DPW-6 Results

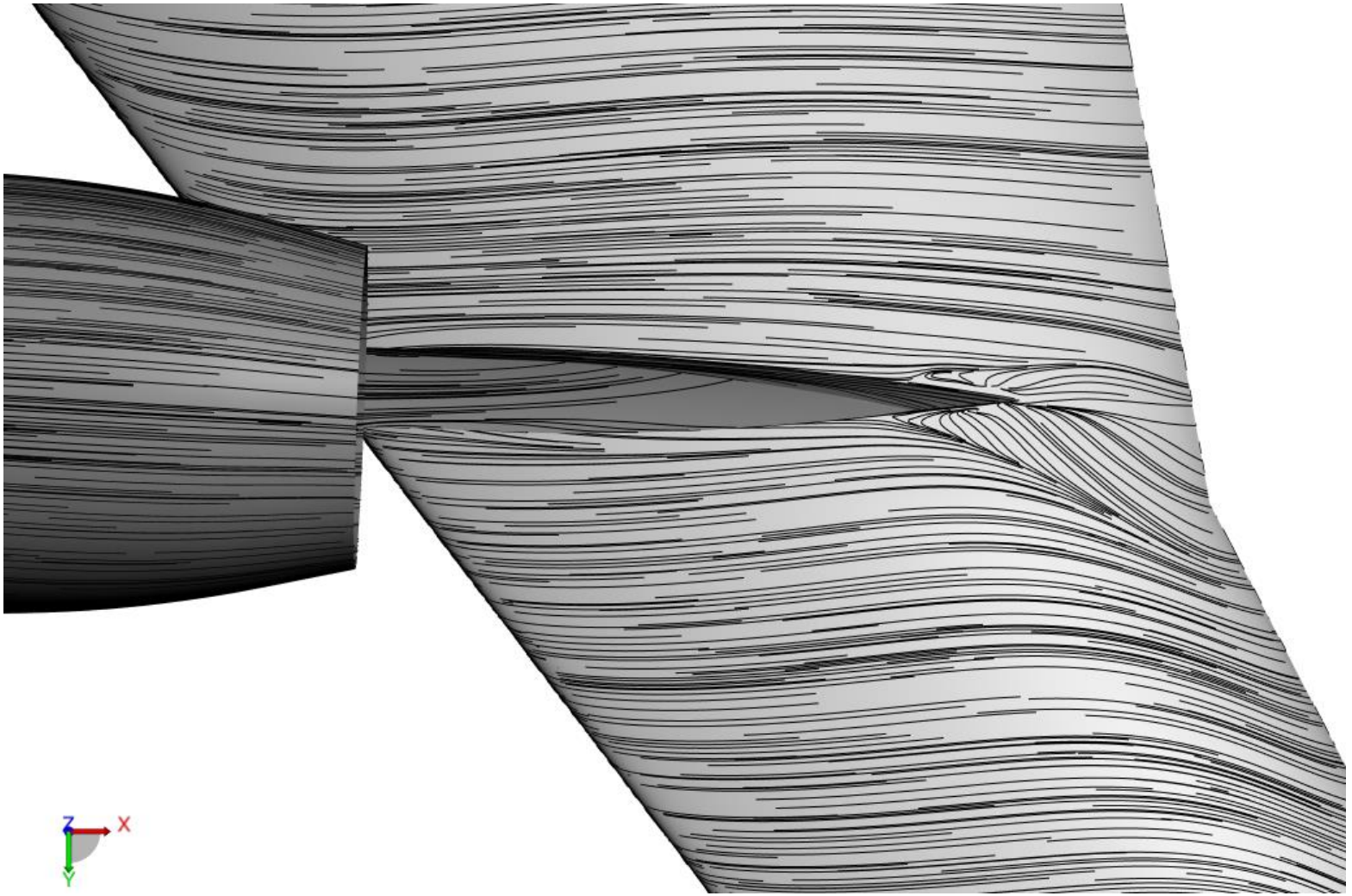
Case 2 Grid Convergence – WB Spanwise Pitching Moment



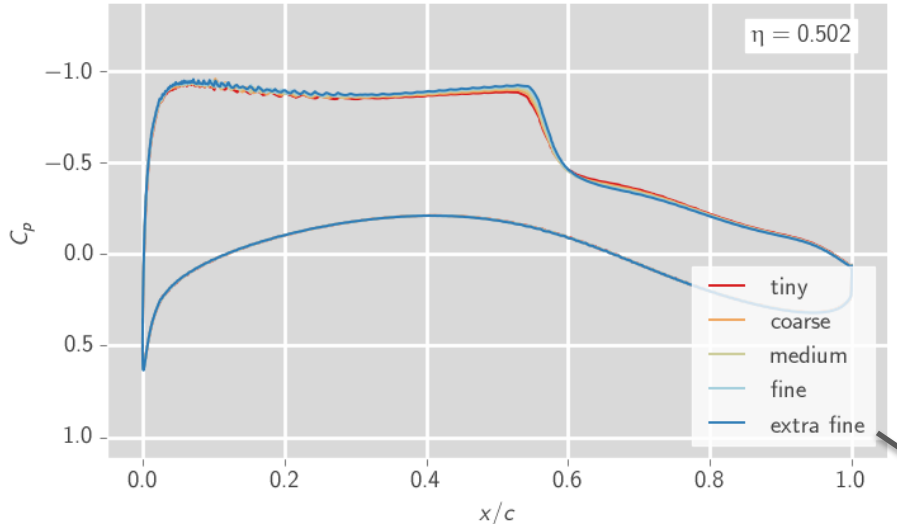
Exa DPW-6 Results
Case 2 Side-of-Body Separation – medium resolution

