LABORATORY

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Sting Influence on Vortex Breakdown on a 65 Degree Delta Wing in Transonic Flow

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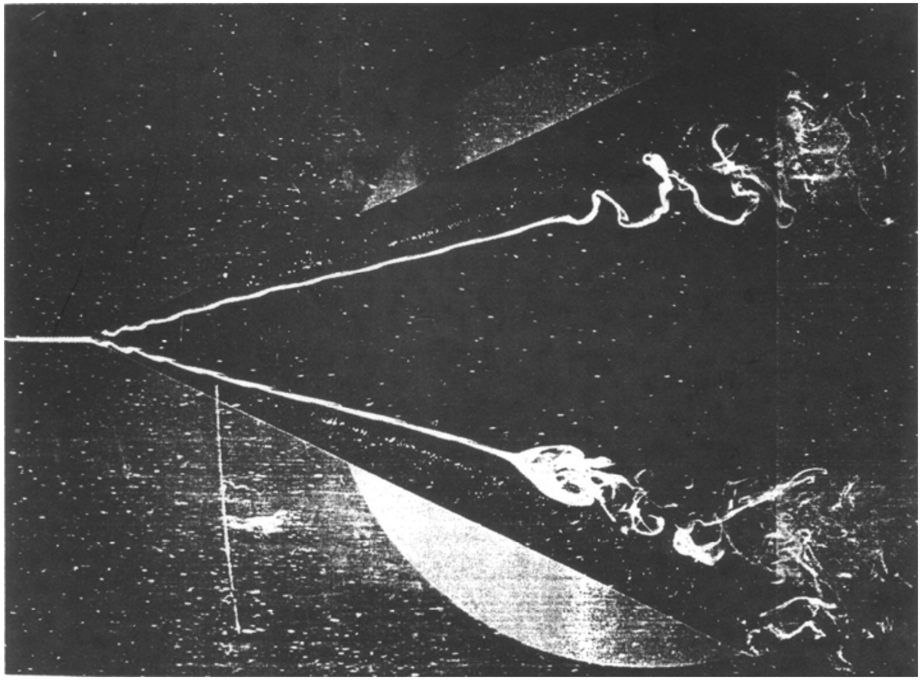
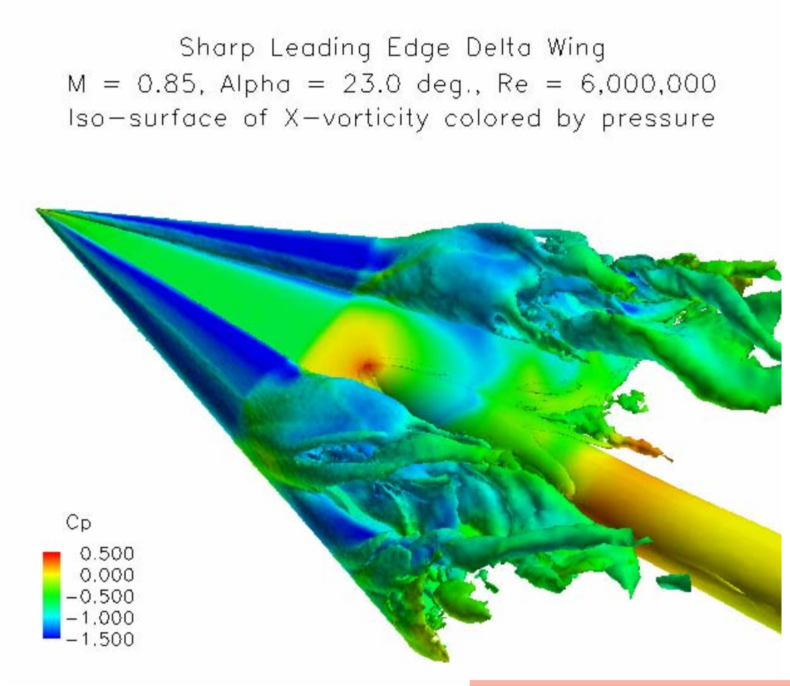
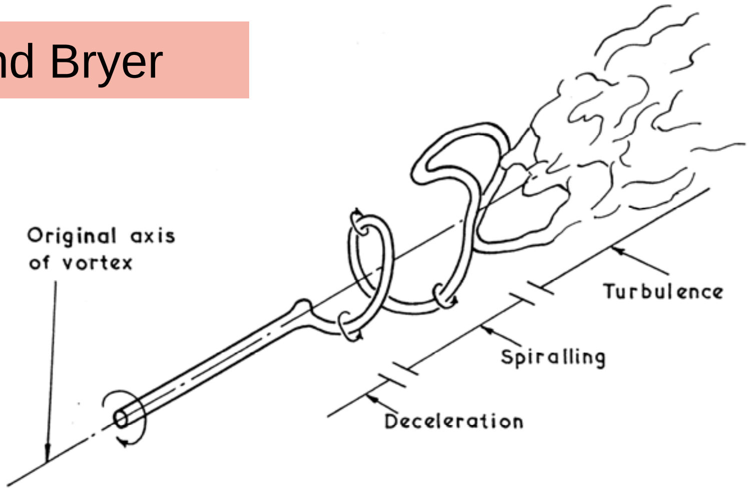
3rd International Symposium on Integrating CFD and Experiments in Aerodynamics

