Cenaero

AS2 - Spanwise periodic DNS/LES of transitional turbine cascades

4th International Workshop on High-Order CFD Methods

Jean-Sébastien Cagnone,
Koen Hillewaert.
Contact: jean-sebastien.cagnone@cenaero.be

Doc. ref.: CMSD-NS-003-00

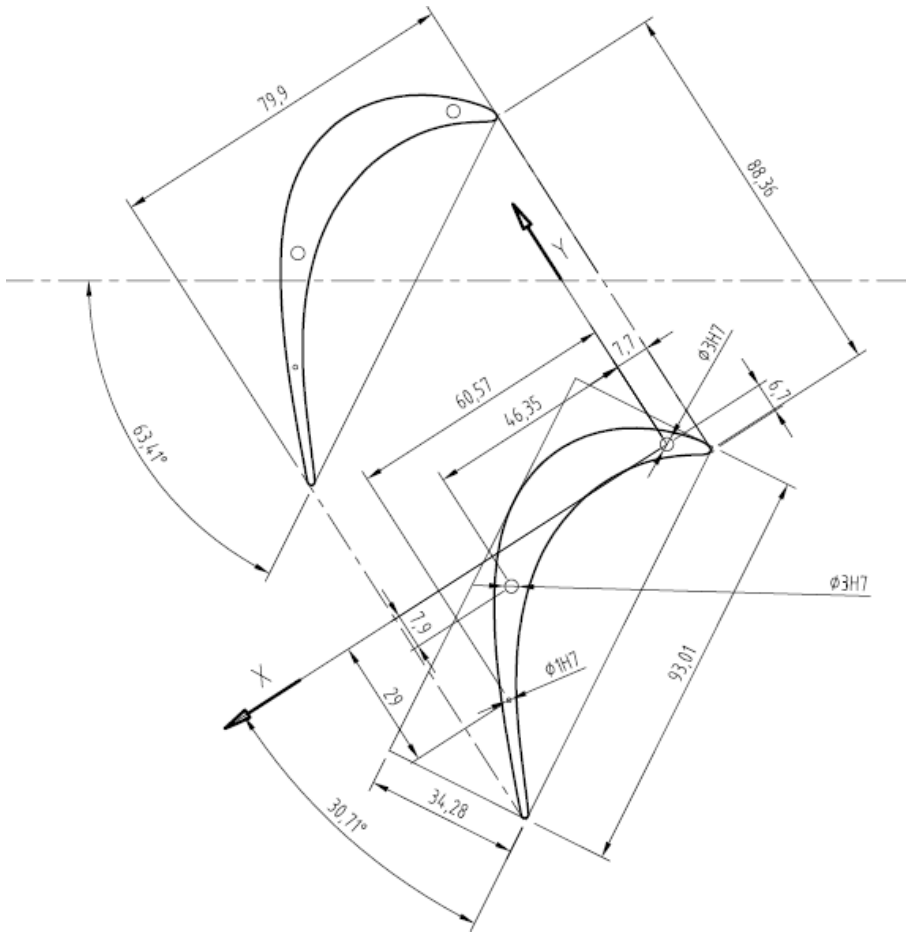
PROD-F-015-01

Case Overview

Case Overview
T106 Low Pressure Turbine

- T106C
  - Re=80K, M=0.65
  - Pitch/Chord = 0.95
  - Span/Chord = 10%

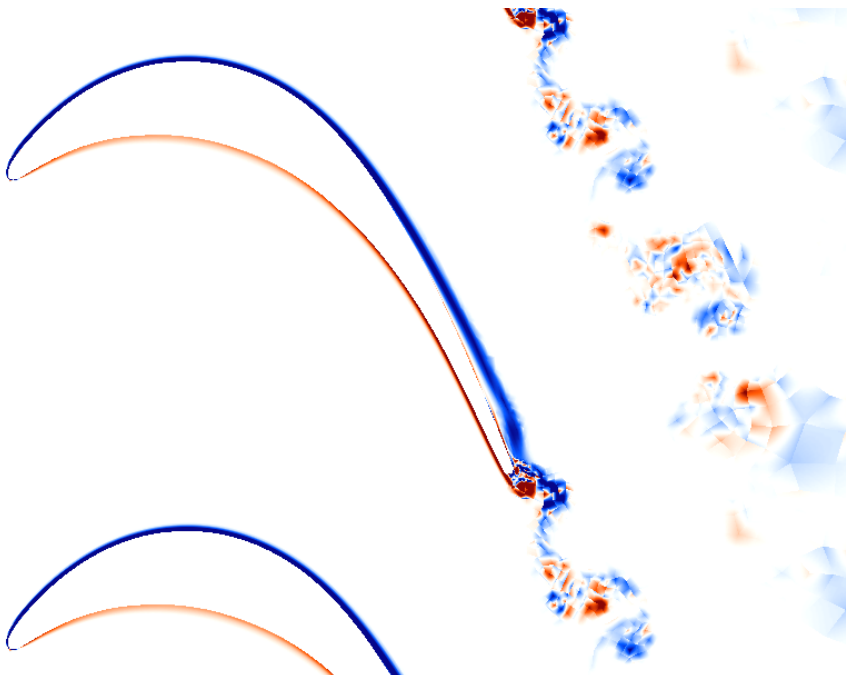
- T106A
  - Re=60K, M=0.4
  - Pitch/Chord = 0.798
  - Span/Chord = 10%



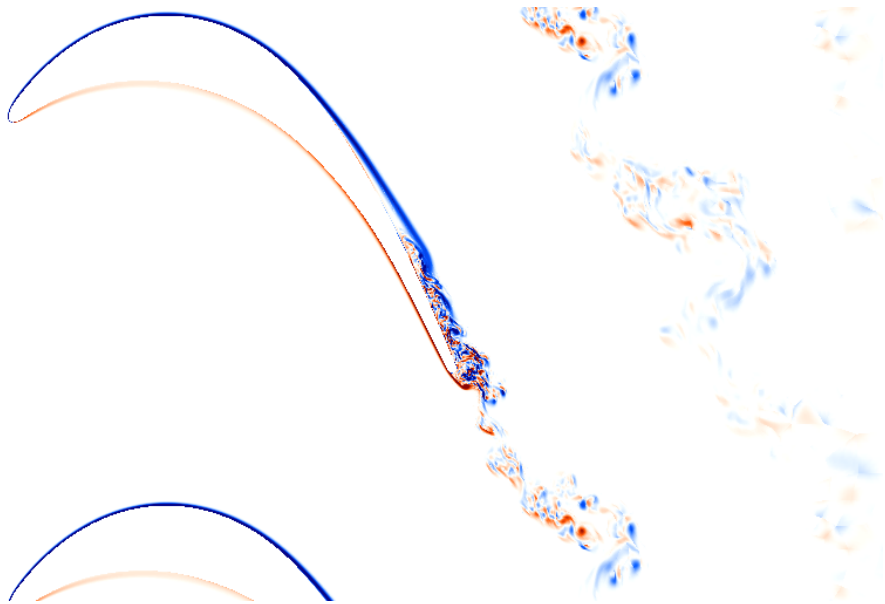
PROD-F-015-01

Cenaero

Case Overview
T106 Low Pressure Turbine



T106A



T106C

Cenaero

Case Overview
Workshop meshes

- T106C coarse(21K Elements)

Case Overview
Workshop meshes

- T106C baseline (118K Elements)

