

Overflow Juncture Flow Computations Compared with Experimental Data

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AIAA SciTech, January 6-12, 2019

Juncture Flow Experiment

Sponsored by NASA's Transformative Aeronautics Concepts Program's Transformational Tools and Technologies (T³) project

- Substantial effort to investigate the origin of separation bubbles found in wing-body juncture zones
- Primary goal is to gather validation level data, for future CFD code & turbulence model development
- Multi-year effort including several large-scale wind tunnel tests
 - First set of entries just finished: Nov 2017-April 2018
 - Planned Entries in the future



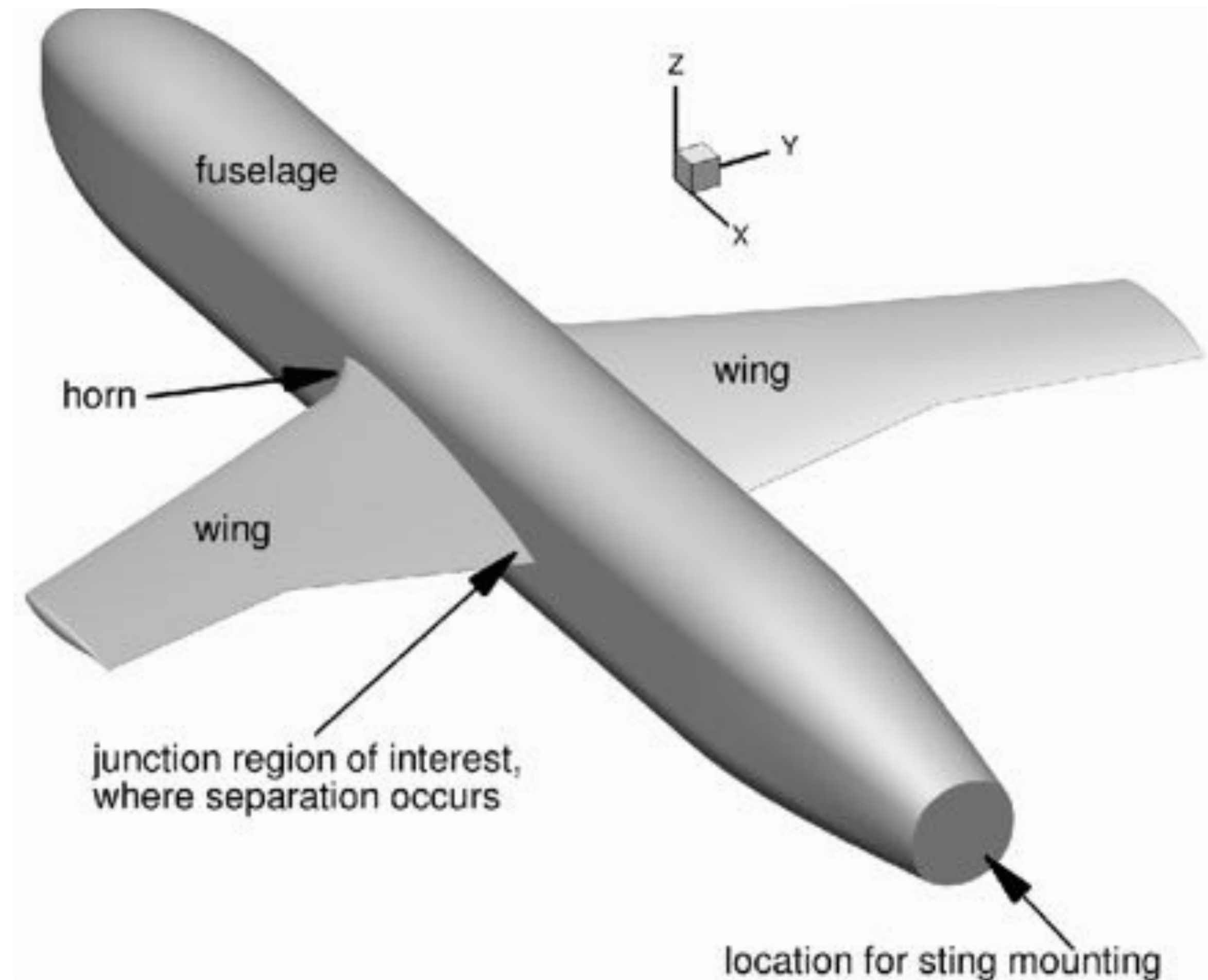


Juncture Flow Experiment

- Heavy collaboration: CFD and WT design team
 - CFD used extensively in the experiment design
 - Companion CFD runs for all risk assessment experiments
- Publications:
 - AIAA 2016-1557, AIAA 2016-1558, AIAA 2017-4127, AIAA 2017-4126, NASA TM-2016-219348, STO-MP-AVT-284-02
- Have experimental data now, how well does CFD RANS (OVERFLOW) do?

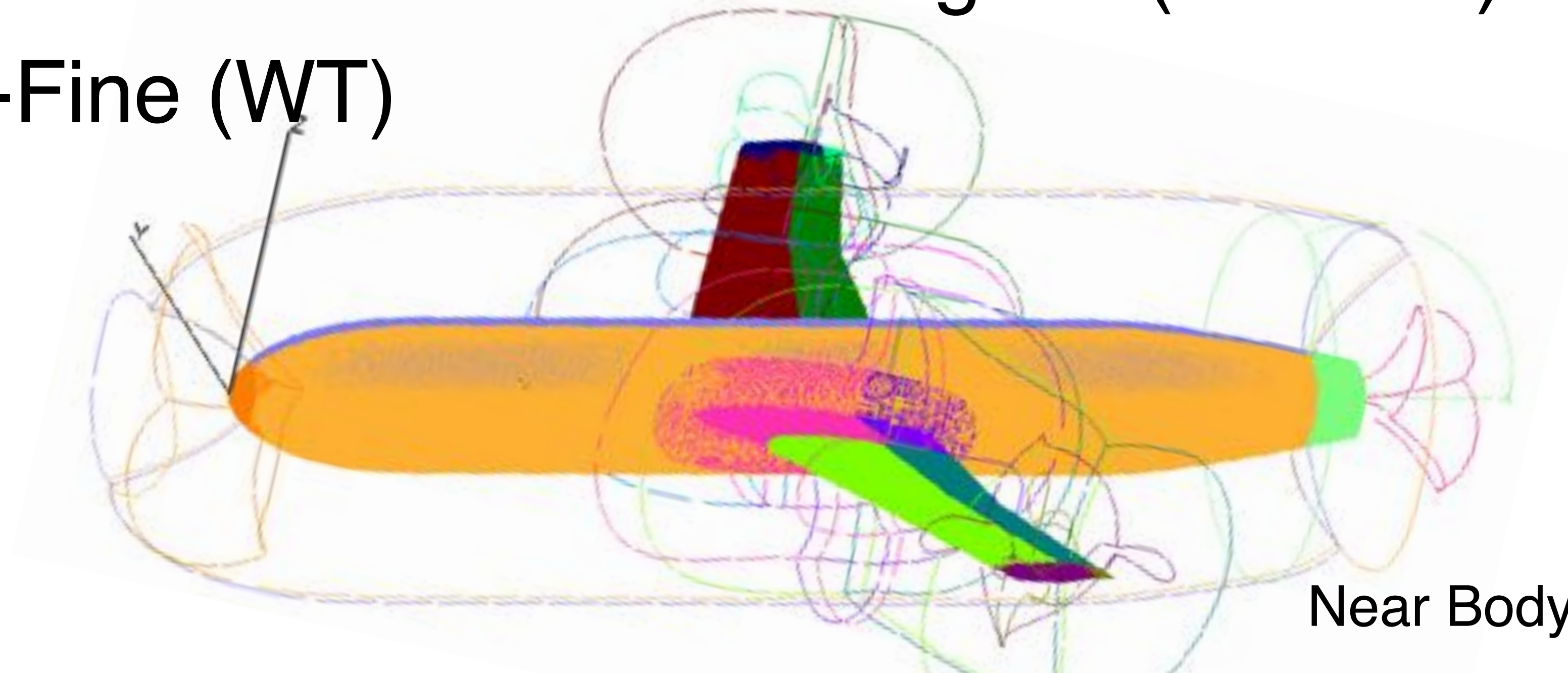
OVERFLOW Approach

- Similar data analysis to prior talk (Chris Rumsey & FUN3D)
- OVERFLOW CFD RANS current “state of the art” evaluation
 - Grid Resolution (in Free Air)
 - Wall Effect, Free Air vs WT walls
 - Turbulence Model (in Free Air)
- Data Comparisons
 - Separation Size
 - Wing Pressure (cuts)
 - Surface Streamlines
 - Velocity Profiles
 - Reynolds Stress Profiles



OVERFLOW Grids

- Structured overset grid system
 - Free Air: Curvilinear near-body, Cartesian off-body
 - WT: Curvilinear near-body, Curvilinear wind tunnel wall grids
- Grid family created using guidelines from DPW series
 - Coarse-Medium-Fine-Extra Fine grids (Free Air)
 - Medium-Fine (WT)



Near Body Grids

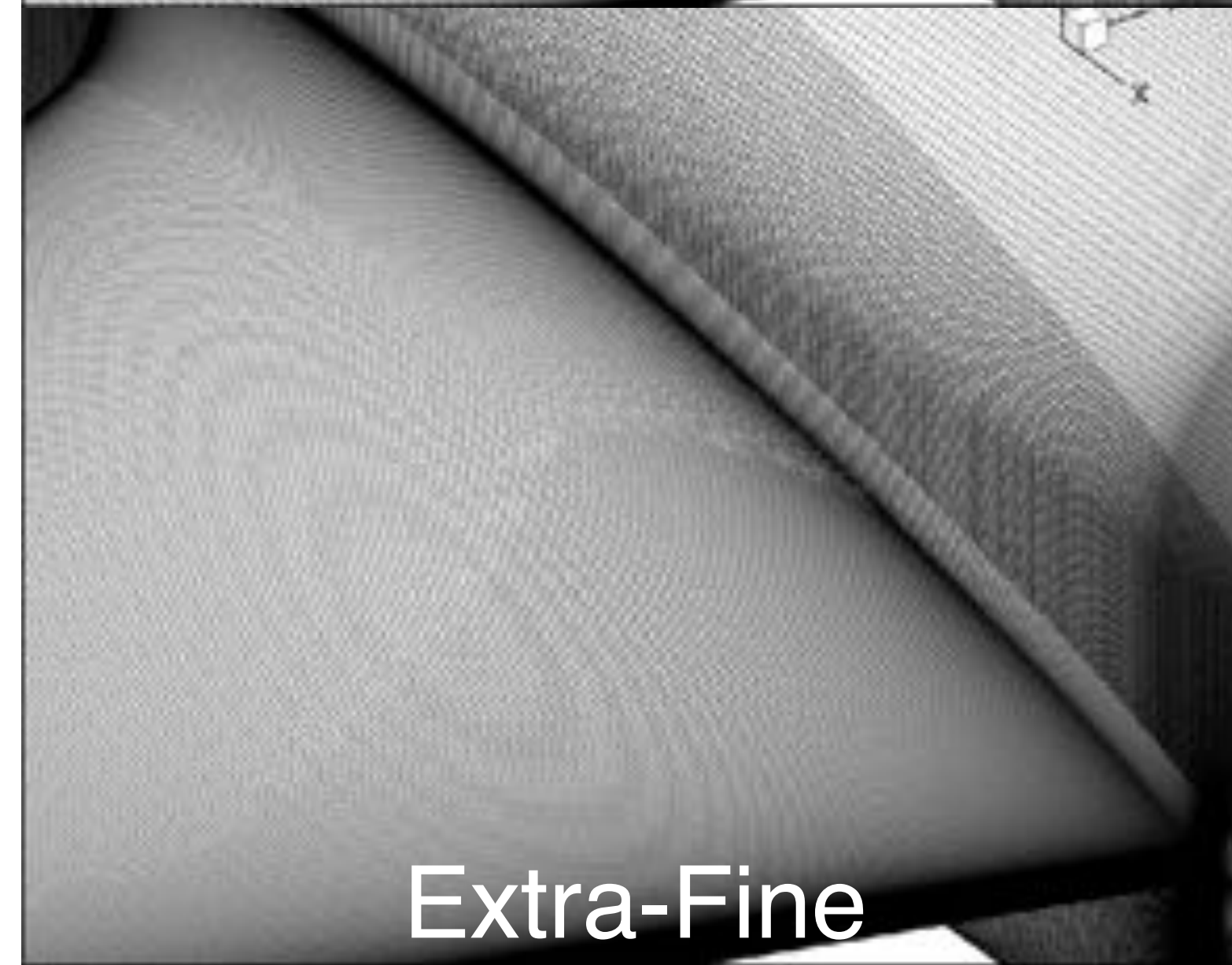
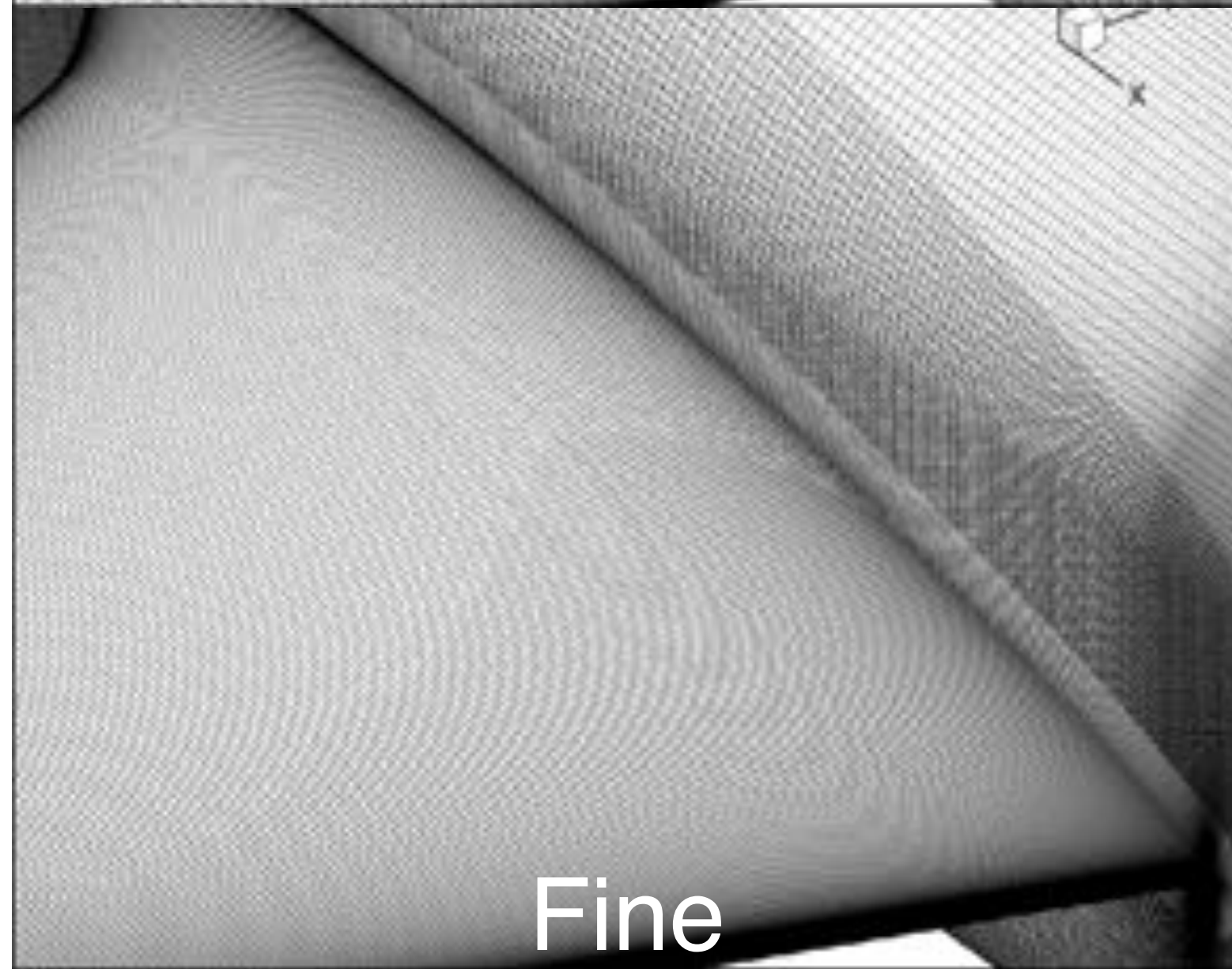
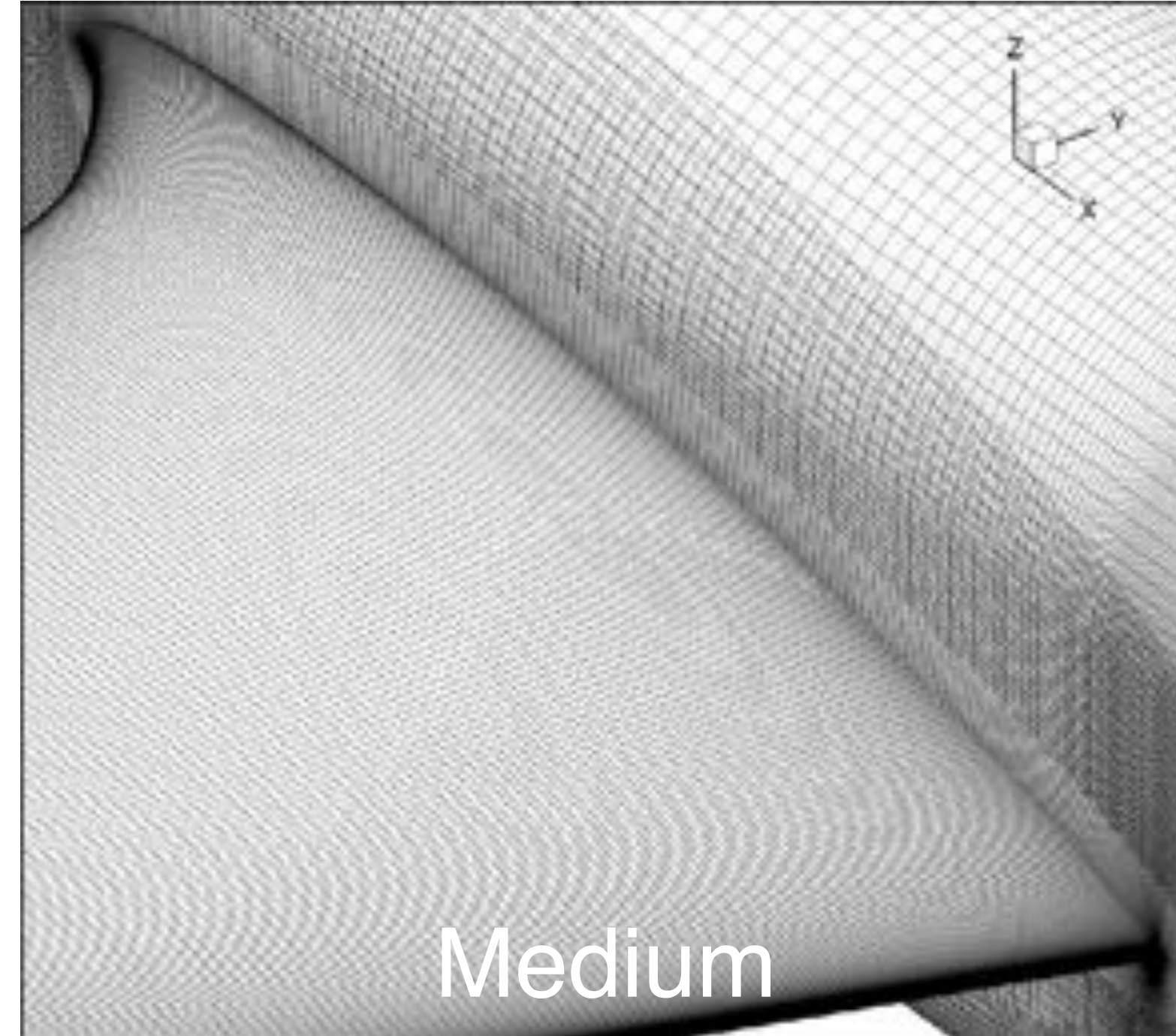
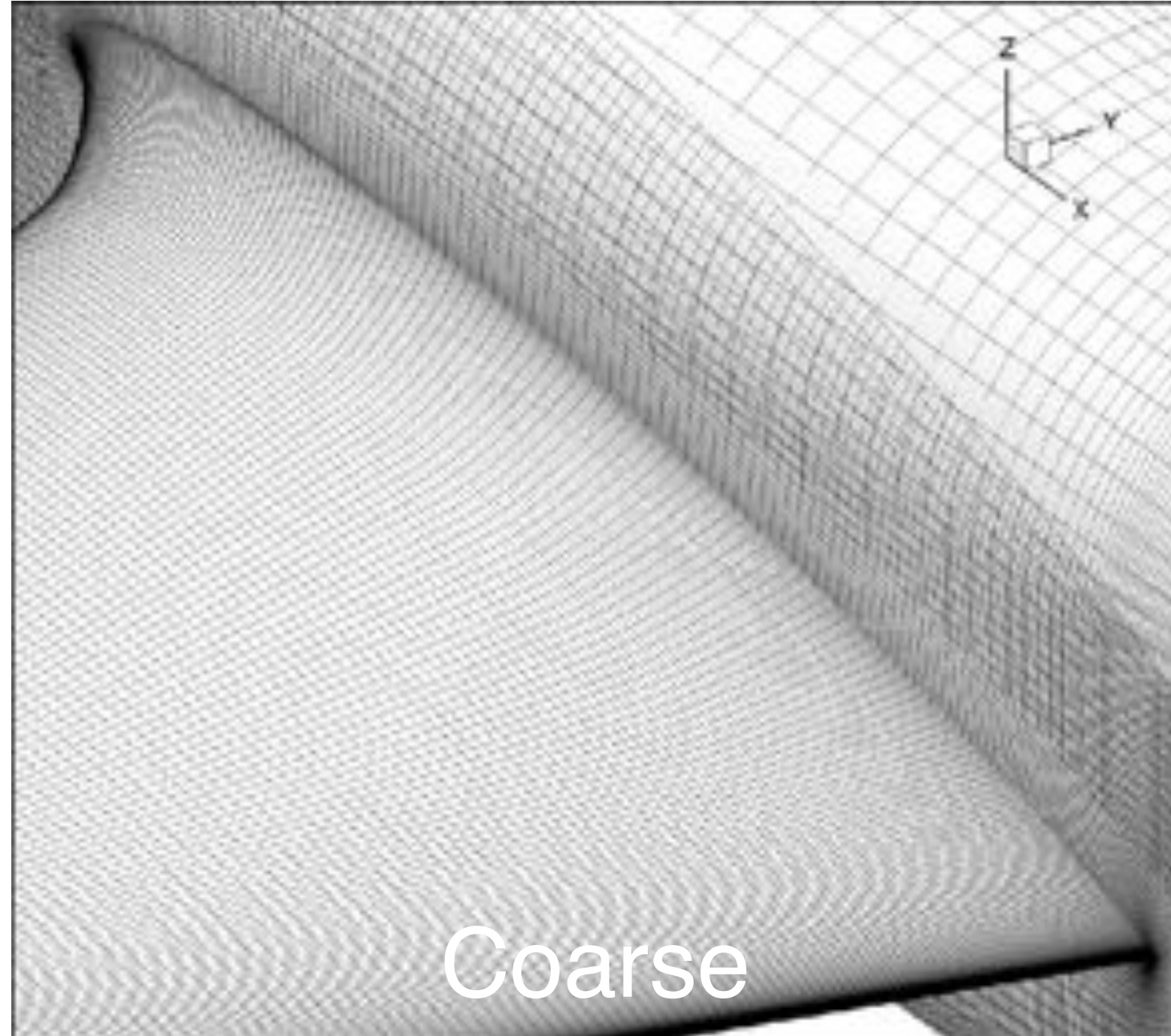
OVERFLOW Grid Parameters