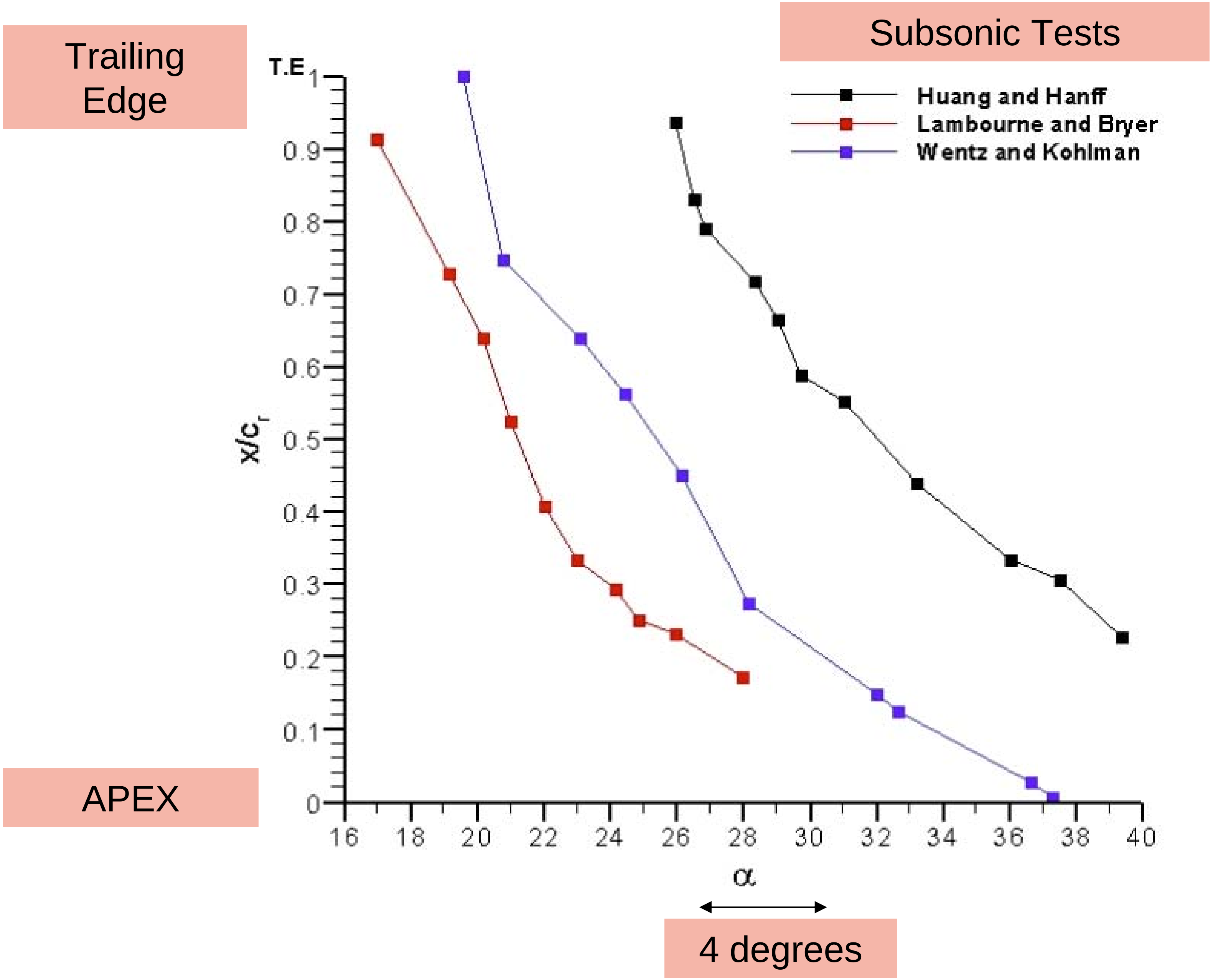




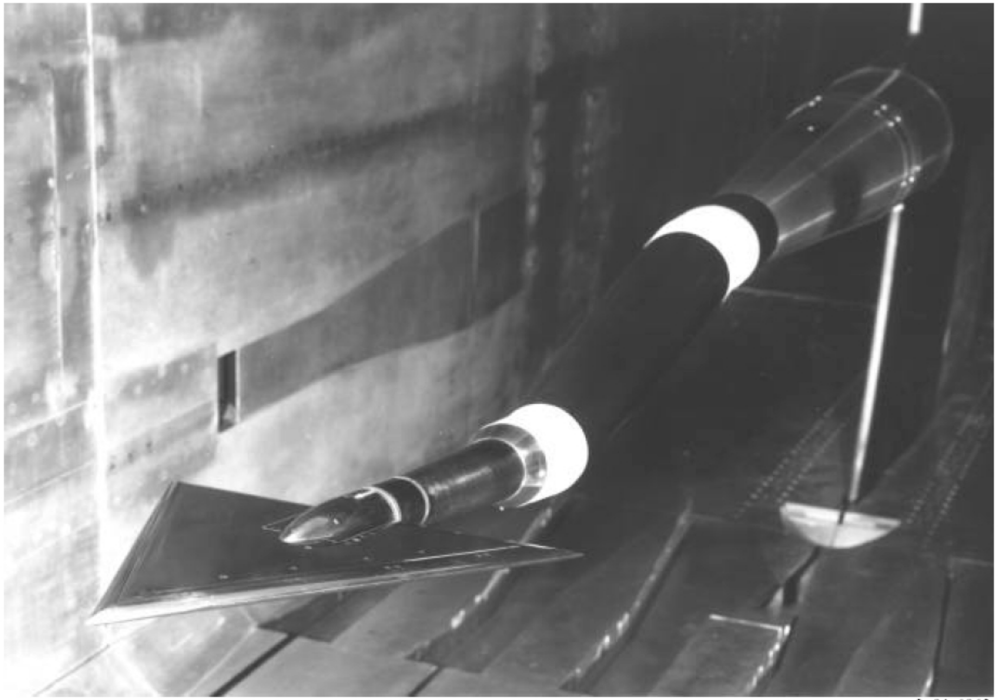
USAFA

Lambourne and Bryer





Subsonic Tests
Trailing Edge
T.E
APEX
Huang and Hanff
Lambourne and Bryer
Wentz and Kohlman
x/c_r
α
4 degrees

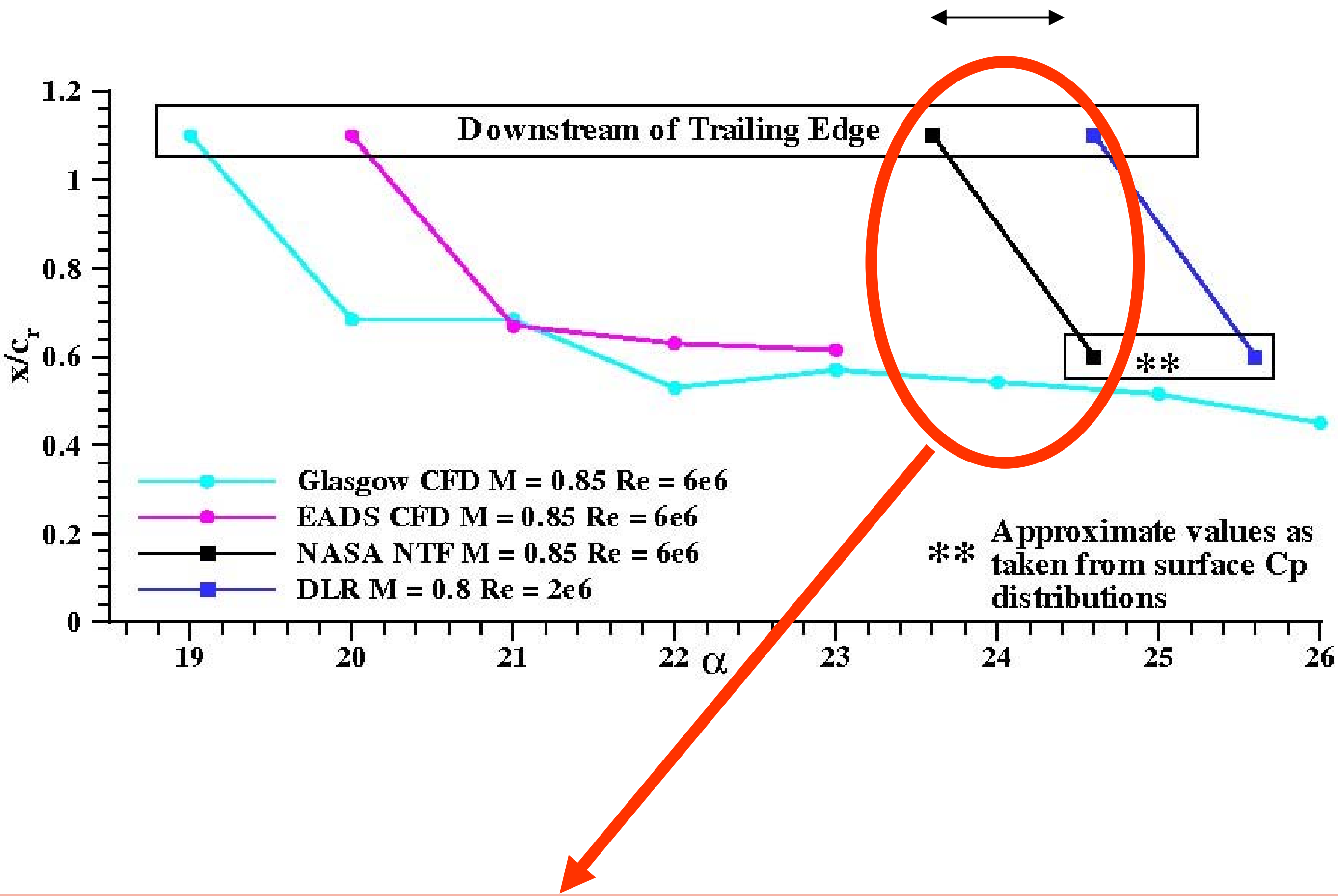


L-91-6963

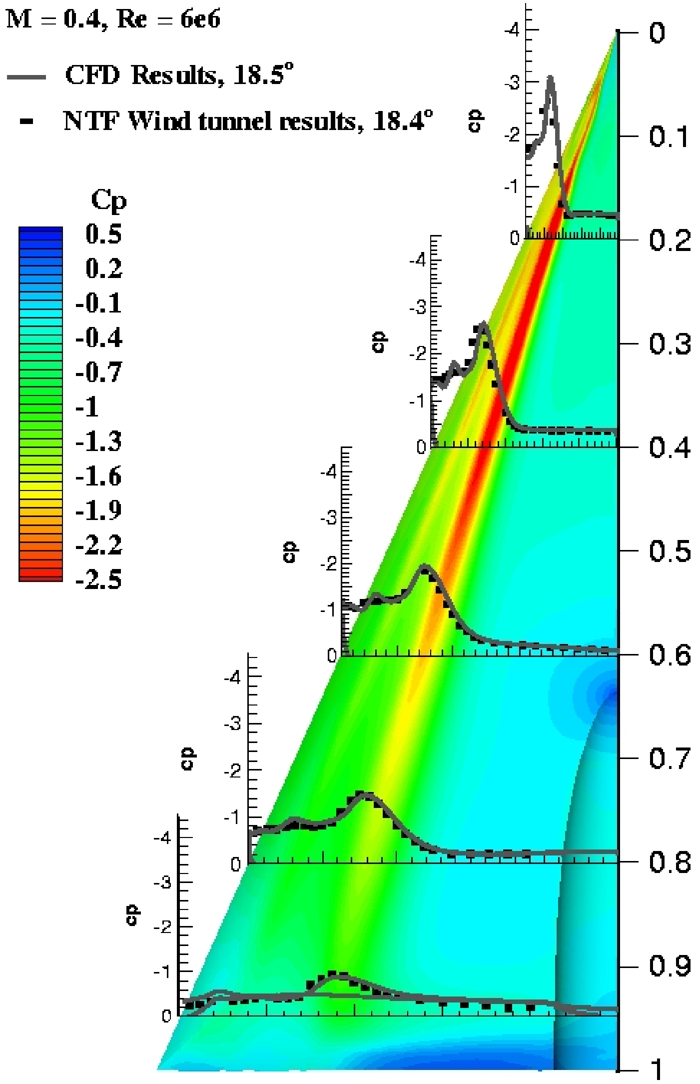
- NASA Langley NTF tests (Chu and Luckring)
  - 65 degree sharp LE
  - Surface pressure measurements
  - Range of freestream Mach numbers
    - 0.4 and 0.85
- These tests formed starting point for VFE-2