Case Overview
IAG Stuttgart meshes

- T106C IAG mesh (4359 Elements)

Results Comparison: T106C

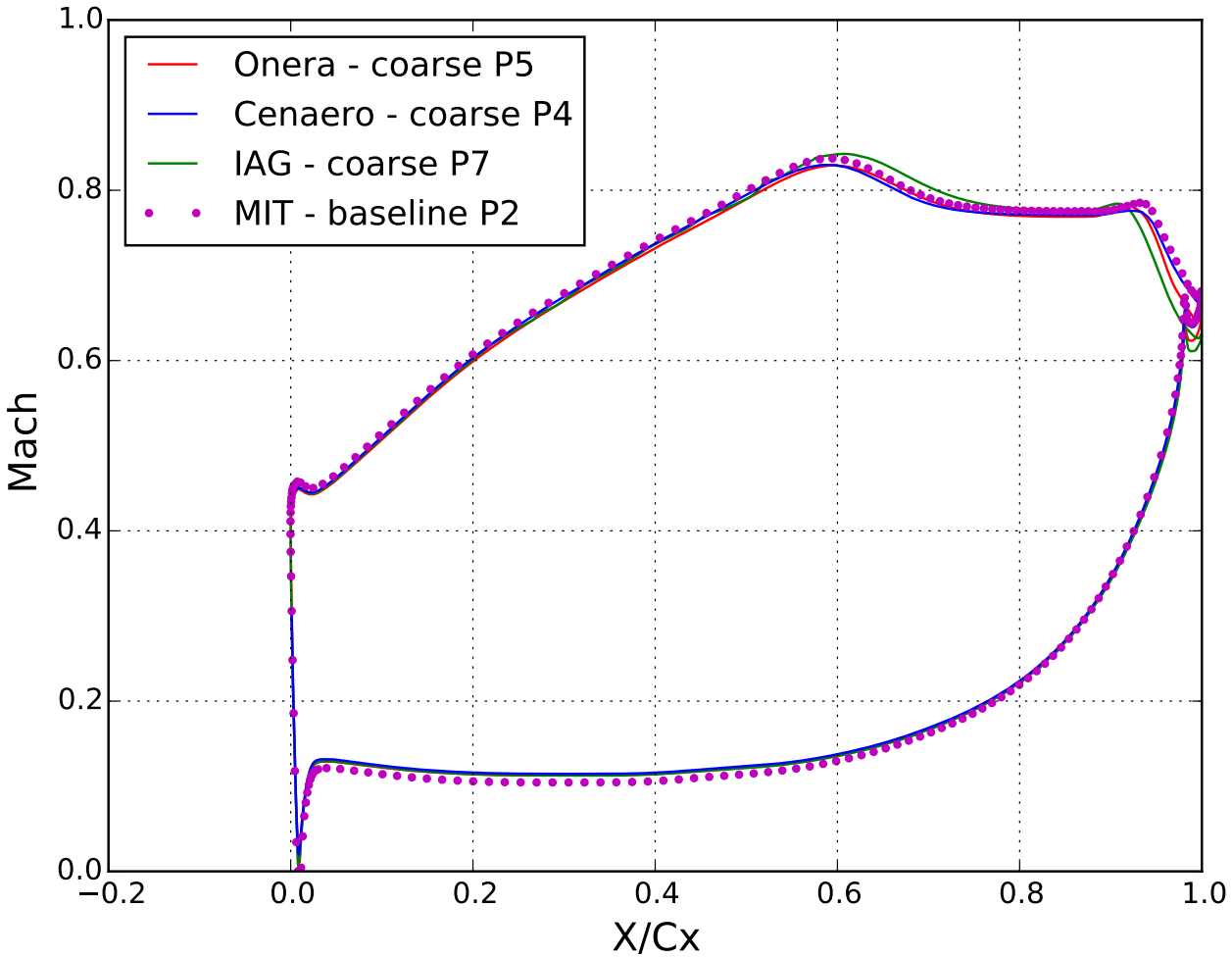
Results Comparison: T106C
Overview

	Method	Resolution	DOF	Avg. CT	Ite/CT
Onera	LLF/SIP	P4 coarse	1.1M	30	64479
		P5 coarse	1.7M	30	135406
	Pascal basis	P3 baseline	2.9M	30	27633
		P4 baseline	5.1M	30	56419
		P5 baseline	8.2M	30	123096
IAG	Roe/BR1	P6 coarse	1.5M	40	4838
	Tensor basis	P7 coarse	2.7M	40	5908
MIT	IEDG [1]	P2 baseline	3.2M[2]	7.7	270
Cenaero	Roe/SIP	P4 coarse	2.6M	20	451
	Tensor basis	P4 baseline	14.8M	18	902