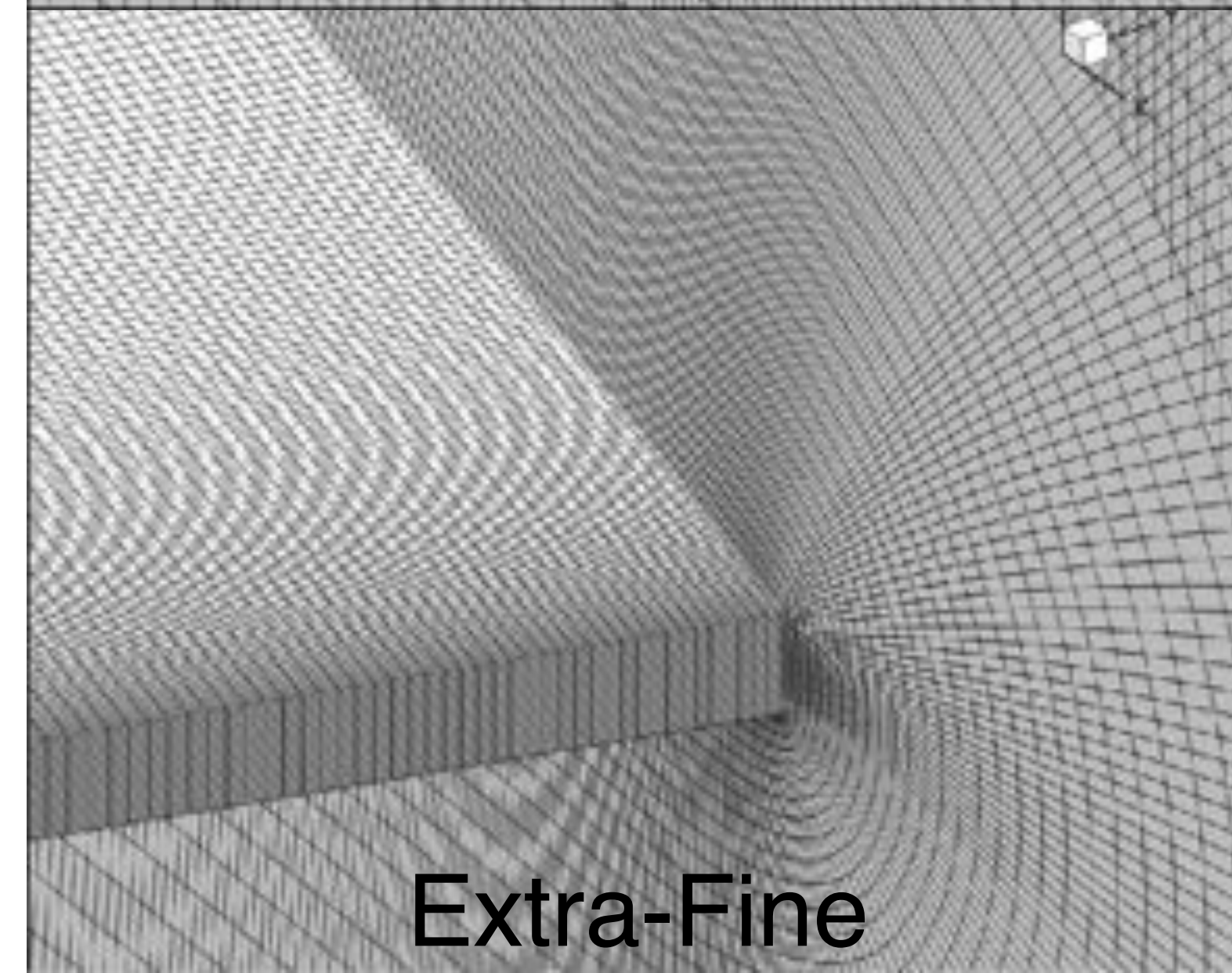
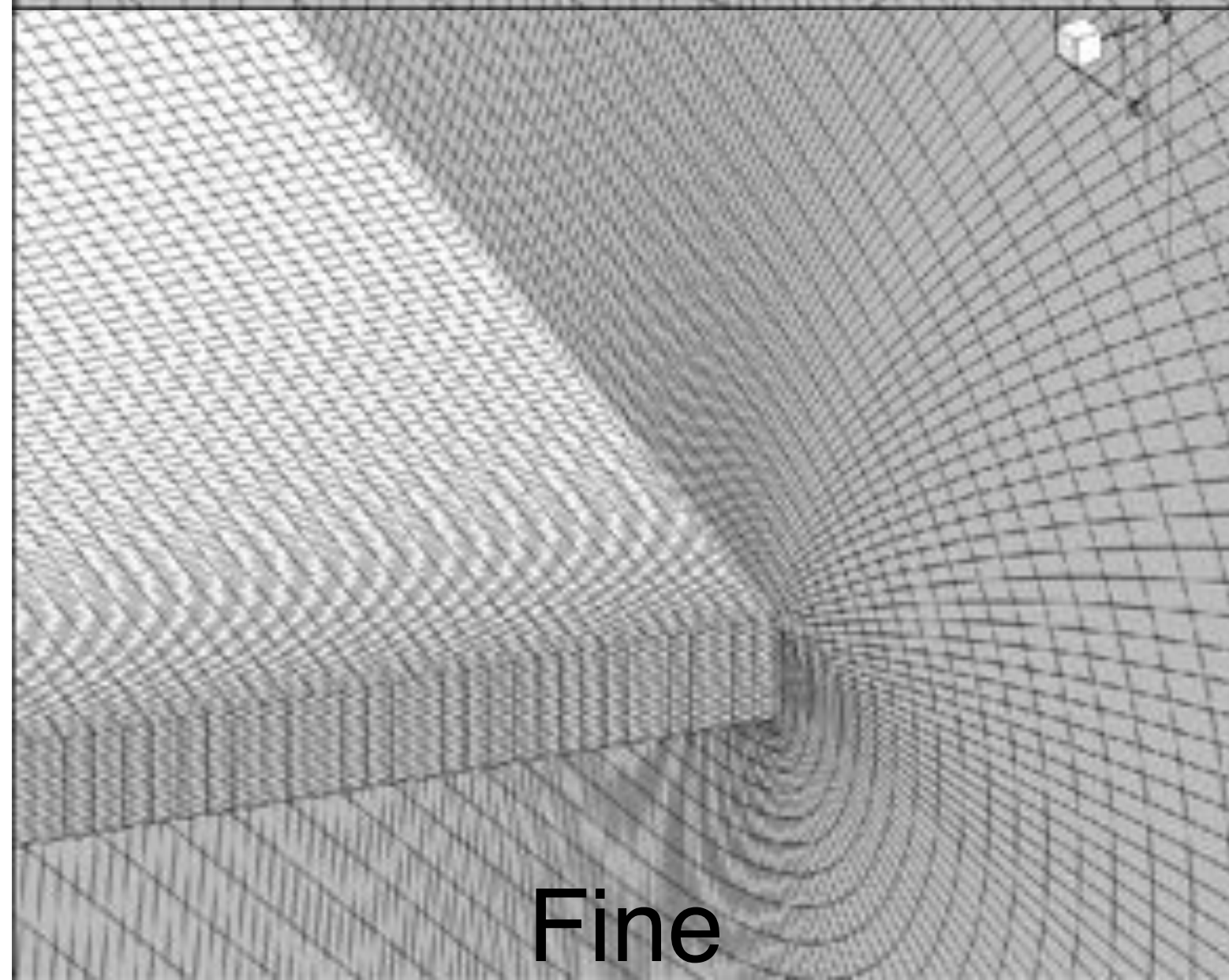
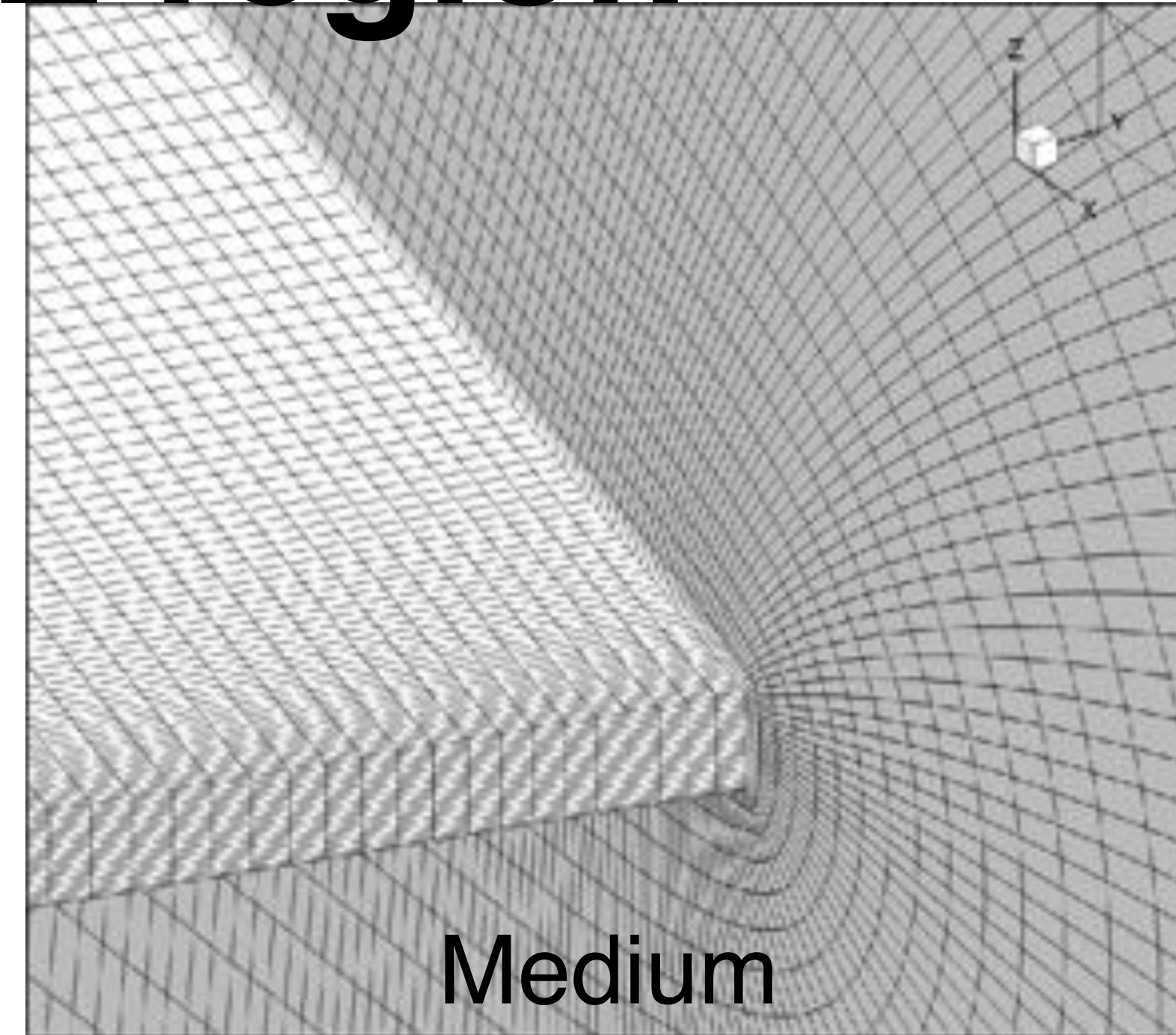
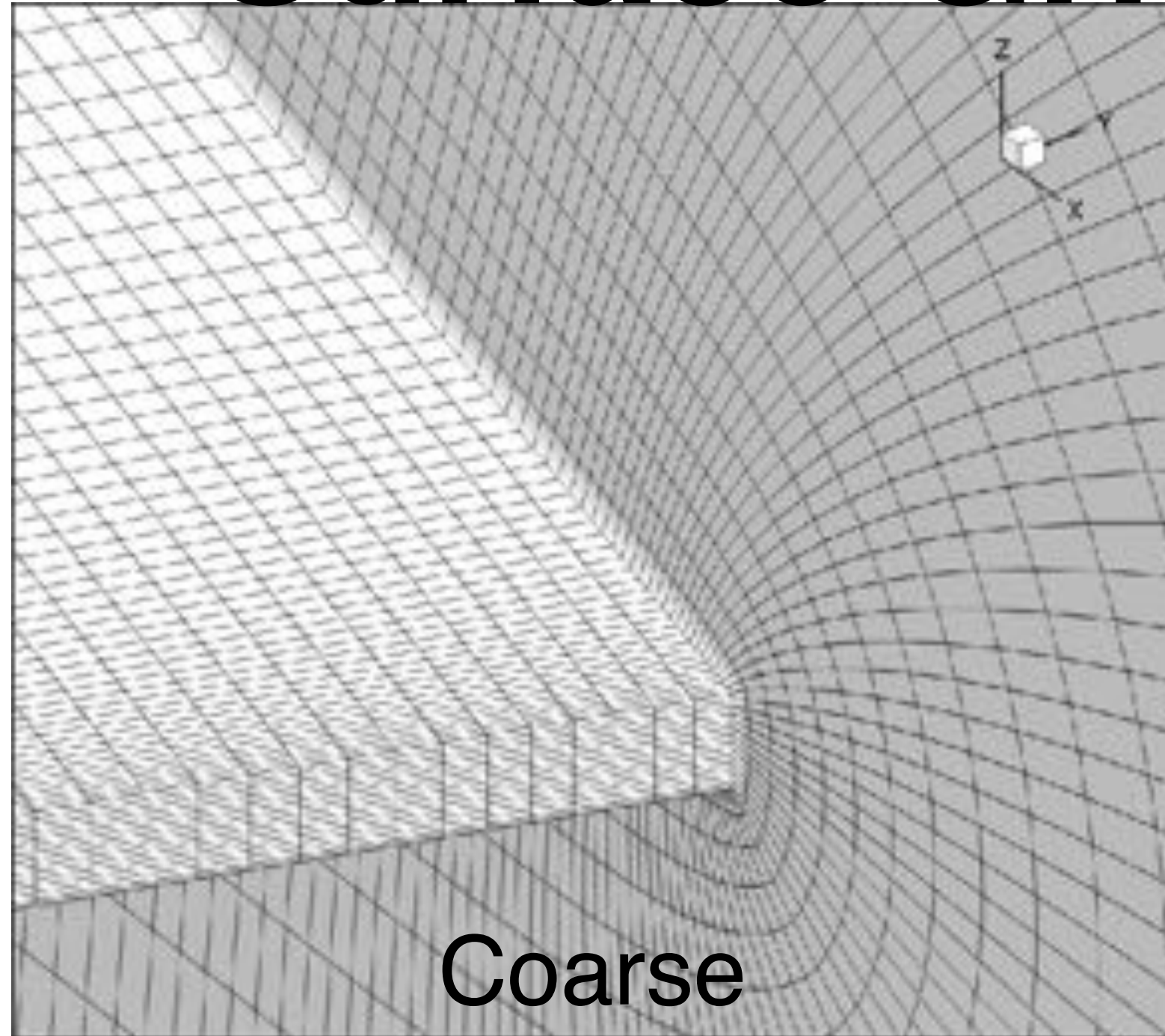
Same Near Body Grids

Configuration	Stretching Ratio	Near Body Grid Points	Total Grid Points
Free Air Coars		19.4M	21.4M
Free Air Medium	1.15	47.6M	48.7M
Free Air Fine	1.10	163.6M	165.7M
Free Air Extra-Fine	1.08	382.1M	398.4M
Wind Tunnel Medium	1.15	47.6M	92.6M
Wind Tunnel Fine	1.10	163.6M	325.5M

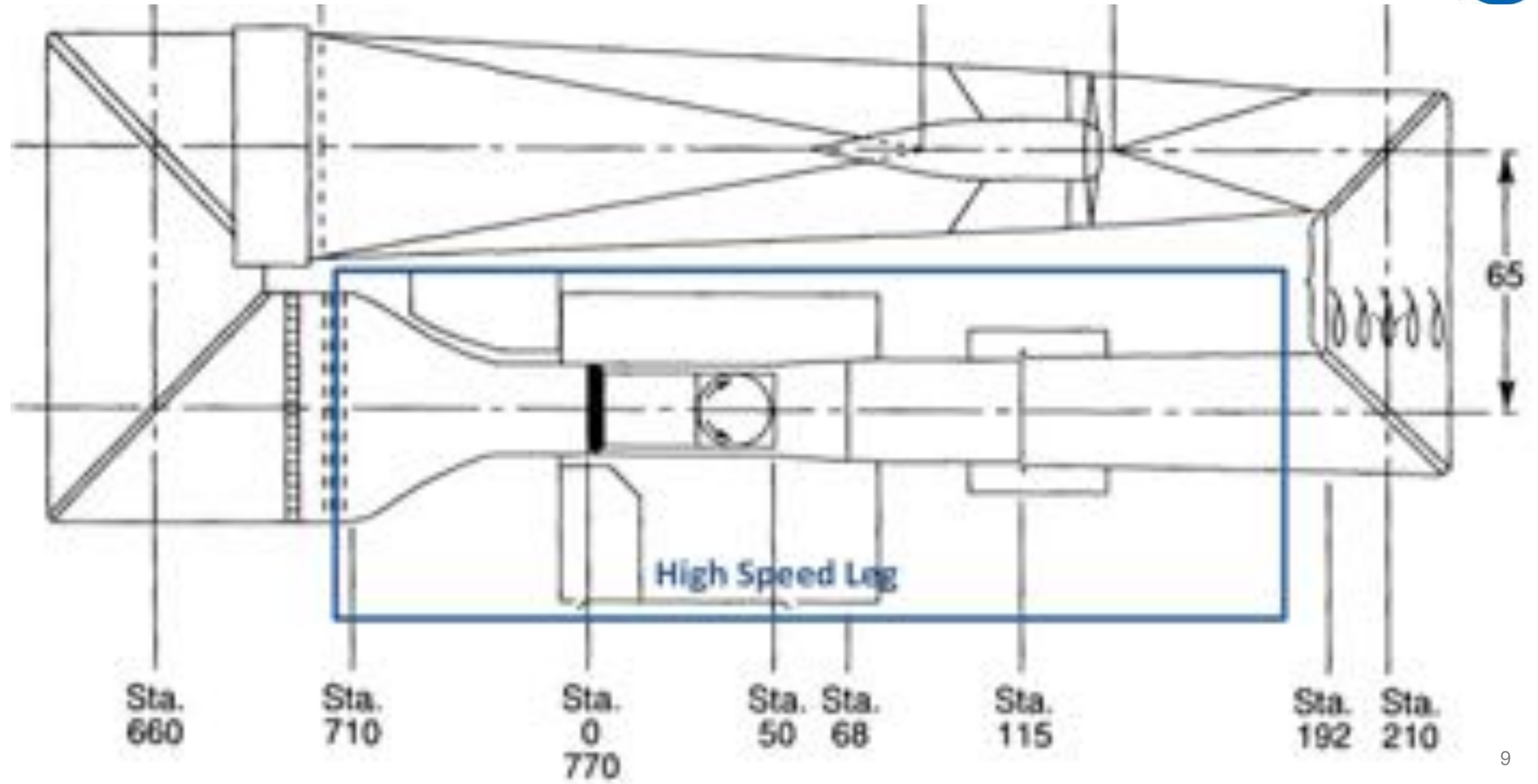
Surface Grid



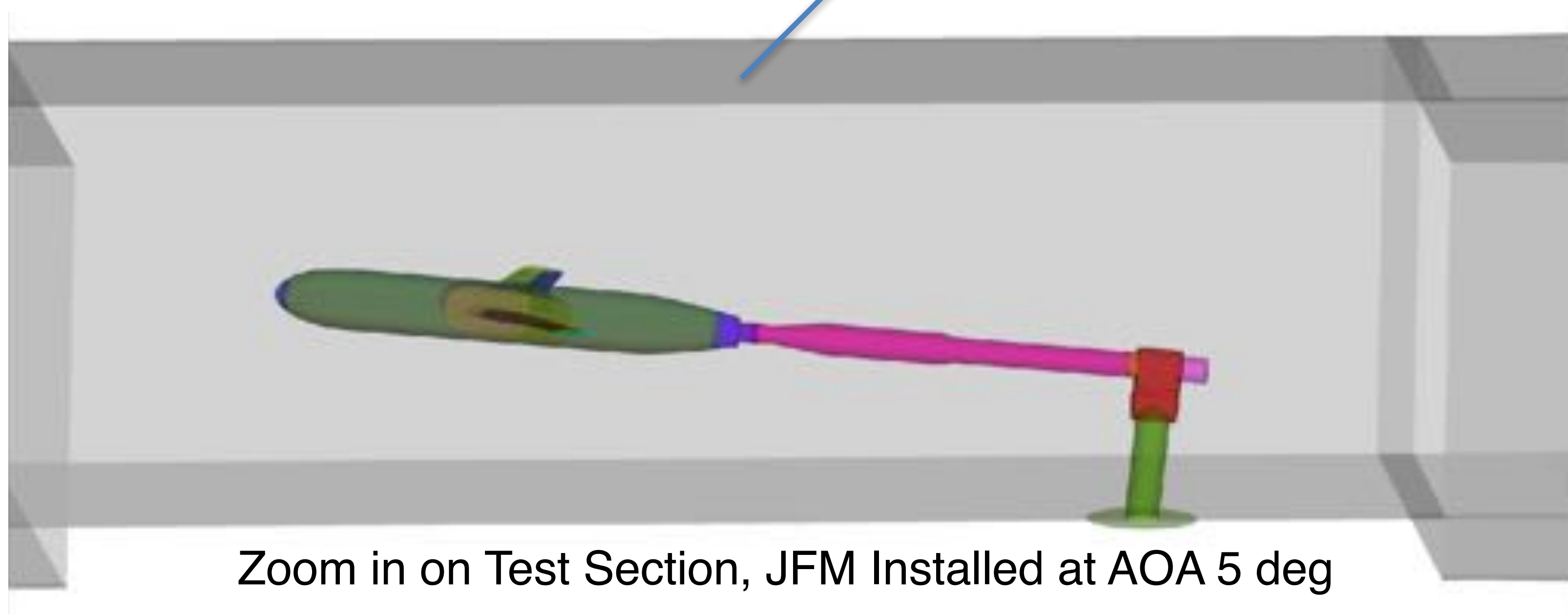
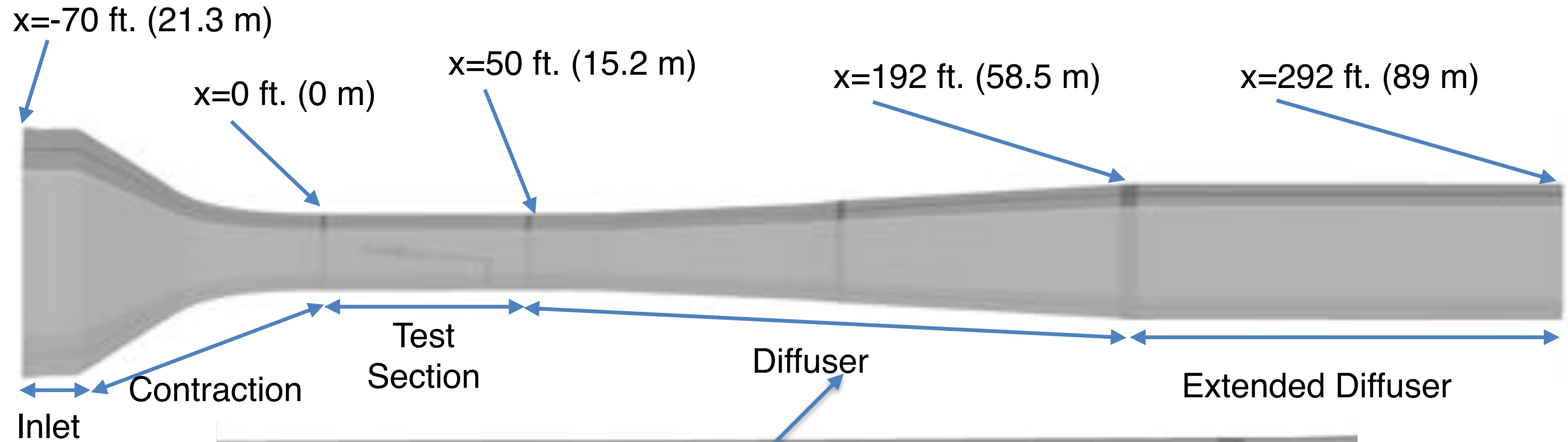
Surface Grid, TE region



Langley 14- by 22-Ft. Subsonic Tunnel (14x22)



CFD 14x22 Wind Tunnel



CFD 14x22 Wind Tunnel Setup



Impose Stagnation conditions
Pressure & Temperature

Blue Regions, Inviscid Wall BC
Grey Regions, Viscous Wall BC



Walls Treatment:

- Inviscid Inlet + Inviscid Diffuser Extension
- Viscous everywhere else

Tunnel speed:

- Uses total pressure & static pressure “probe” values from their locations
- Calibrated equations -> tunnel speed
- Ref: Lee, et.al. STO-MP-AVT-284-02

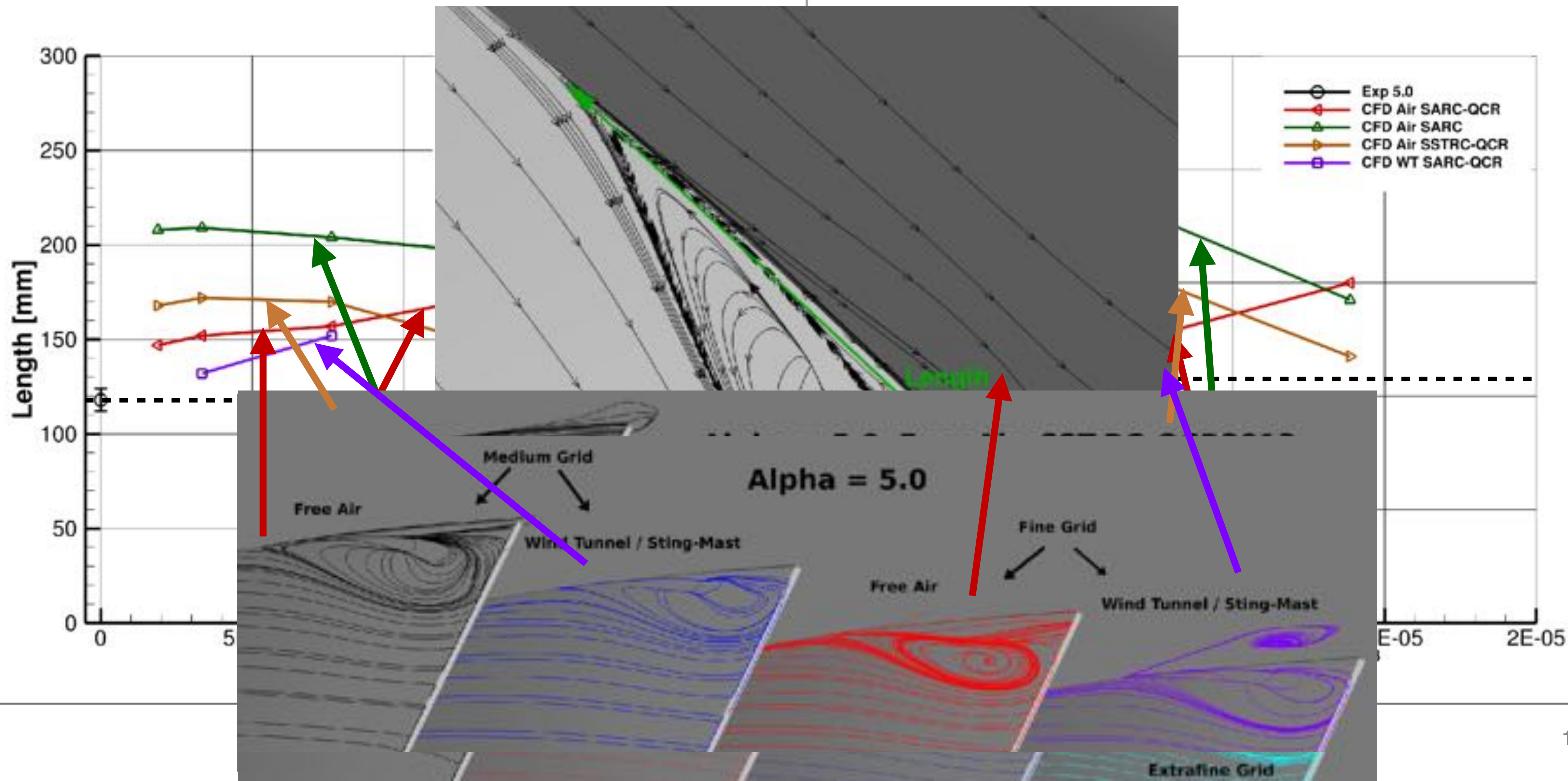
Iterate Back Pressure
ratio to match tunnel speed