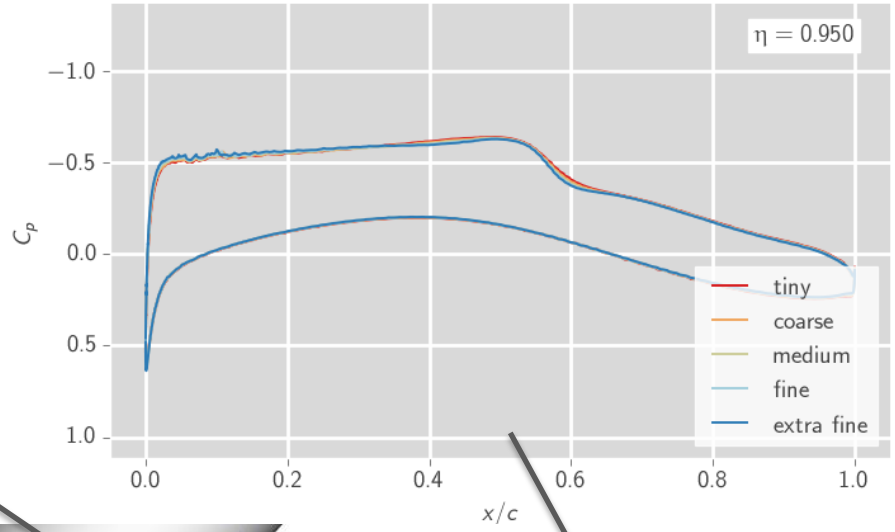


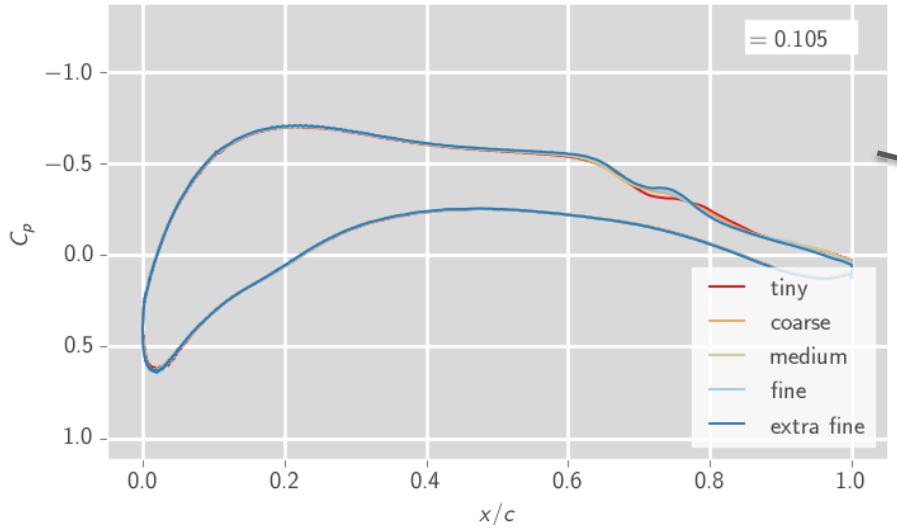
Exa DPW-6 Results
Case 2 Pylon Separation – medium resolution