[1] Interior Embedded DG
[2] Before static condensation

Results Comparison: T106C

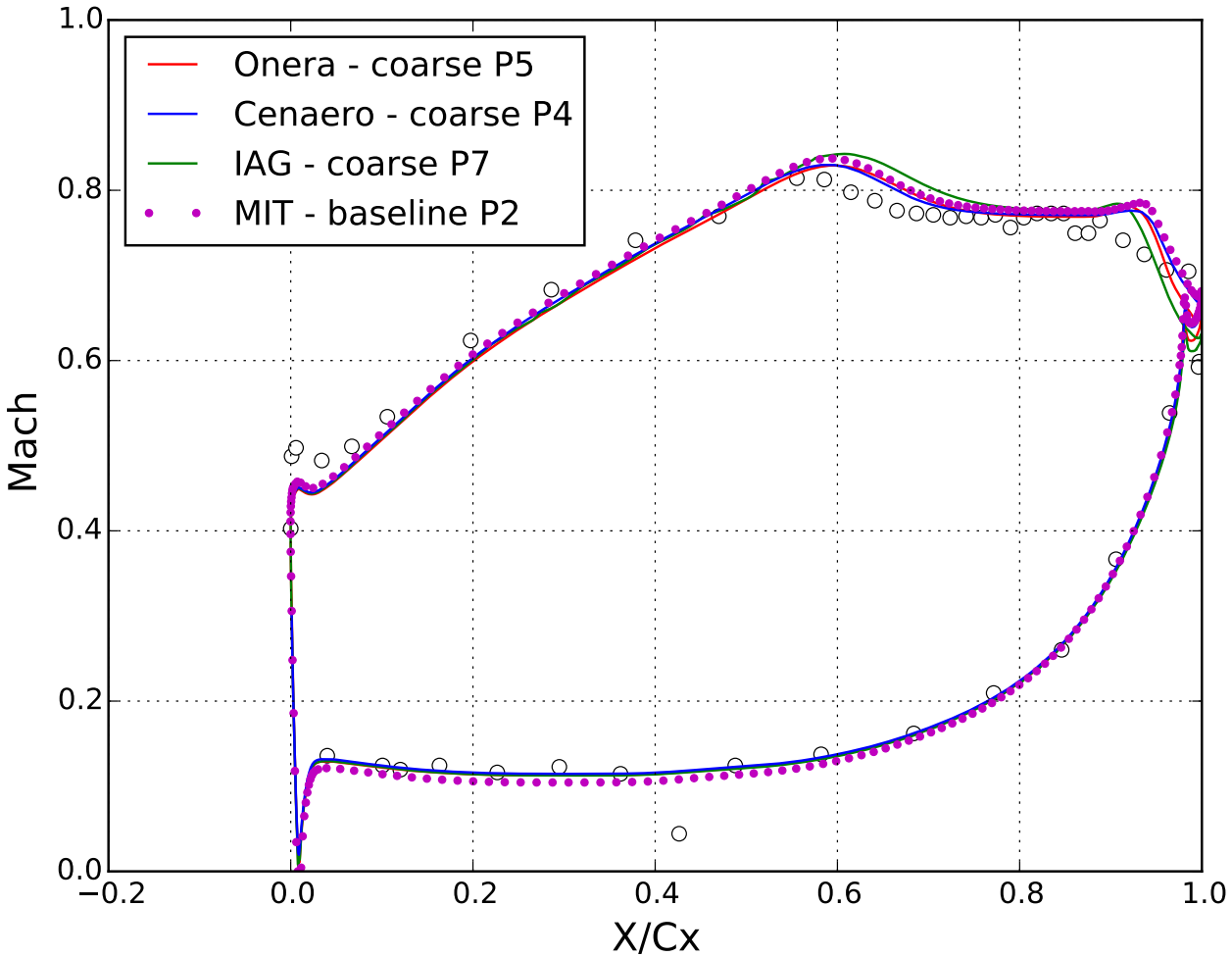
Comparison: Isentropic Mach



Cenaero

Results Comparison: T106C

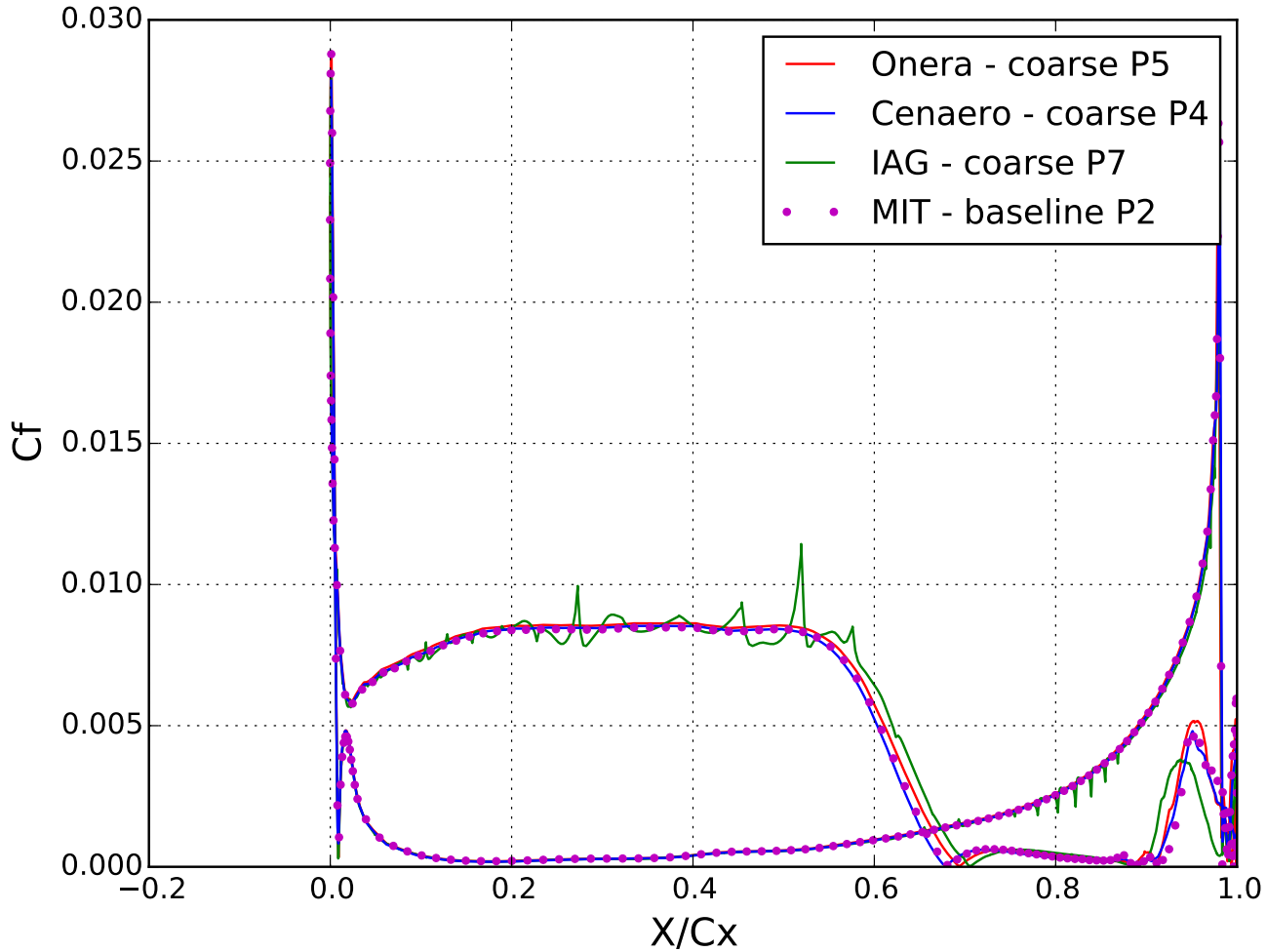
Comparison: Isentropic Mach



Cenaero

Results Comparison: T106C

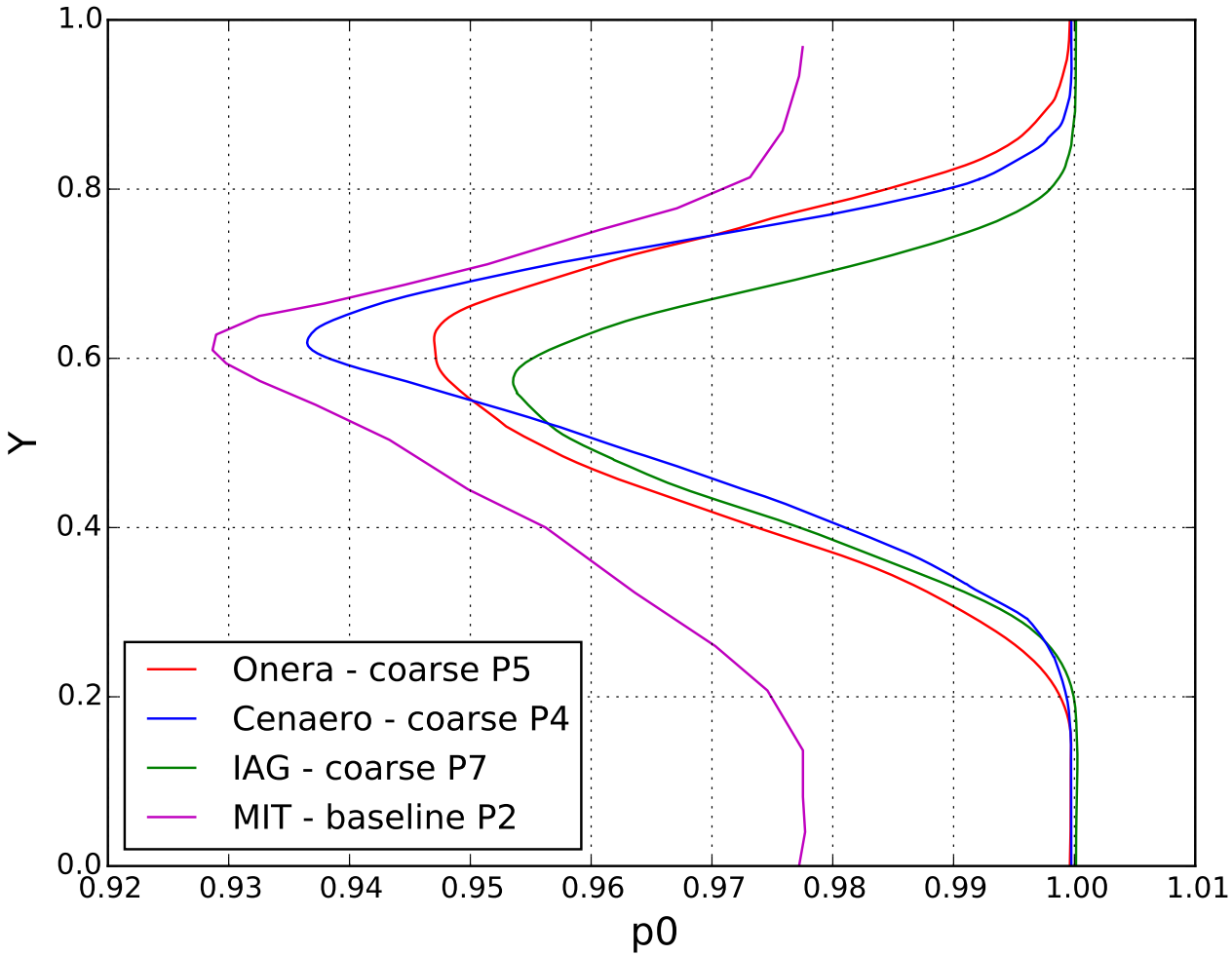
Comparison: Friction Coefficient



Cenaero

Results Comparison: T106C

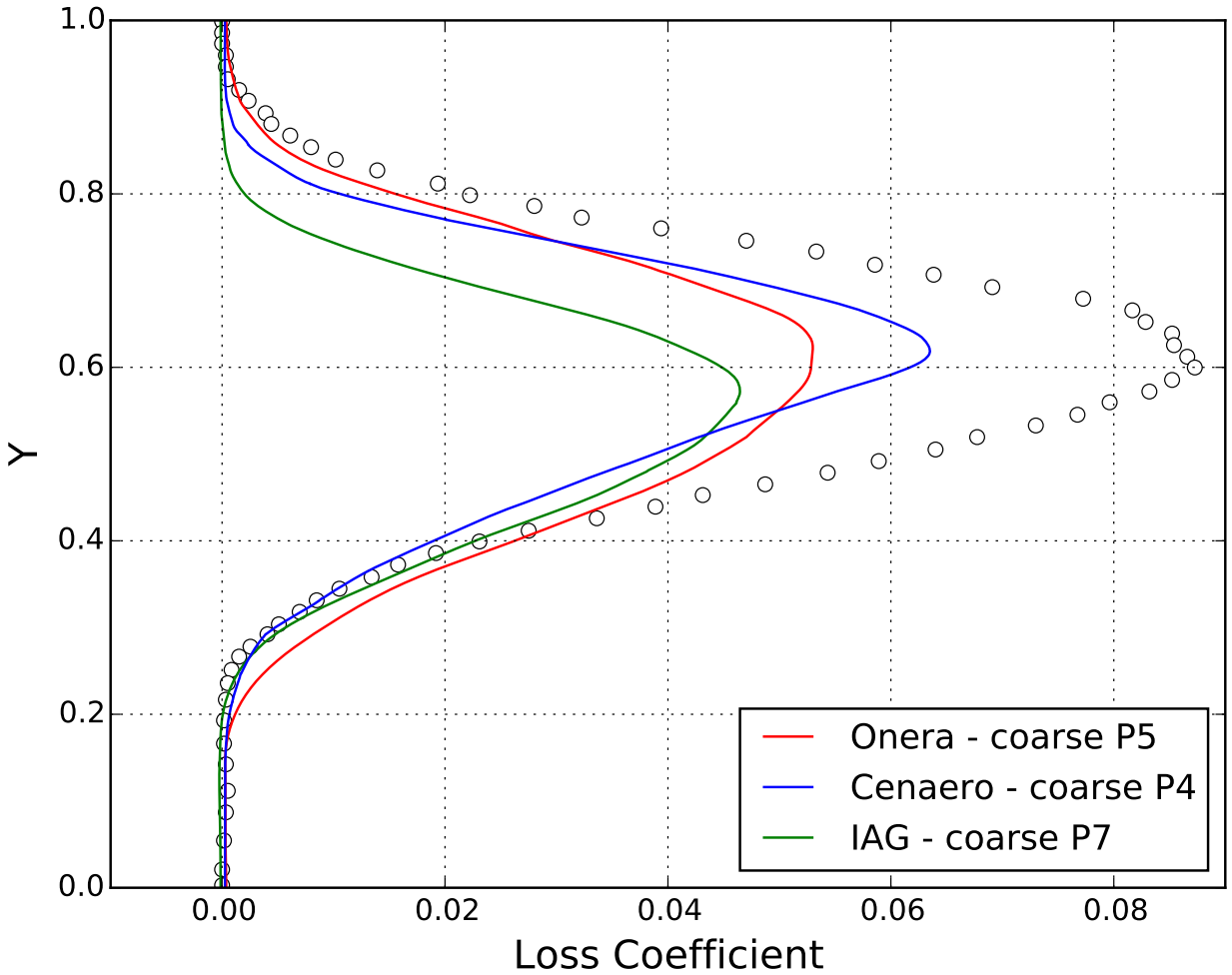
Comparison: Wake Total Pressure