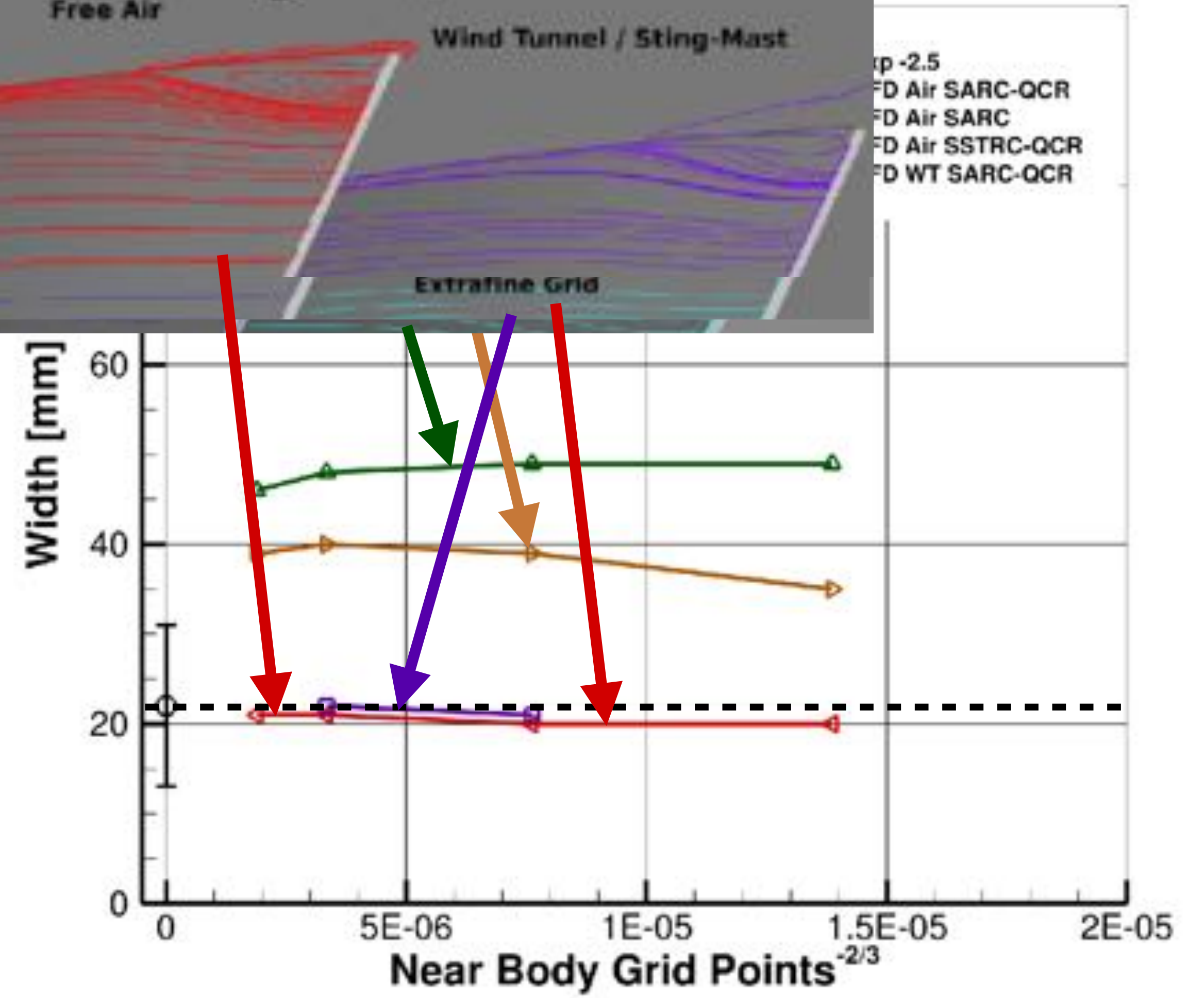
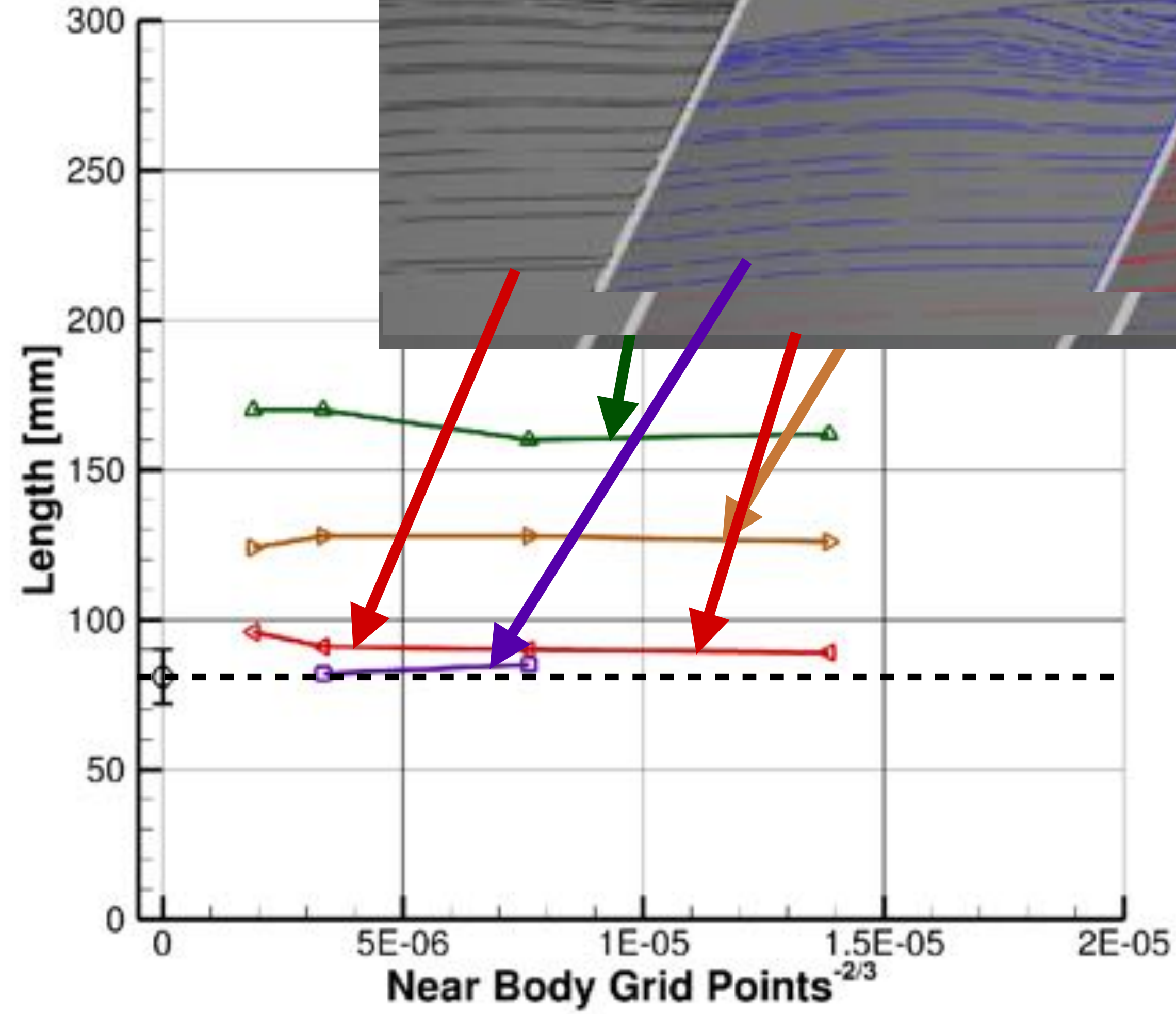
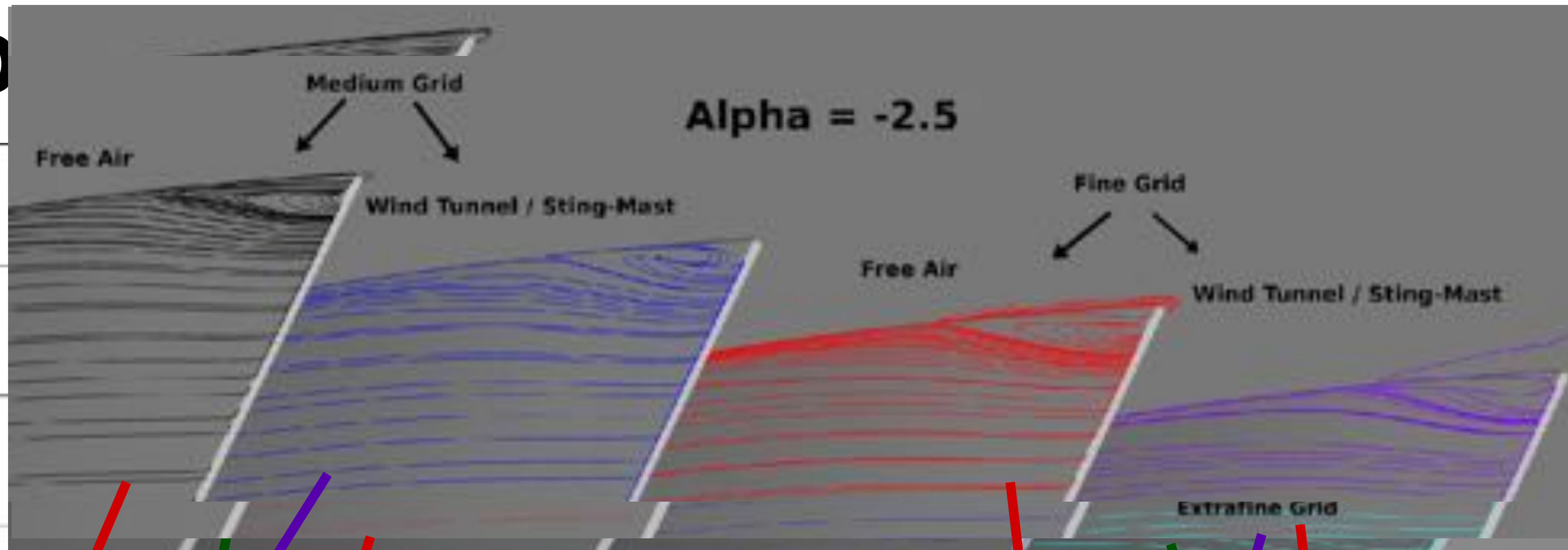


Overflow Run Parameters

- OVERFLOW 2.2n
- 3rd-Order Roe upwind RHS
- ARC3D scalar pentadiagonal LHS
- Low-Mach preconditioning (in CFD WT)
- Fully Turbulent, Steady State
- RE = 2.4 Million based on crank chord
- Mach= 0.189, T= 519 Rankine (288.8 Kelvin) (median of run conditions)
- Turbulence Models:
 - SA-Noft2-RC-QCR2013 (SARC-QCR)
 - SA-Noft2-RC (SARC)
 - SST-RC-QCR2013 (SSTRC-QCR)

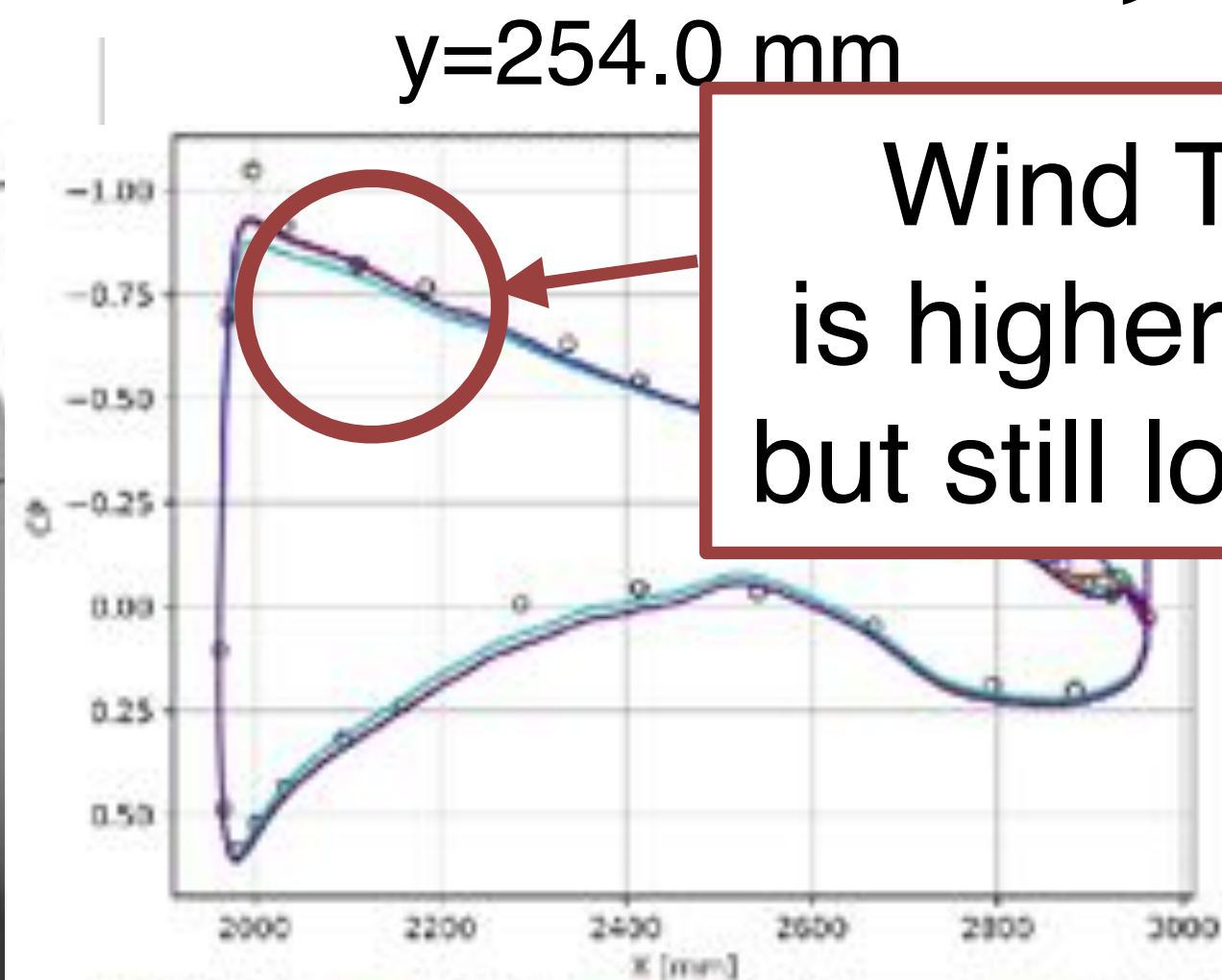
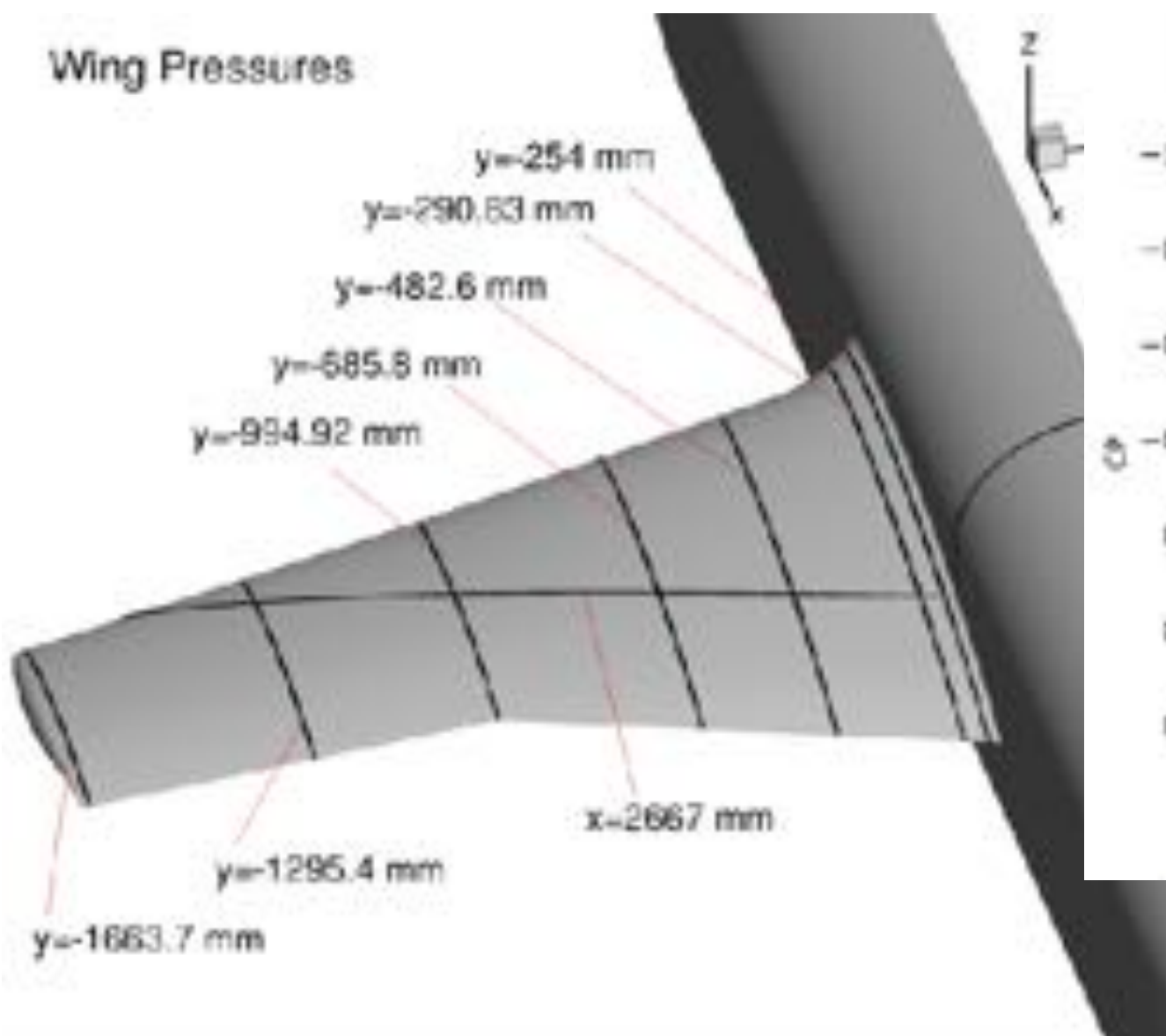
Side of Body Separation $\text{AOA} = 5.0$ deg