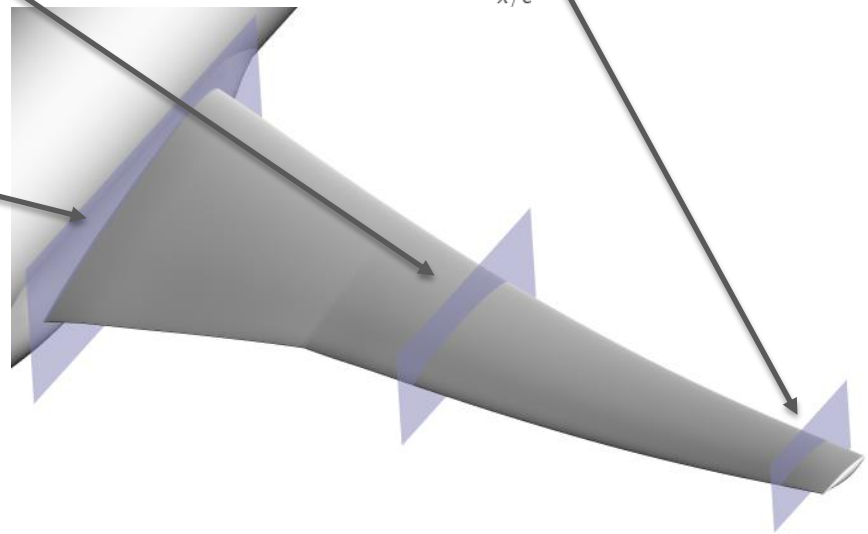


Exa DPW-6 Results
Case 2 Grid Convergence – Pressure Distributions

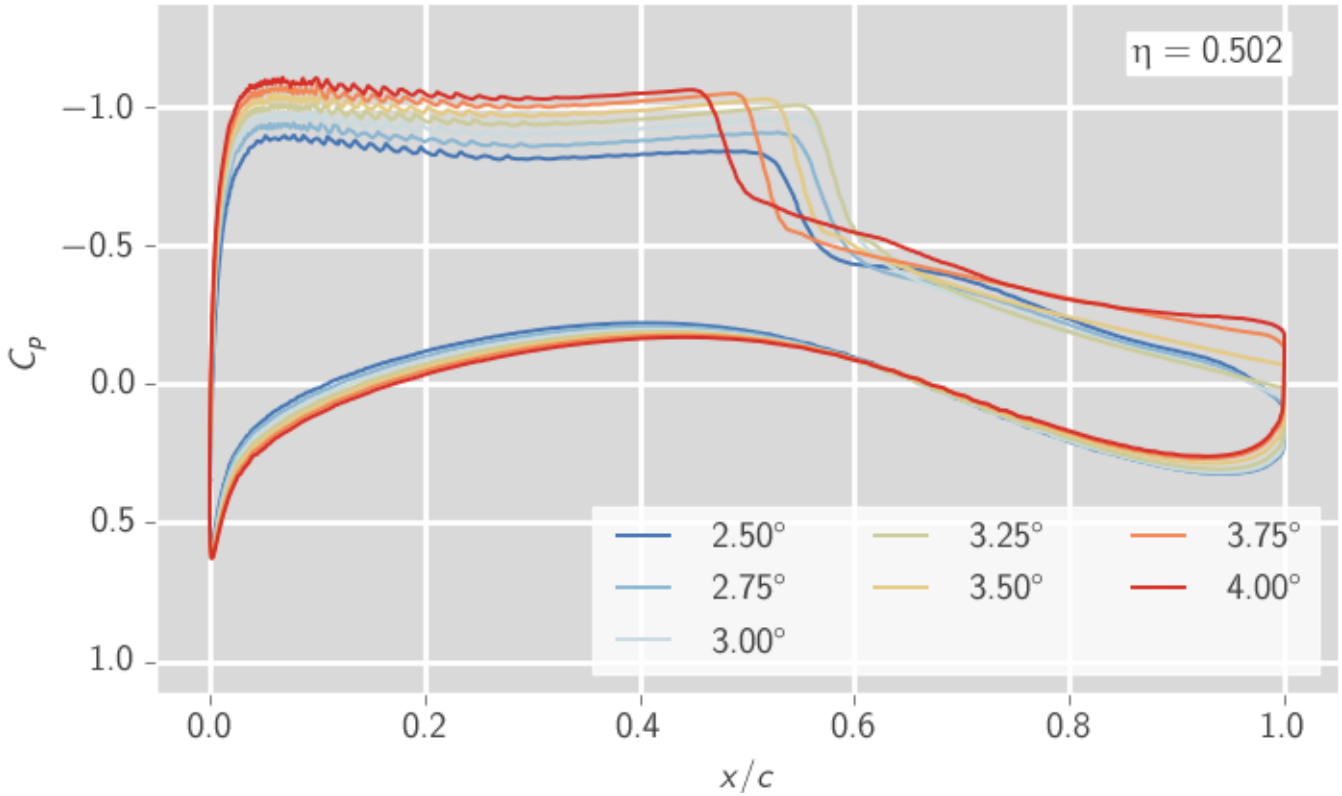






