Transitional Flow Computations of the NASA Trapezoidal Wing with the DLR TAU Code

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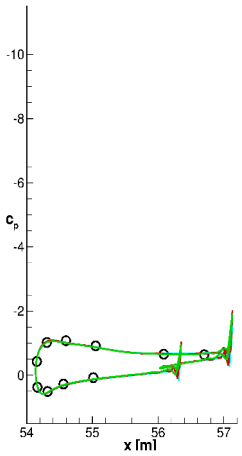
First AIAA High Lift Prediction Workshop (HiLiftPW-1)

- Workshop in June 2010
- Focus on NASA Trapezoidal Wing
- Objectives
  - Assess the capabilities of TAU for high-lift
  - Observe state-of-the-art and networking with community
  - Identify areas needing additional research and development

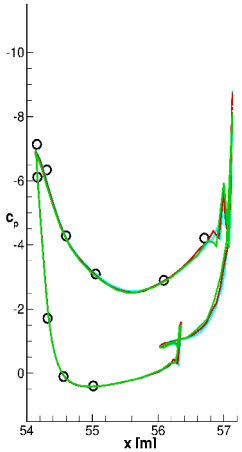
HiLiftPW-1 – Results

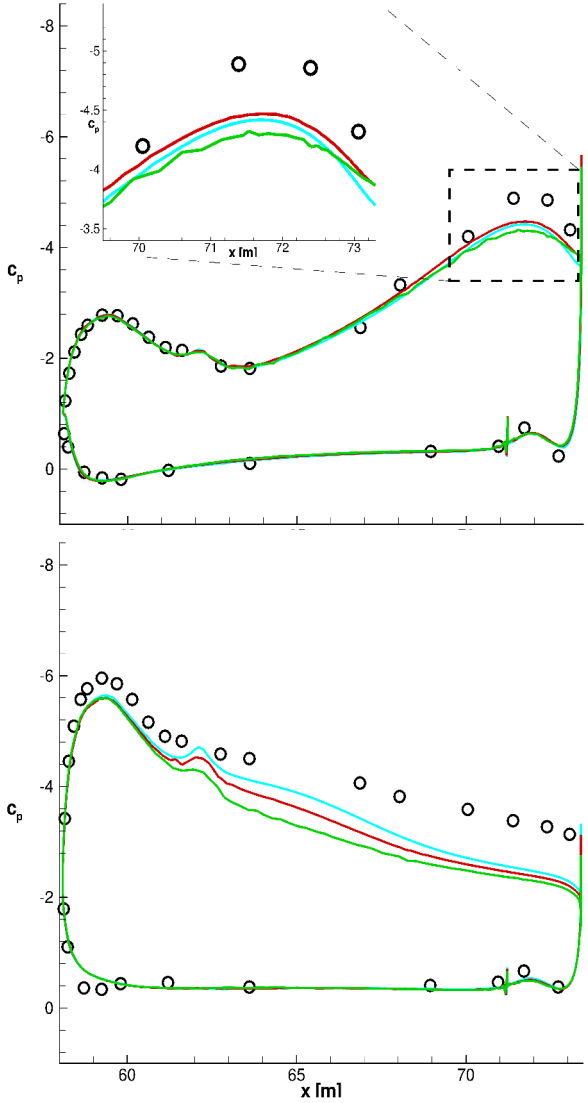
- c_p at $\eta = 0.98$

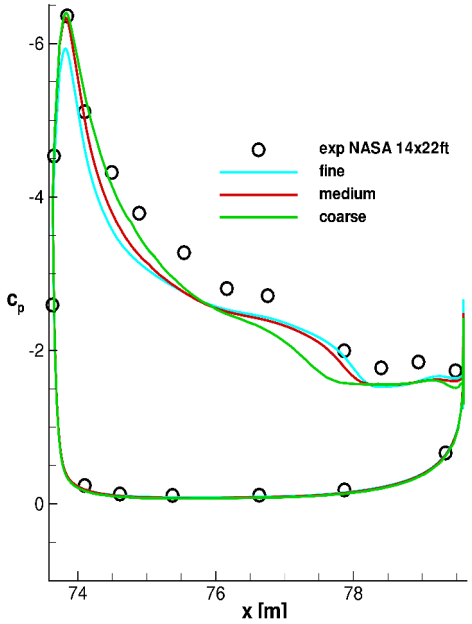
$\alpha = 13°$

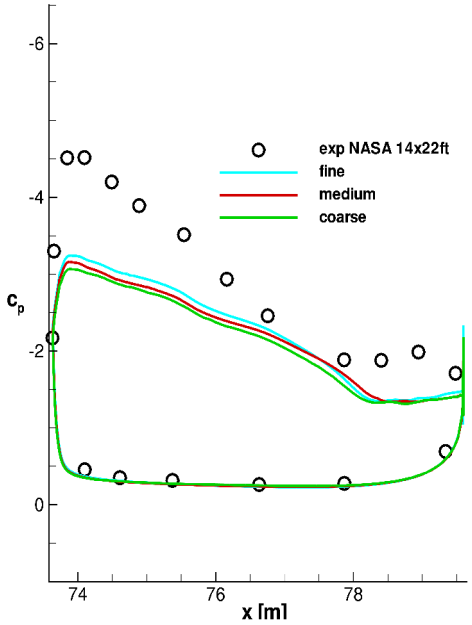


$\alpha = 28°$