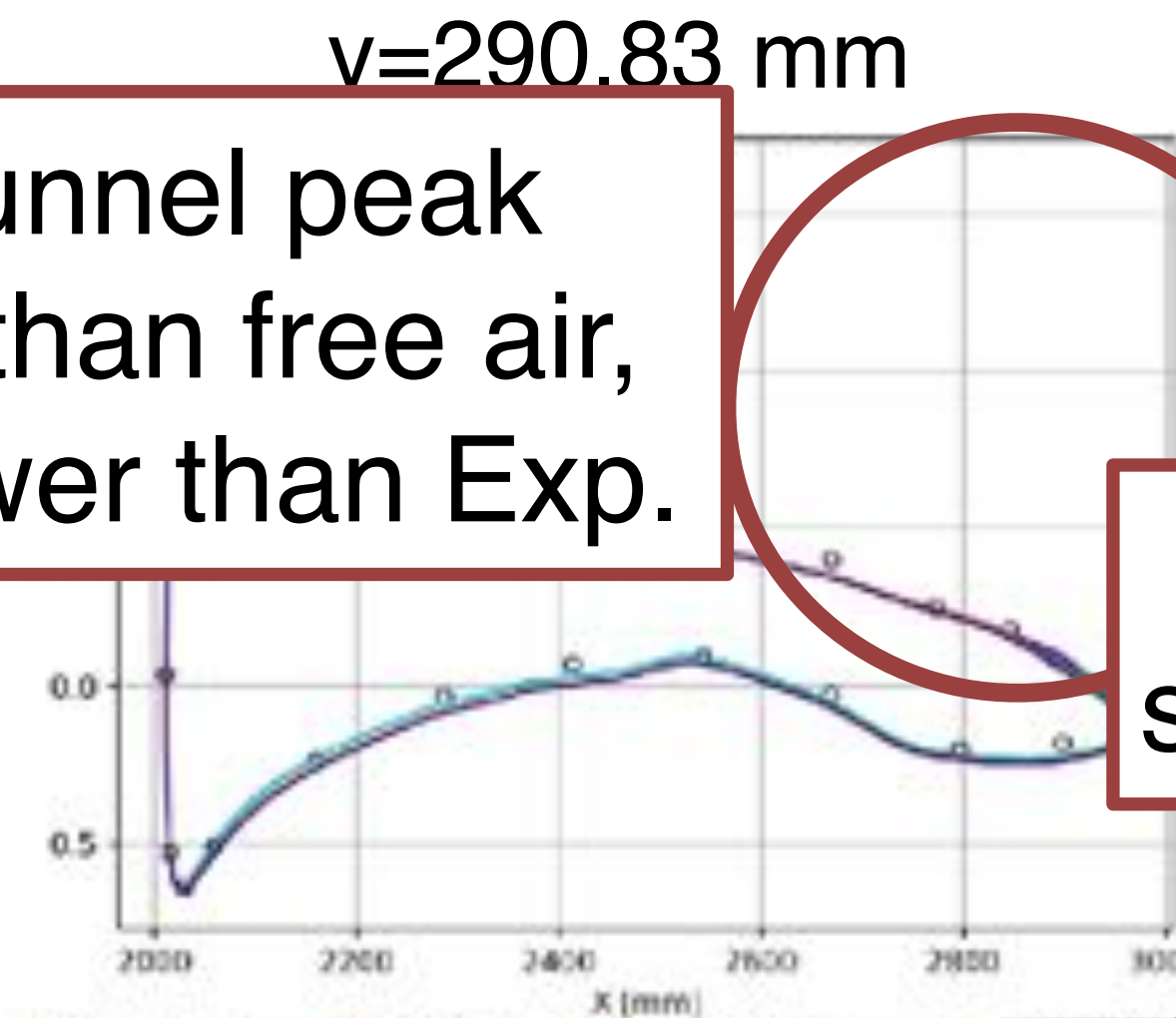


Alpha = -2.5
FD Air SARC-QCR
FD Air SARC
FD Air SSTRC-QCR
FD WT SARC-QCR

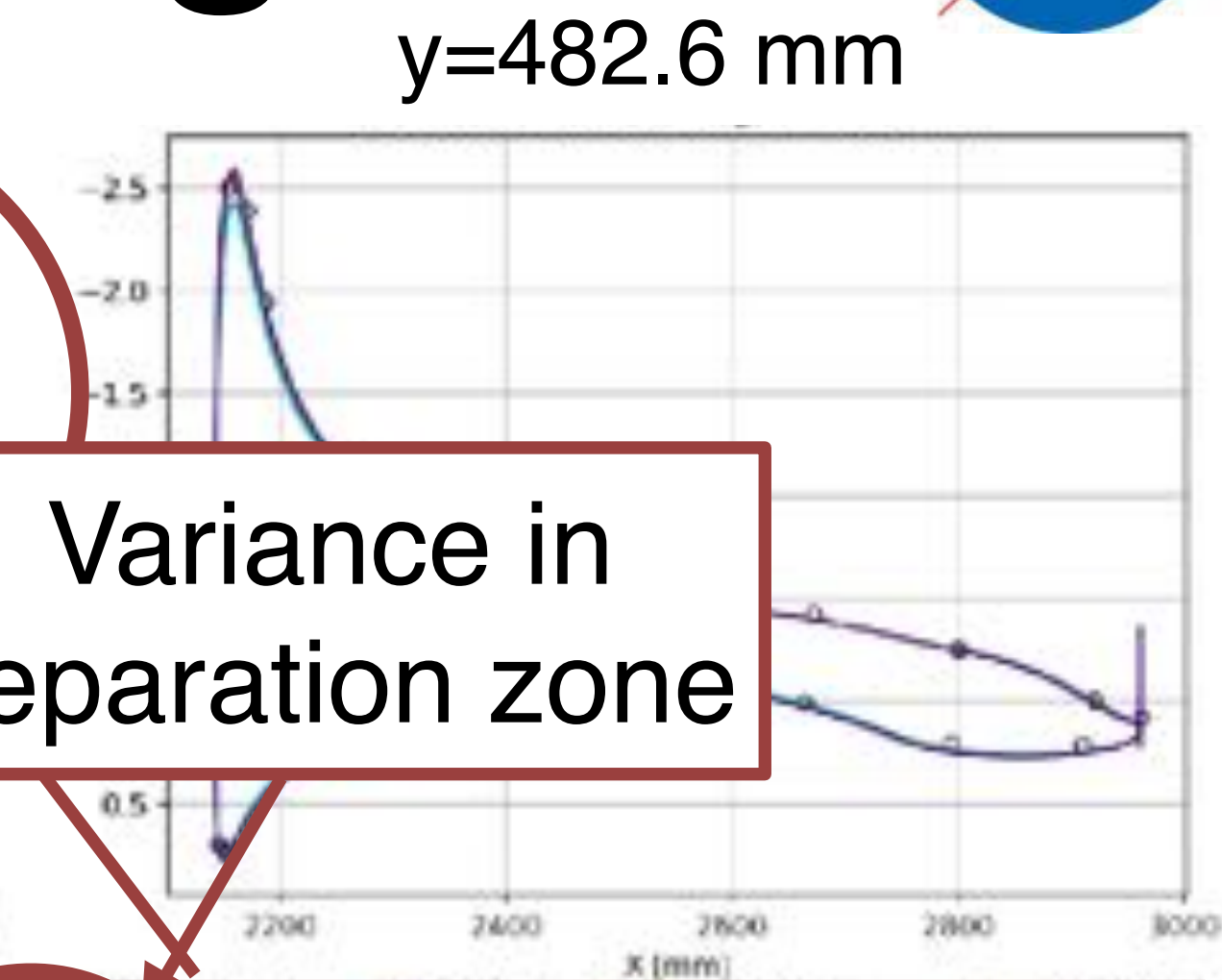
Wing Pressures, AOA = 5.0 deg



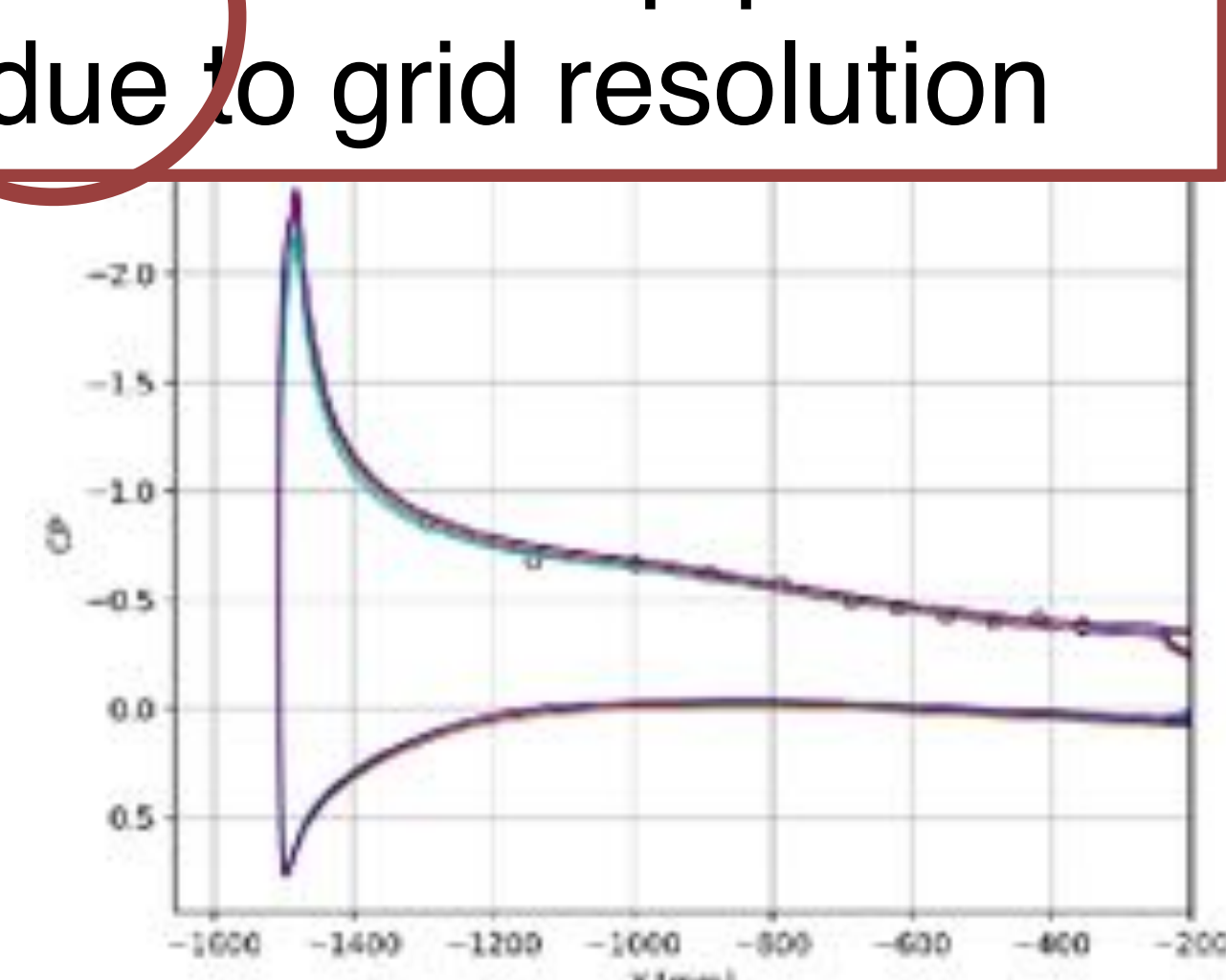
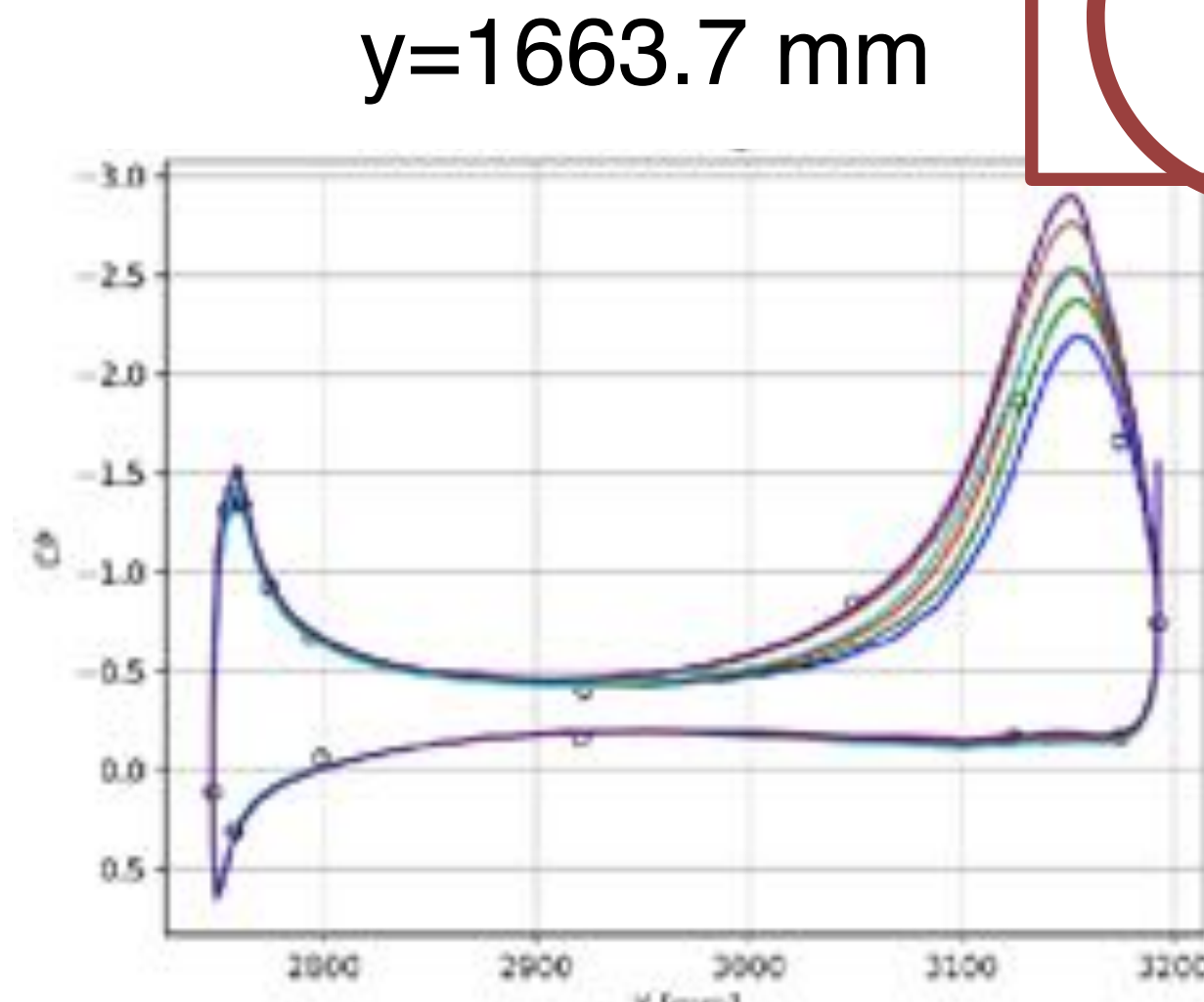
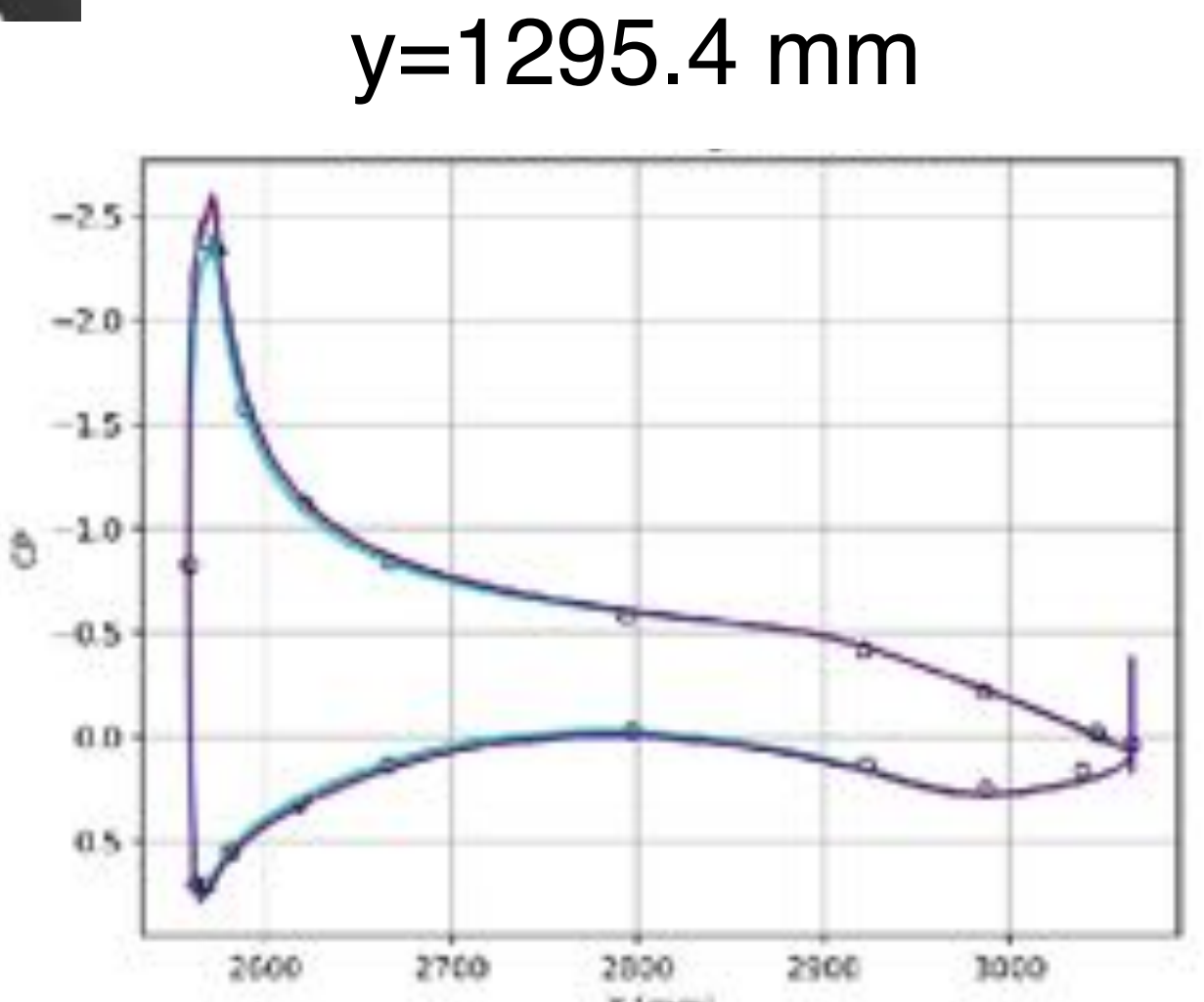
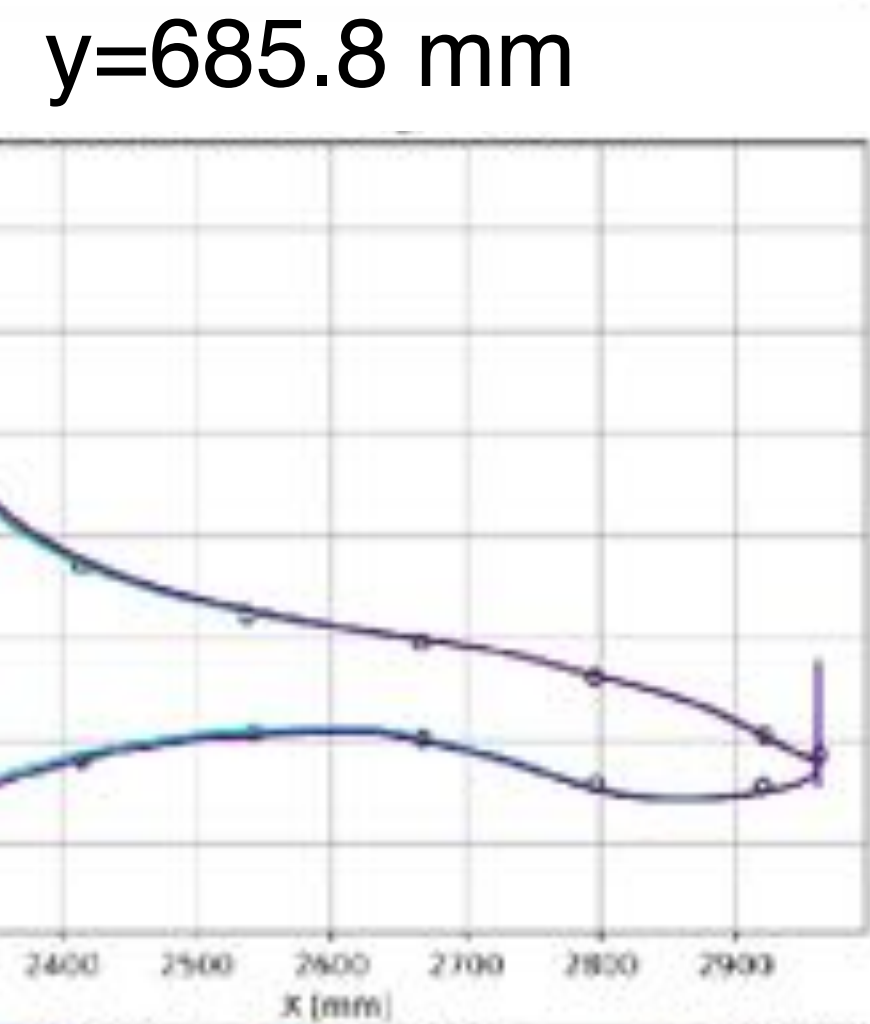
Wind Tunnel peak is higher than free air, but still lower than Exp.



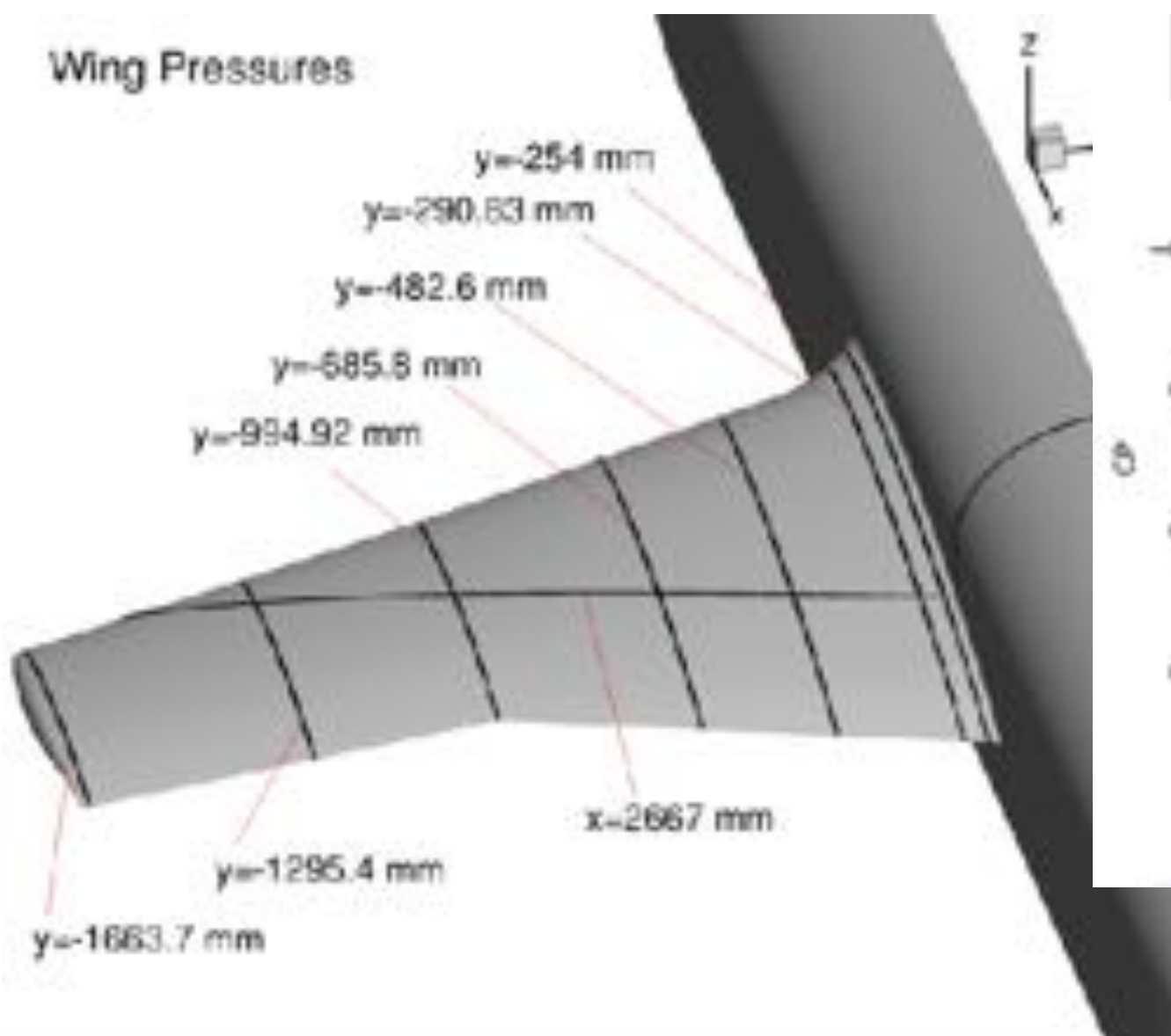
Variance in separation zone



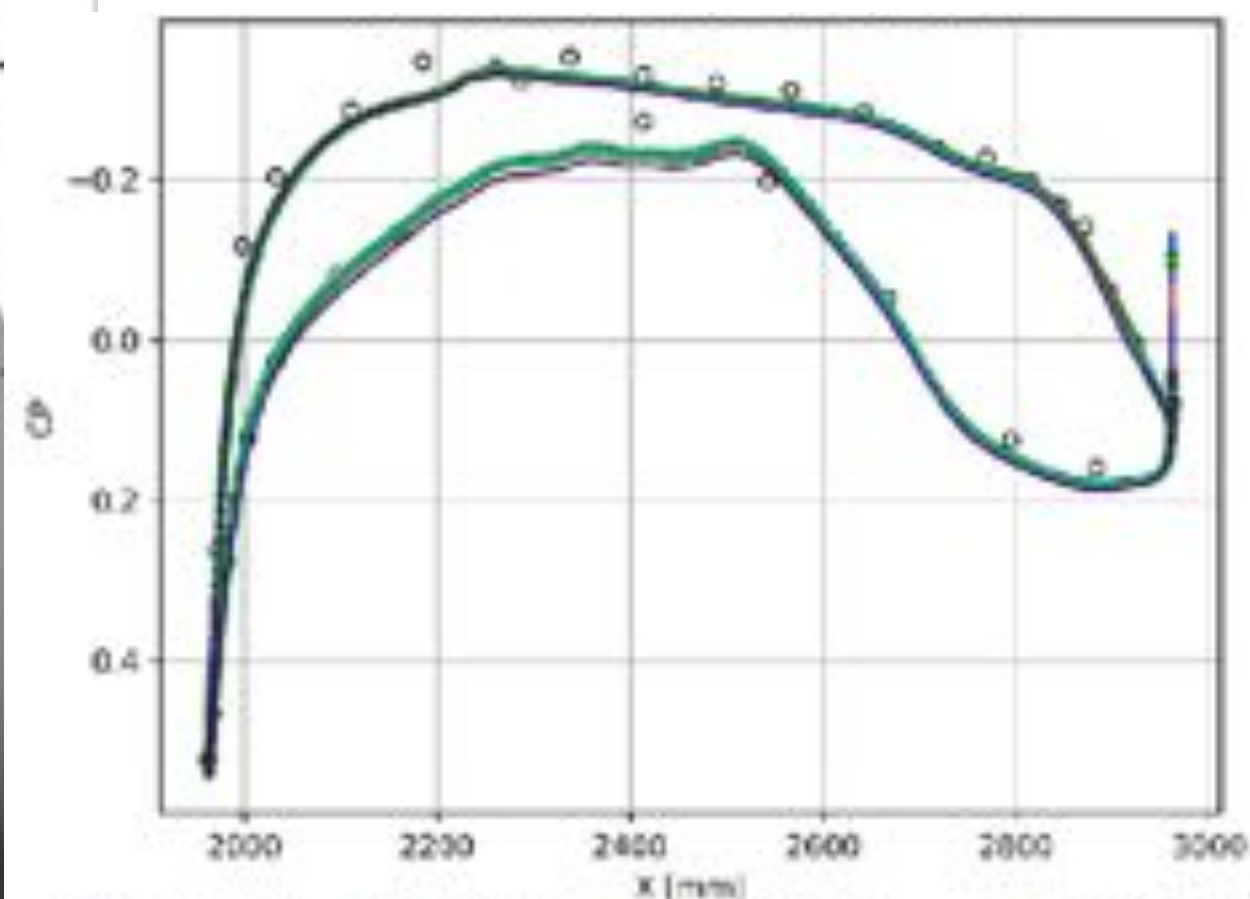
Differences in tip pressure due to grid resolution