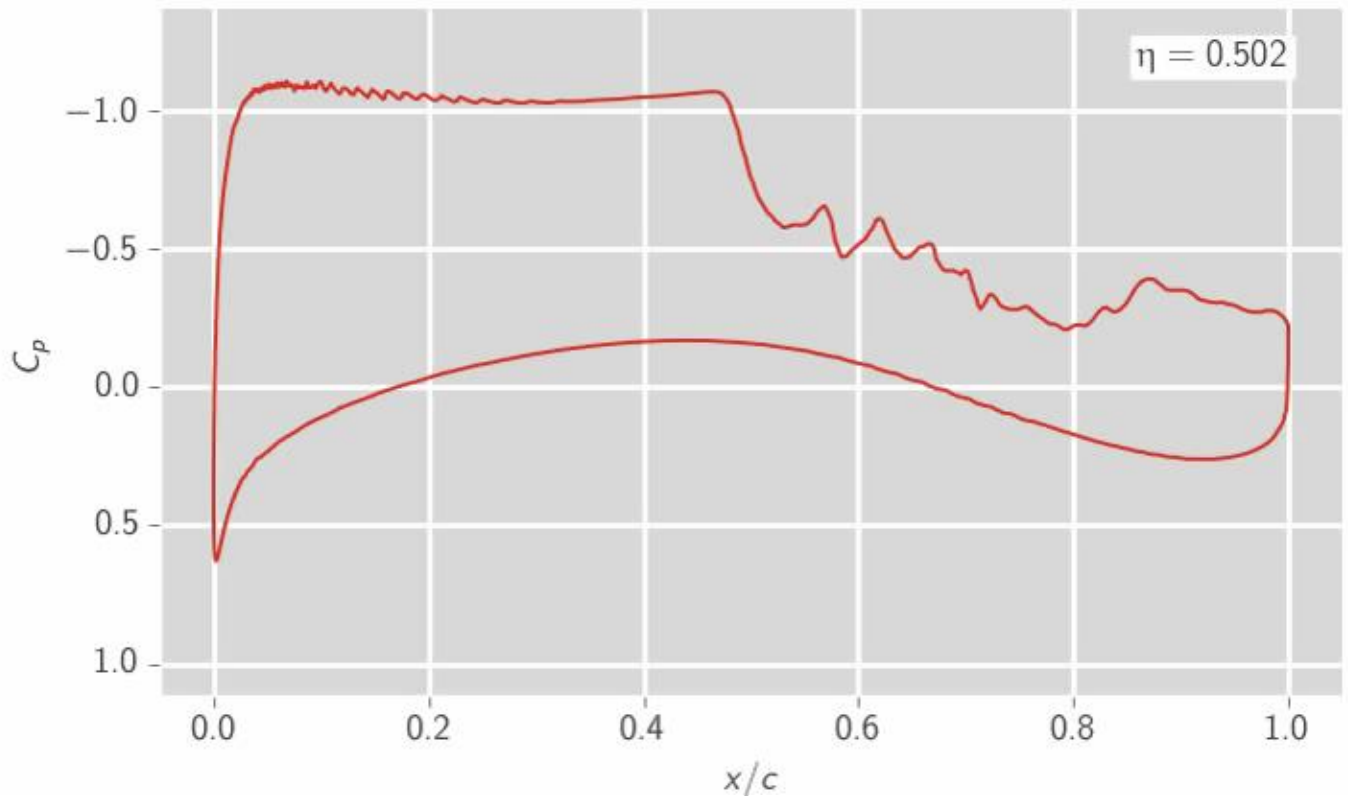


Exa DPW-6 Results
Case 3 Polar Study – Pressure Distributions

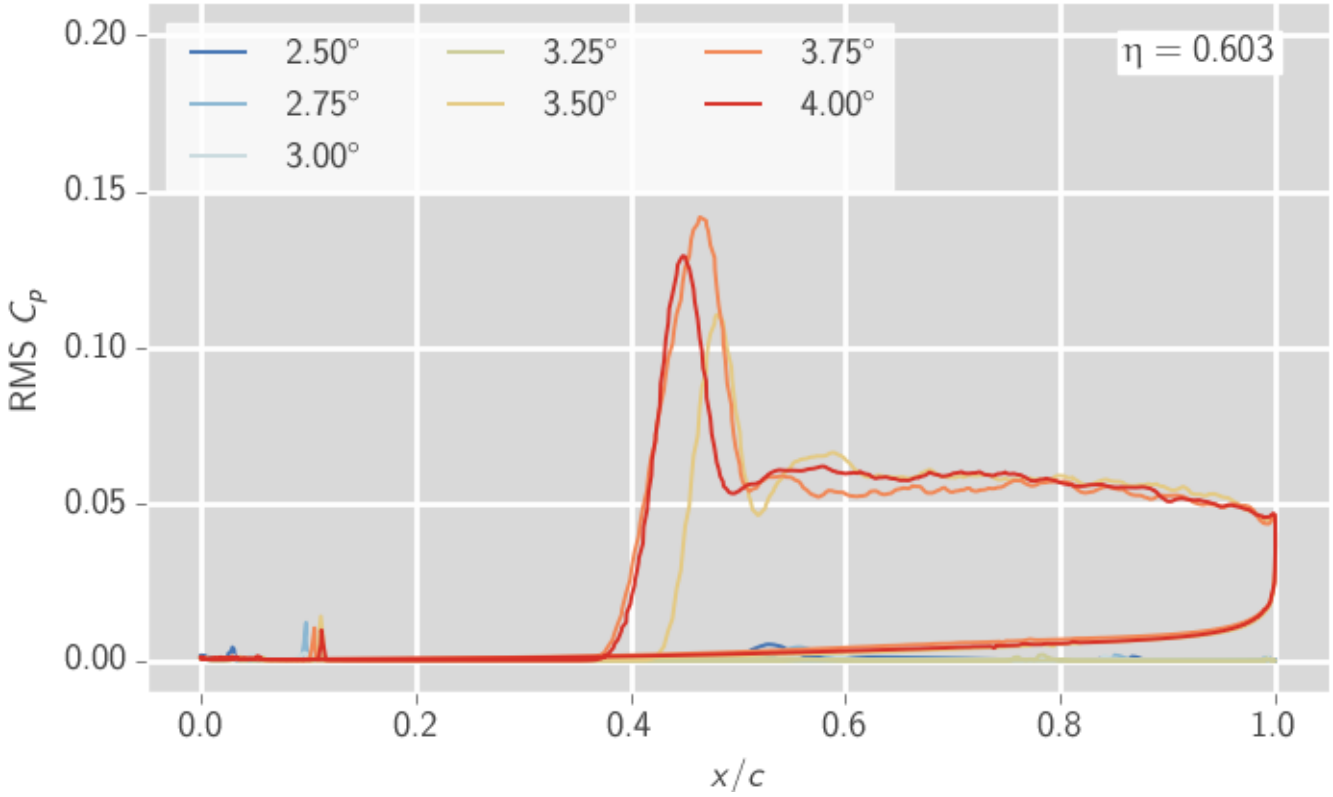


Exa DPW-6 Results