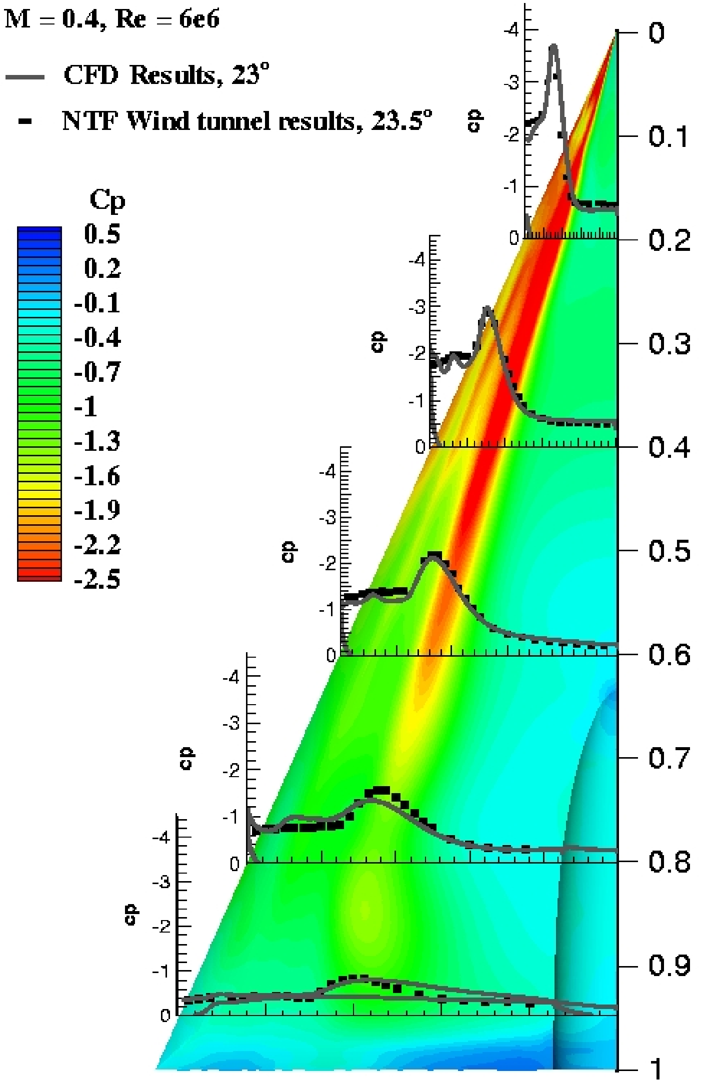
Transonic Tests

1 degree



Question: why does breakdown move towards the apex so suddenly?