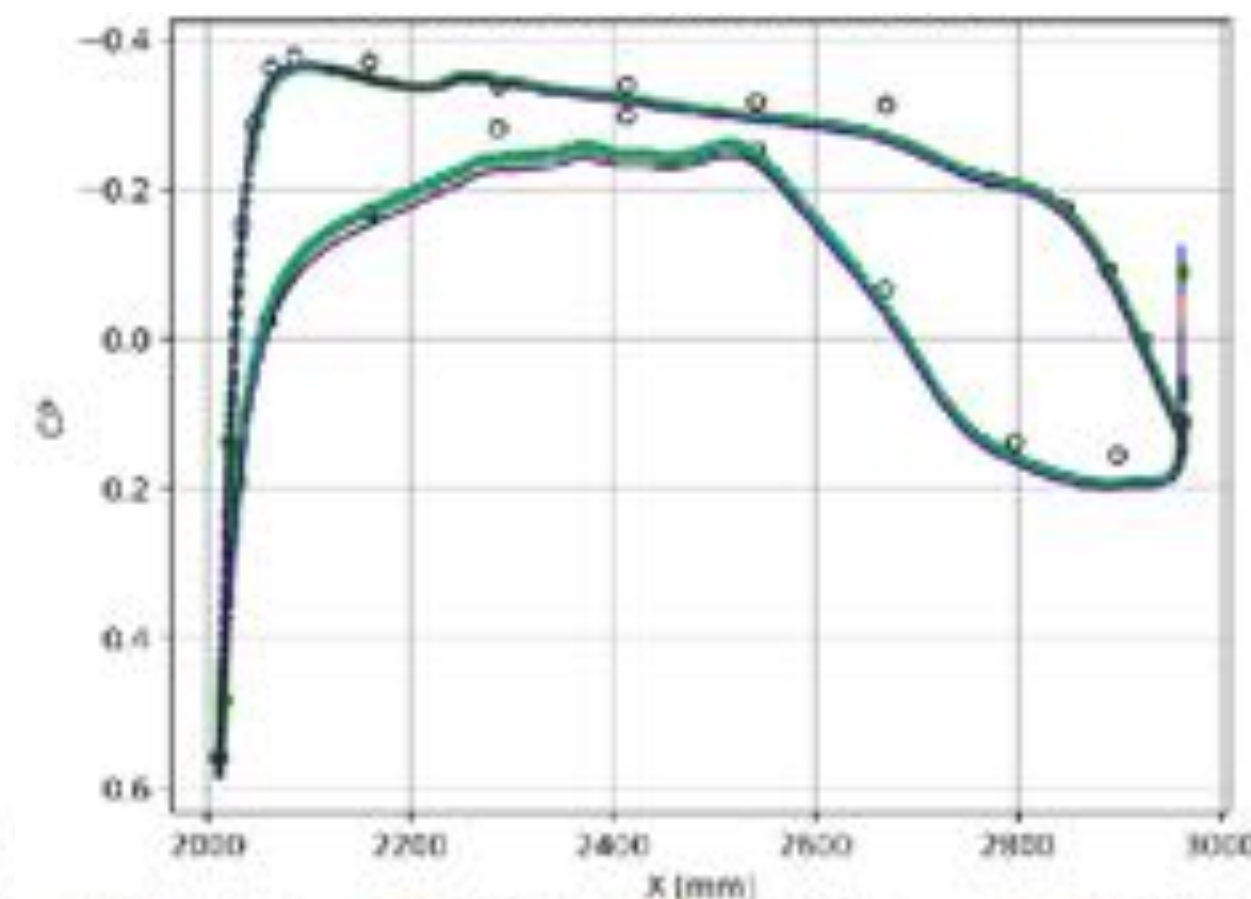
Wing Pressures, AOA = -2.5 deg



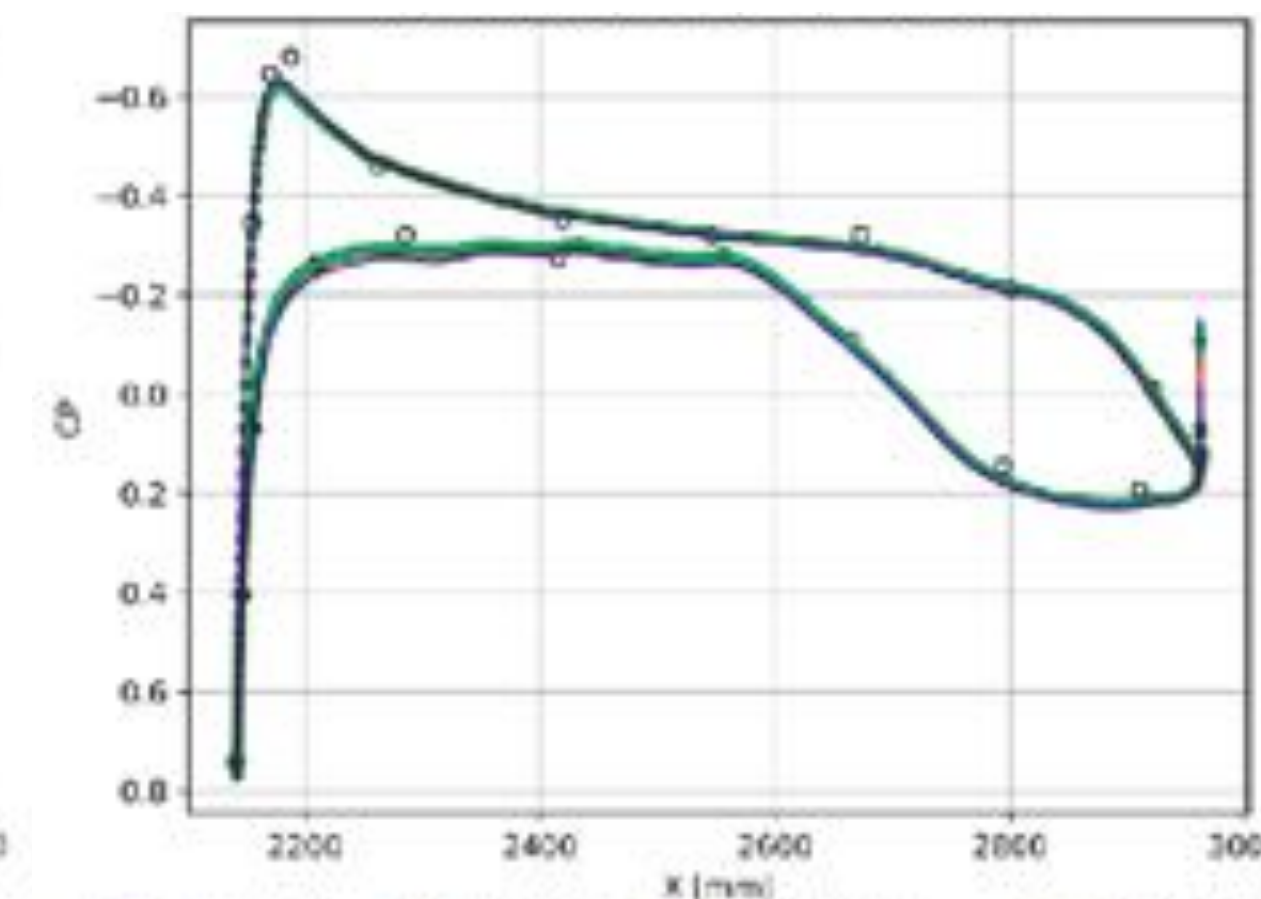
y=254.0 mm



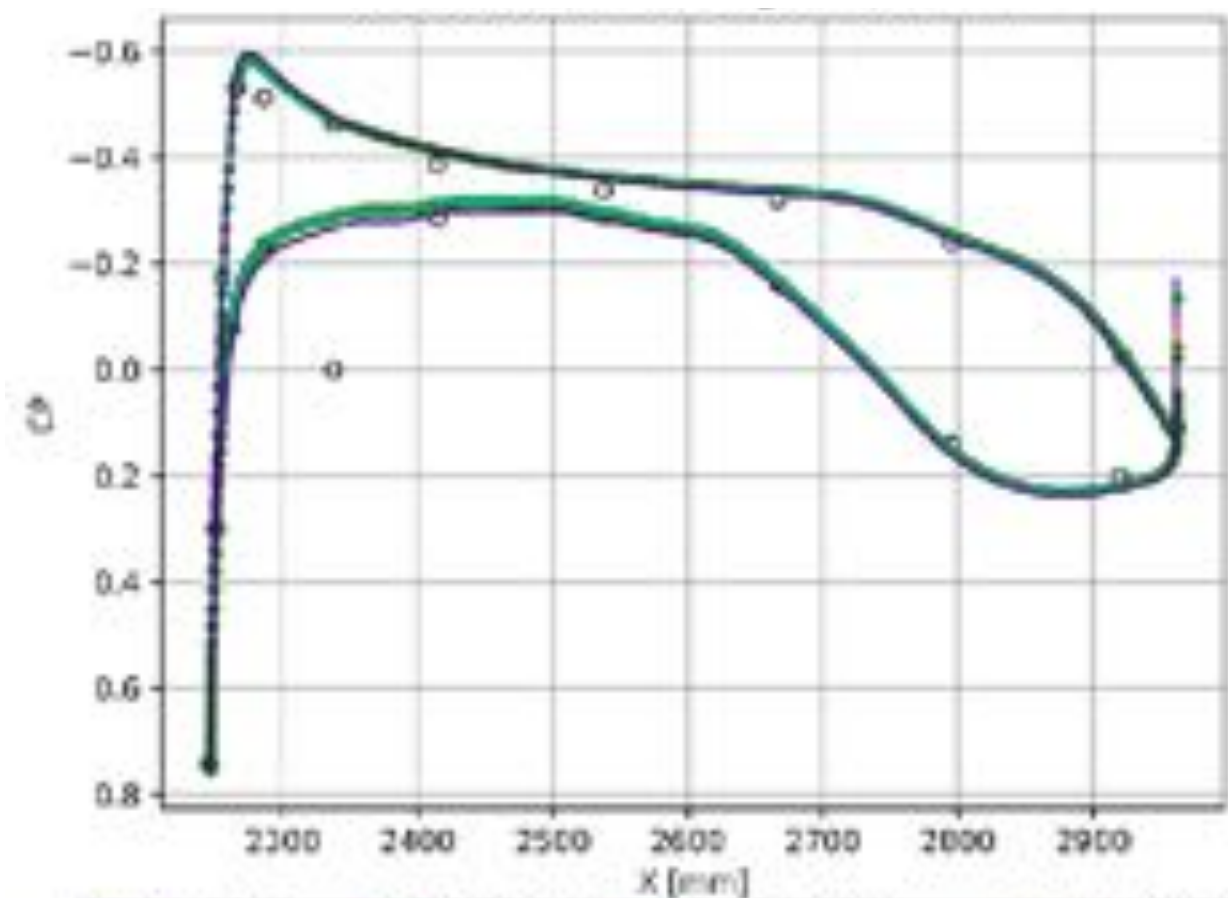
y=290.83 mm



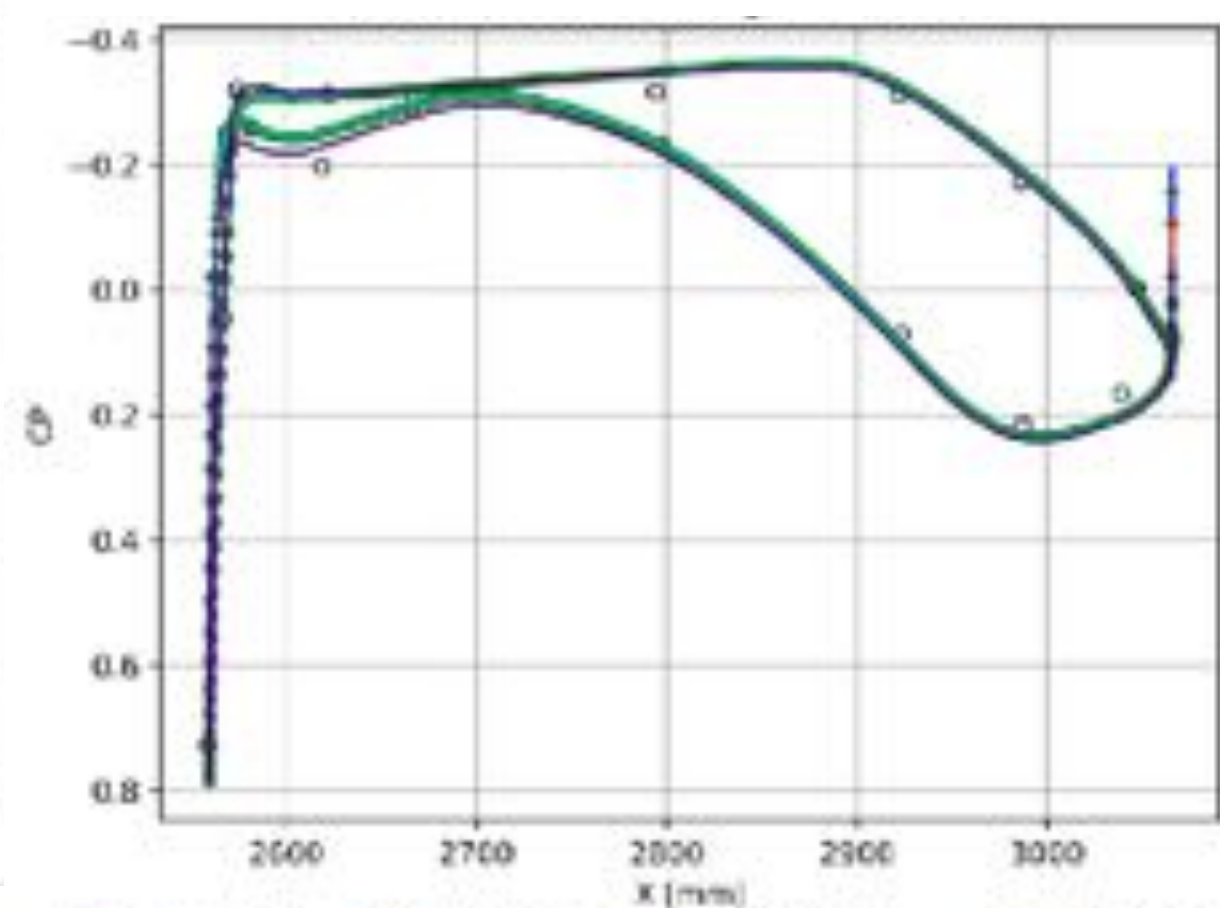
y=482.6 mm



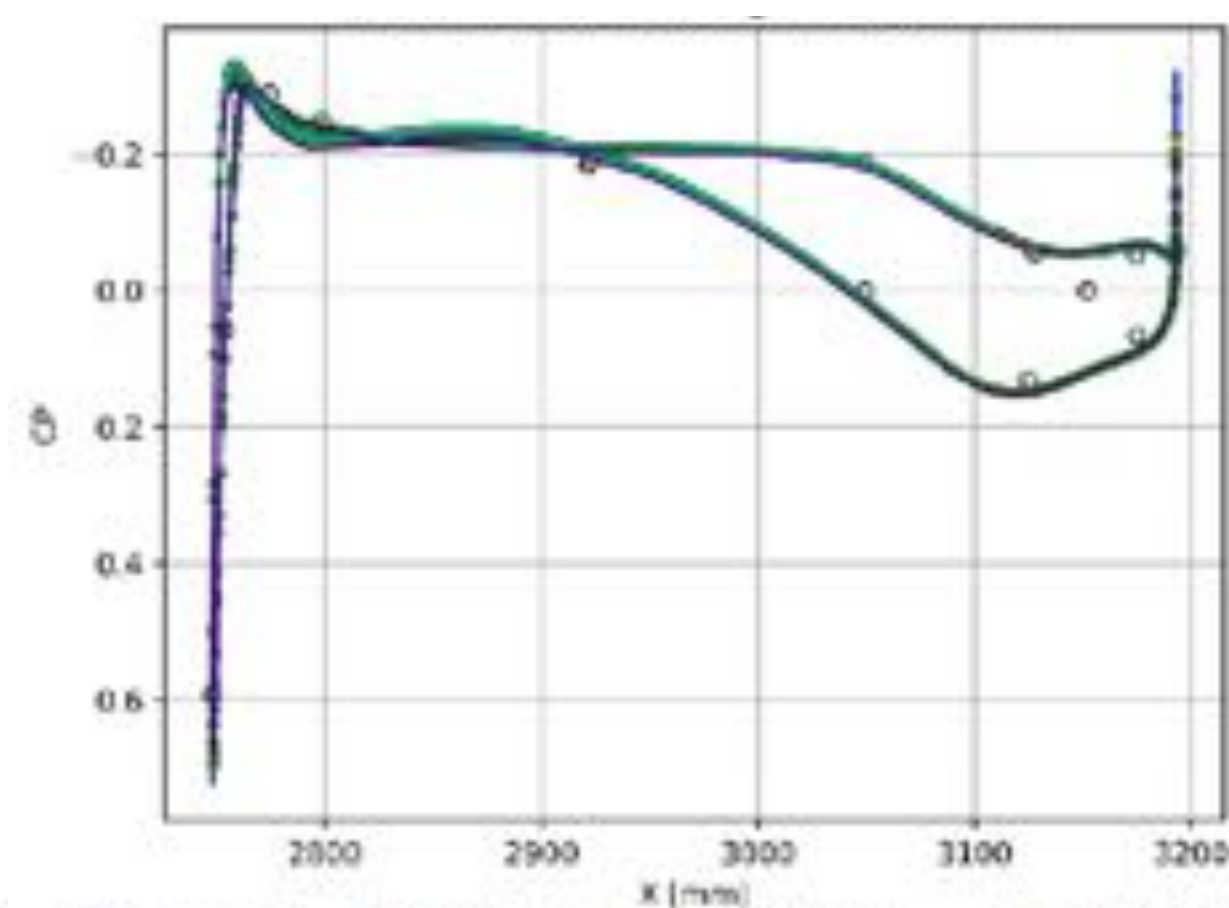
y=685.8 mm



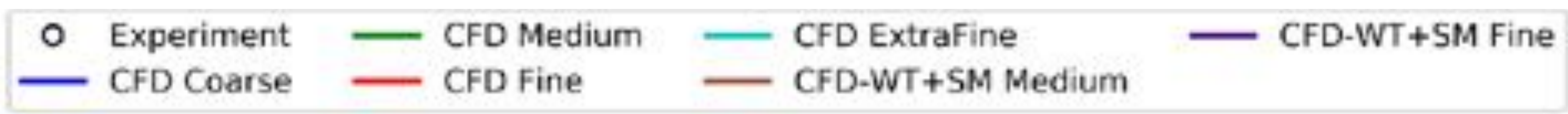
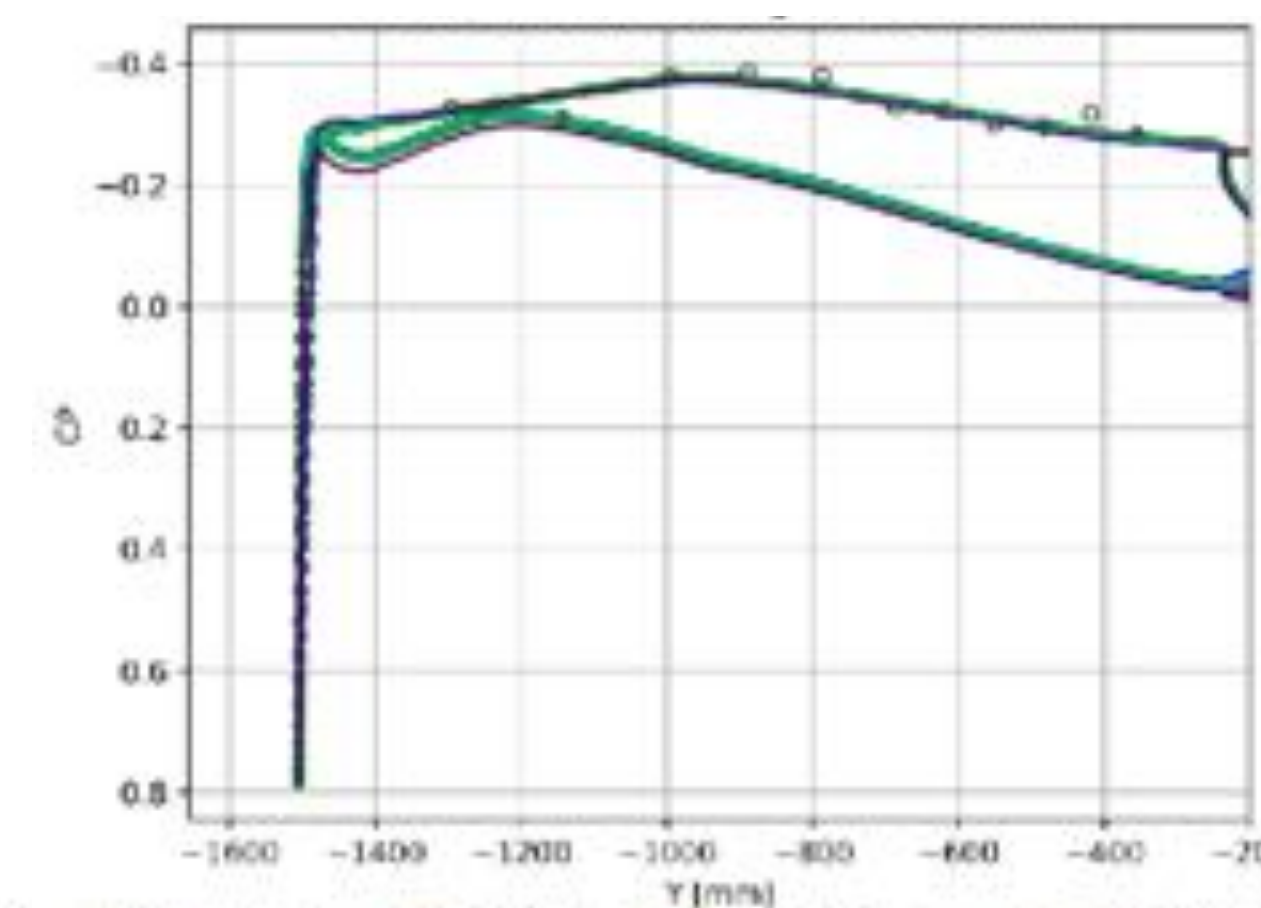
y=1295.4 mm



y=1663.7 mm



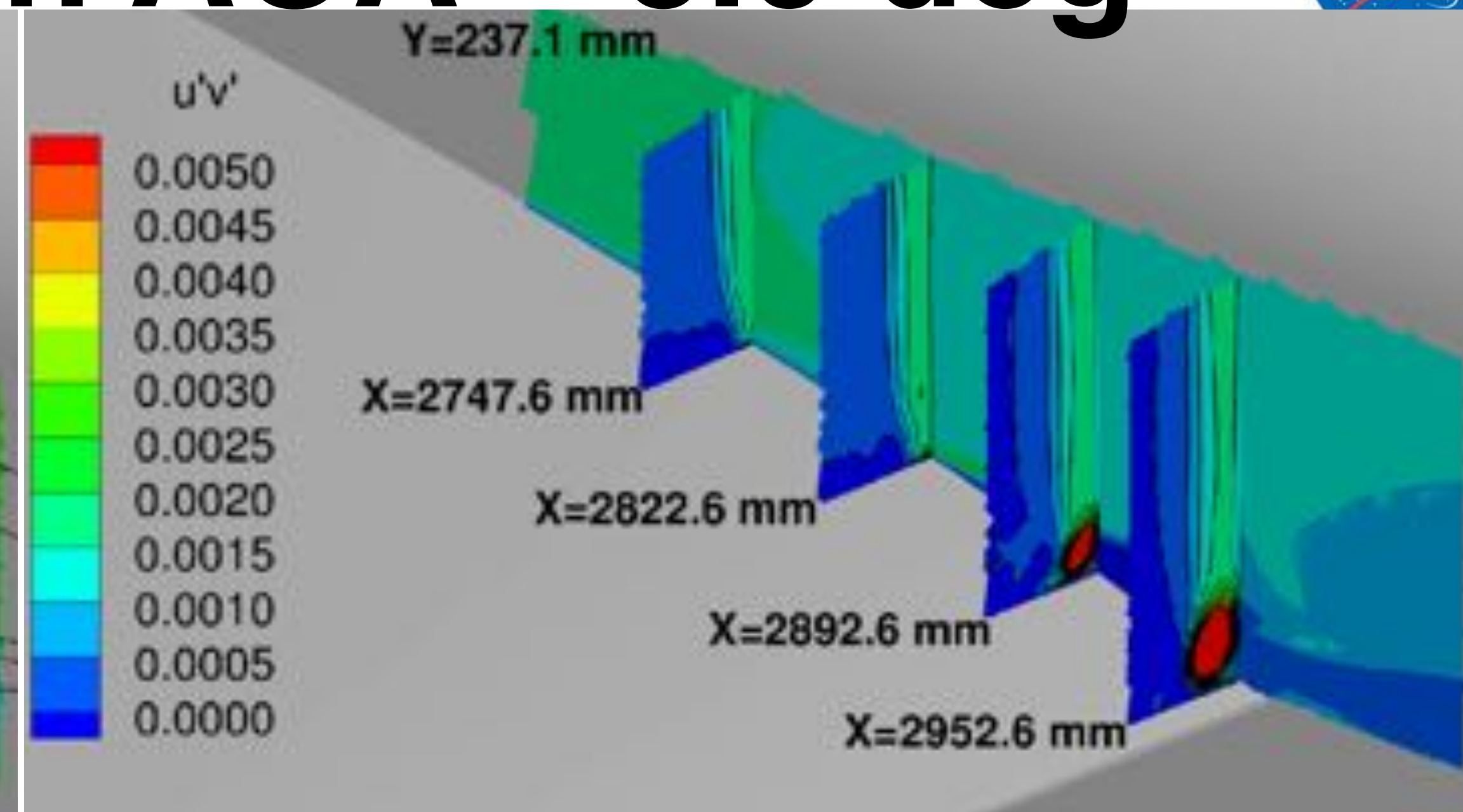
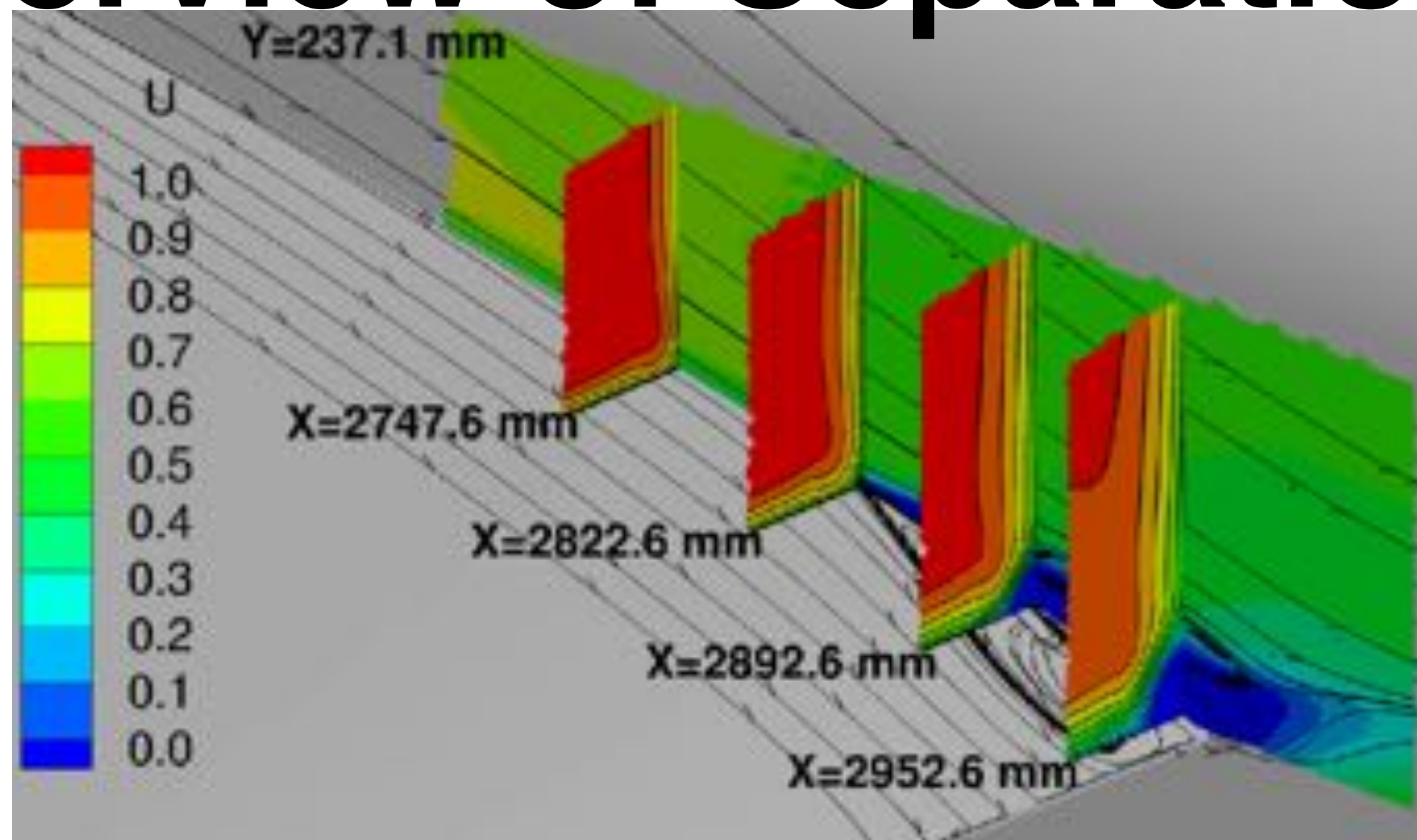
x=2667 mm



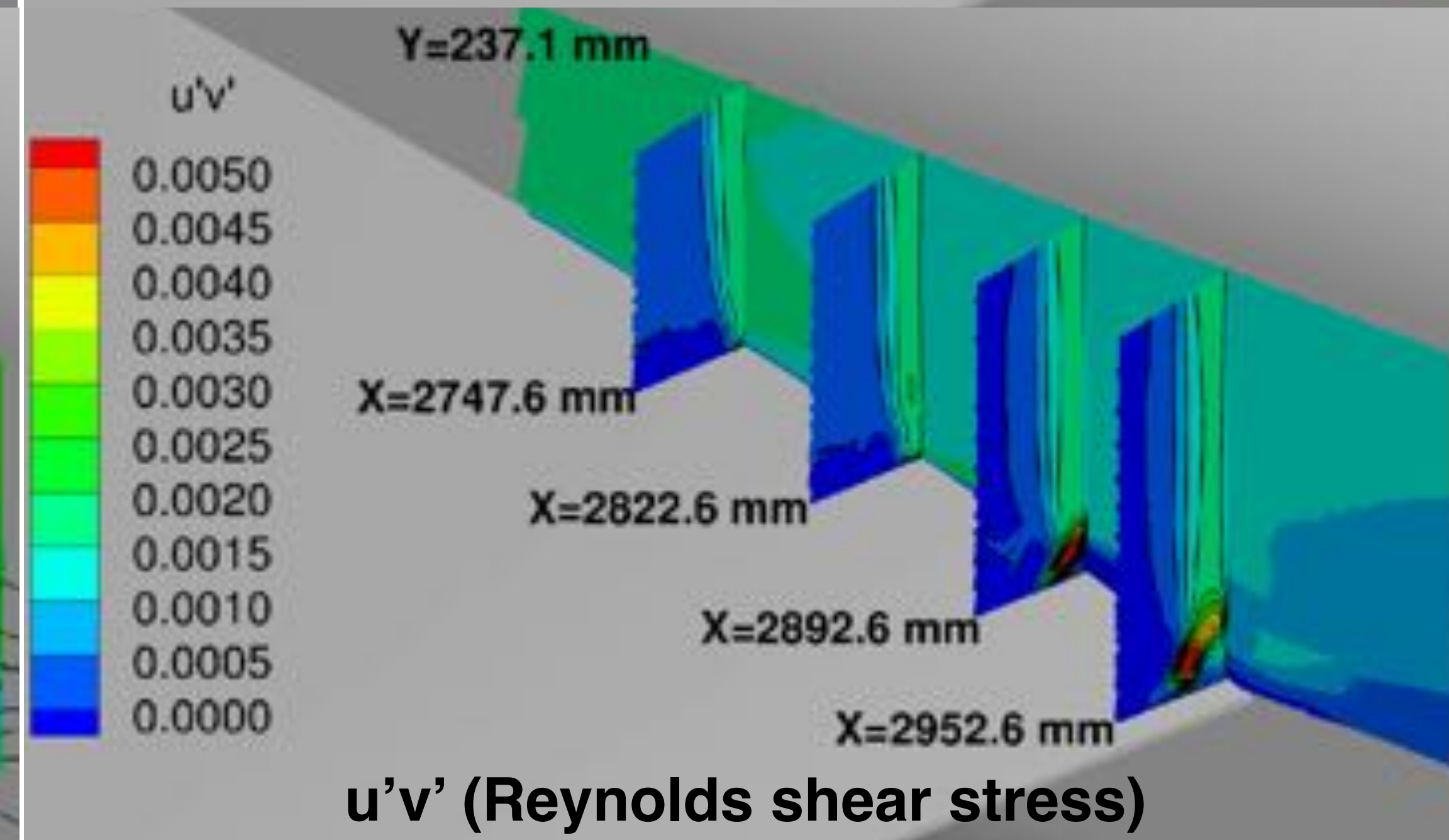
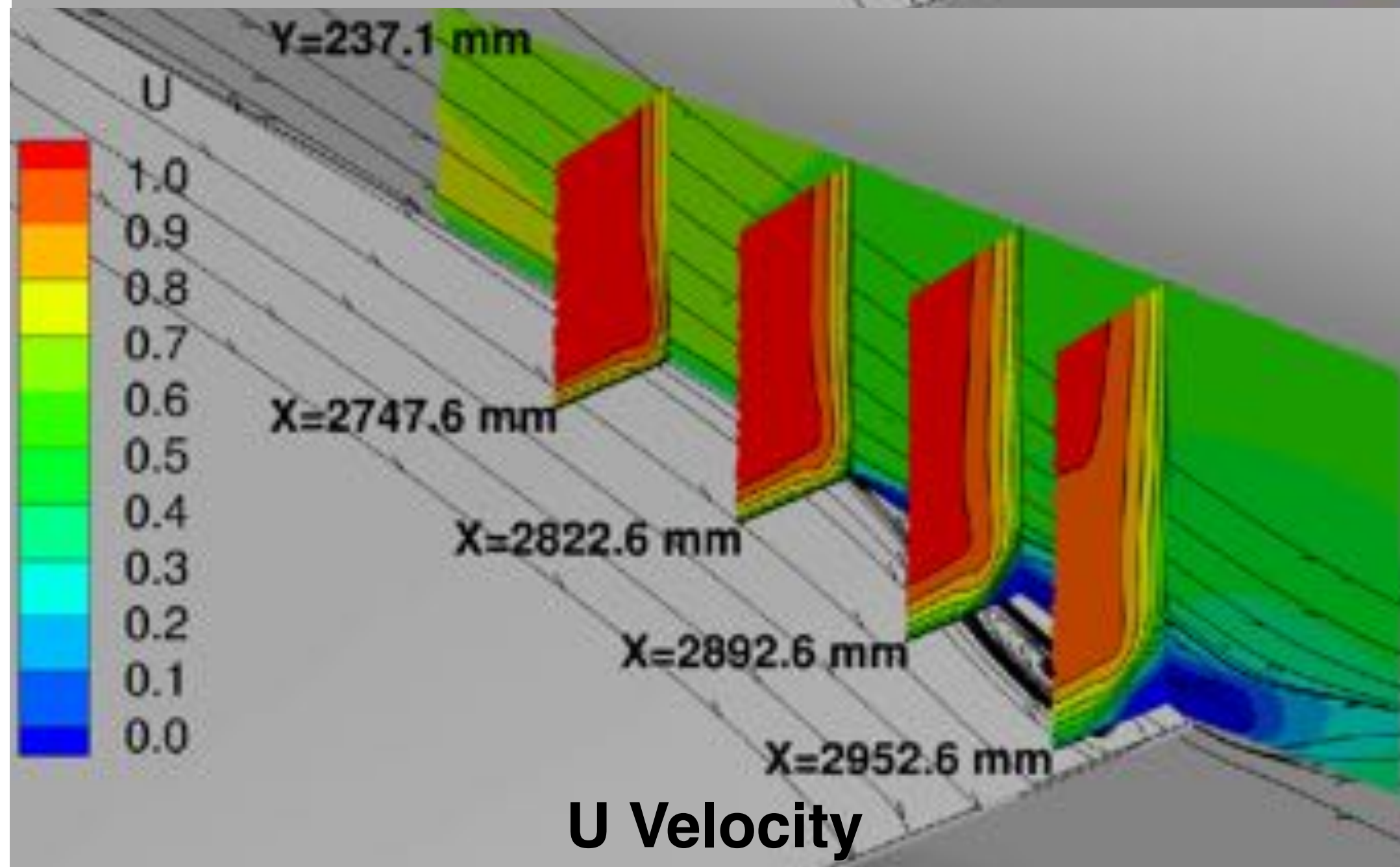
Overview of Separation AOA = 5.0 deg