Case 3 Polar Study – Pressure Distribution at α=4°

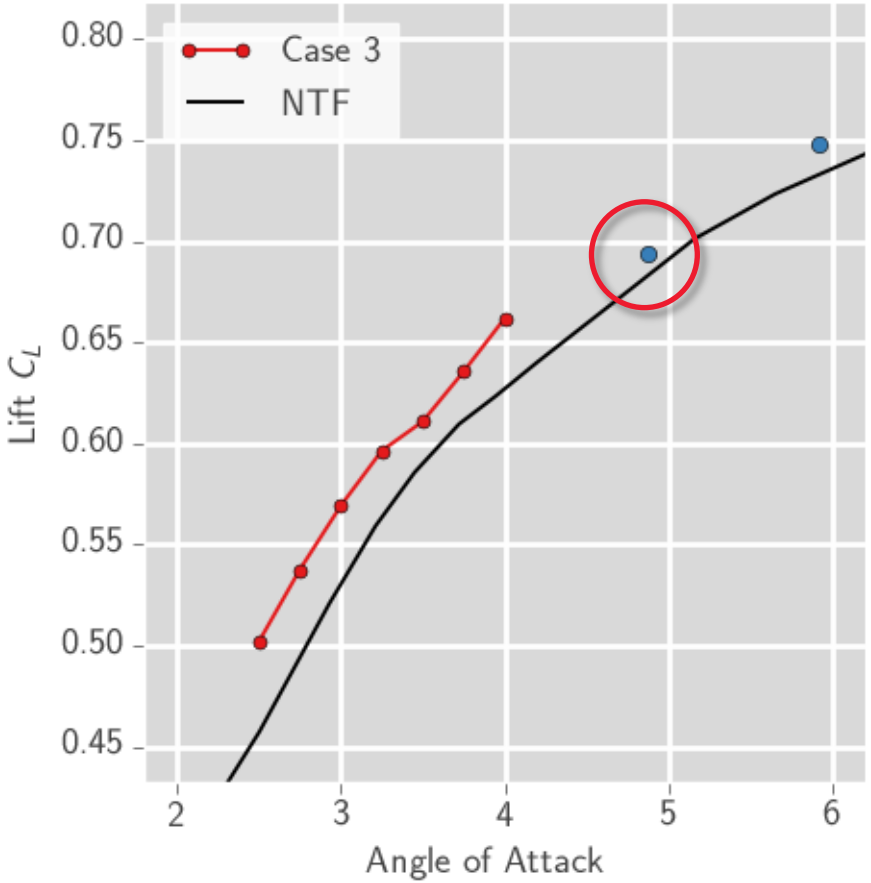


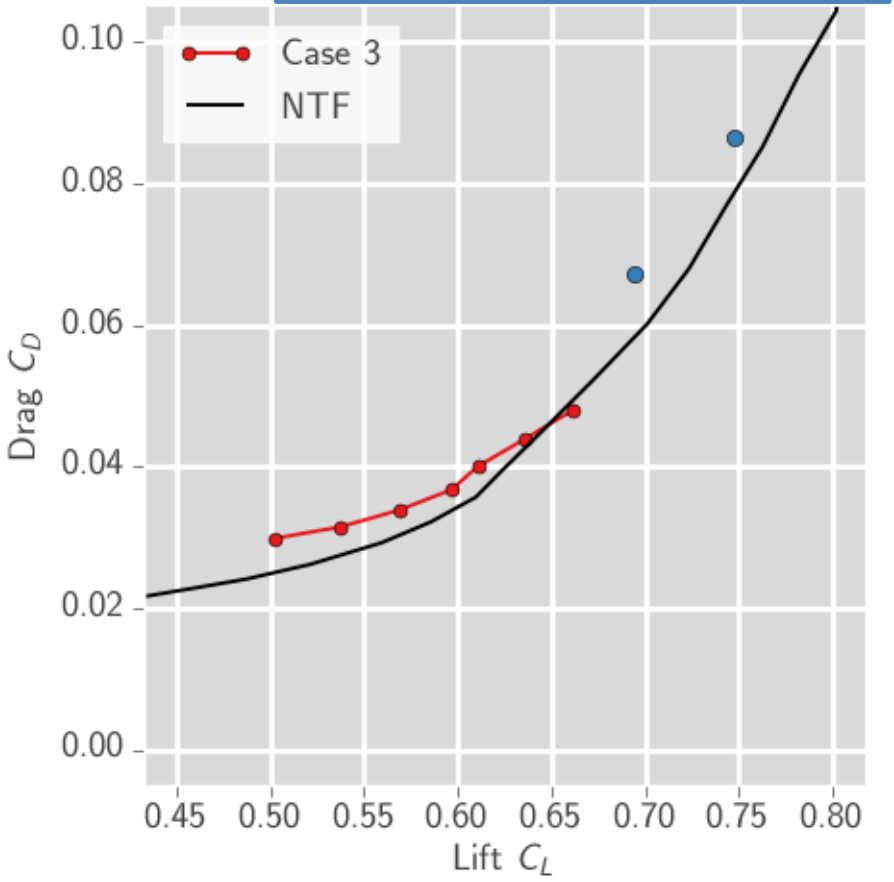
Exa DPW-6 Results
Case 3 Polar Study – Pressure Distributions



