Cenaero

TestCase C3.7 - DNS / LES the transitional flow in the T106C cascade at Re=80.000

Introduction and result summary

Koen Hillewaert
Argo team leader
Contact: koen.hillewaert@cenaero.be

PROD-F-015-01

Doc. ref.:

Testcase description
Geometry and flow conditions

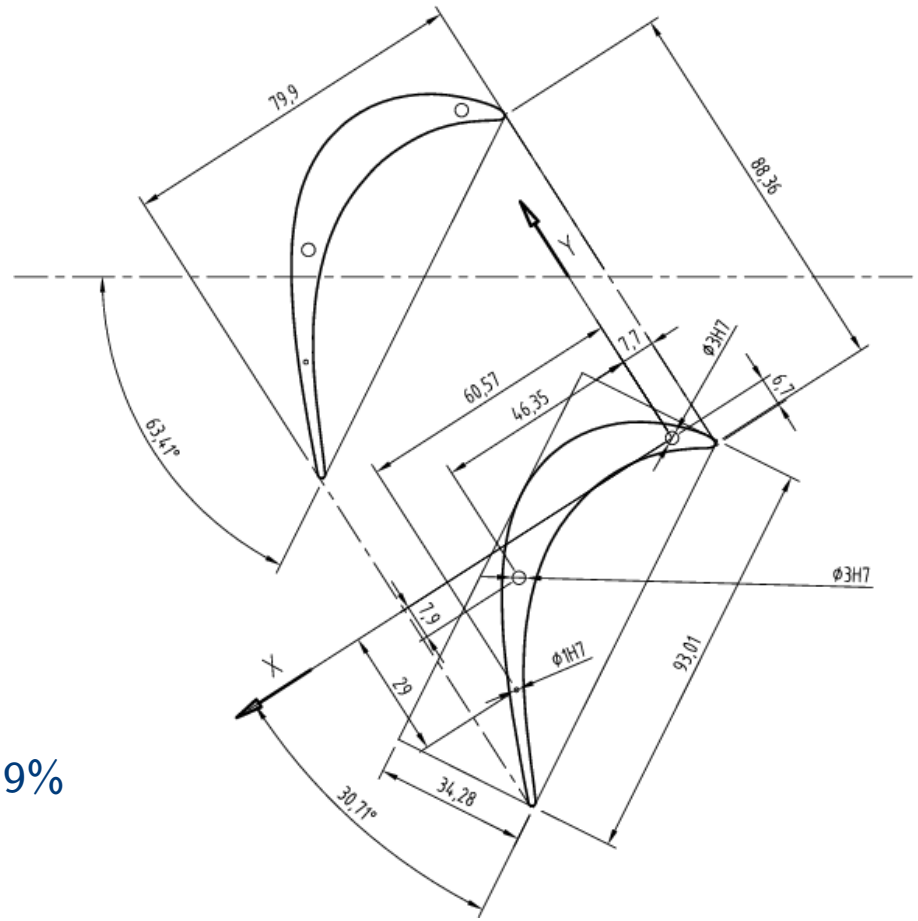
Based on outlet isentropic conditions

- transitional $Re_{2s} = 80.000$
- high subsonic flow $M_{2s} = 0.65$
- $\alpha_1 = 63.41° - 30.71° = 32.7°$
- $C = 0.09301\mathrm{m}$, $C_{ax} = 0.079901\ \mathrm{m}$

Measurements
in continuous wind tunnel at
VKI during project UTAT (Prof. T. Arts)

- Inlet
  - 6 prismatic blades, $h/C = 2.4$
  - $p_{1t} = 7198\ \mathrm{Pa}$
  - $T_{1t} = 298\ \mathrm{K}$
  - negligeable inlet turbulence $I = 0.9\%$
- Outlet
  - $p_2 = 5419.3\ \mathrm{Pa}$
  - $v_{2s} = 216.07\ \mathrm{m/s}$

Characteristic time $t_c = C/v_{2s} = 4.3\ 10^{-}4\mathrm{s}$



Comparison to

- distribution of pressure on the blade

$$M_{is} = \sqrt{\frac{2}{\gamma - 1}\left(\left(\frac{p_{t1}}{p}\right)^{\frac{\gamma-1}{\gamma}} - 1\right)}$$