Medium
Grid (Air)



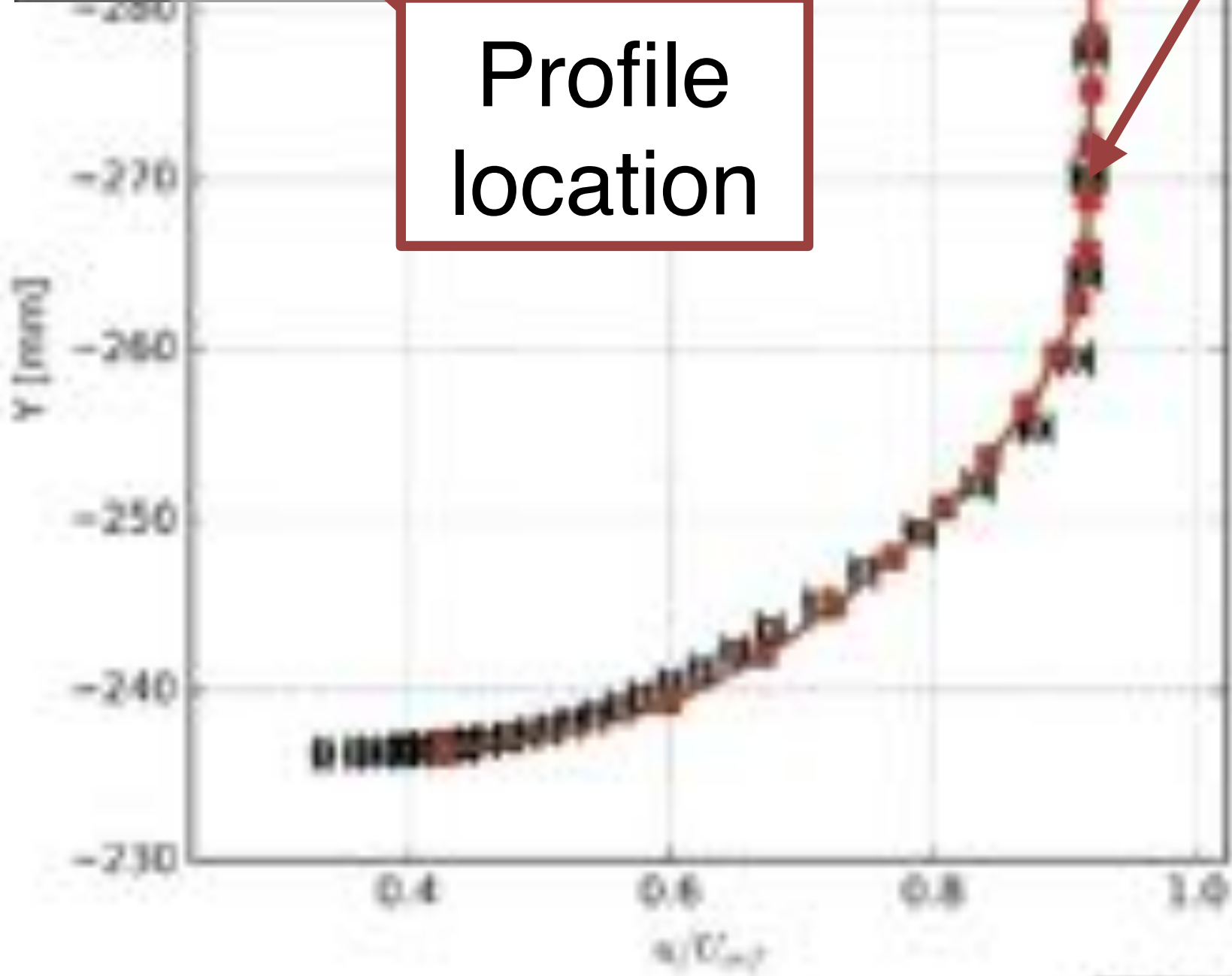
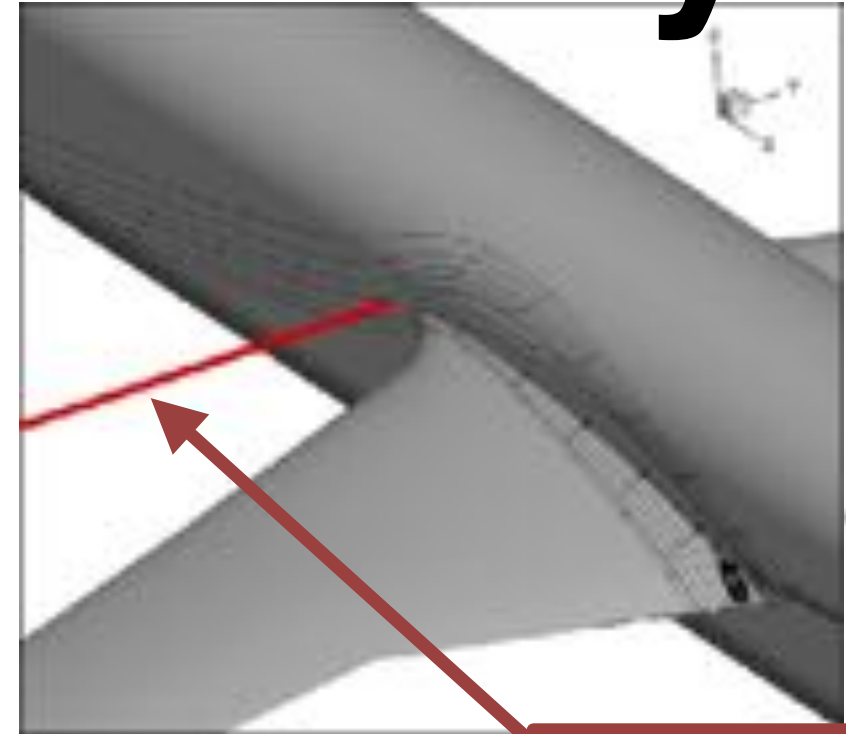
Fine
Grid (Air)





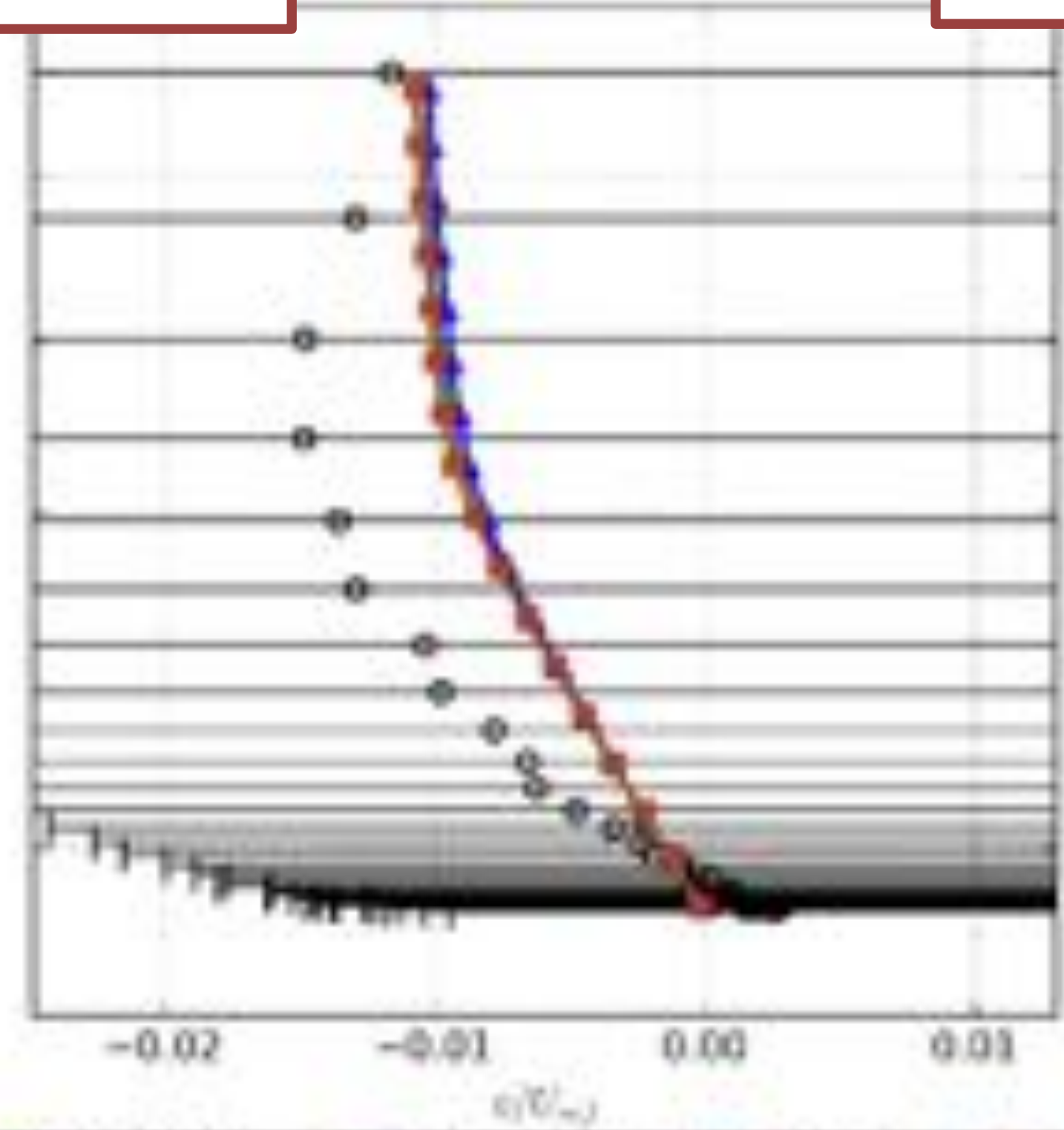
Velocity Profiles: Grid Resolution (Free Air)

Before LE of wing

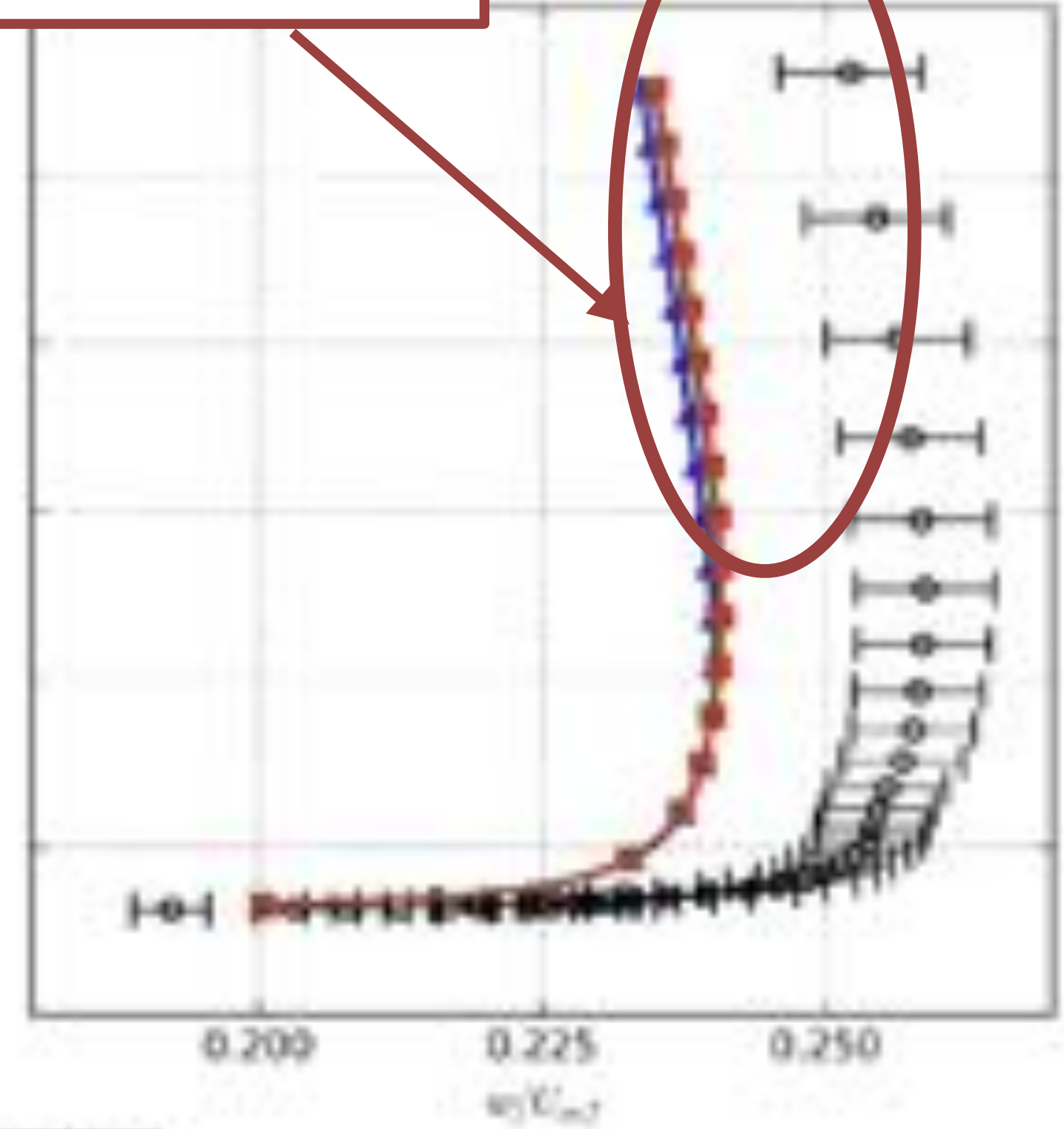


u-component agrees with Exp.

Profile location



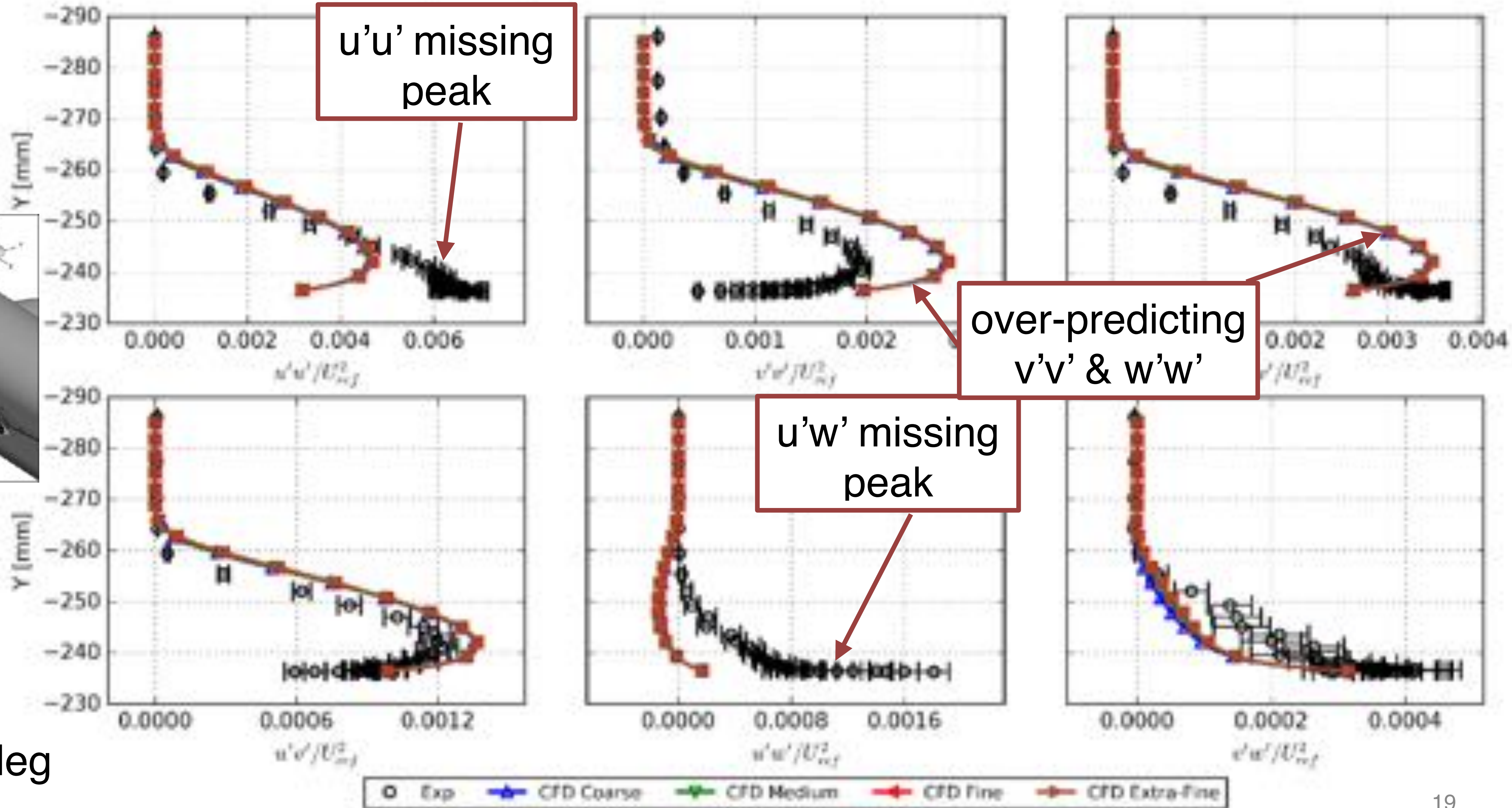
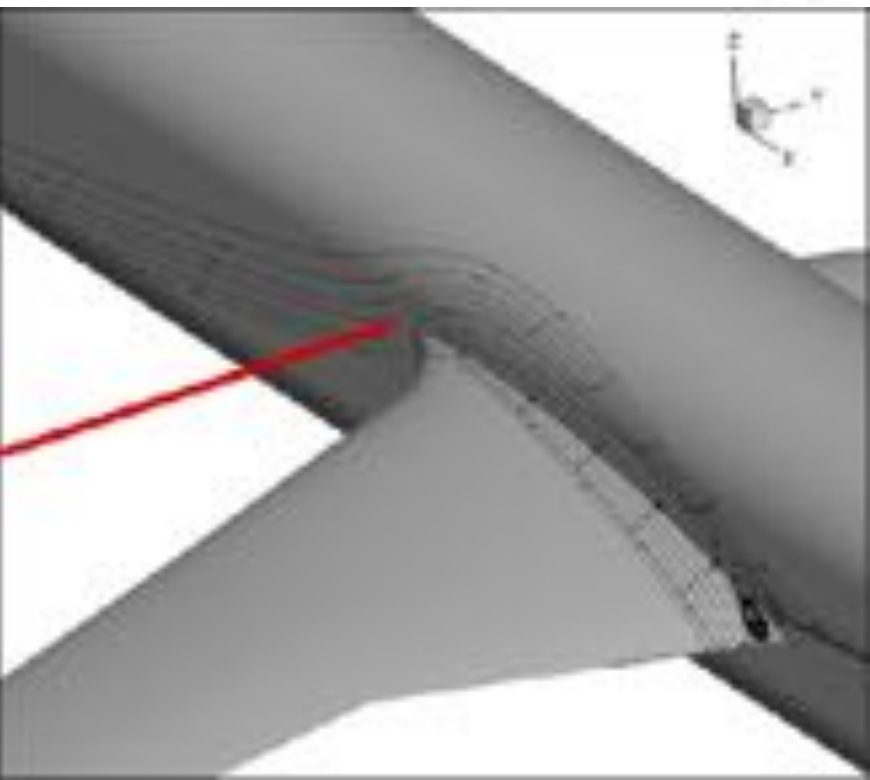
w-component is lower than Exp.



AOA = 5 deg

Reynolds Stress Profiles: Grid Resolution (Free Air)

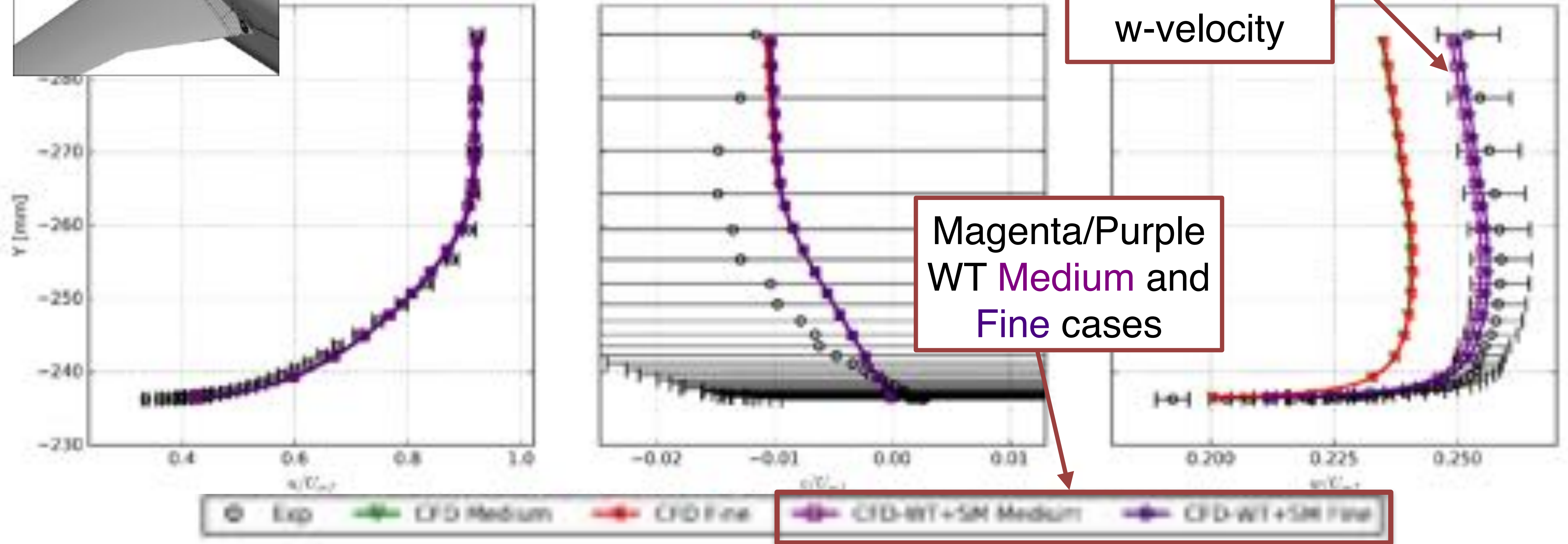
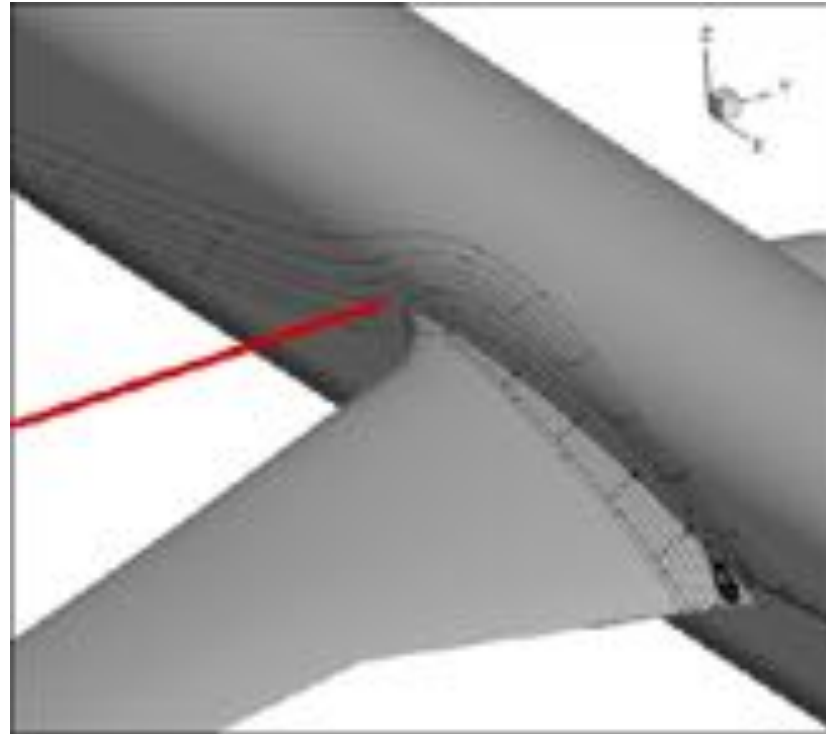
Before LE of wing