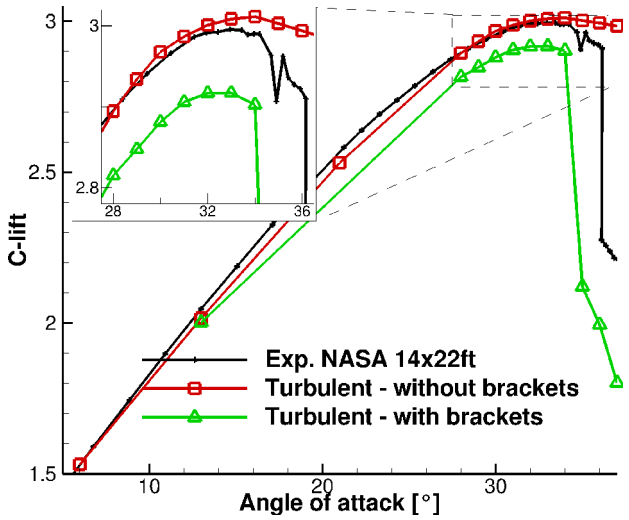


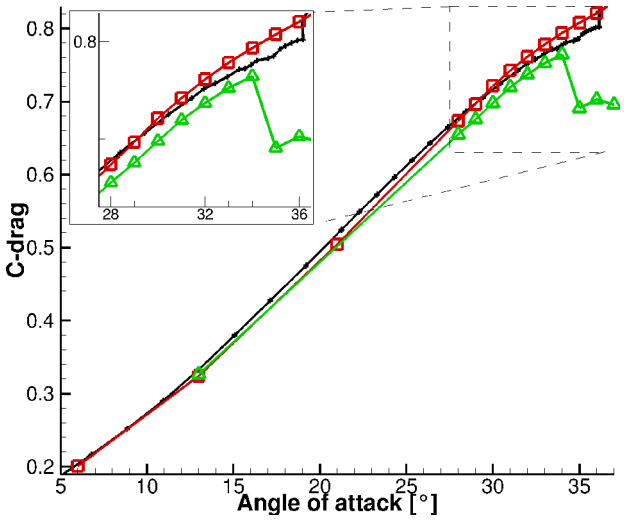


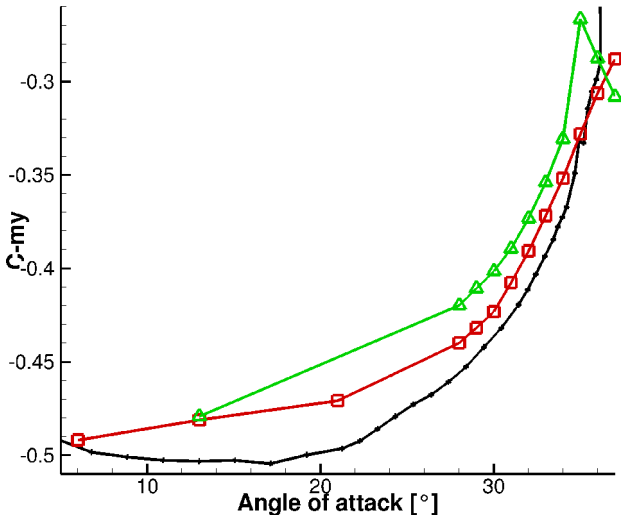


HiLiftPW-1 – Conclusions

- Grid convergence not satisfactory at tip
  - Simplified computed geometry vs. full WT geometry
  - Turb. computations vs. transitional experiments
  - Under-resolved vortical structures
- Turb. results on simplified configuration match better exp. data





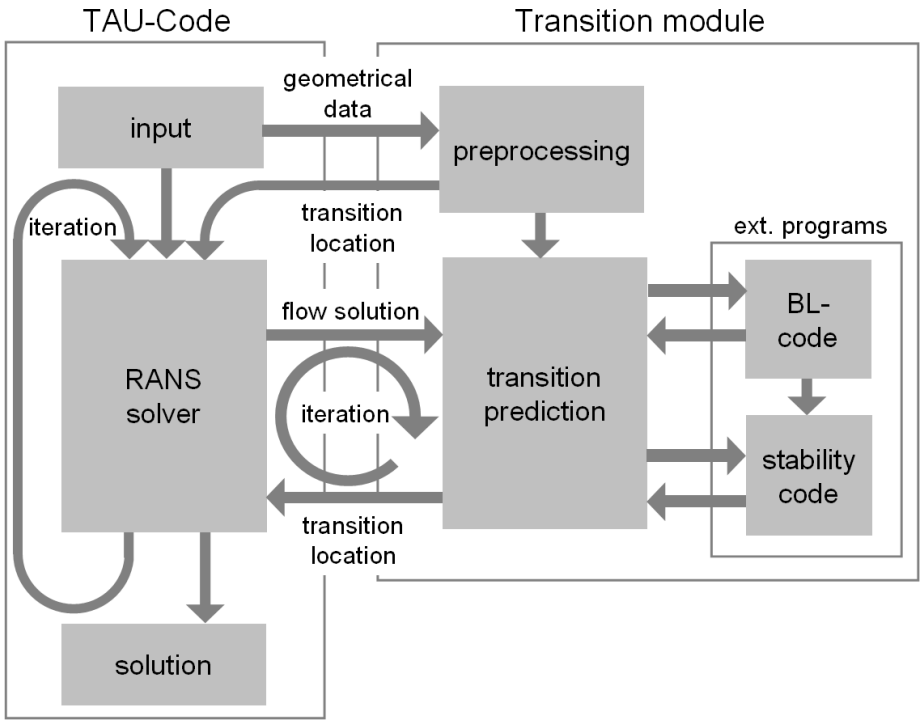


Methods and Tools – Grids

- Quad/hexa-dominant, unstructured Solar grids
  - HiLiftPW-1 ftp: Unst-Mixed-Nodecentered-B-v1
- Configuration 1, **no brackets**: 12.3, **36.9**, 110.7 million points
- Configuration 1, **with brackets**: **39.7** million points