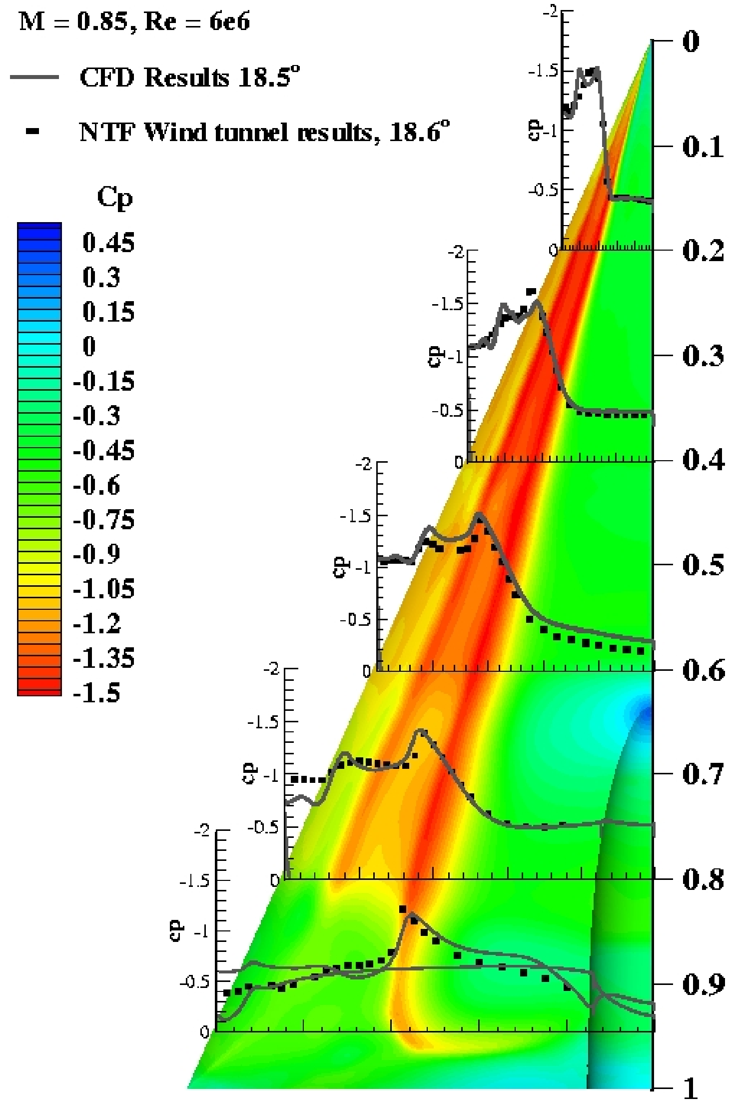




No Breakdown

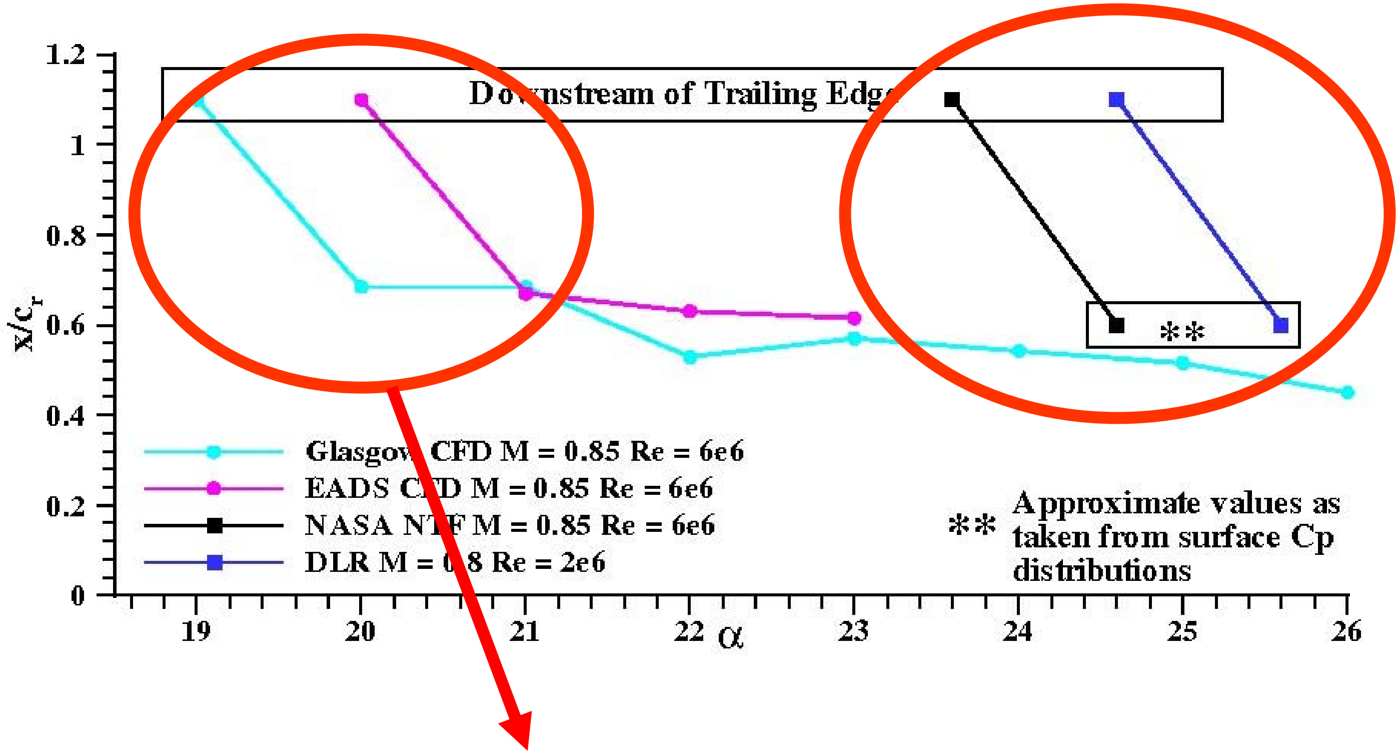
Breakdown

Mach 0.4

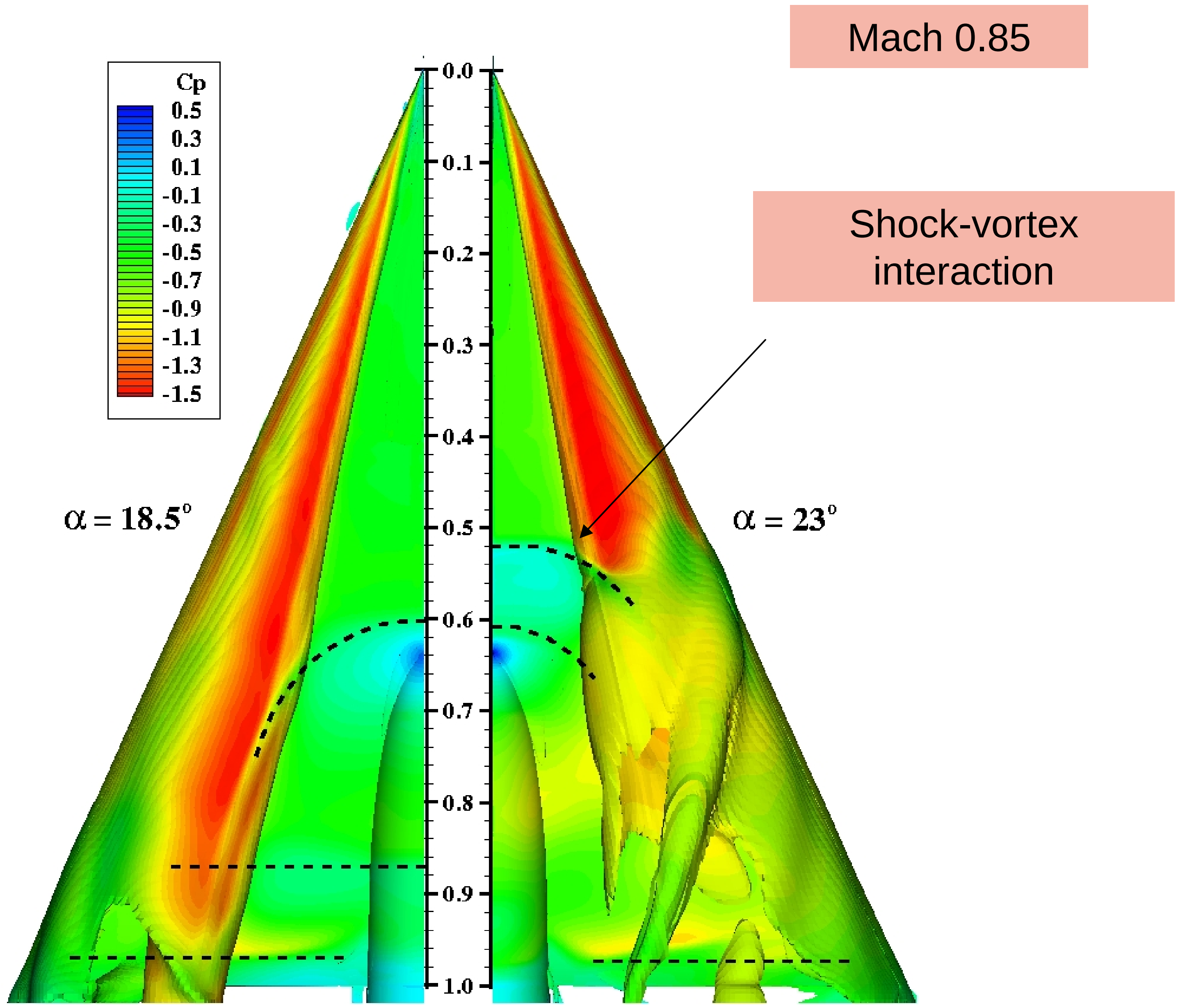


No Breakdown

Mach 0.85



Question: why is critical angle different in measurements and CFD?



Mach 0.85
Shock-vortex interaction
Cp
0.5
0.3
0.1
-0.1
-0.3
-0.5
-0.7
-0.9
-1.1
-1.3
-1.5
α = 18.5°
α = 23°
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

CFD Sensitivity Study

Participants:

EADS	Flower	10.6m	k-w and RSM
NLR	Enflow	4m	k-w with RC
Glasgow	PMB	7m (2.4m)	k-w with RC, NLEVM
USAFA	Cobalt	6m	SA-DES

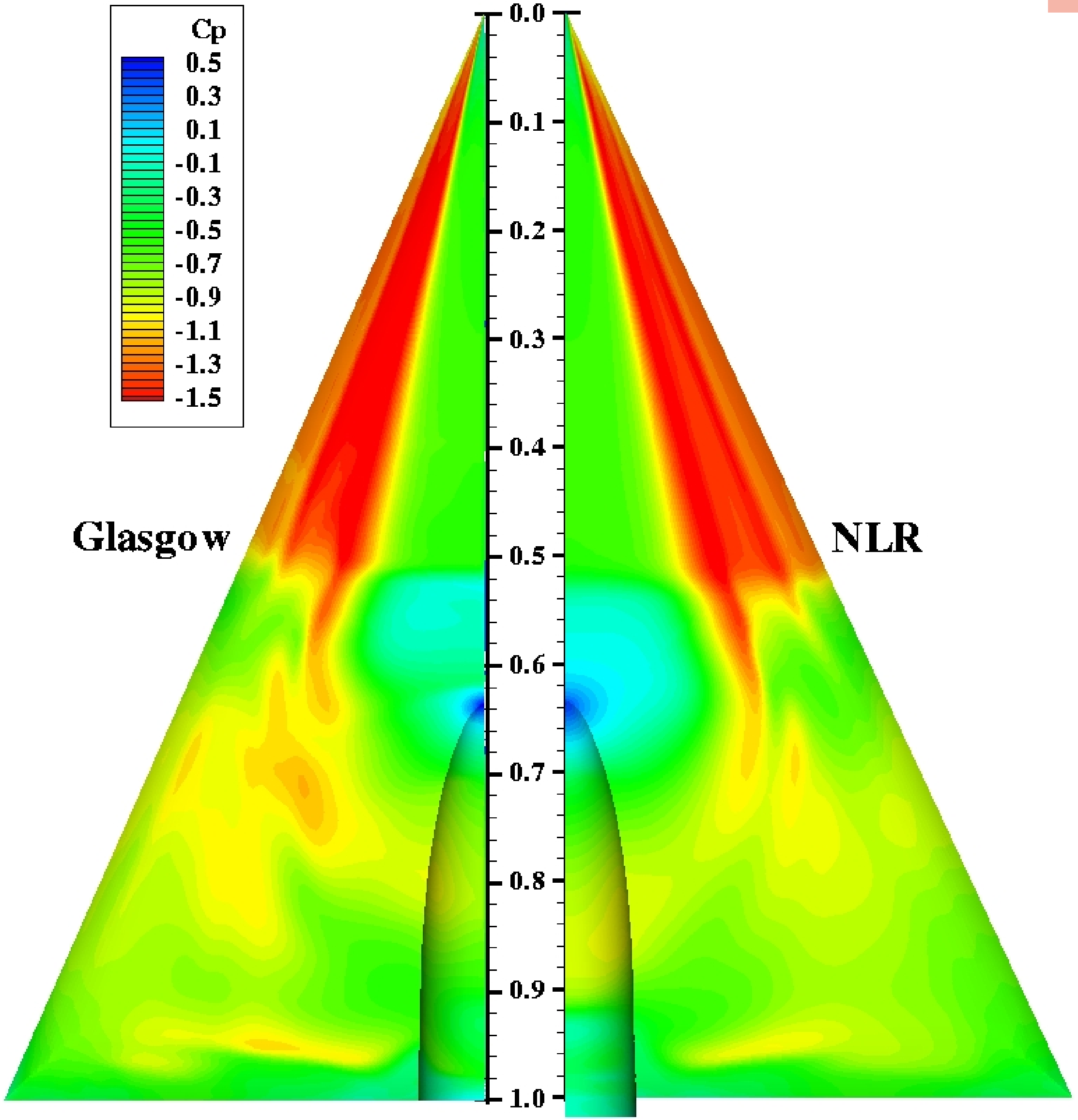
Tests:

Code-to-Code	Glasgow, NLR, EADS
Grid refinement	Glasgow coarse and fine
Turbulence Model	k-w, k-w with RC, RSM, NLEVM
Time Accuracy	Glasgow (steady) and USAFA (DES)

Purpose:

(1) Interested in the mechanism – does the sting shock always trigger the breakdown?
(2) Interested in the influence of the shock strength and the axial flow on the critical angle