- total pressure distribution in the wake

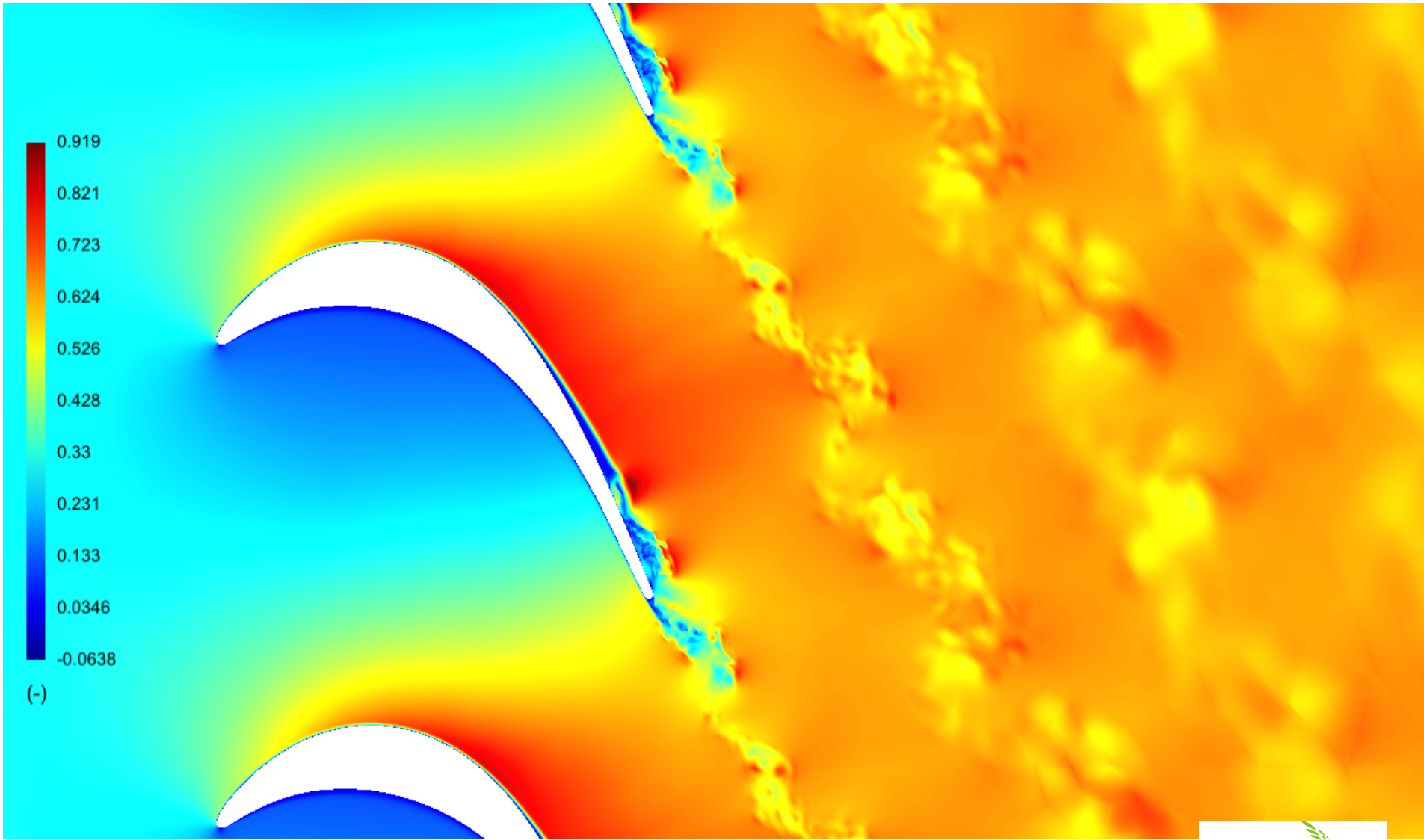
$$\xi = 1 - \frac{1 - (p/p_t)^{\frac{\gamma-1}{\gamma}}}{1 - (p/p_{t1})^{\frac{\gamma-1}{\gamma}}}$$