Cenaero

Results Comparison: T106C

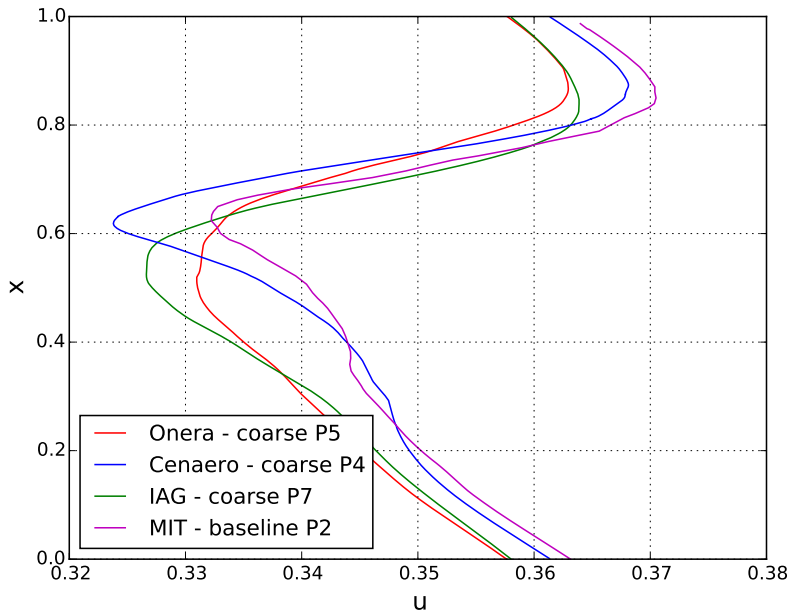
Comparison: Wake Loss Coefficient

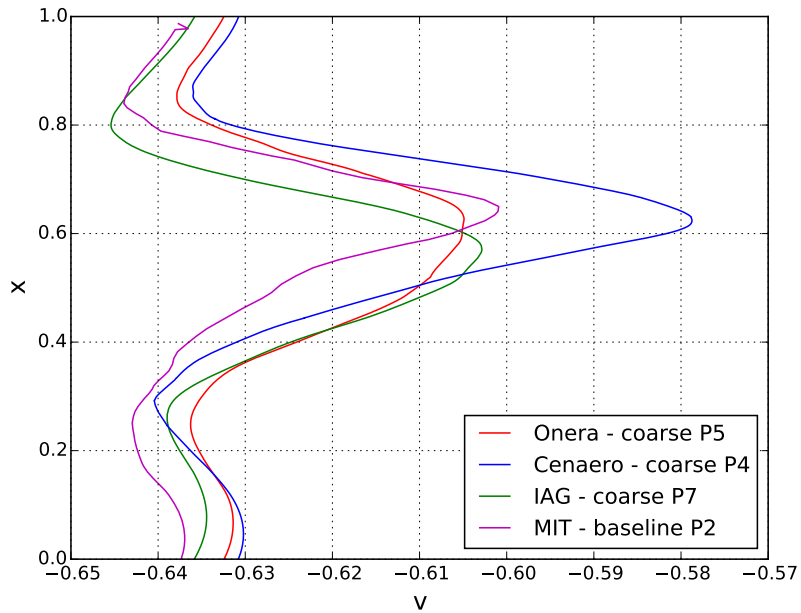


Cenaero

Results Comparison: T106C

Comparison: Wake Velocities

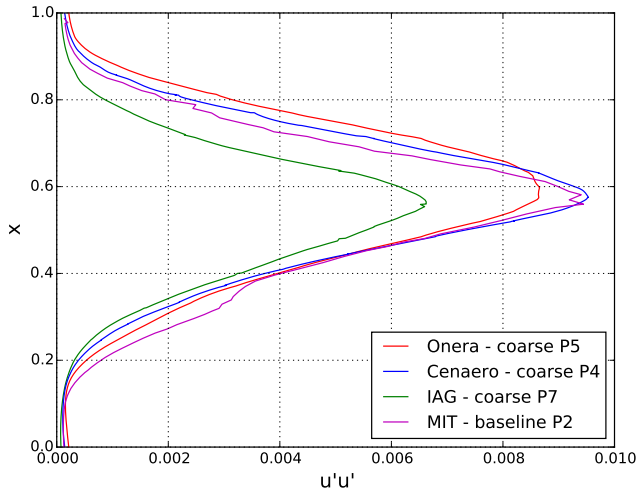


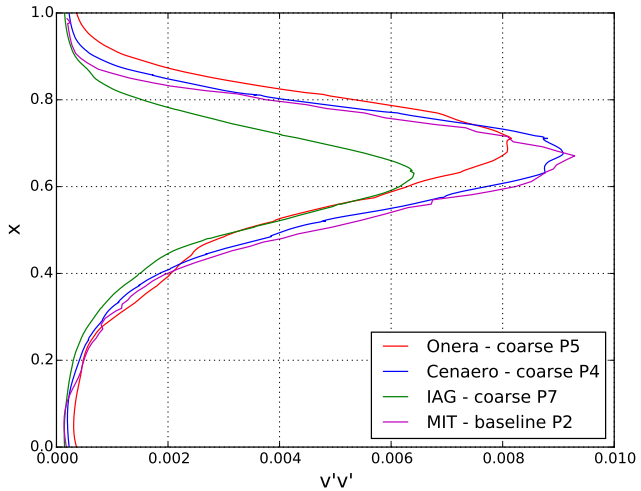


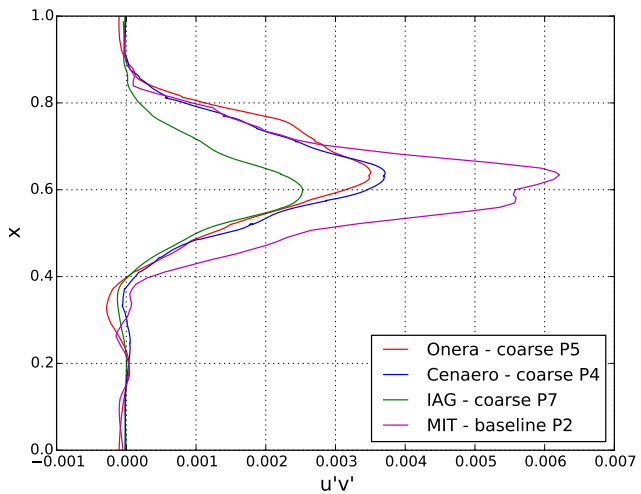
Cenaero

Results Comparison: T106C

Comparison: Fluctuations







Cenaero

Results Comparison: T106C
Comparison: Timings

	Method	Resolution	DOF	Ite/CT	WU/CT	WU/DOF/CT
Onera	LLF/SIP Pascal basis	P4 coarse	1.1M	64479	0.31M	0.292
		P5 coarse	1.7M	135406	1.23M	0.716
		P3 baseline	2.9M	27633	0.45M	0.141
		P4 baseline	5.1M	56419	1.70M	0.332
		P5 baseline	8.2M	123096	4.64M	0.566
IAG	Roe/BR1 Tensor basis	P6 coarse	1.5M	4838	0.10M	0.069
		P7 coarse	2.7M	5908	0.15M	0.068
MIT	IEDG	P2 baseline	3.2M	270	0.04M	0.013
Cenaero	Roe/SIP Tensor basis	P4 coarse	2.6M	451	0.29M	0.110
		P4 baseline	14.8M	902	4.38M	0.295