AOA = 5 deg

Velocity Profiles: Wall Effect

Before LE of wing



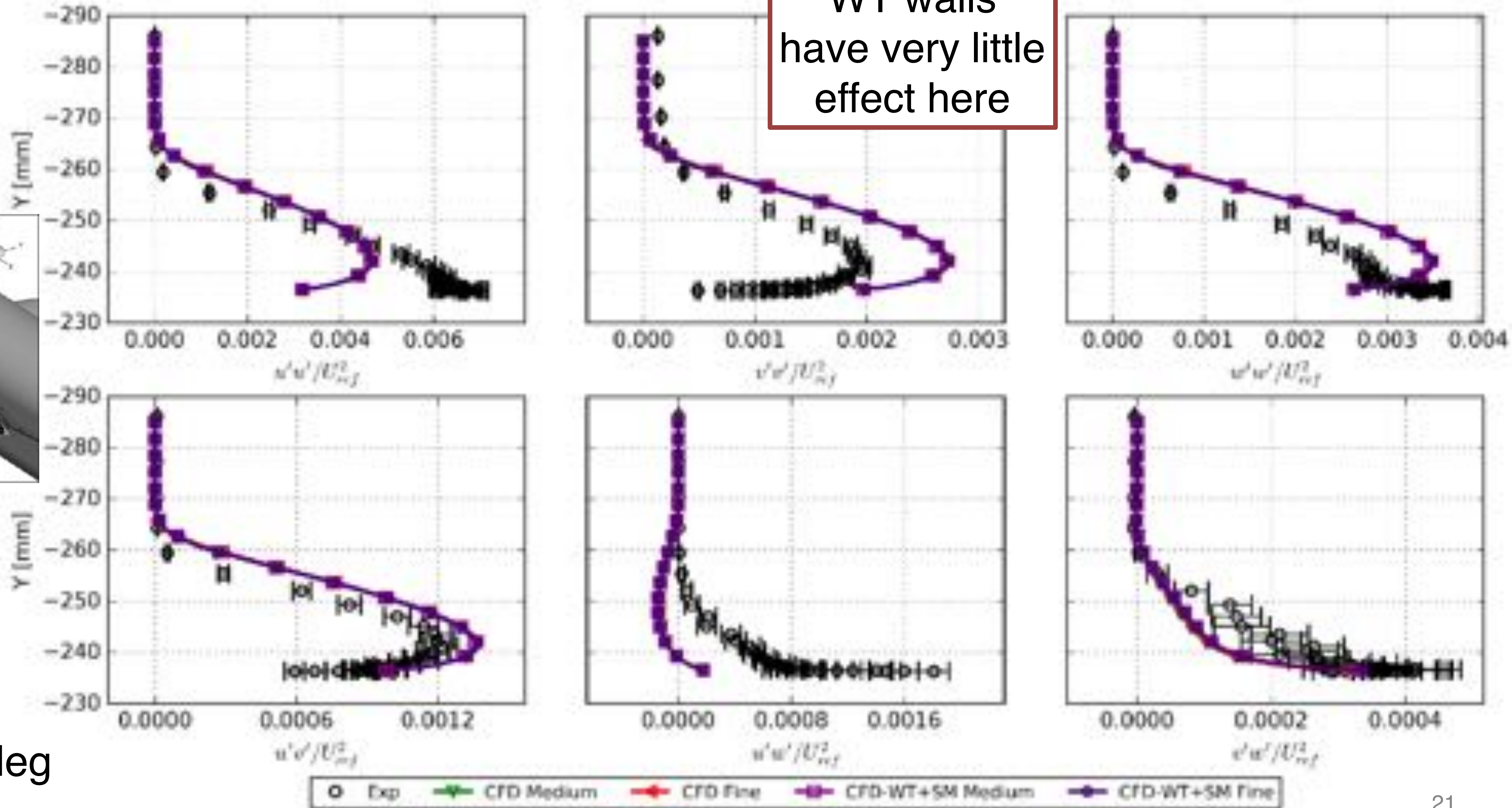
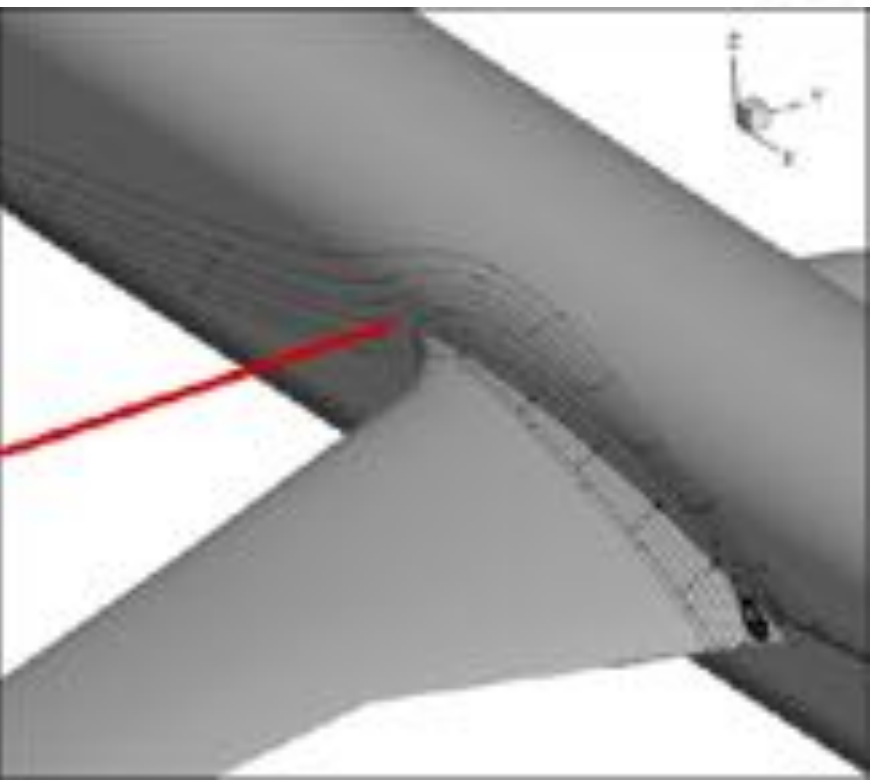
AOA = 5 deg

Reynolds Stress Profiles: Wall Effect



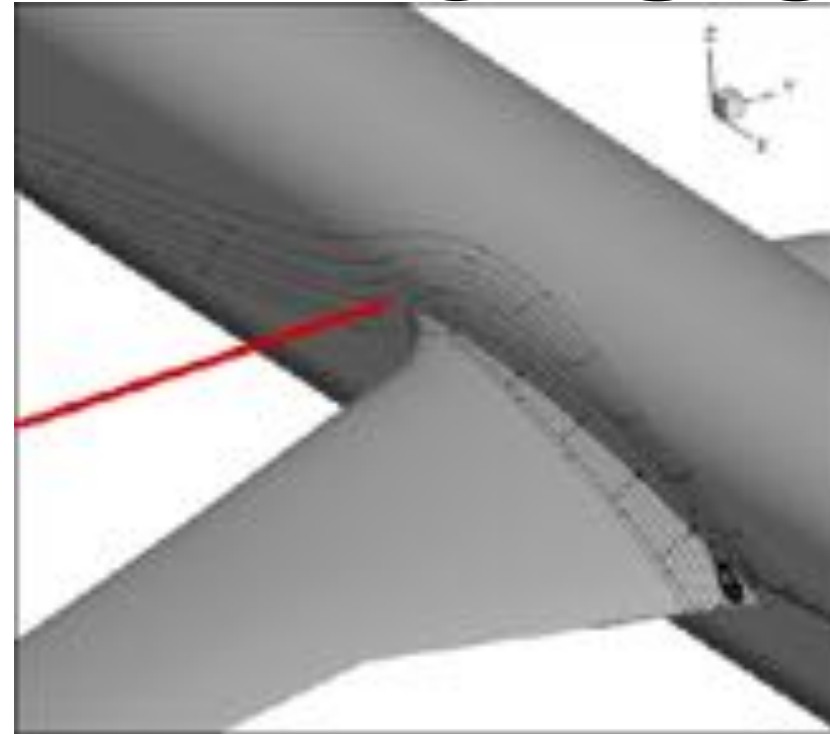
Before LE of wing

WT walls have very little effect here



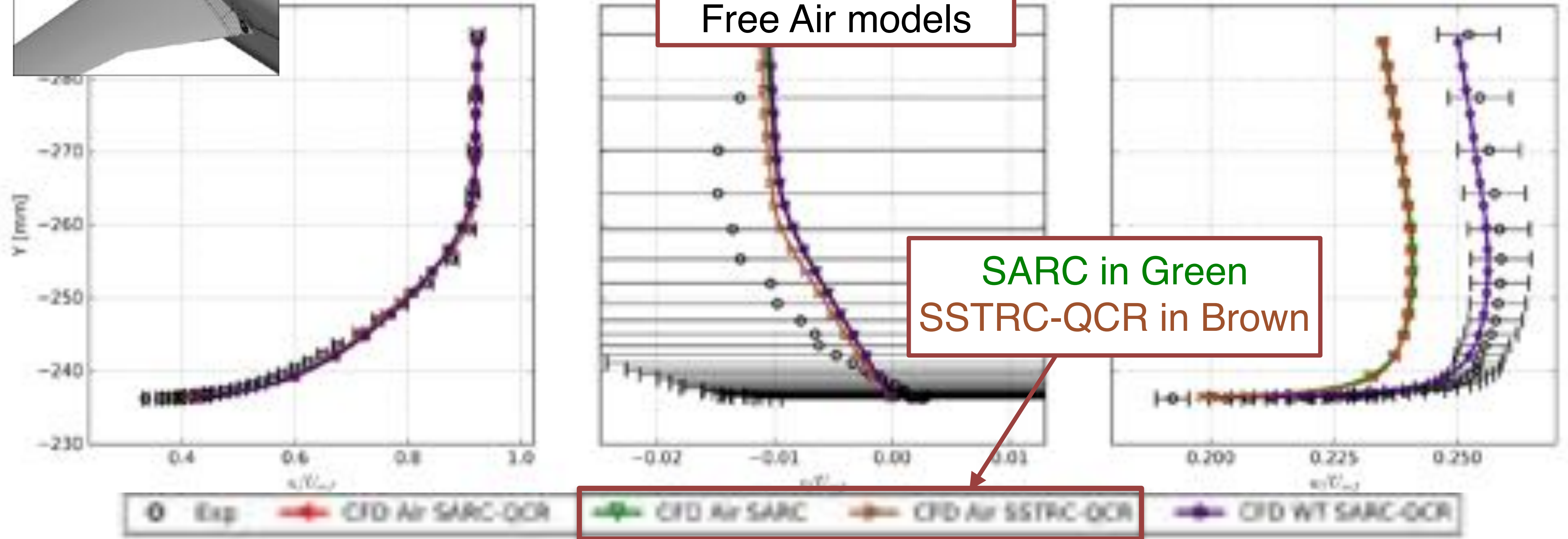
AOA = 5 deg

Velocity Profiles: Turbulence Model



Before LE of wing

Profiles look similar between all Turb. Free Air models

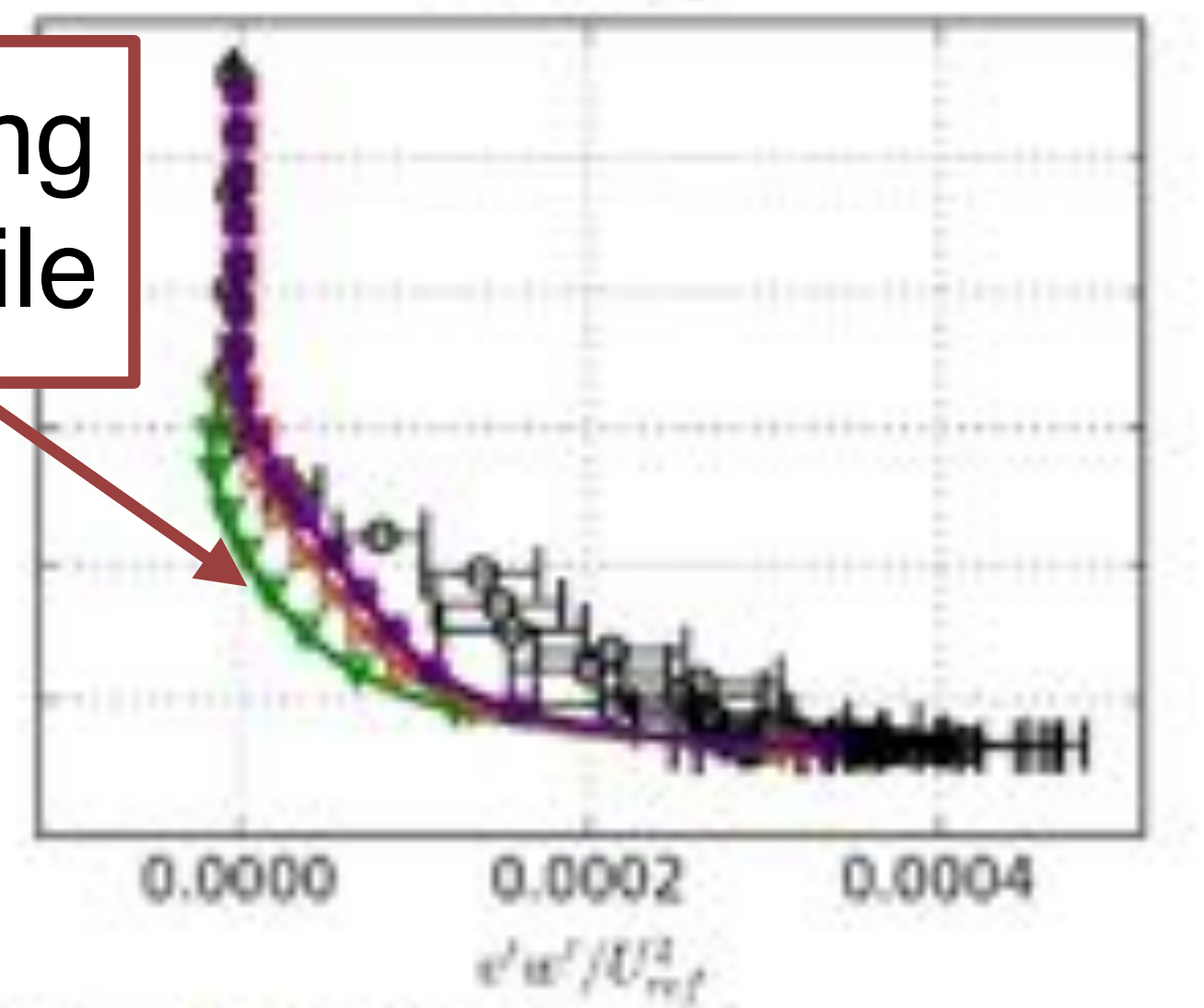
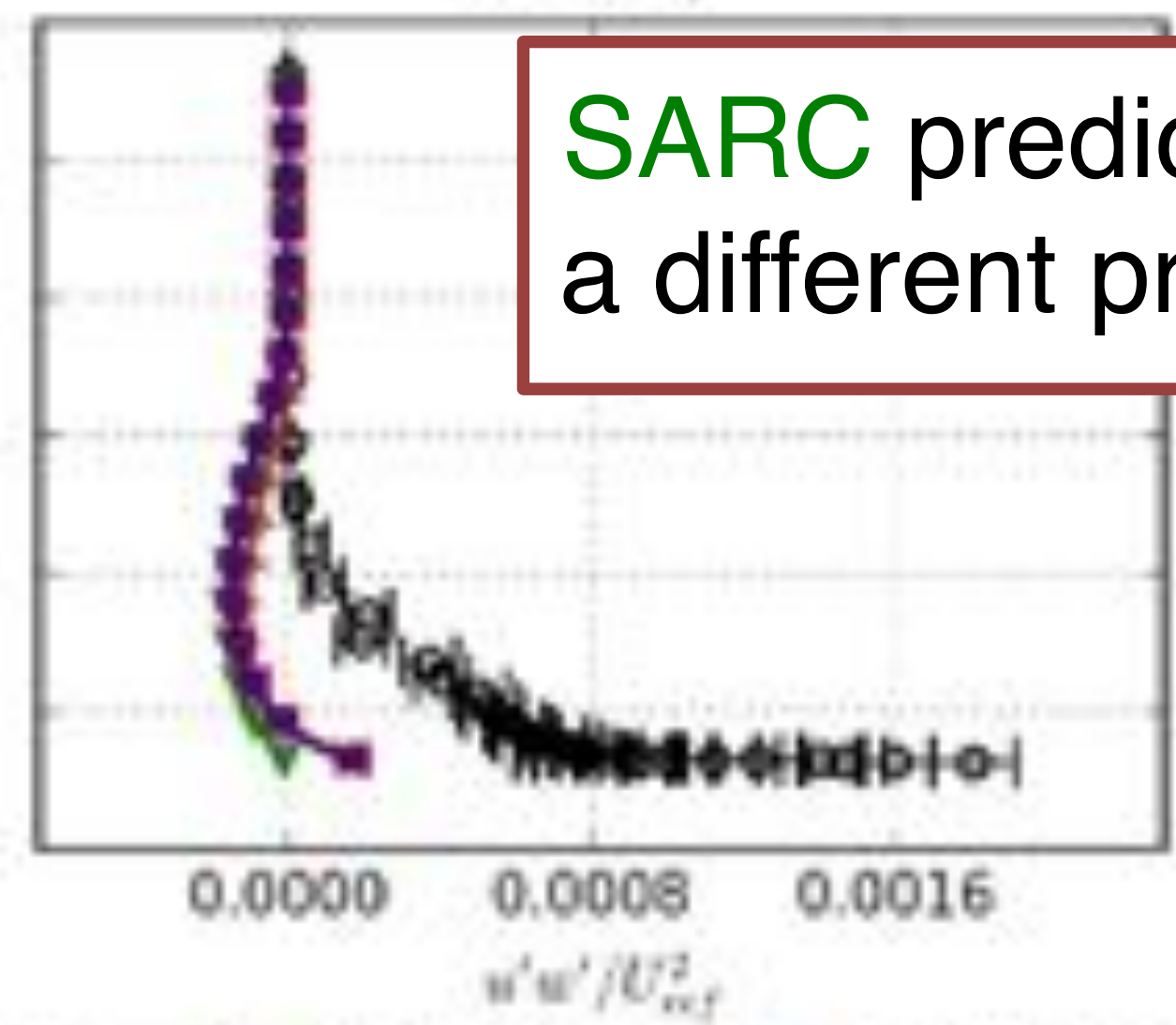
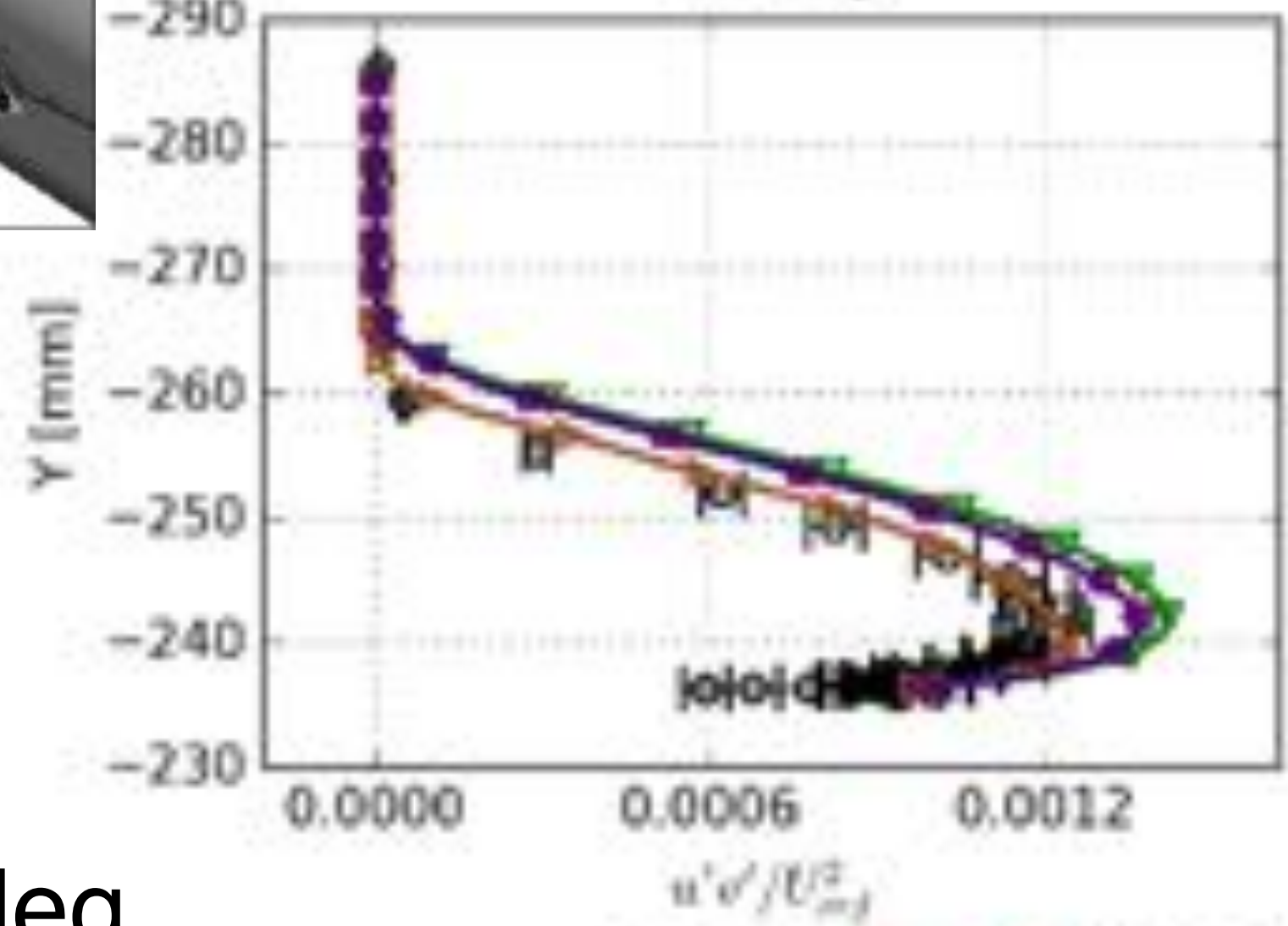
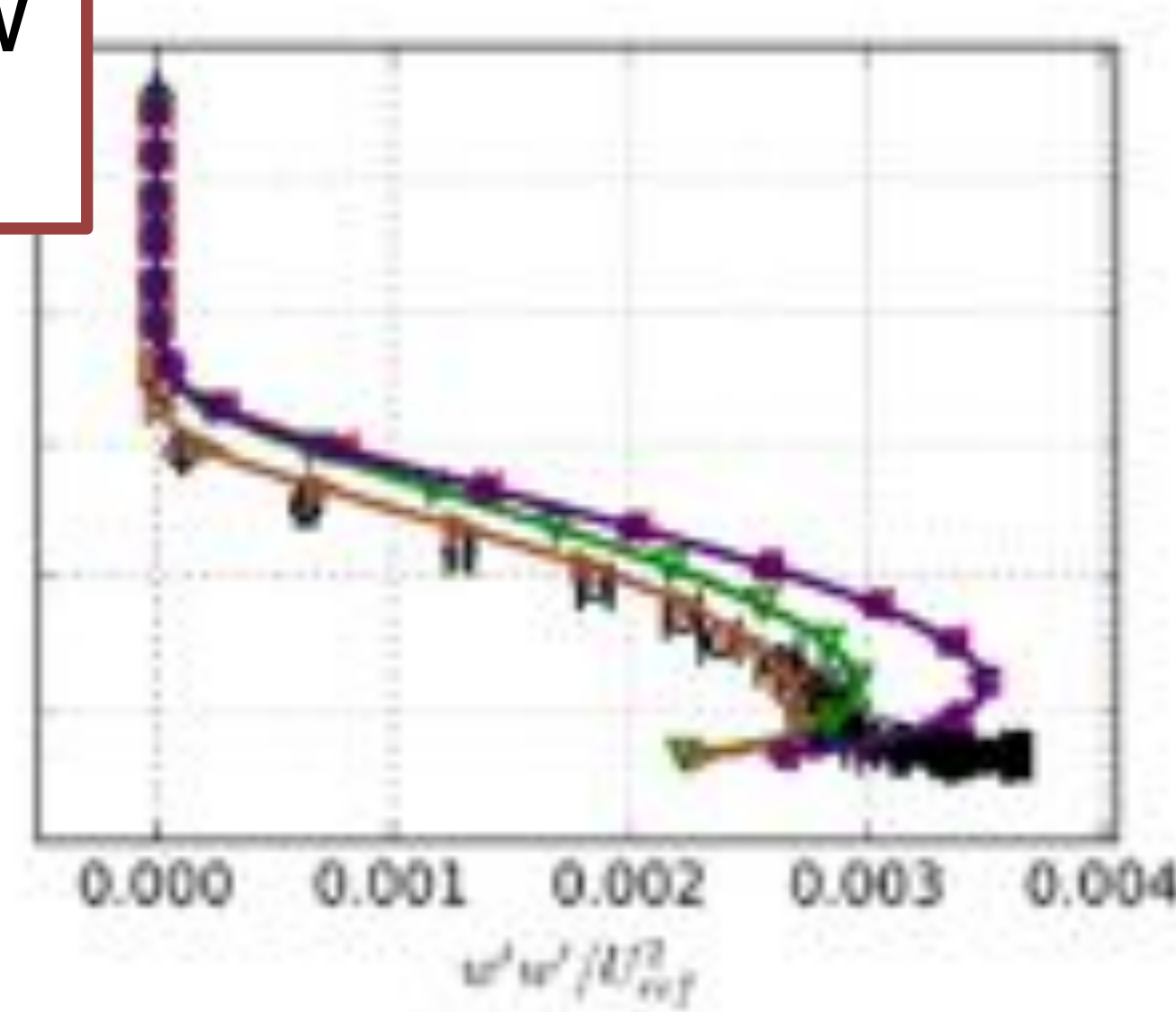
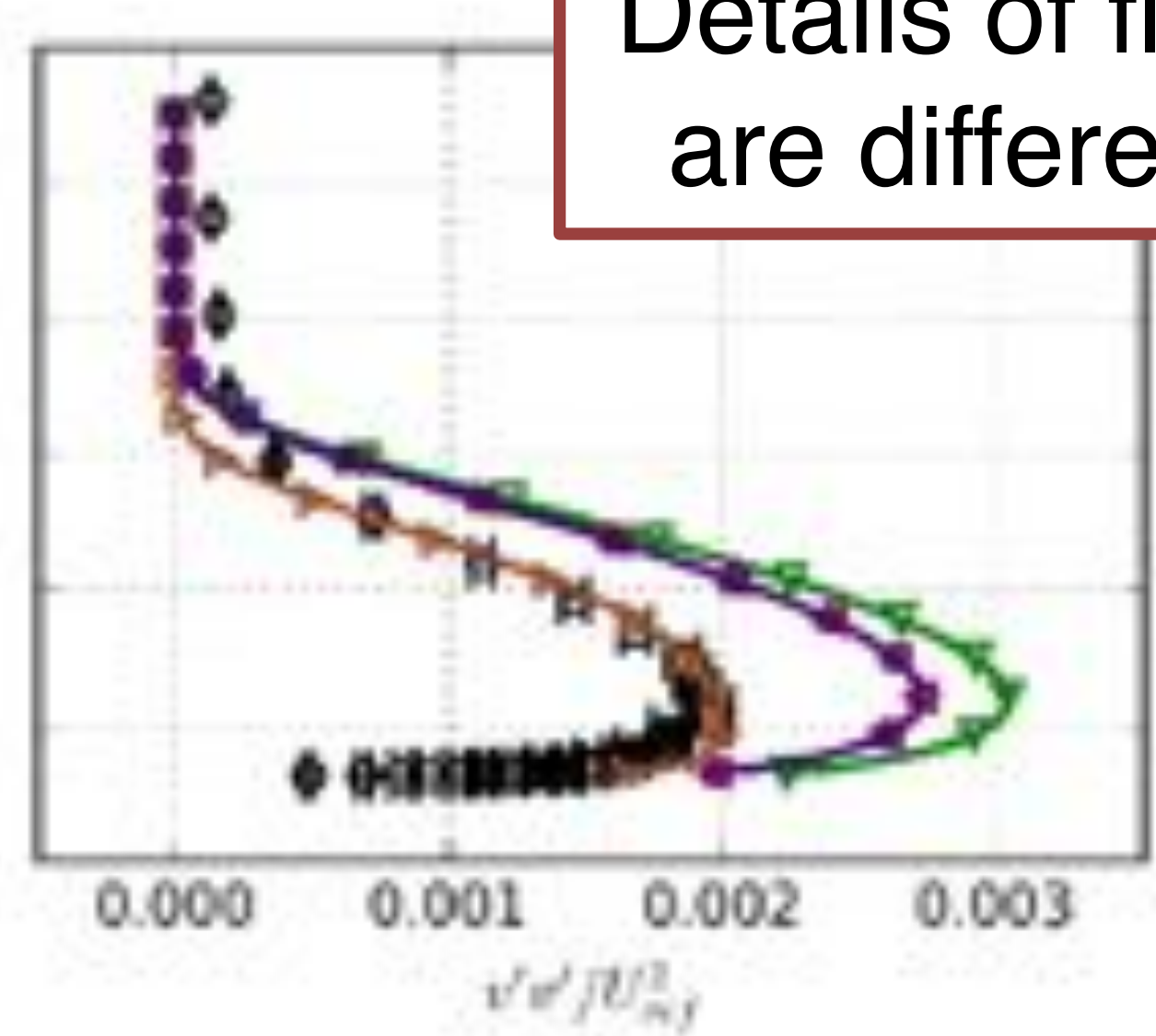
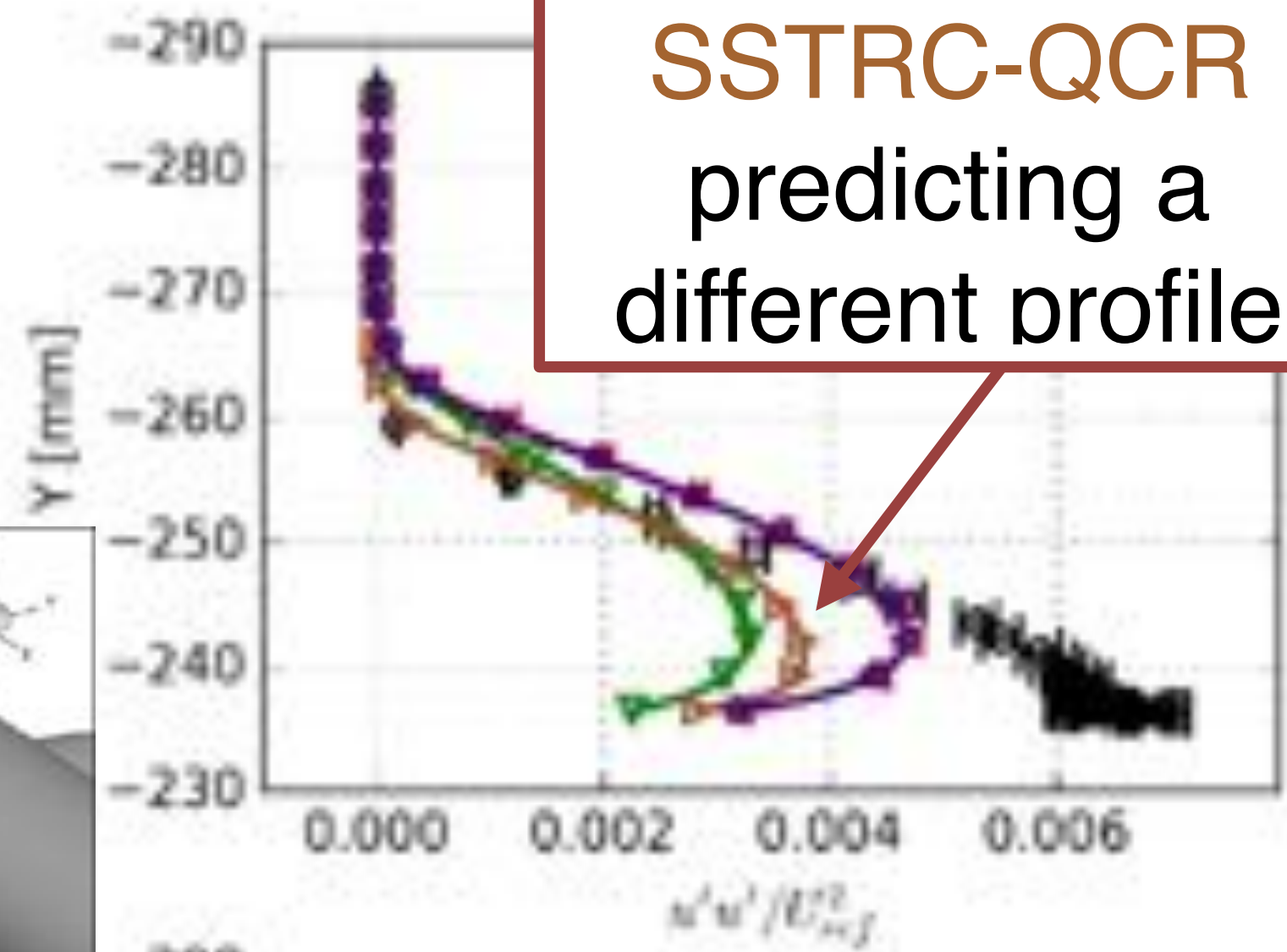
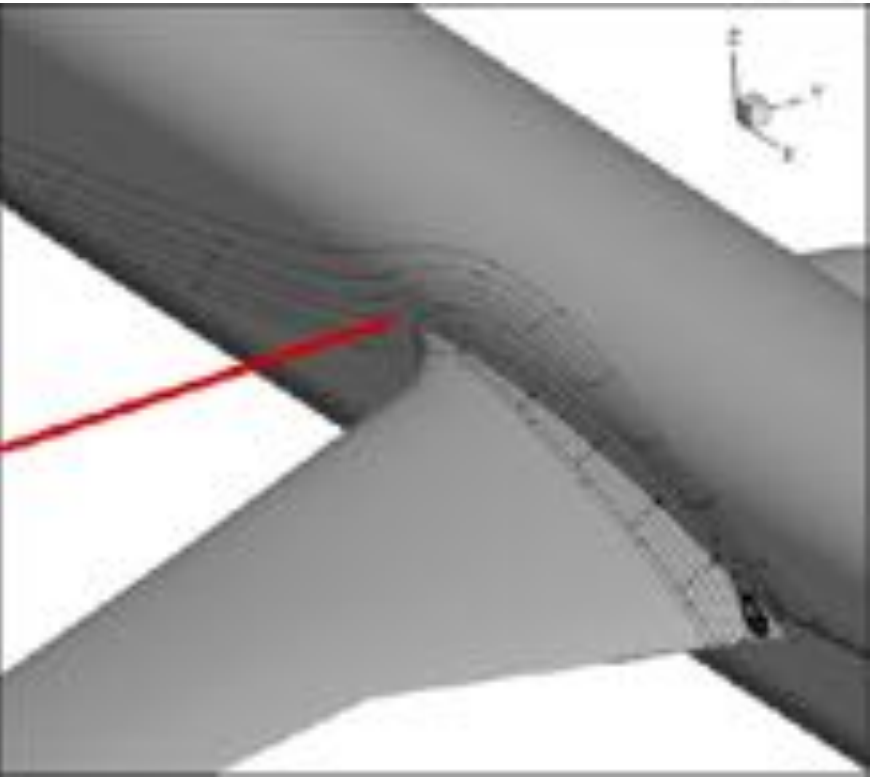