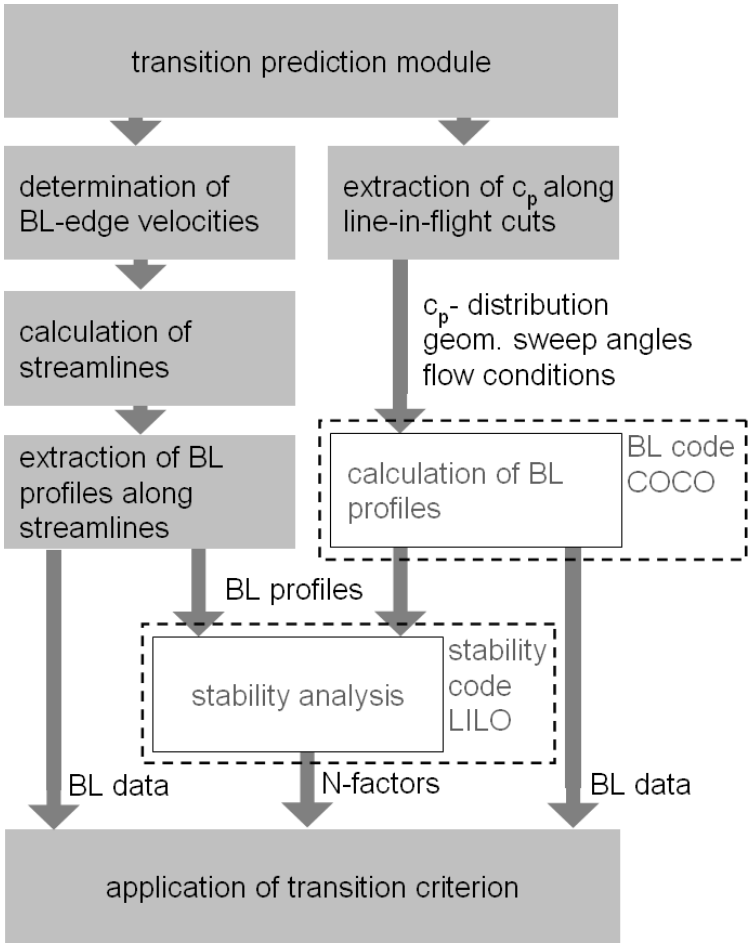
Methods and Tools – Solver

- Solver: TAU
  - Central scheme with JST-derived matrix dissipation
  - Spalart-Allmaras
  - LU-SGS Backward Euler
  - Multigrid 4w cycle & SG
  - Integrated 2N-factors transition prediction module



Methods and Tools – Transition Prediction

- BL-data from RANS or laminar BL-code (COCO)
- Separate Tollmien-Schlichting (N_{TS}) and cross-flow (N_{CF})
  - Model interaction N_{TS} vs. N_{CF}
- Line-in-flight approach: COCO/LILO
  - BLsep
  - N_{TS} , N_{CF} , N_{TS}/N_{CF}

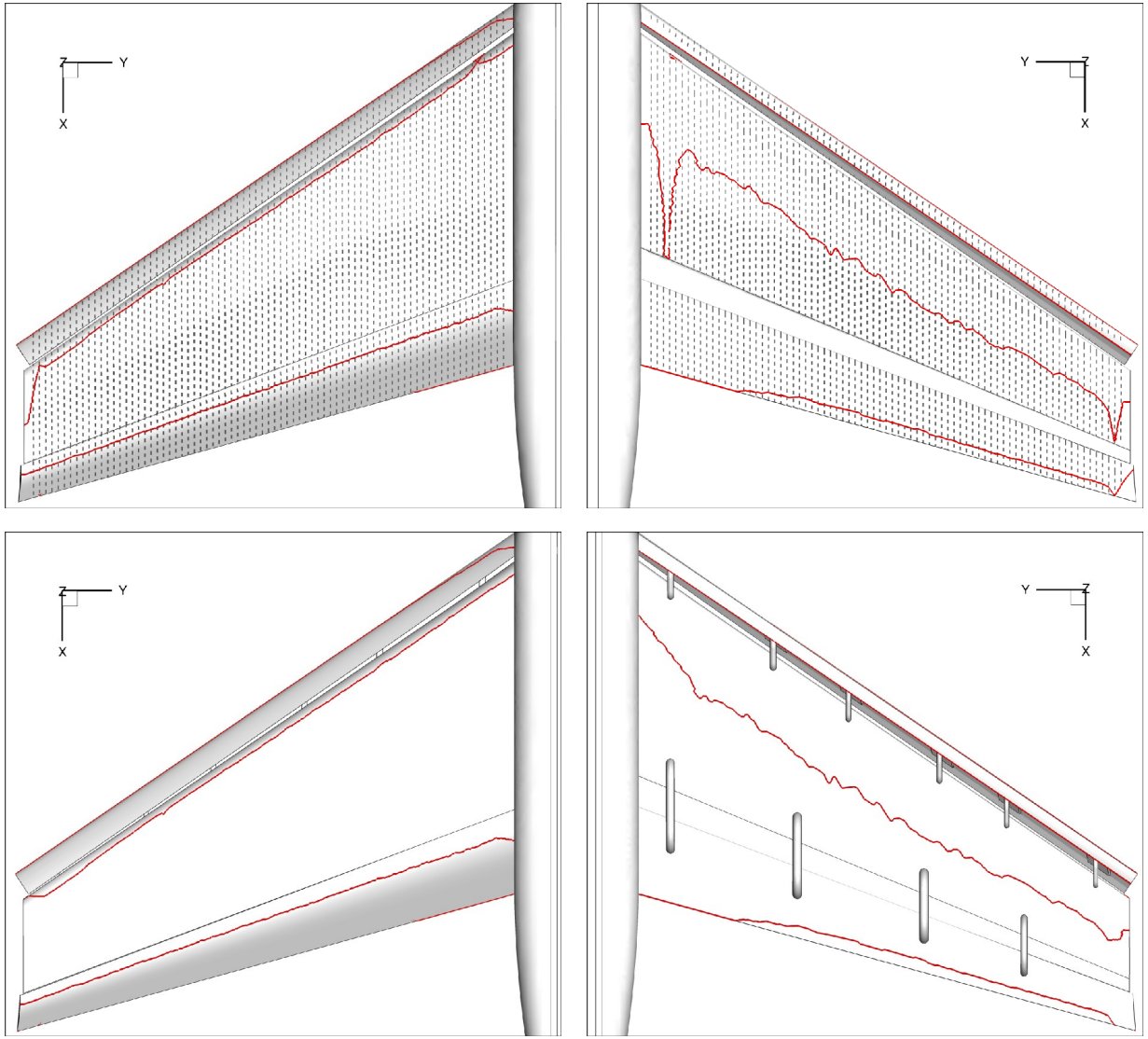


Results – Transition Prediction

- Non-iterative procedure
  - For each AoA 6°, 13°, 21°, 28°, 30°-34°, 36°, and 37°
    - C_p from turbulent conf. 1/no brackets
    - Transition prediction; N_{TS}-crit.=8.5, N_{CF}-crit.=8.5
    - Run solver with transition locations on conf. 1/with brackets

Results – Transition Prediction

- 77 line-in-flight cuts, Δy=0.5"