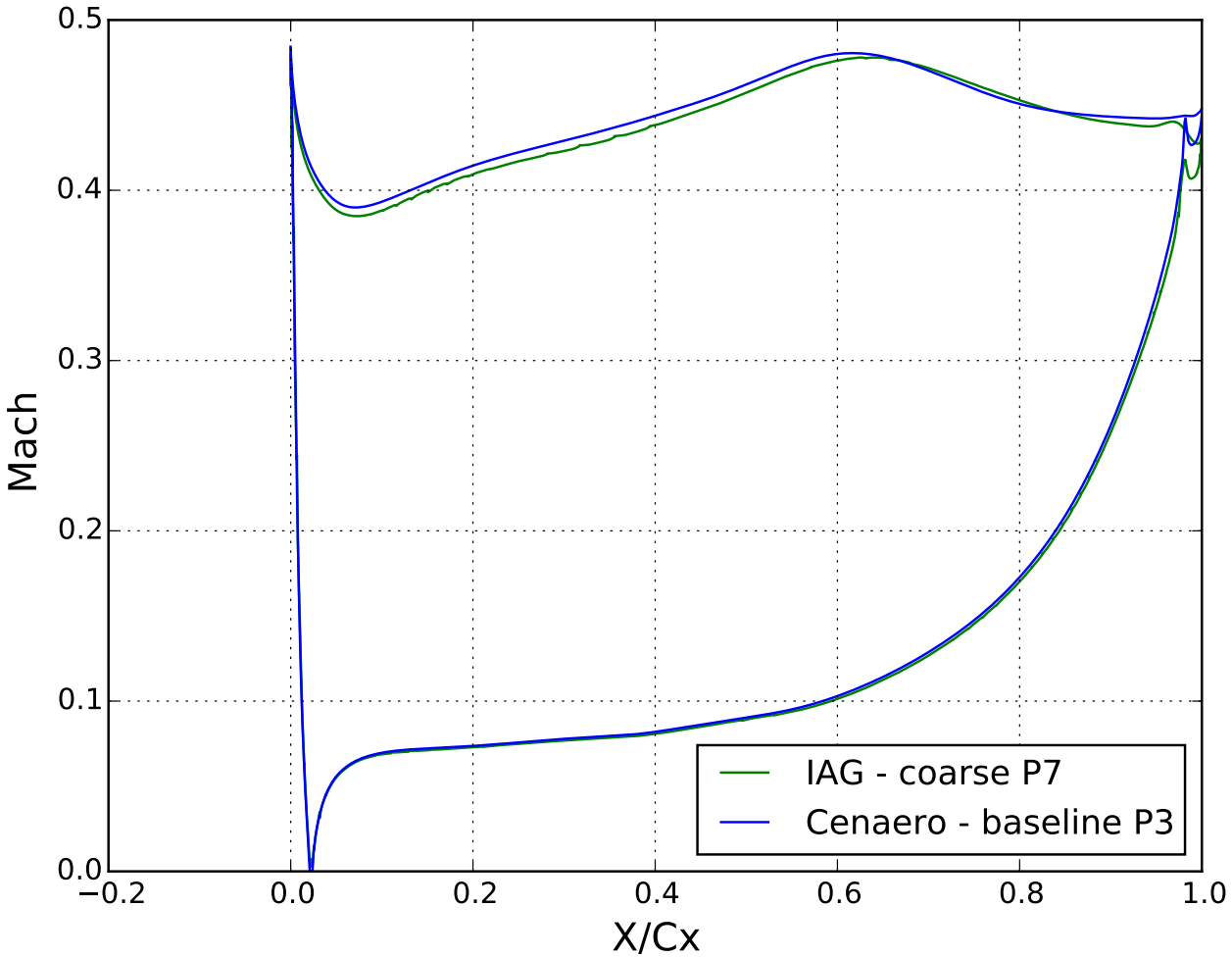
Results Comparison: T106C
Comparison: Timings

	Method	Resolution	DOF	Ite/CT	WU/CT	WU/DOF/RES
Onera	LLF/SIP Pascal basis	P4 coarse	1.1M	64479	0.31M	1.13μ
		P5 coarse	1.7M	135406	1.23M	1.32μ
		P3 baseline	2.9M	27633	0.45M	1.27μ
		P4 baseline	5.1M	56419	1.70M	1.47μ
		P5 baseline	8.2M	123096	4.64M	1.15μ
IAG	Roe/BR1 Tensor basis	P6 coarse	1.5M	4838	0.10M	2.87μ
		P7 coarse	2.7M	5908	0.15M	2.31μ
MIT	IEDG	P2 baseline	3.2M	270	0.04M	0.17μ
Cenaero	Roe/SIP Tensor basis	P4 coarse	2.6M	451	0.29M	2.68μ
		P4 baseline	14.8M	902	4.38M	3.63μ