Additionnally

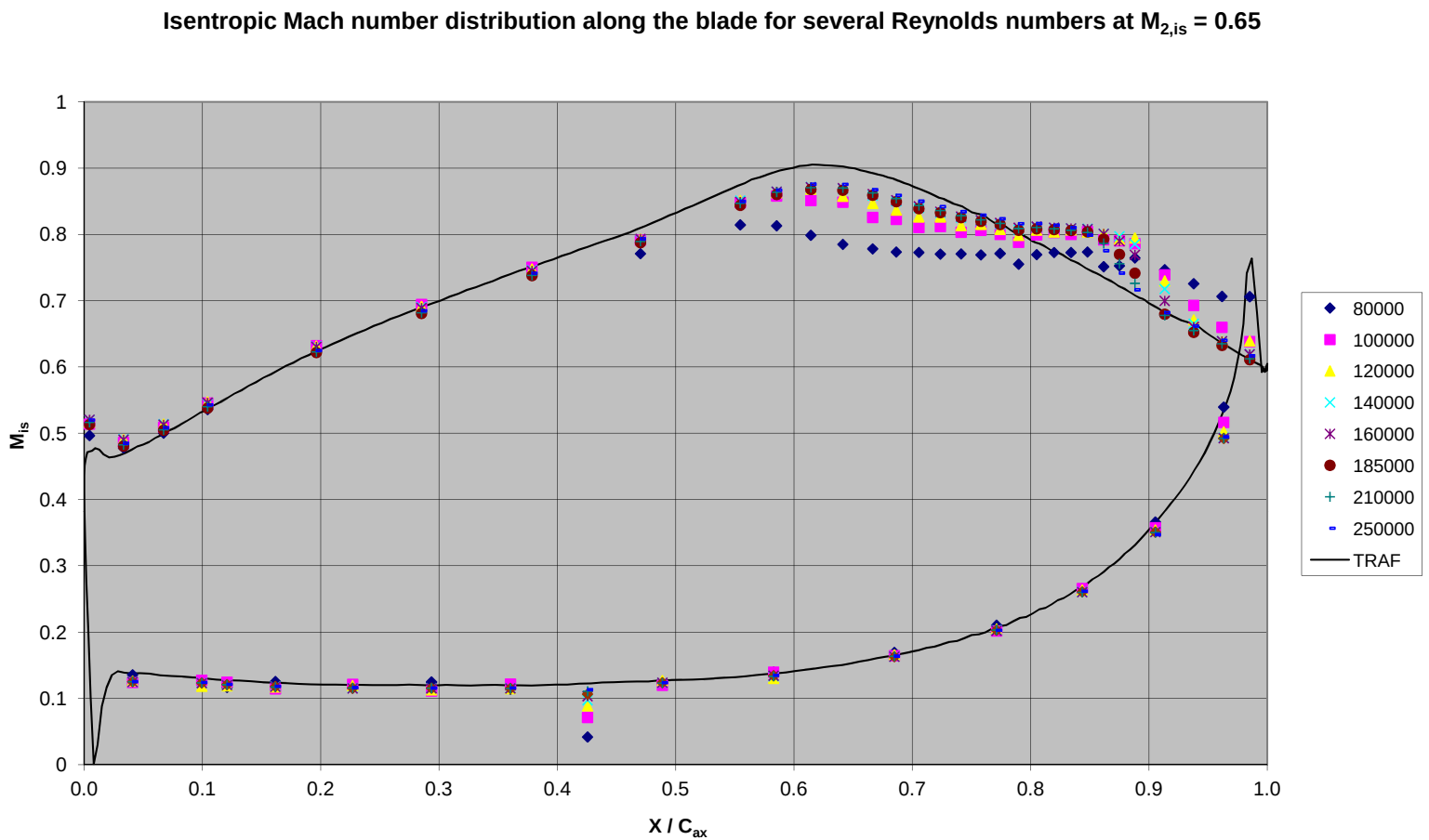
- unsteady flow field : vorticity on the periodic plane and skin friction
- time and span average of vorticity, total pressure on the periodic plane and skin friction on the blade
- correlations of velocity on the periodic plane and rms of pressure on the surface