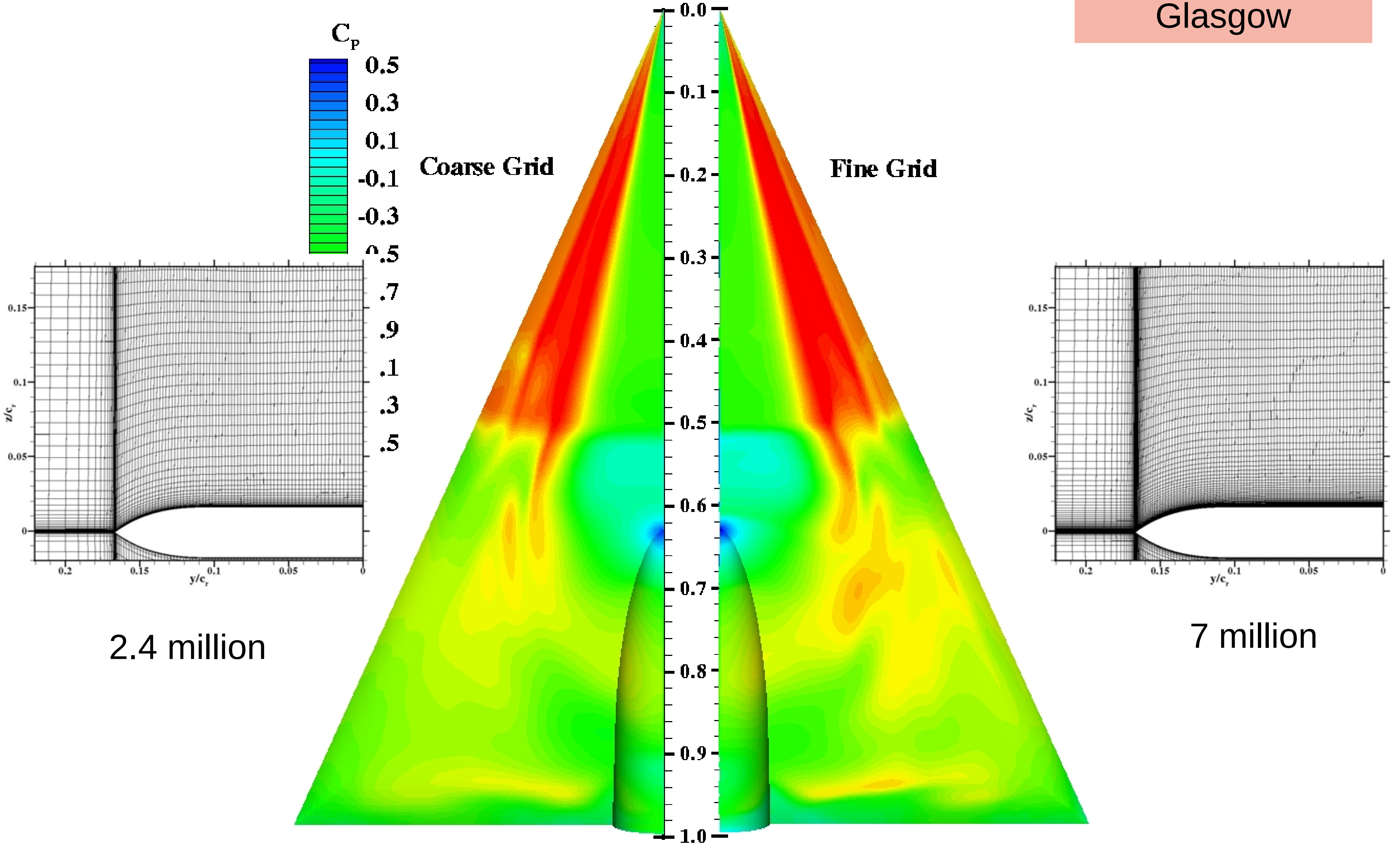
Code-to-code



Cp
0.5
0.3
0.1
-0.1
-0.3
-0.5
-0.7
-0.9
-1.1
-1.3
-1.5
Glasgow
NLR
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Grid Refinement