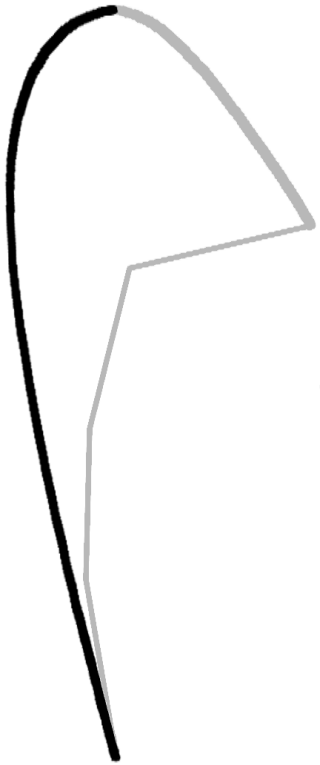


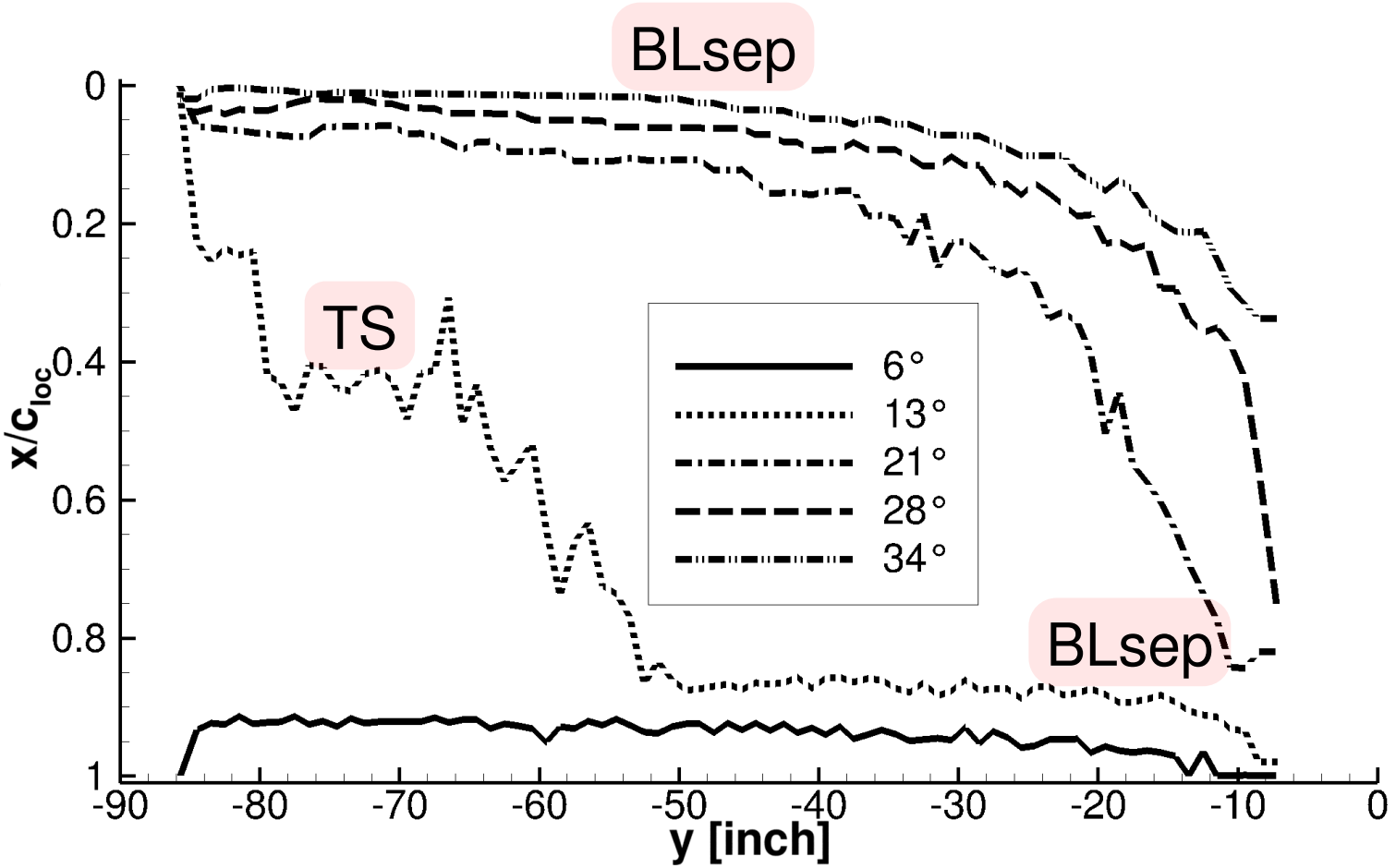
Adapt transition loc.