Testcase description

Overview of flow field

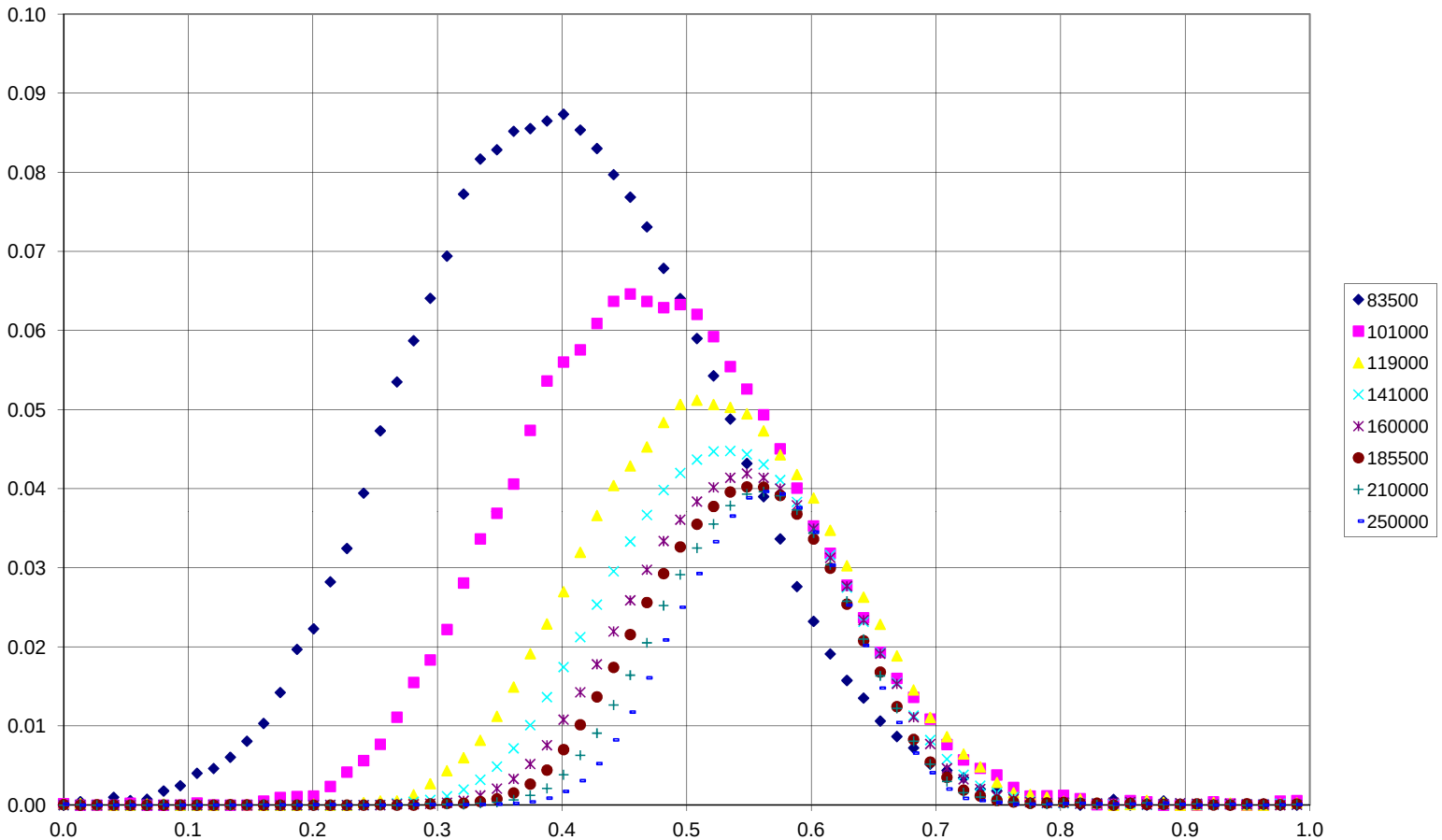


PROD-F-015-01



Testcase description

Measured total pressure distribution in the wake at $x/c = 0.465 C_{ax}$

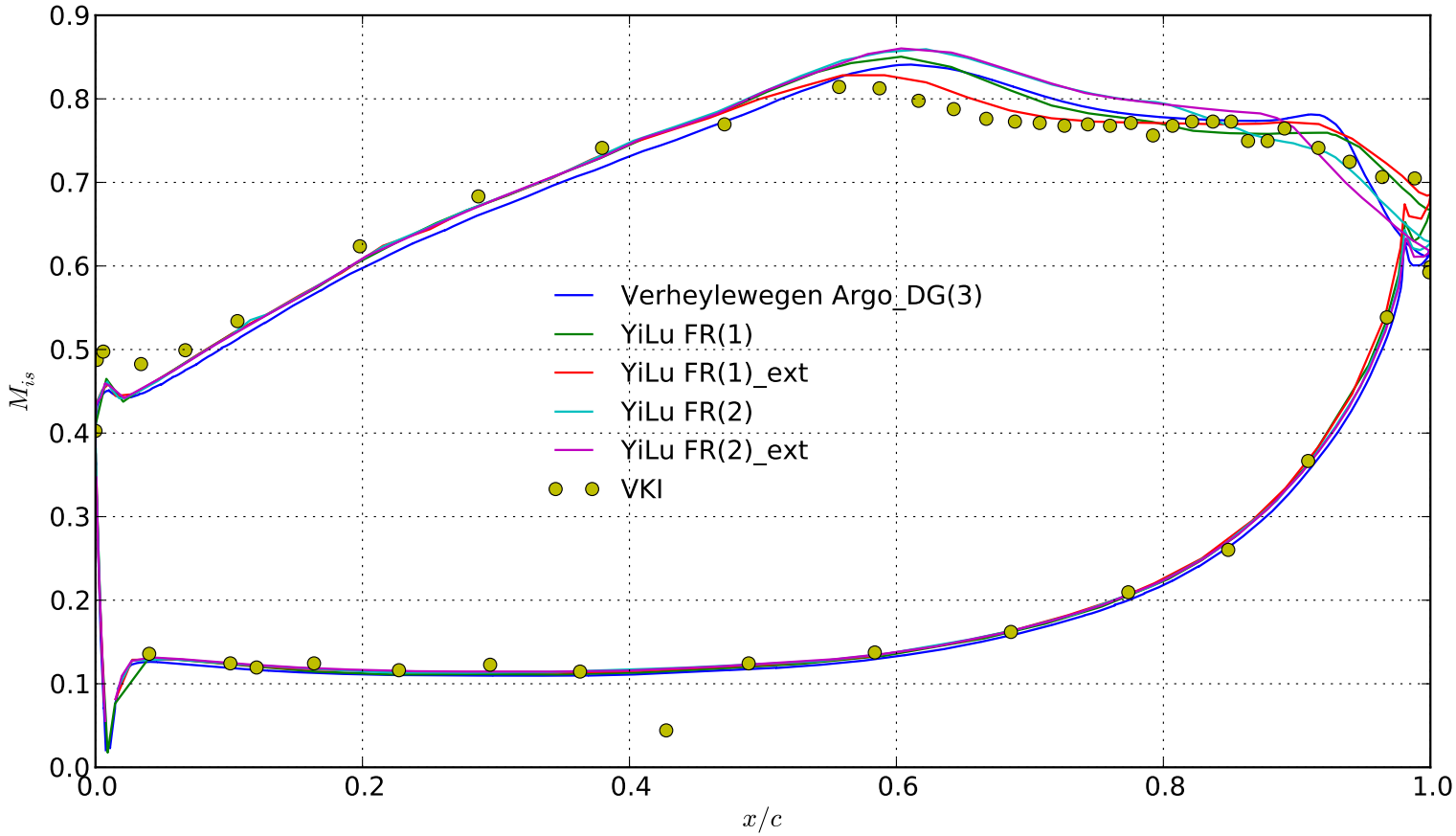


PROD-F-015-01

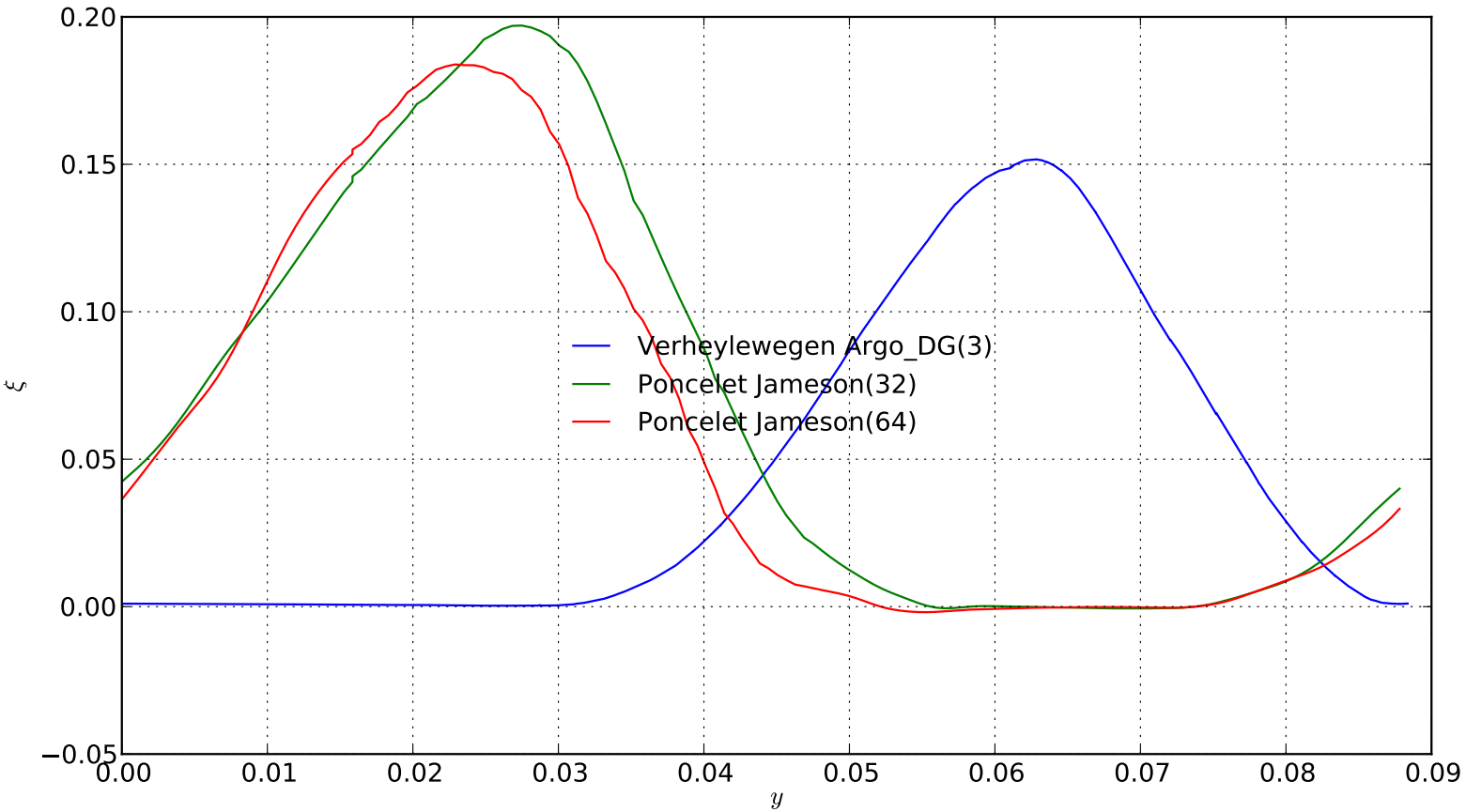
Contributions

- Yi Lu, UCambridge, Flux Reconstruction, 3PtBDF, Block LU-SGS, $dt = 10^{-7}$
  - p=1, extruded : 485760 prisms, 2513440 hex, $2.5\,10^7$ dof, $7.25628\,10^6/\tau\ WU/t_c$
  - p=2, extruded : 58860 prisms, 293490 hex, $9.\,10^6$ dof, $7.784228\,10^6/\tau\ WU/t_c$