Glasgow

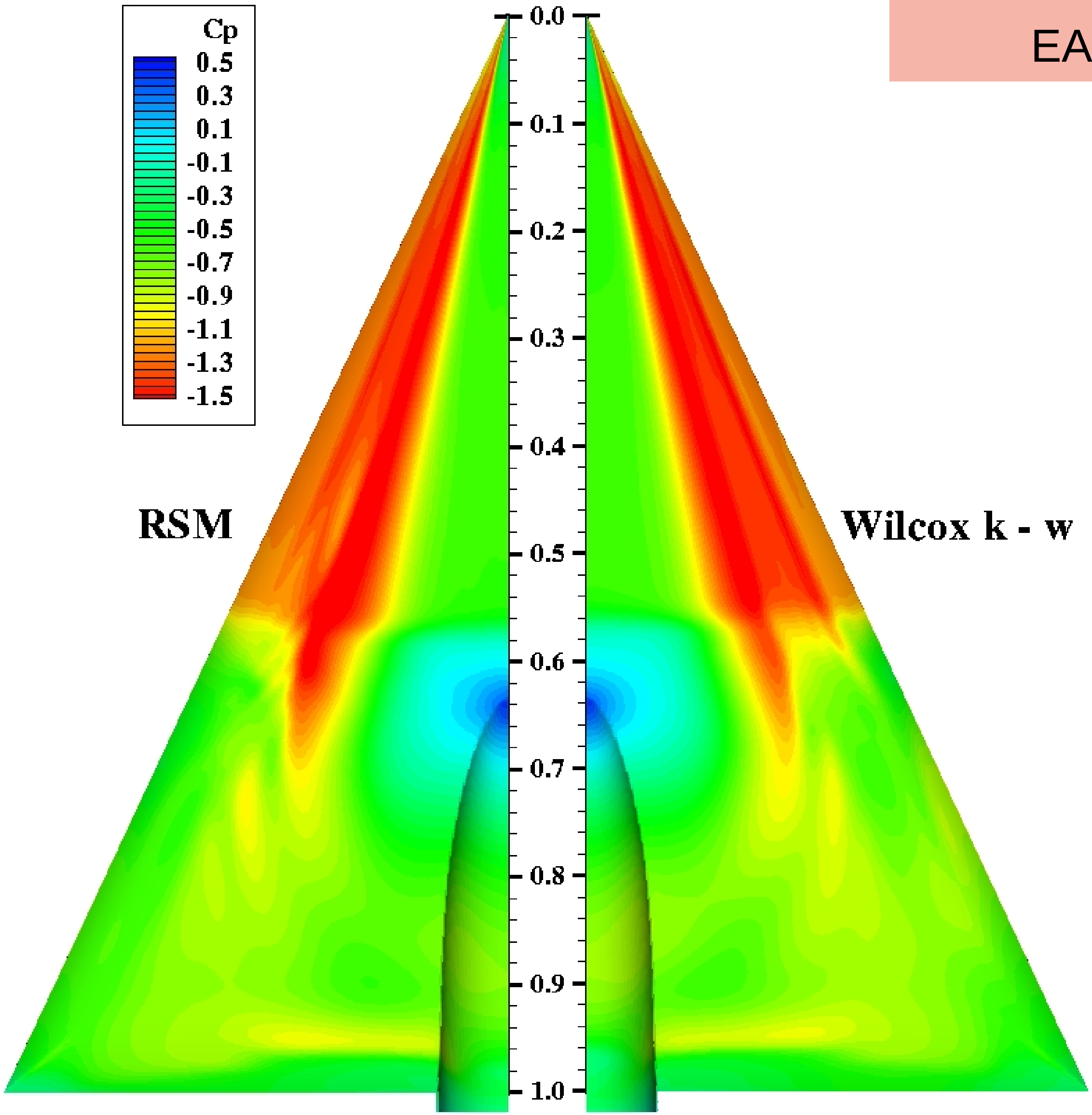


2.4 million

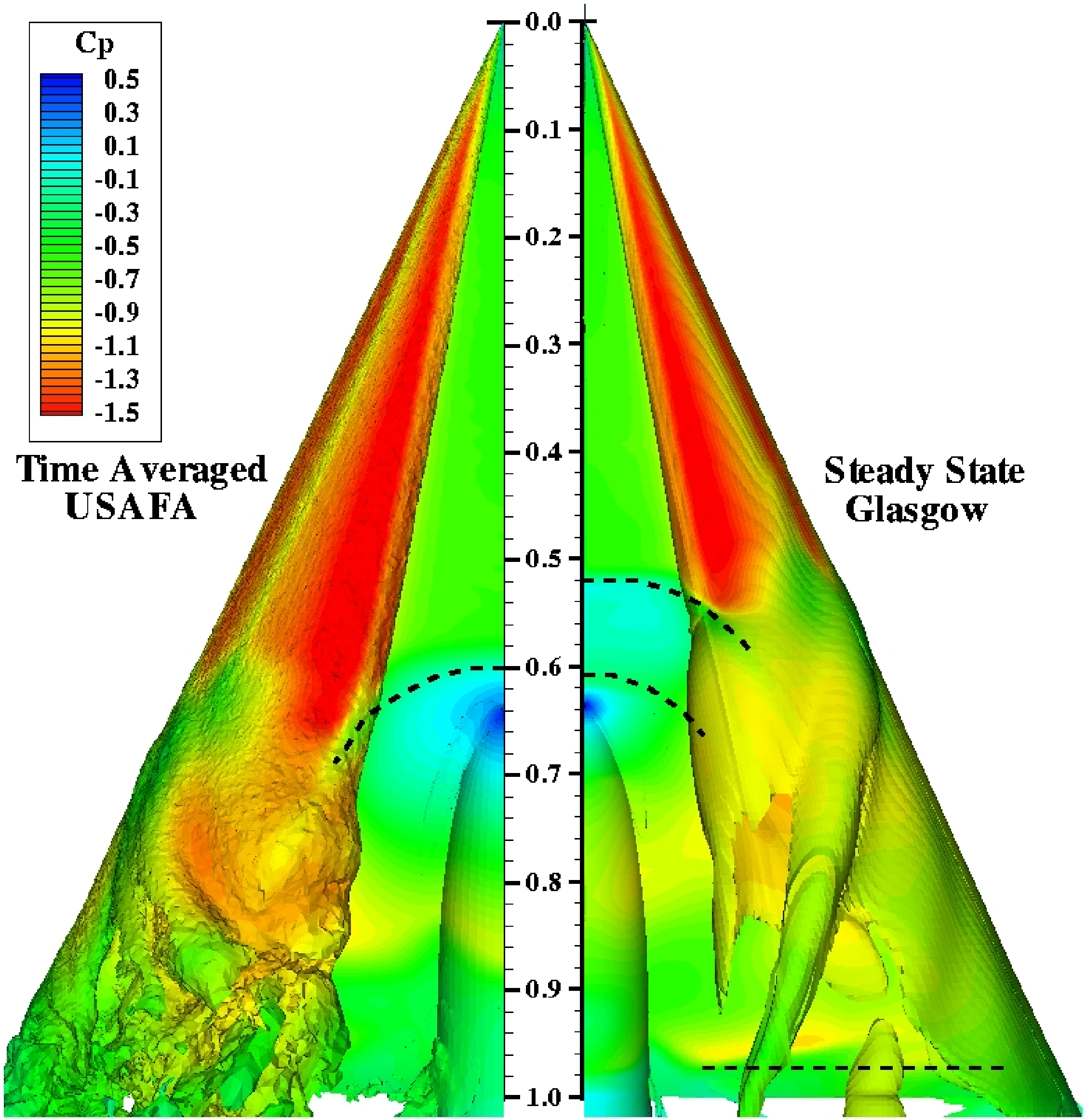
7 million

Turbulence Model

EADS



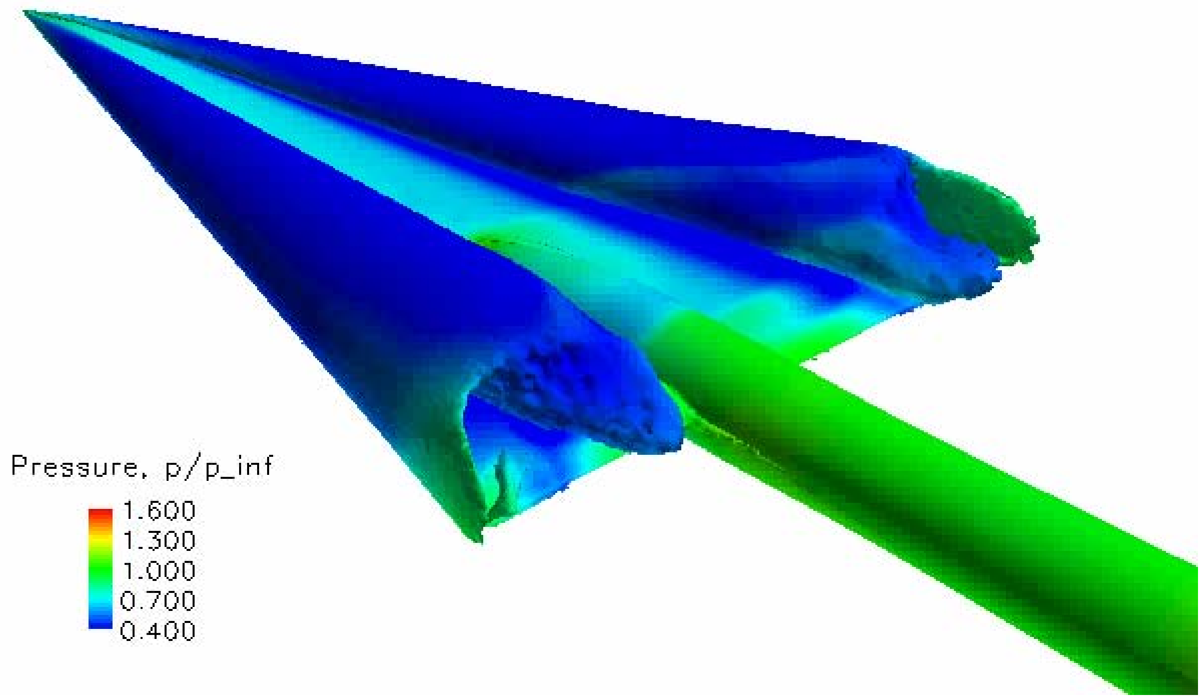
Steady/unsteady

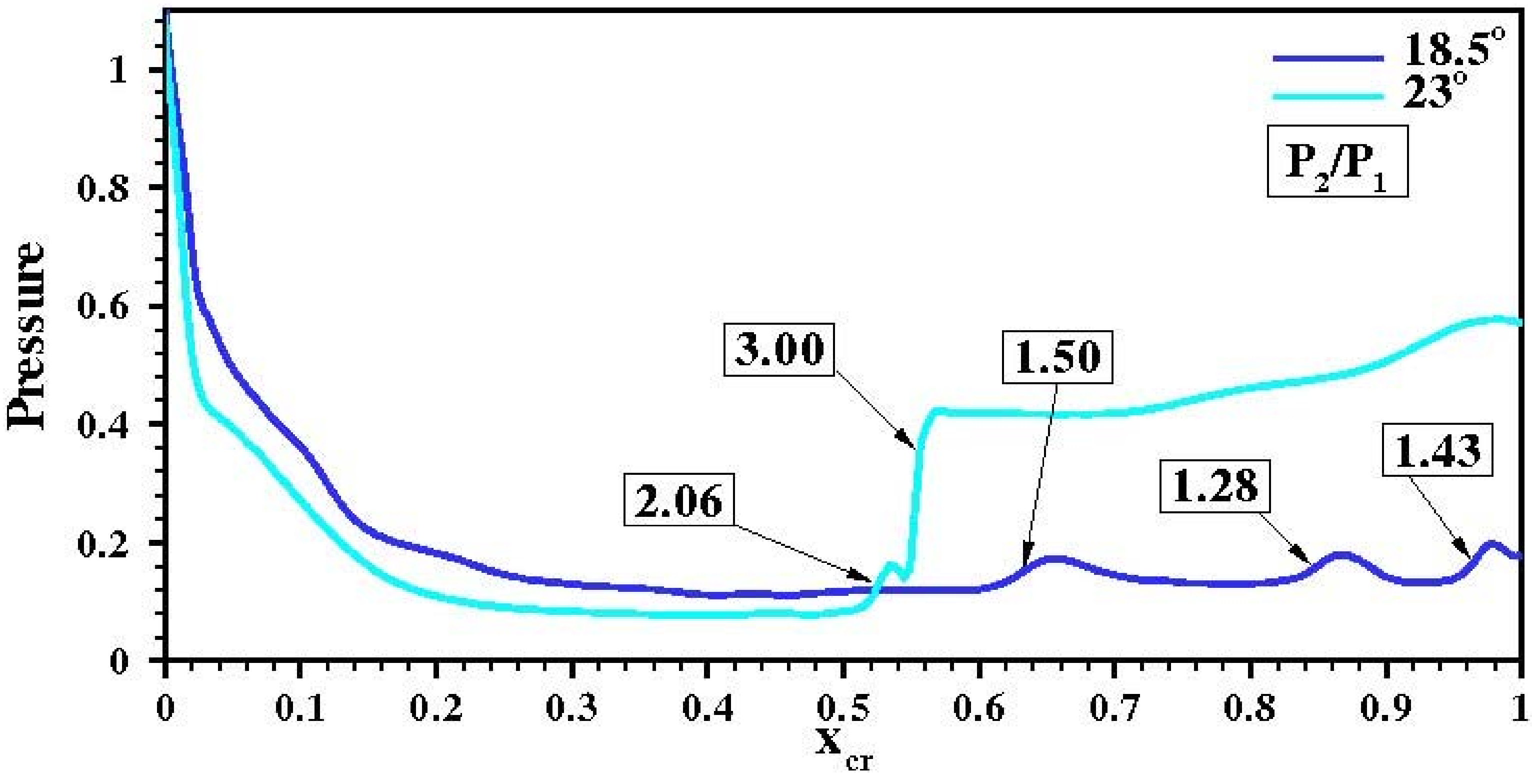


Sharp Leading Edge Delta Wing

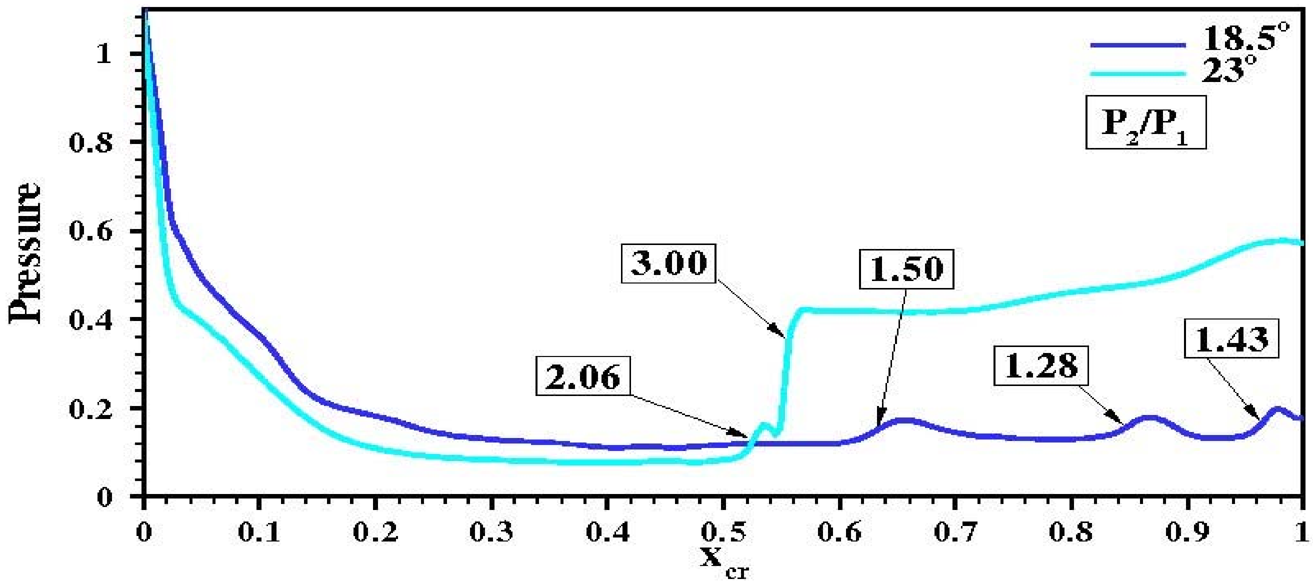
M = 0.85, Alpha = 23.0 deg., Re = 6,000,000