Results Comparison: T106A

Results Comparison: T106A

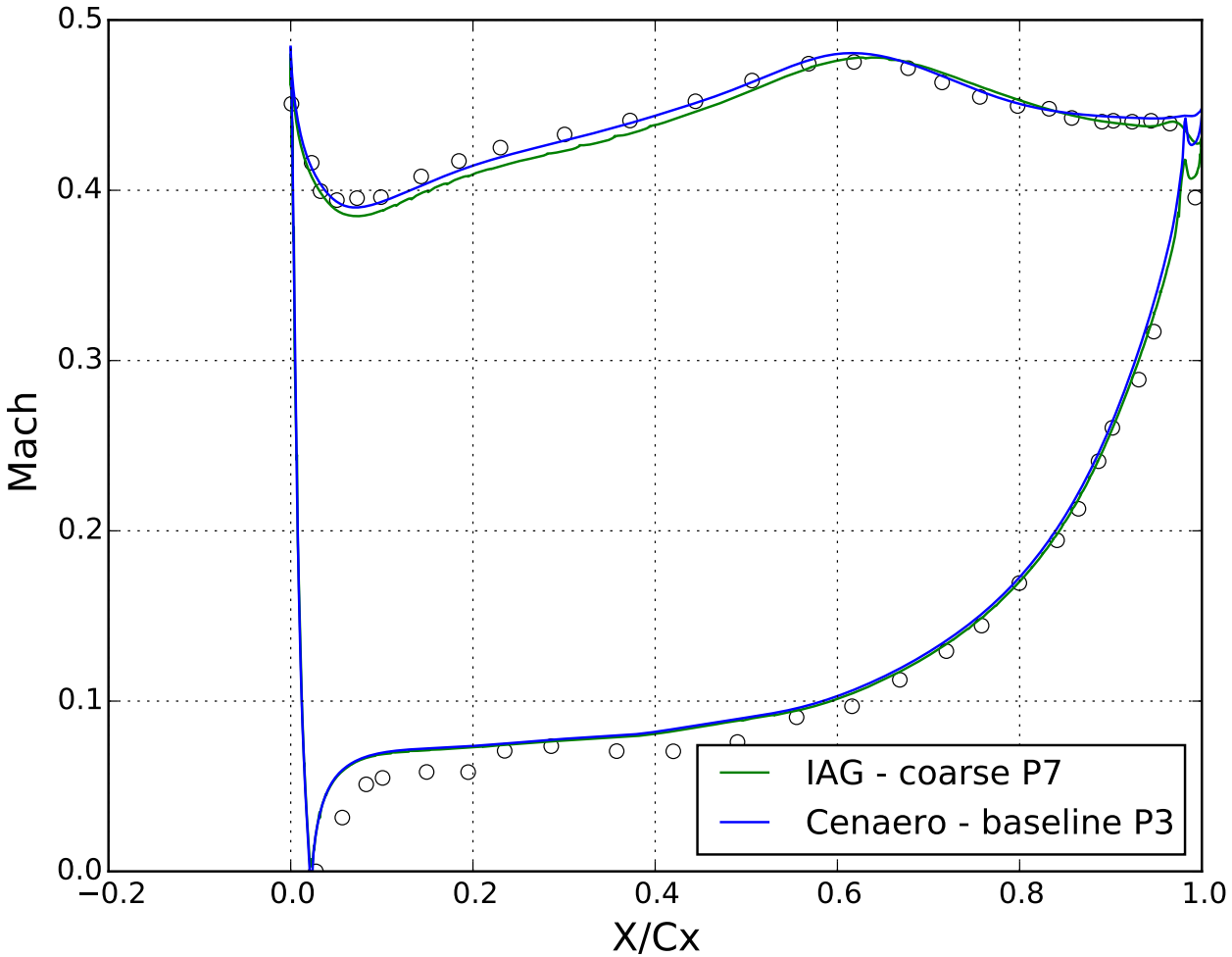
Comparison: Isentropic Mach



Cenaero

Results Comparison: T106A

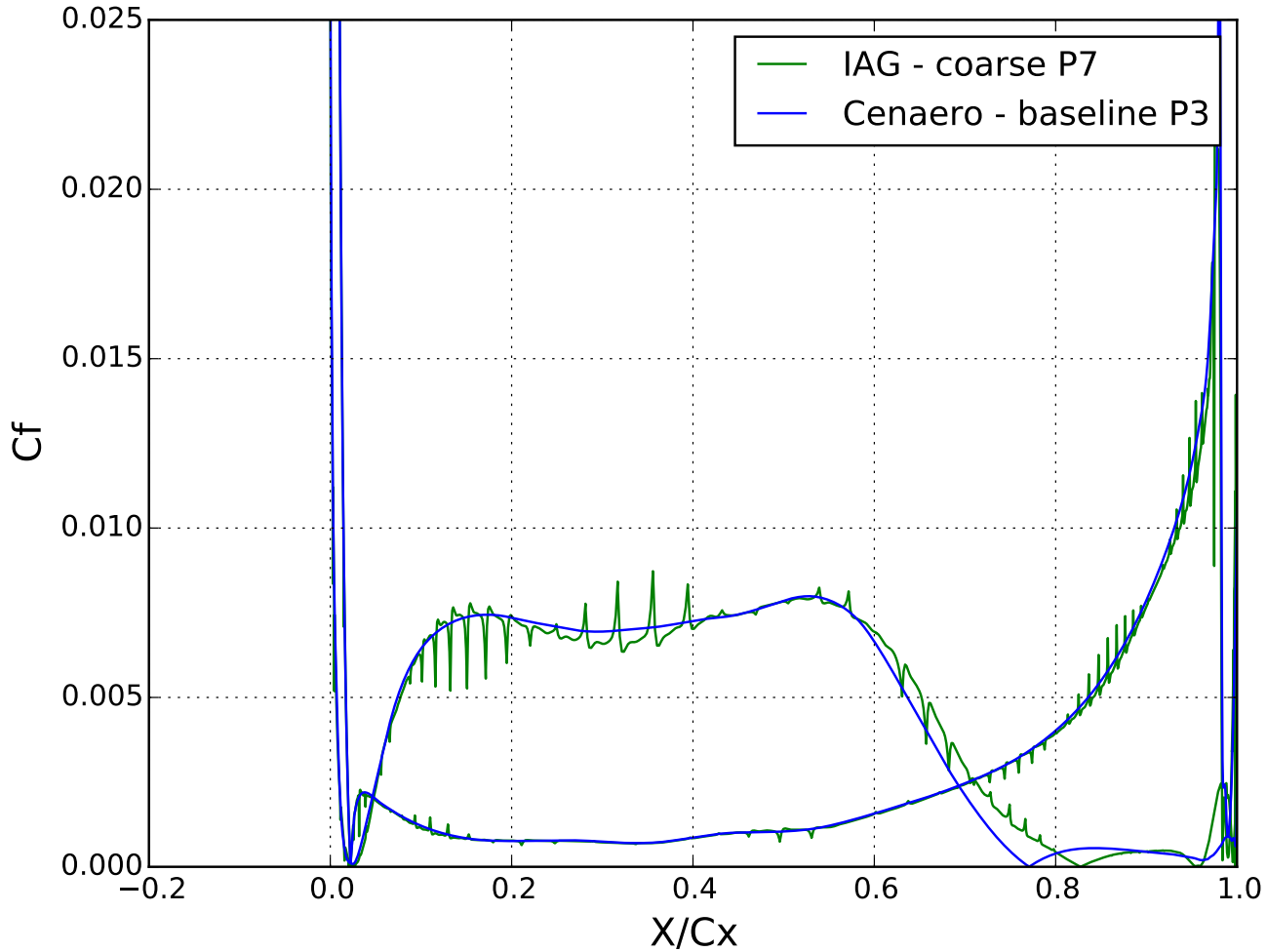
Comparison: Isentropic Mach



Cenaero

Results Comparison: T106A

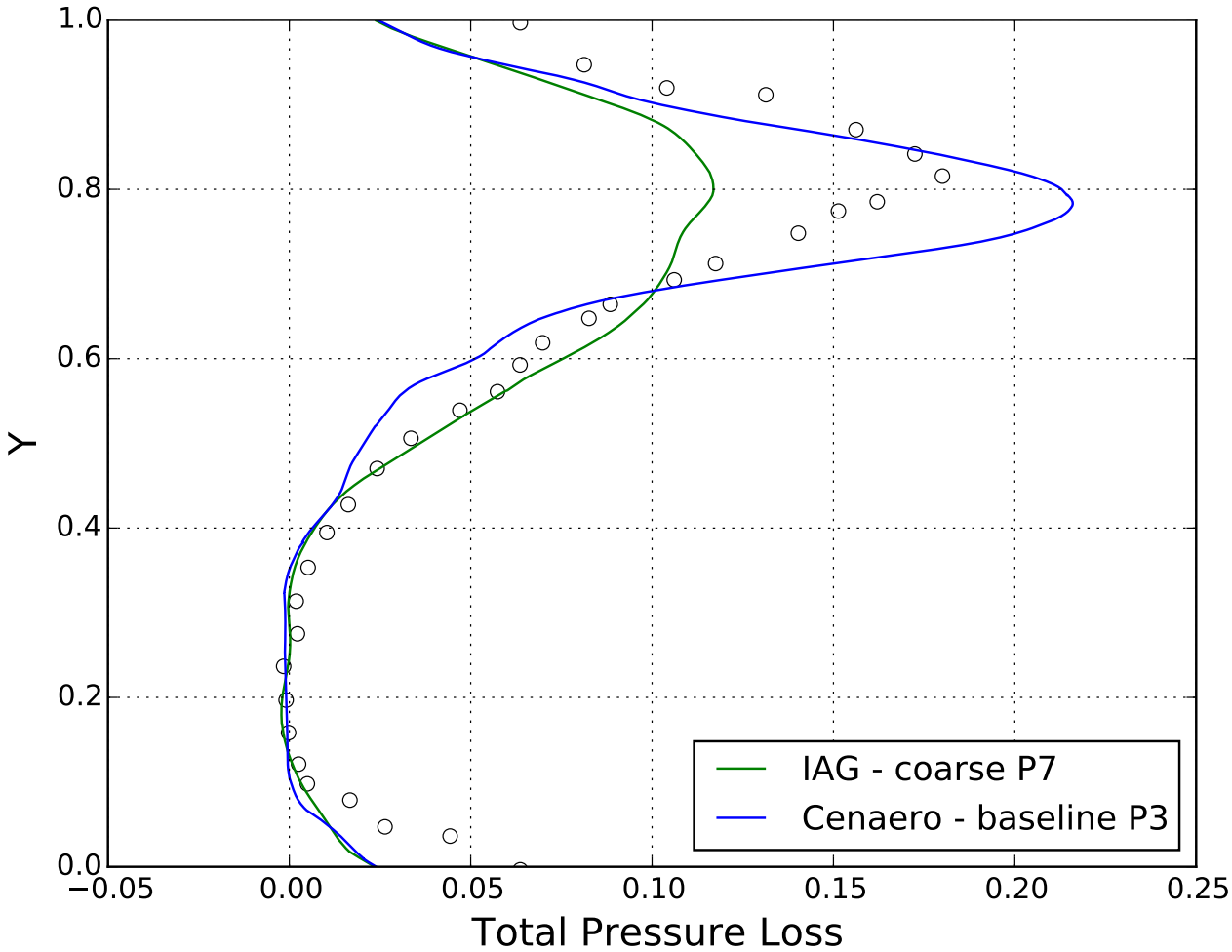
Comparison: Friction Coefficient



Cenaero

Results Comparison: T106A

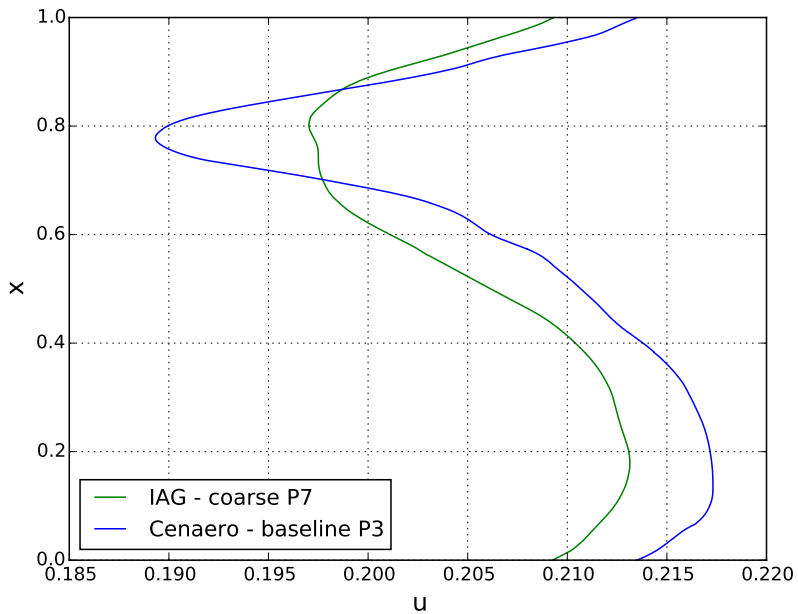
Comparison: Total Pressure Loss

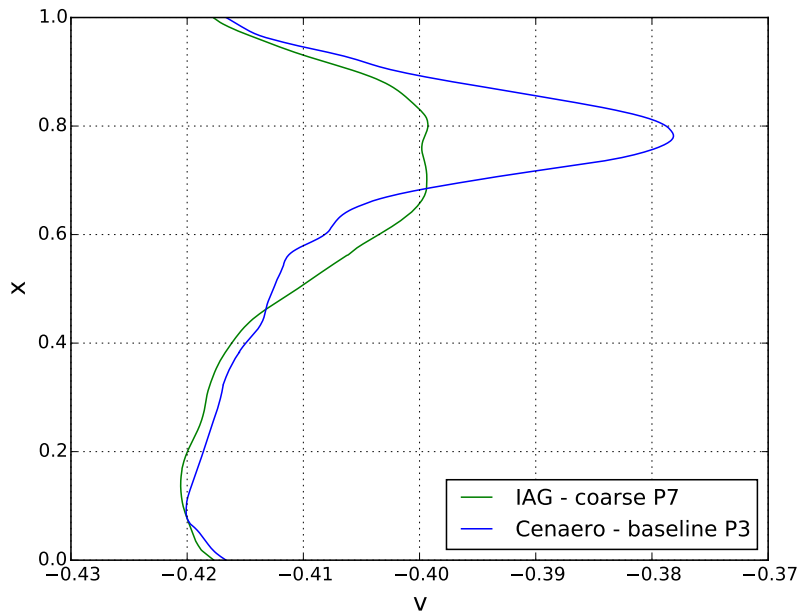


Cenaero

Results Comparison: T106A

Comparison: Wake Velocities

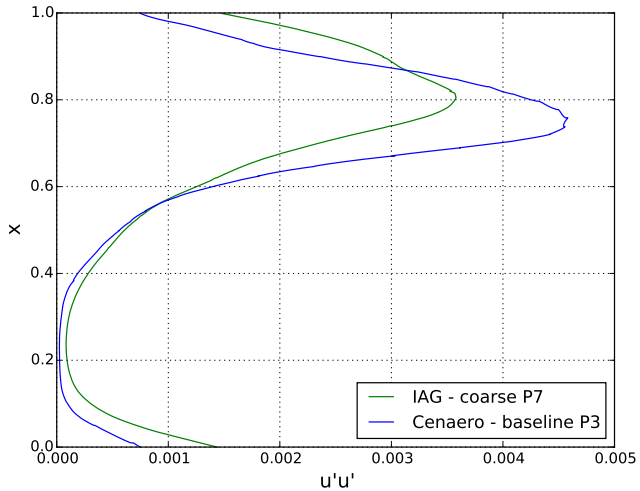


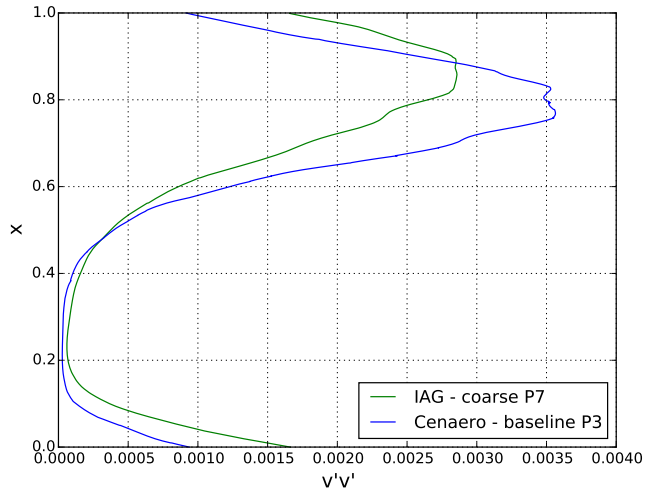


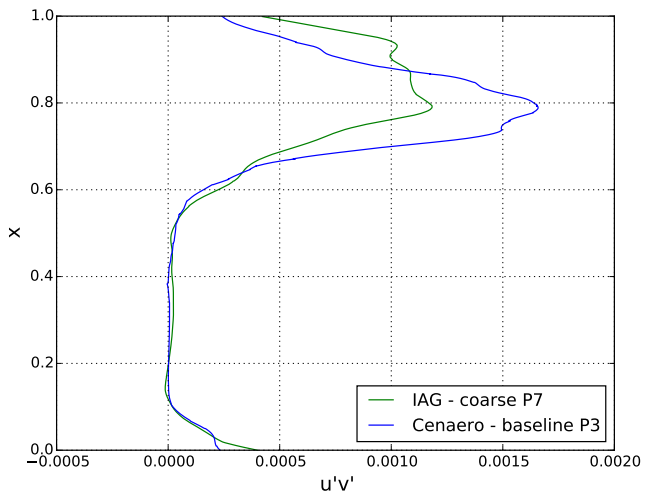
Cenaero

Results Comparison: T106A

Comparison: Fluctuations







Cenaero

Conclusions

Conclusions

Results comparison

- Onera/Cenaero: showed closest results
  - Similar numerical implementations
  - Used the same meshes!!
- IAG: prabably not mesh independent
  - Mesh is inadequate (smoothness of normals) ?
  - Wake refinement probably needed
  - Workshop-provided grids would likely close the gap

Timings

- Comparison are difficult
- Onera/Cenaero: comparable (despite EXP/IMP)
- IAG: Faster but not more efficient (large time-step)
- MIT: EIDG seems promising (DOF count? Dealiasing?)

Experiemental match

- Confirmed disagreement identified during HOW2
- Marginally better for T106A