  - p=1, unstructured : 153928 tetrahedra, 191702 pyra, 58718 prisms, 1586230 hex, $7.620923\,10^6/\tau\ WU/t_c$
  - p=2, unstructured : 55880 tet, 69020 pyra, 31502 prisms, 352440 hex, $8.256\,10^6/\tau\ WU/t_c$
- Guillaume Verheylewegen, Cenaero : DG, 3PtBDF, GMRES-ILU, $dt = 10^{-6}$
  - p=3 : 240.440 prisms, 75.960 hex,$1.5\,10^7$ dof , $1.8\,10^6\ WU/t_c$
- Boris Poncelet, Cenaero : FVM (Jameson), $2.1\,10^7$ hex/dof
  - $\alpha_4 = 1/32$: $10^6\,WU/t_c$
  - $\alpha_4 = 1/64$: $2.5\,10^6\,WU/t_c$

Results
Computed pressure distribution



Results
Computed loss distributions



Concluding remarks

Conclusions

- blade front loading not the same
  - all computations give consistently same loading
  - flow angle defined by side walls and verified at $x = -C_{ax}/2$
  - blockage effect compensated on spanwise sidewalls, but not on pitchwise
  - loading not consistent with higher Re
- no grid convergence was obtained
  - insufficient resolution (comparison different meshes)
  - long averaging times ~ averaged p_{RMS}, f_{RMS}
- pressure losses need to be reprocessed

How to go forward ?

- experiments at transitional Re rather rare, MTU T106C well documented blade at higher Re for bypass transition ...
- code to code comparison for this case ?
- or for other in public domain ?