Iso-surface of X-vorticity colored by pressure

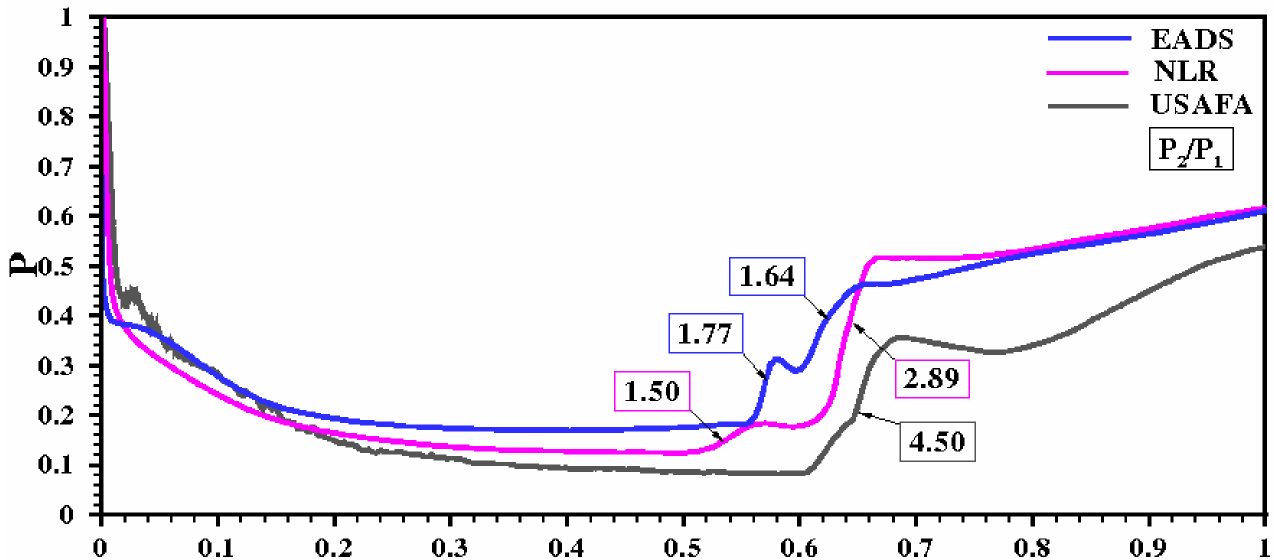




On-wing pressure gradient along symmetry plane

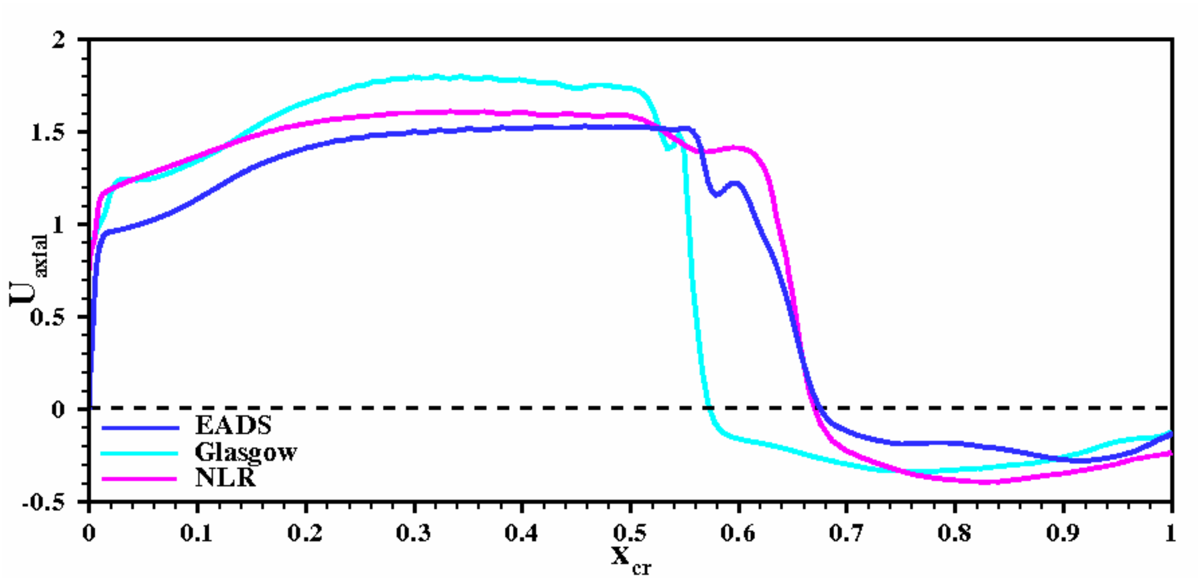


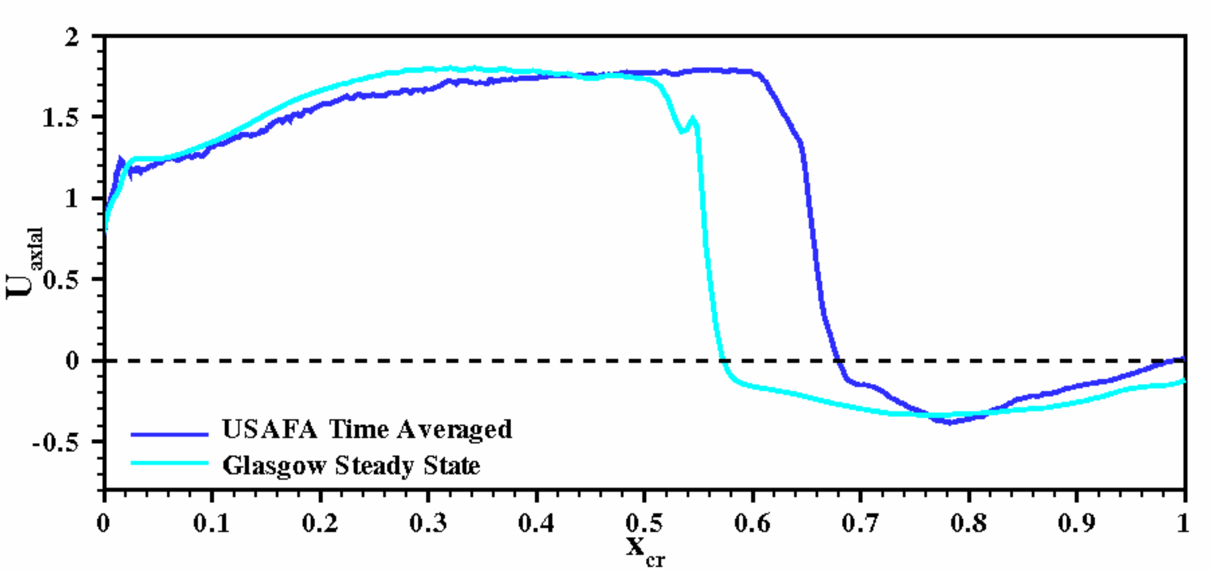
18.5°
23°
P2/P1
3.00
1.50
2.06
1.28
1.43
Pressure
xcr



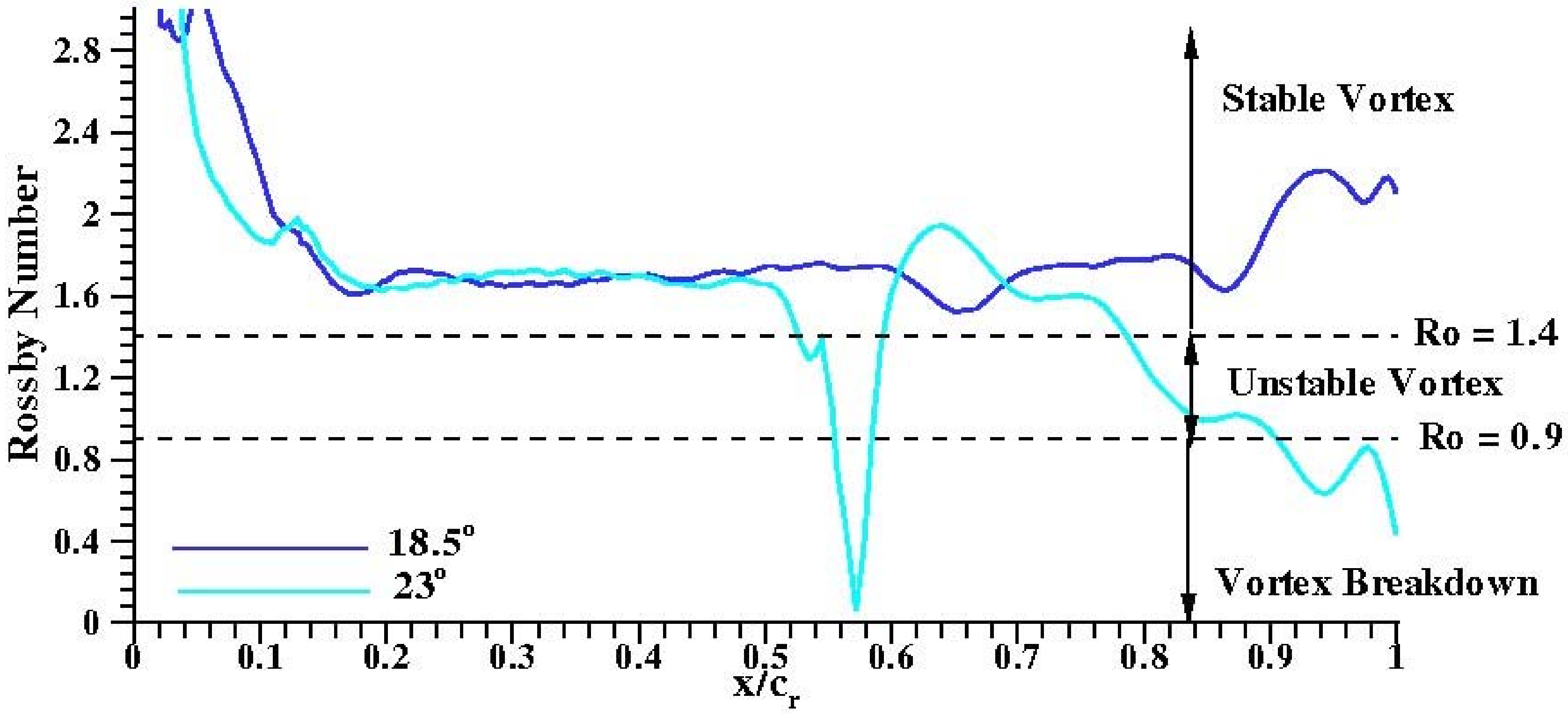
EADS
NLR
USAFA
P2/P1
1.64
1.77
1.50
2.89
4.50
P