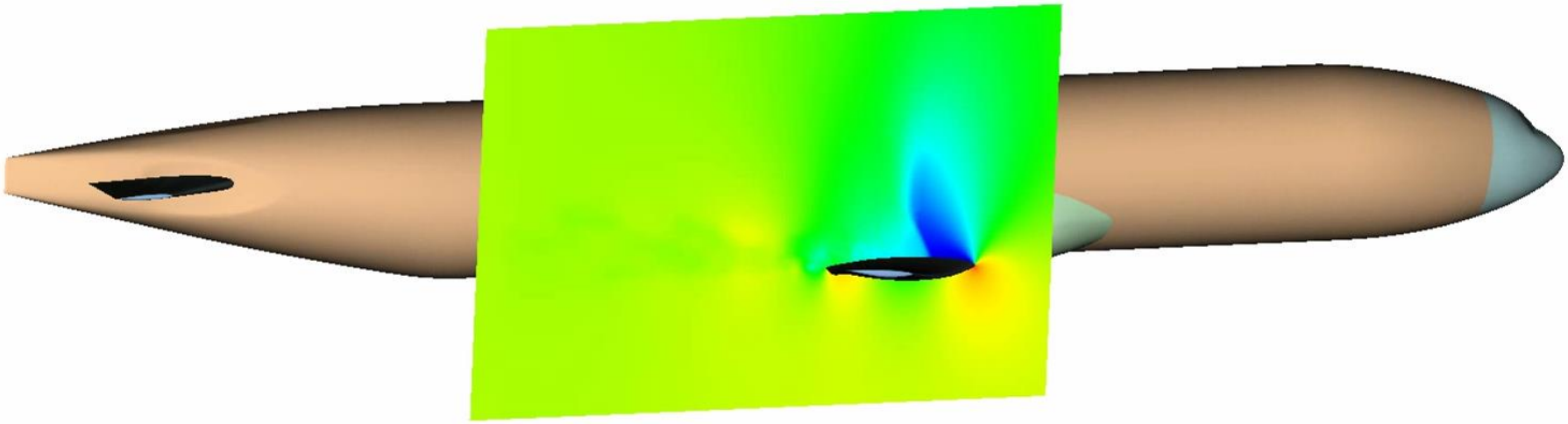
Exa DPW-6 Results
Case 3 Polar Study – Lift and Drag

Additional data points run for JAXA Second Aerodynamics Prediction Challenge (APC-II, https://cfdws.chofu.jaxa.jp/apc/) at Re=1.5x10^6