- Full geometry
- Wing tip and body pod

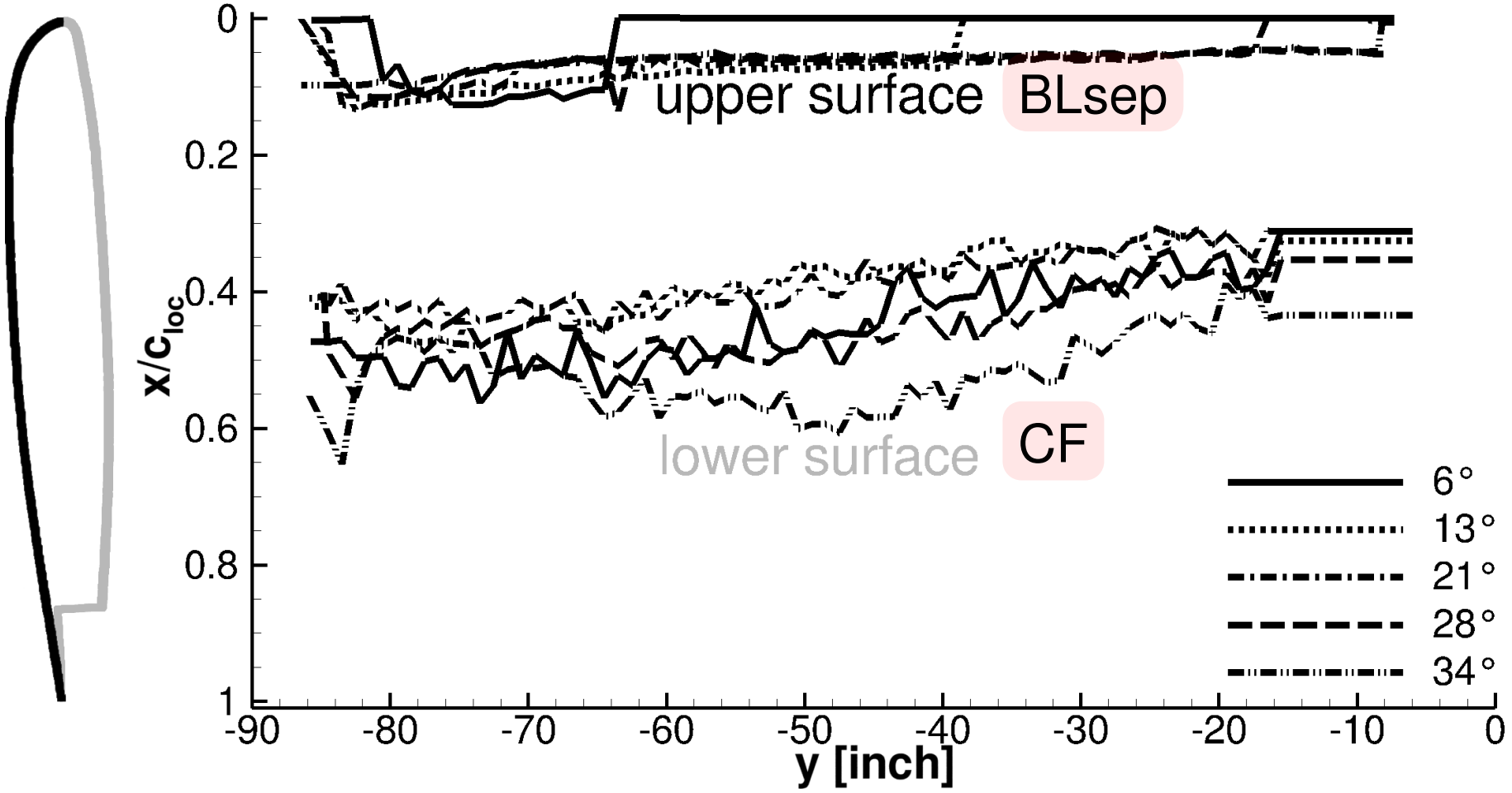
α = 28°

Results – Transition Prediction

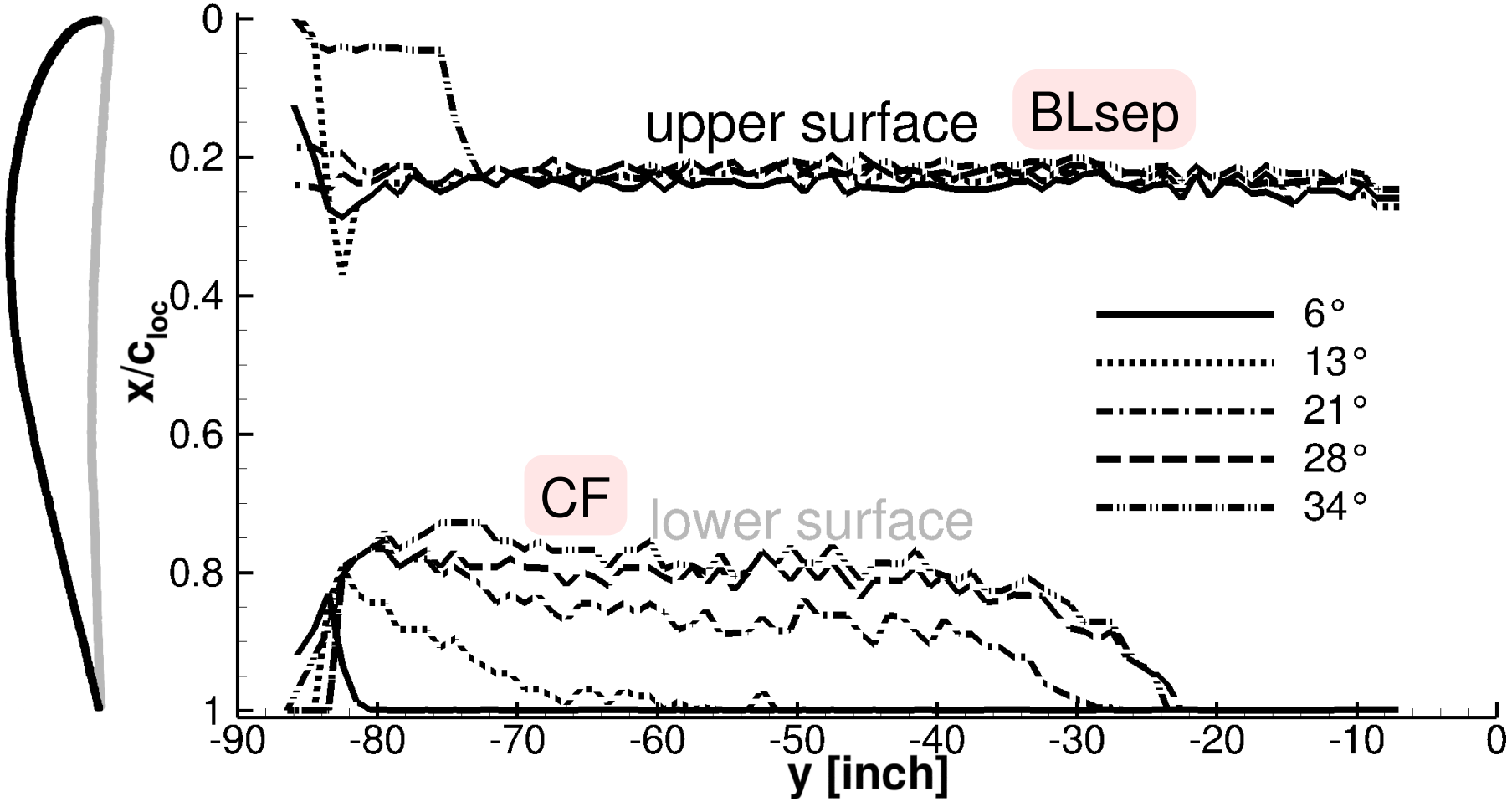




Results – Transition Prediction



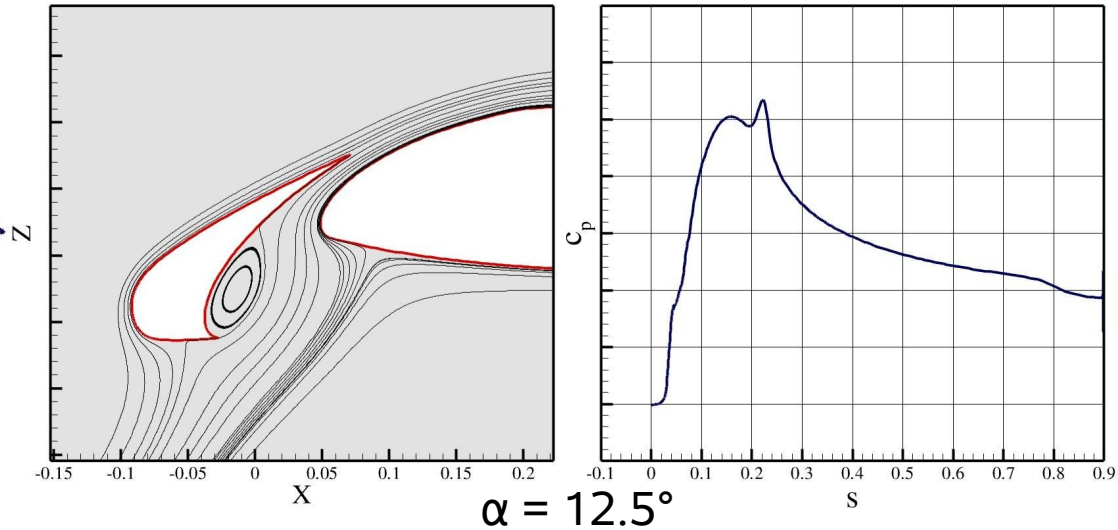