Axial Velocity Distribution Along Vortex Core



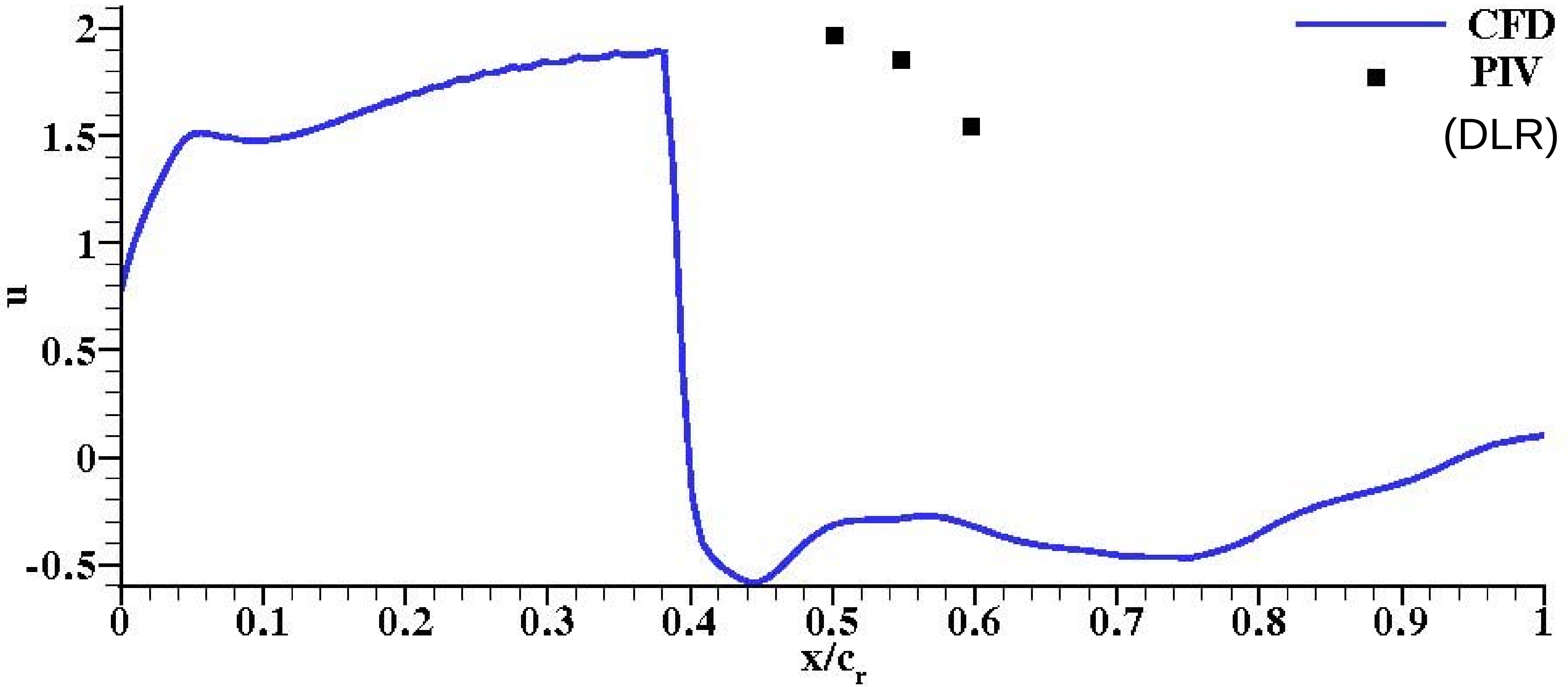


Rossby number=axial component/azimuthal component



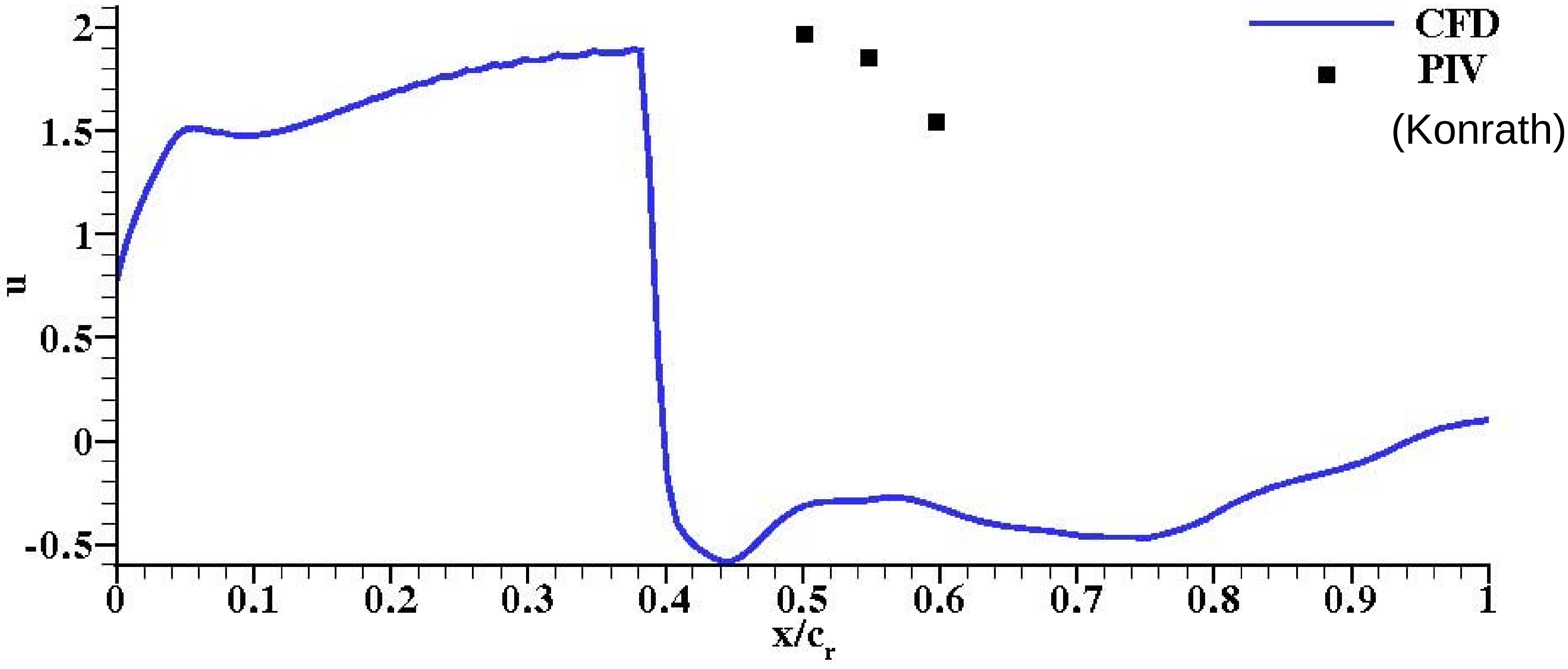
Robinson et al, AIAA Journal, 1994

Ashley et al, J Fluids and Structures, 1991



Mach 0.8, incidence 26 degrees, Re=3 million

On same scale but not that illuminating!



Mach 0.8, incidence 26 degrees, Re=3 million

Comments

- Here balance is between
  - Axial flow
  - Sting shock strength
- Closely coupled CFD-Experimental effort needed to nail this problem
- More to be extracted from the CFD trends

Incidence	Breakdown	Maximum Axial Speed	Maximum Pressure Ratio
18.5	No	1.74	1.50
19	No	1.76	1.67
20	Yes	1.74	3.73
21	Yes	1.74	4.87
22	Yes	1.79	4.67
23	Yes	1.80	5.25

PSP measurements to locate shocks

Incidence	Breakdown	Maximum Axial Speed	Maximum Pressure Gradient
18.5	No	1.74	1.50
19	No	1.76	1.67
20	Yes	1.74	3.73
21	Yes	1.74	4.87
22	Yes	1.79	4.67
23	Yes	1.80	5.25

PIV slices (from apex to TE) to assess axial flow

Conclusions

- sting-shock and primary vortex
  - sudden upstream motion of breakdown
- critical angle consistently different
  - large scatter in published measurements also
  - More coordinated effort needed
- artefact of the experimental setup