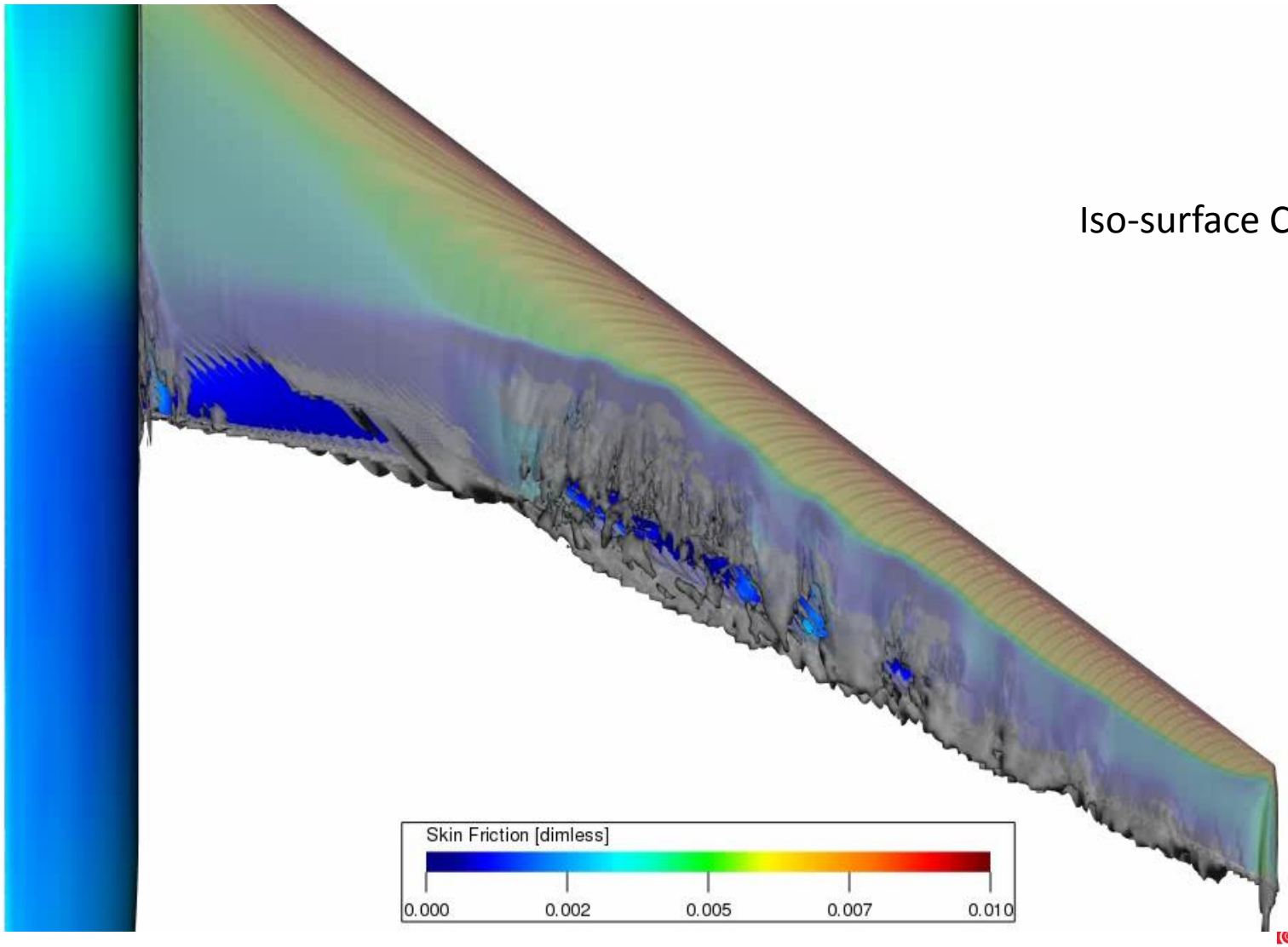




Beyond DPW-6
Buffet Plane Visualization at α = 4.87°

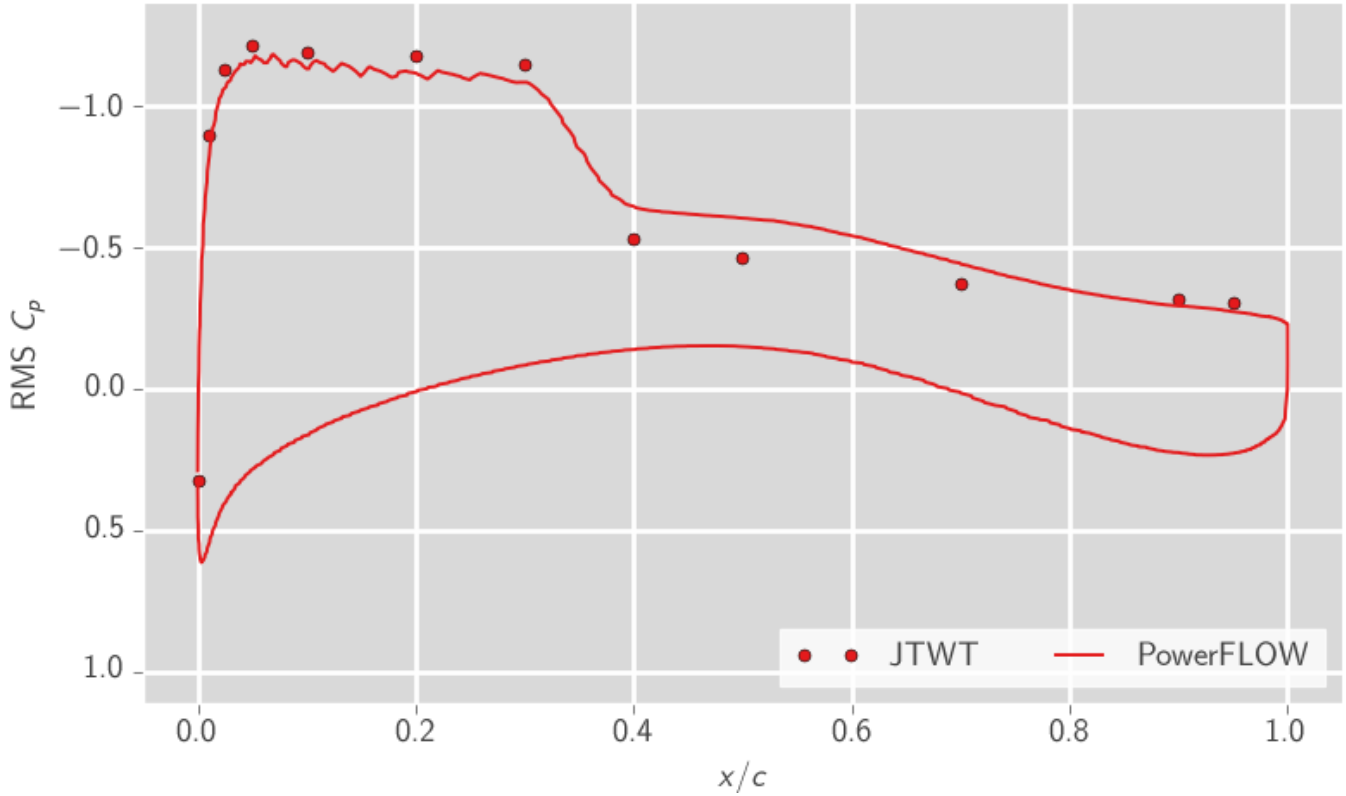


Beyond DPW-6
Buffet Iso-Surface Visualization at α = 4.87°



Beyond DPW-6
Pressure Fluctuations at α = 4.87°

Measurement data from JAXA Second Aerodynamics Prediction Challenge (APC-II, https://cfdws.chofu.jaxa.jp/apc/)



Beyond DPW-6
Pressure Fluctuations at α = 4.87°