Results – Transition Prediction

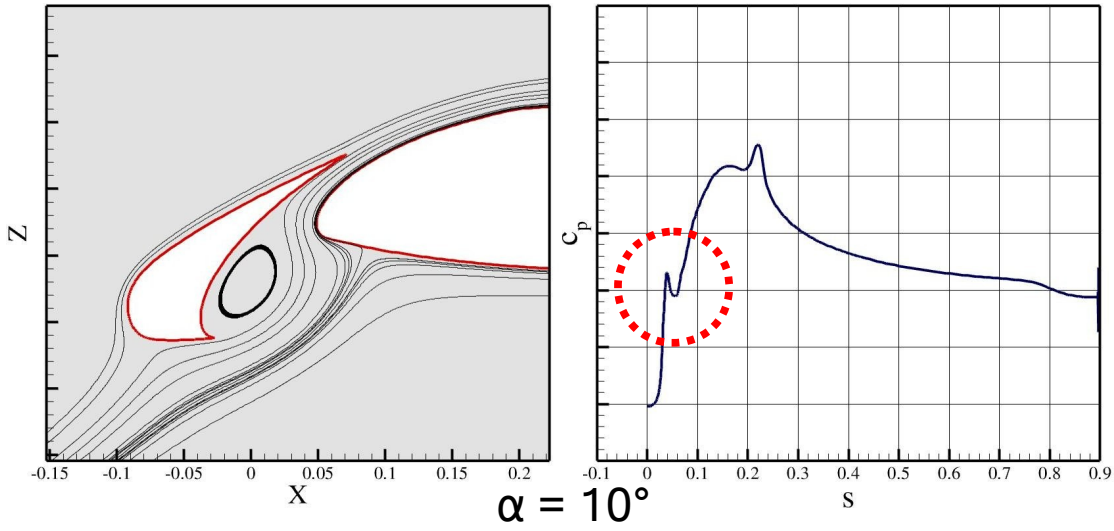


Transition Peculiarity at Leading Edge

Example in 2D: A310

- Usually investigated at AoA = 21.4°
- “Off-design” at lower AoA
  - C_p peak at main leading edge triggers BLsep

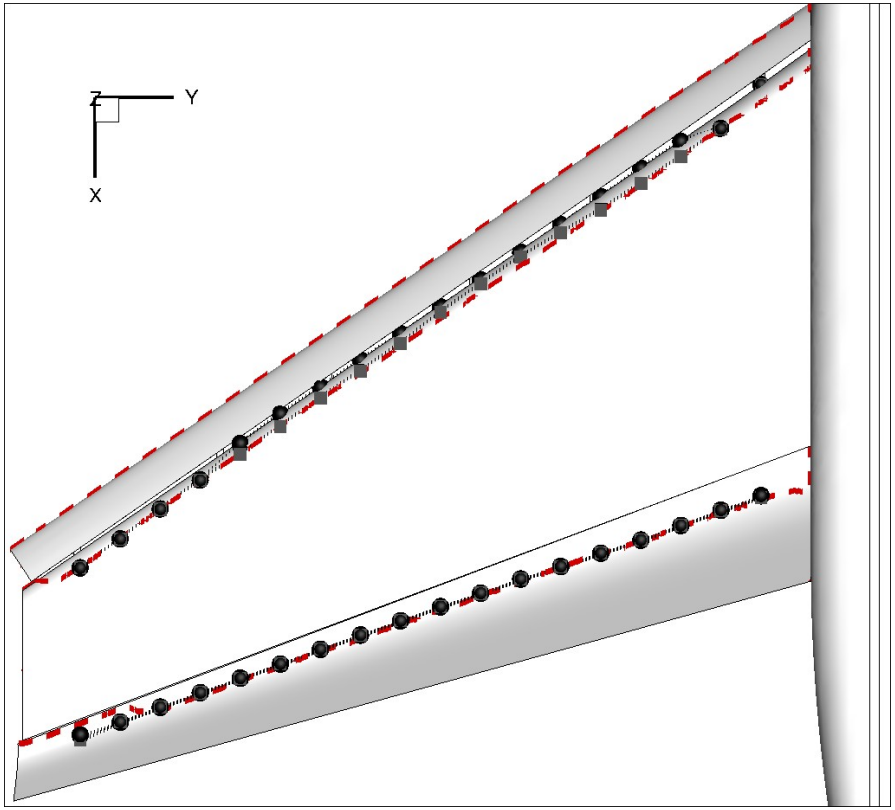


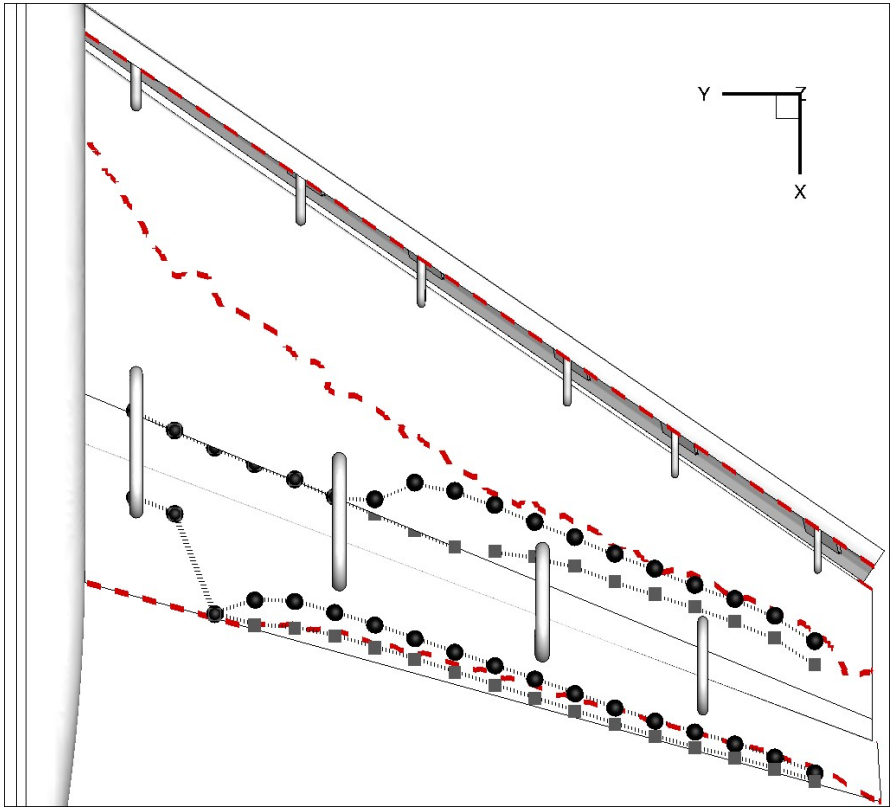


N. Krimmelbein, „Industrialization of automatic transition prediction for three-dimensional configurations with the e^N-method“, 17. DGLR-Fach-Symposium der STAB, 2010

Results – Transition Prediction

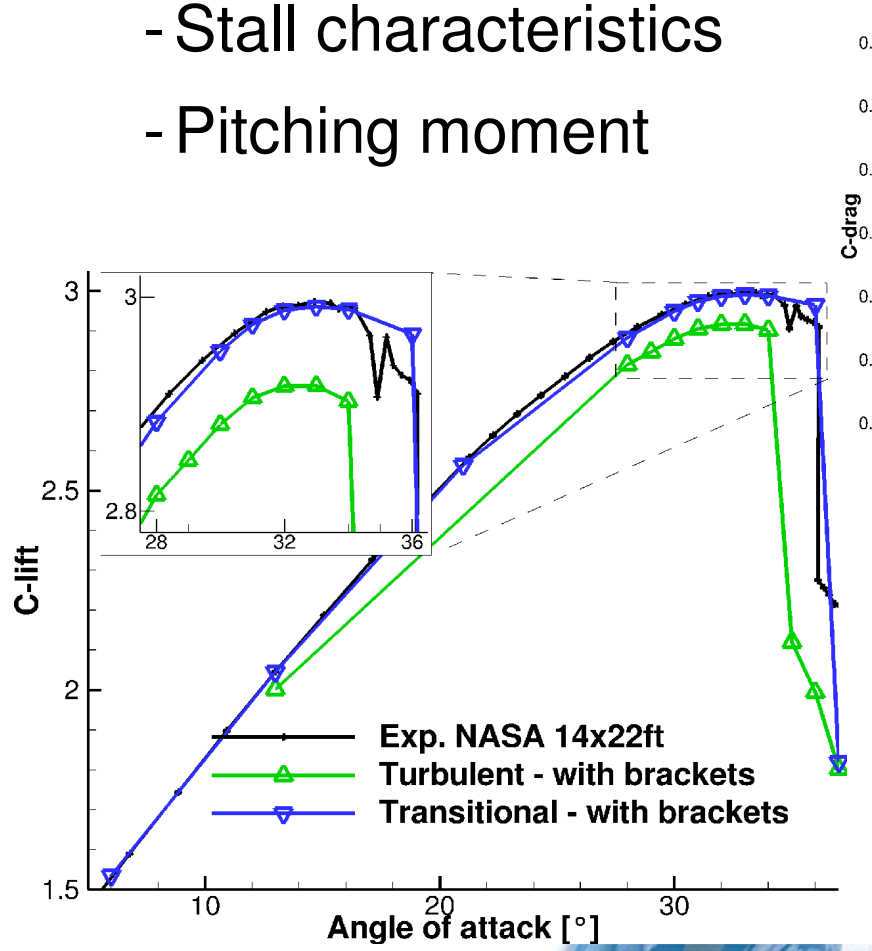
- Comparison to FOI data with N-crit. = 7 – 10
- Good agreement all over AoA range, apart AoA = 34°