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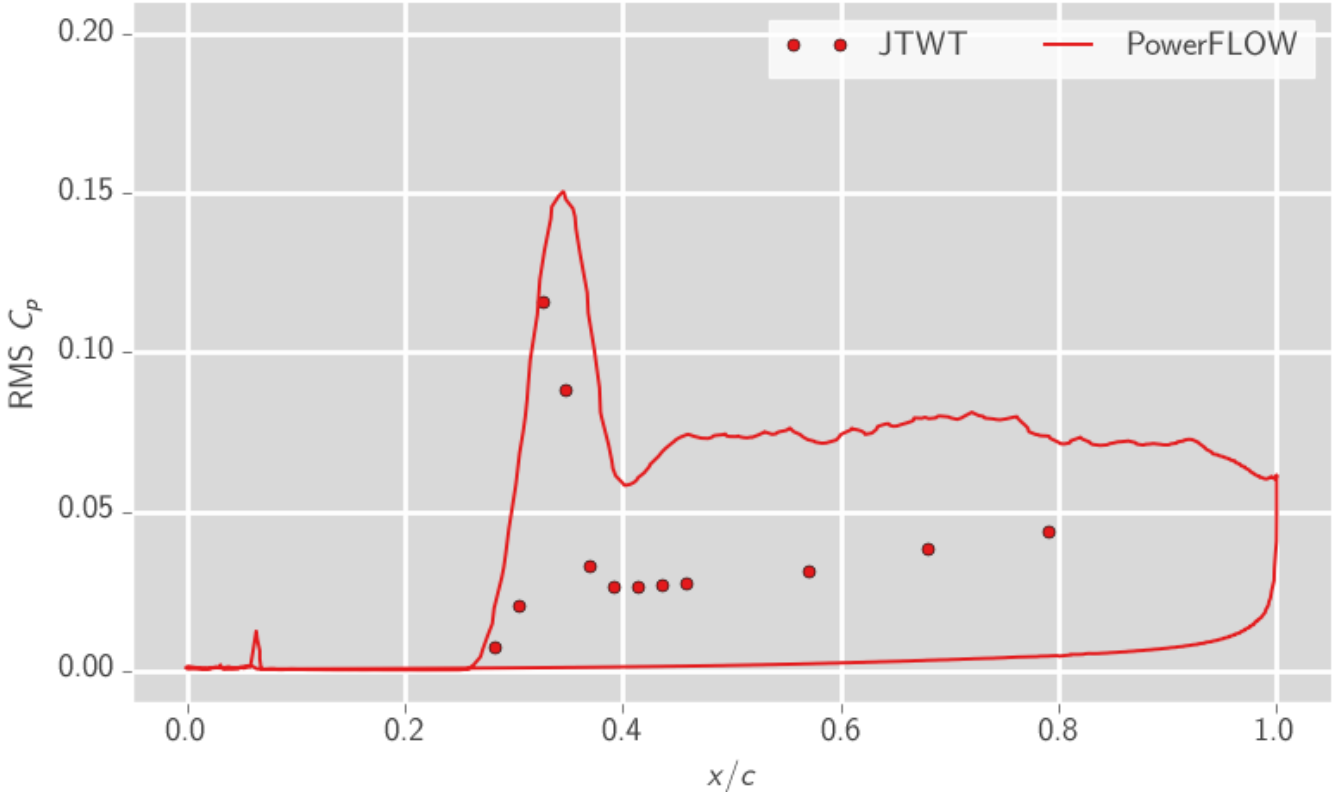

Summary

- New transonic Lattice-Boltzmann available
  - *Breakthrough technology for LBM*
  - *Current version still beta-stadium*
- Absolute drag sensitive to resolution
  - *Refinement shows convergence towards CFD consensus*
  - *Drag increment (WBNP-WB) well captured*
- Significant flow unsteadiness found for $\alpha \geq 3.5^{\circ}$
- Beyond drag prediction: Buffet prediction