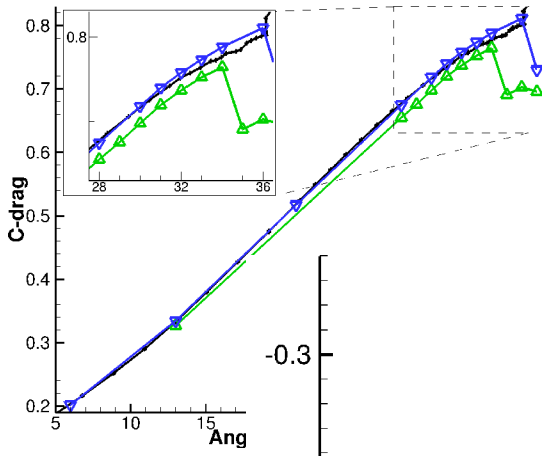


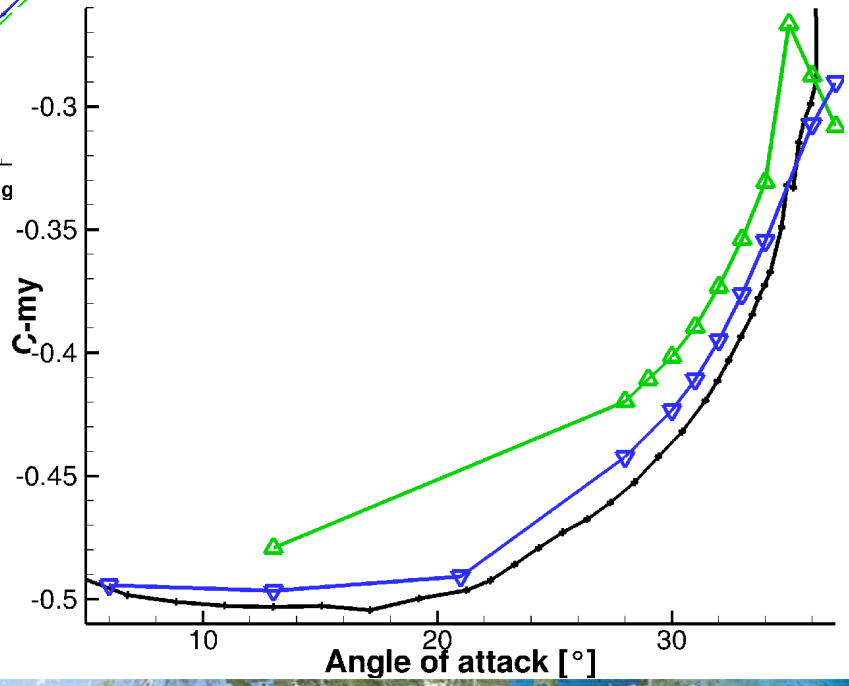


Results

- Transitional results show improvements
  - Stall characteristics
  - Pitching moment

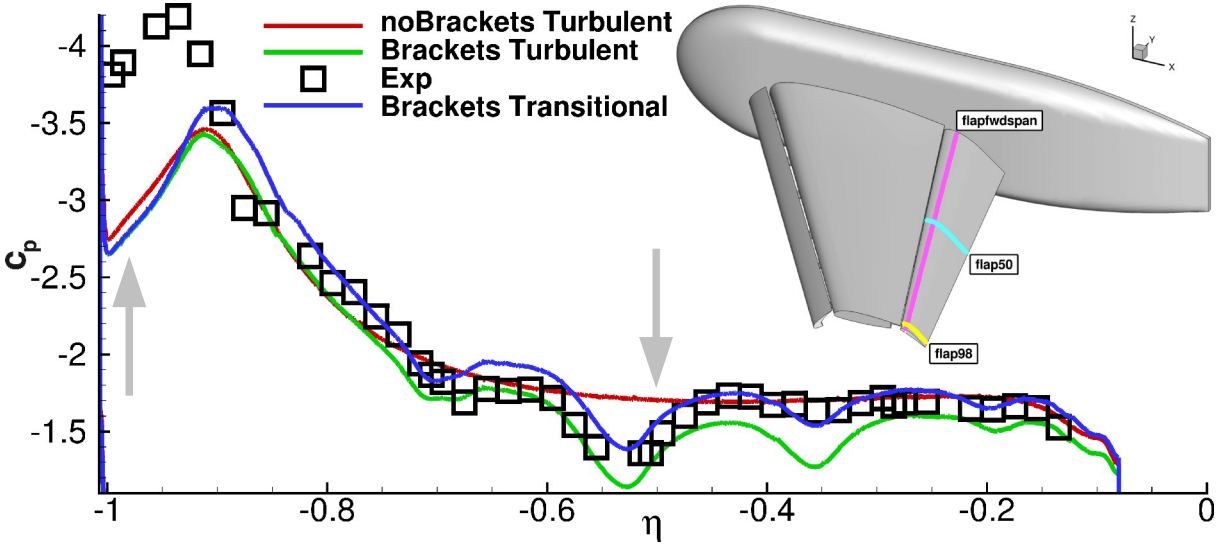


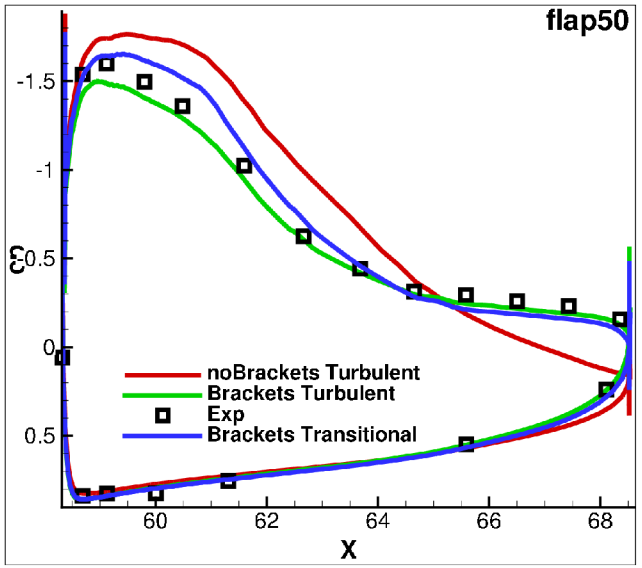


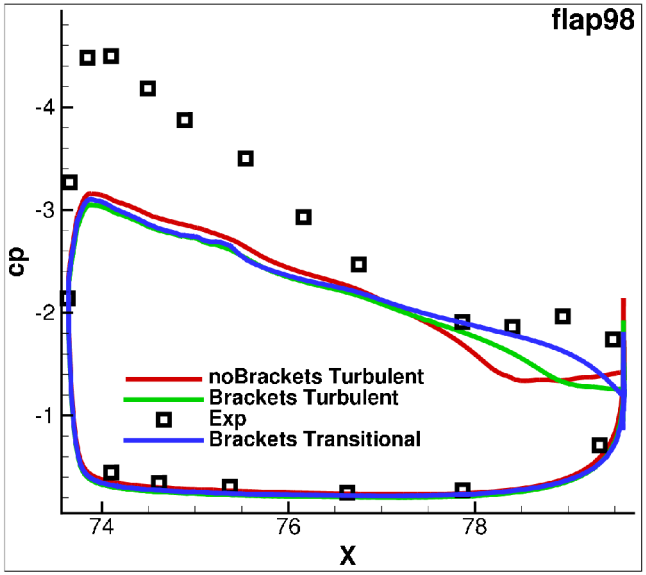


Results

- Flap loading deficiency at tip
- AoA = 28°







Conclusions and Outlook

- Successful application of TAU transition prediction module
  - Need to check trans. locations on new configuration
- Transitional flow computations of the full geometry lead to substantial improvement
  - Detailed flow features
  - Integrated forces and moments
- What is still missing?
  - Correct resolution of the tip vortical system
  - Flap tip deformation under load(?)