SARC in Green
SSTRC-QCR in Brown

AOA = 5 deg

Reynolds Stress Profiles: Turbulence Model

Before LE of wing



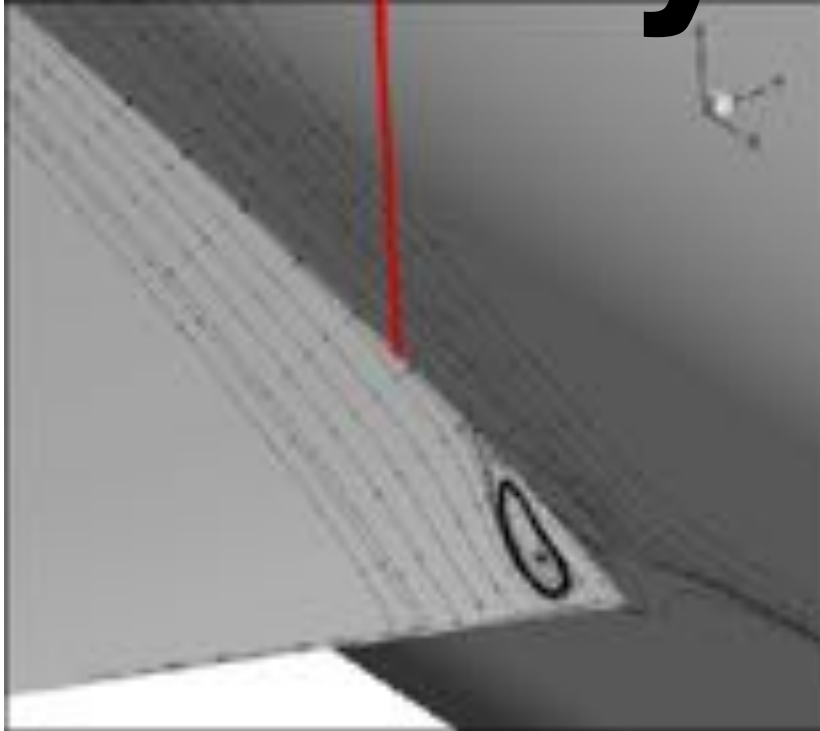
AOA = 5 deg





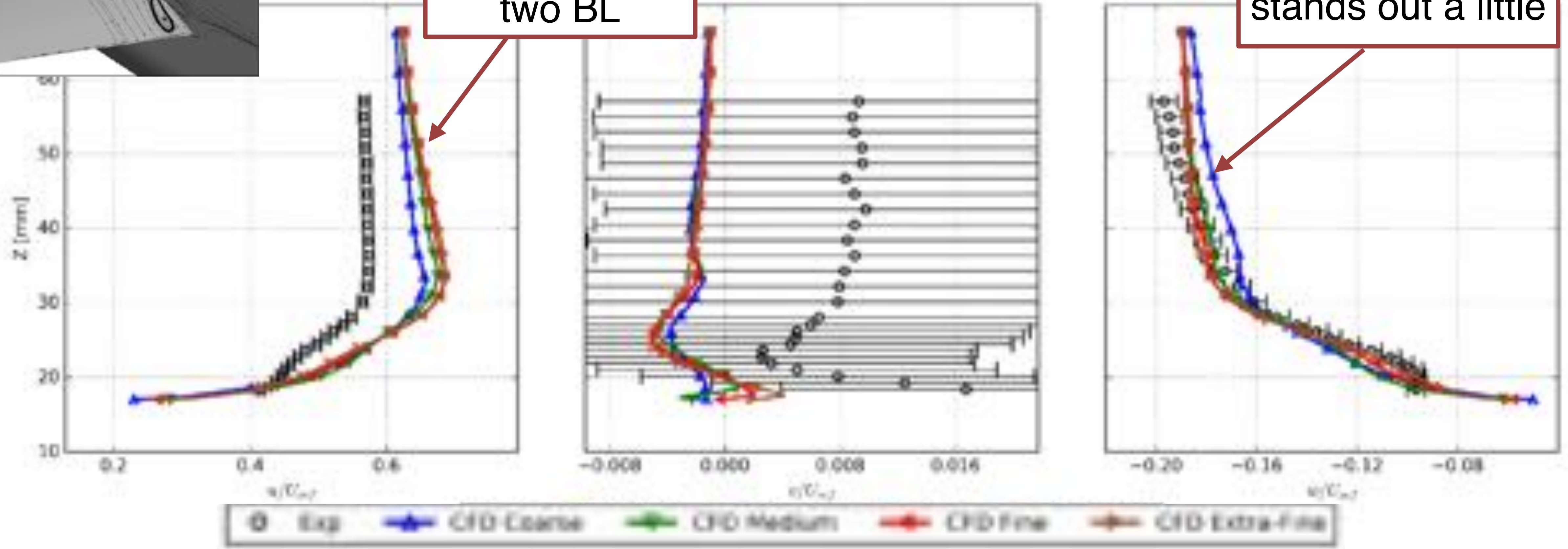
Velocity Profiles: Grid Resolution (Free Air)

Upstream of Separation, 1 mm from fuselage



Shift may be caused by the two BL

Coarse grid stands out a little

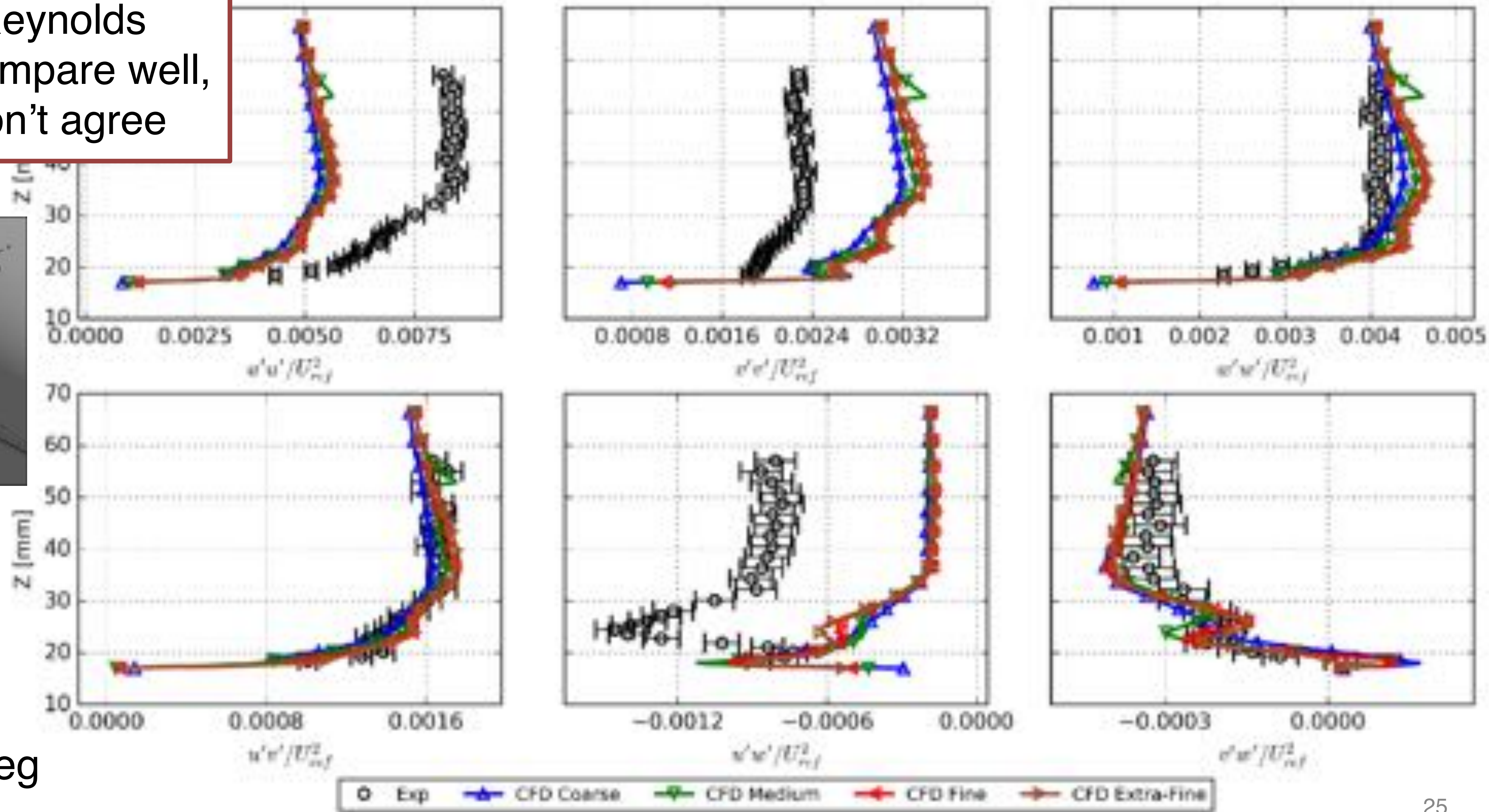
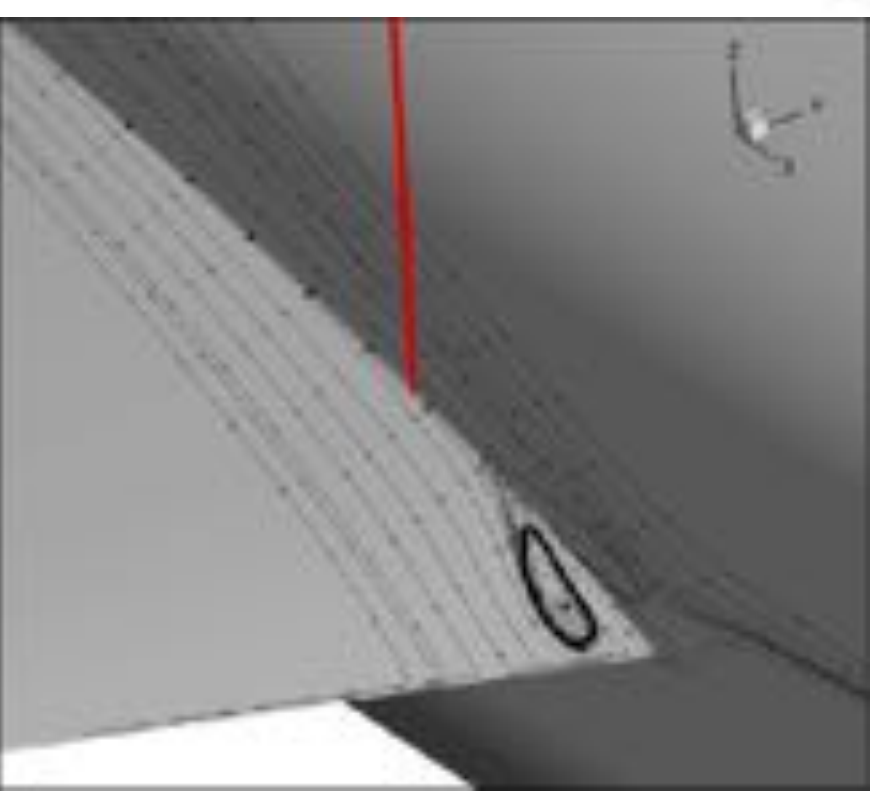


AOA = 5 deg

Reynolds Stress Profiles: Grid Resolution (Free Air)

Upstream of Separation, 1 mm from fuselage

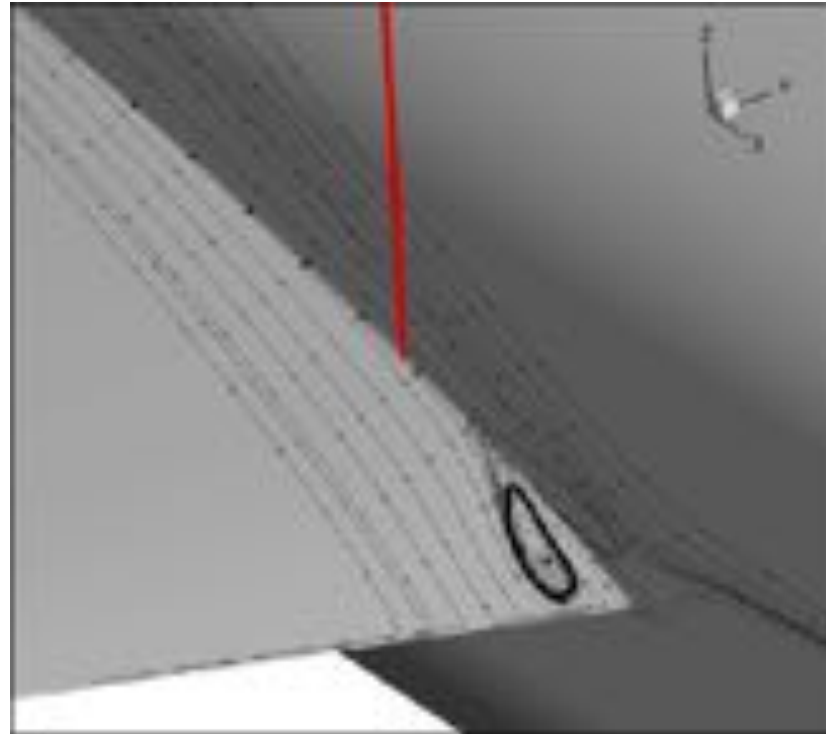
Some Reynolds stresses compare well, others don't agree



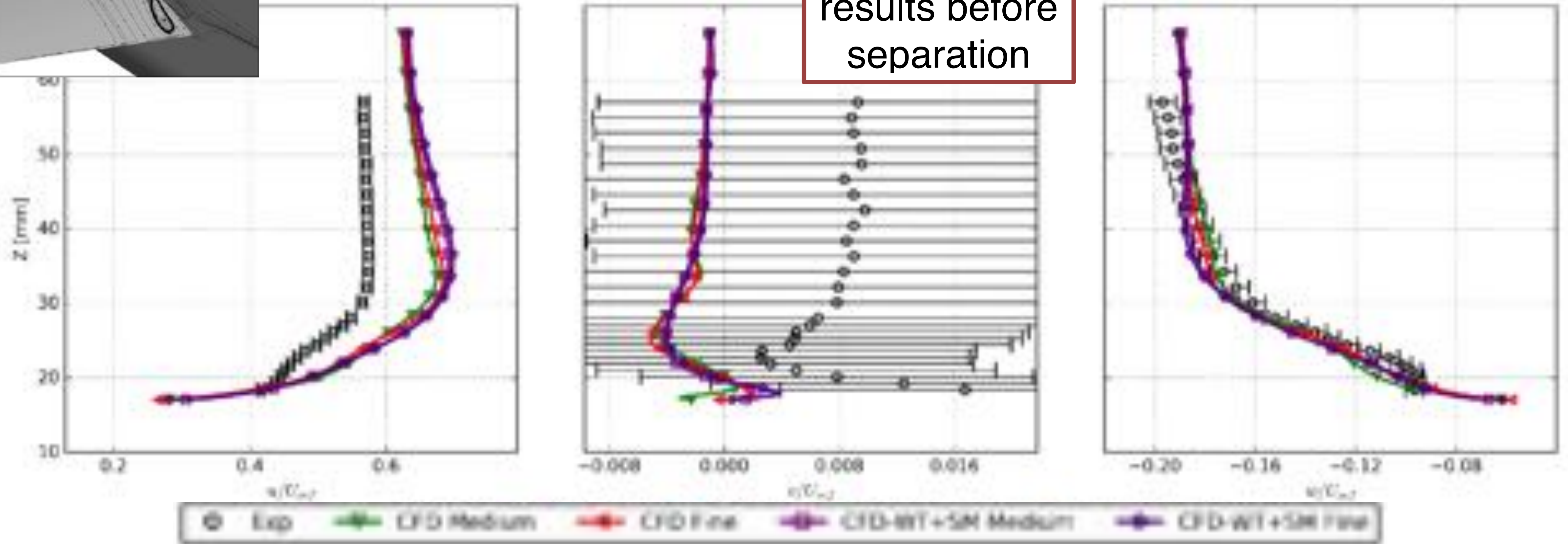
AOA = 5 deg

Velocity Profiles: Wall Effect

Upstream of Separation, 1 mm from fuselage



Very similar results before separation

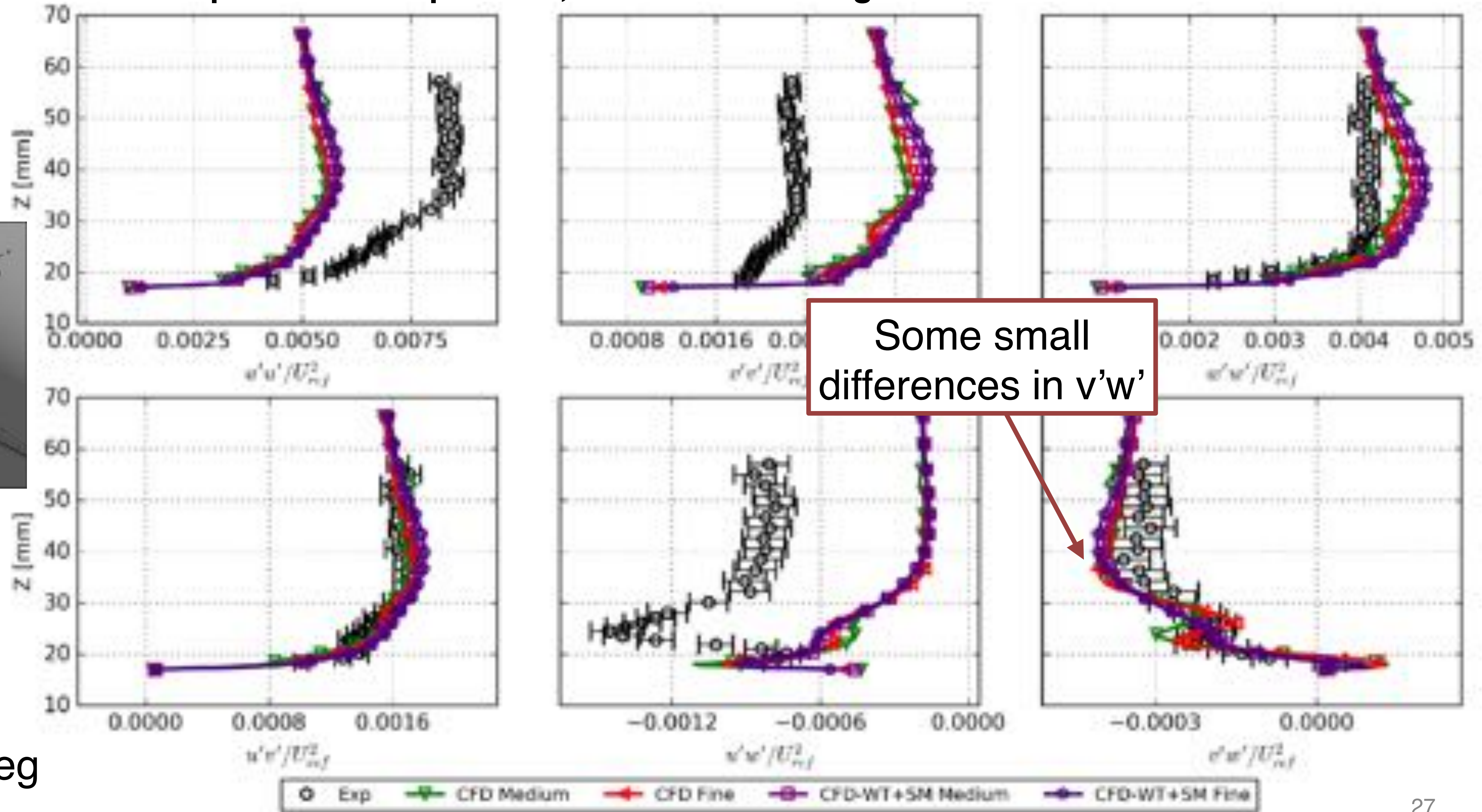
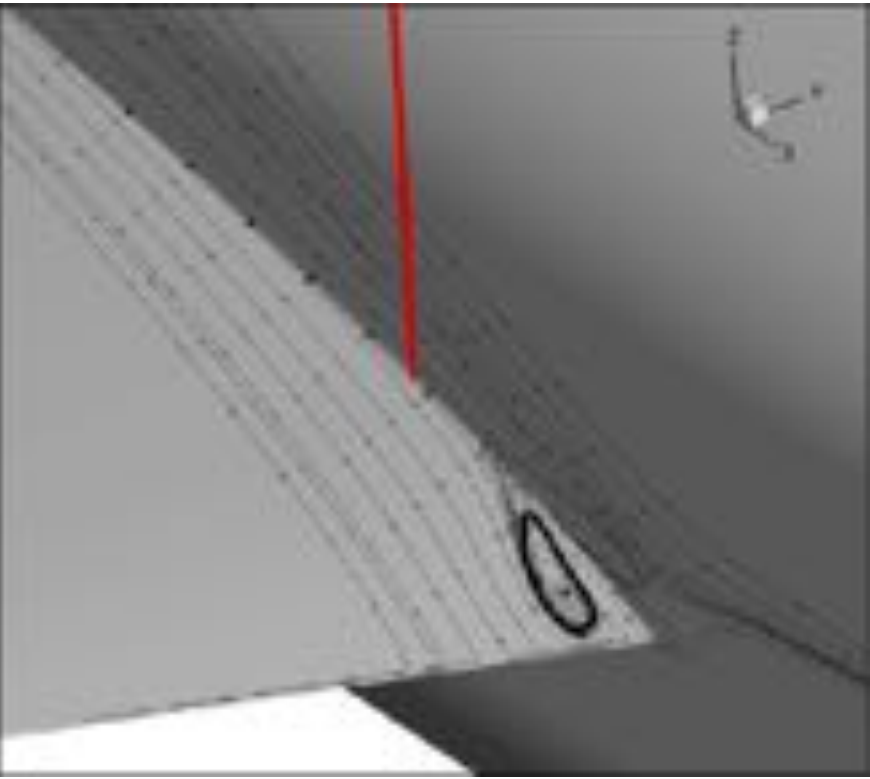


AOA = 5 deg

Reynolds Stress Profiles: Wall Effect



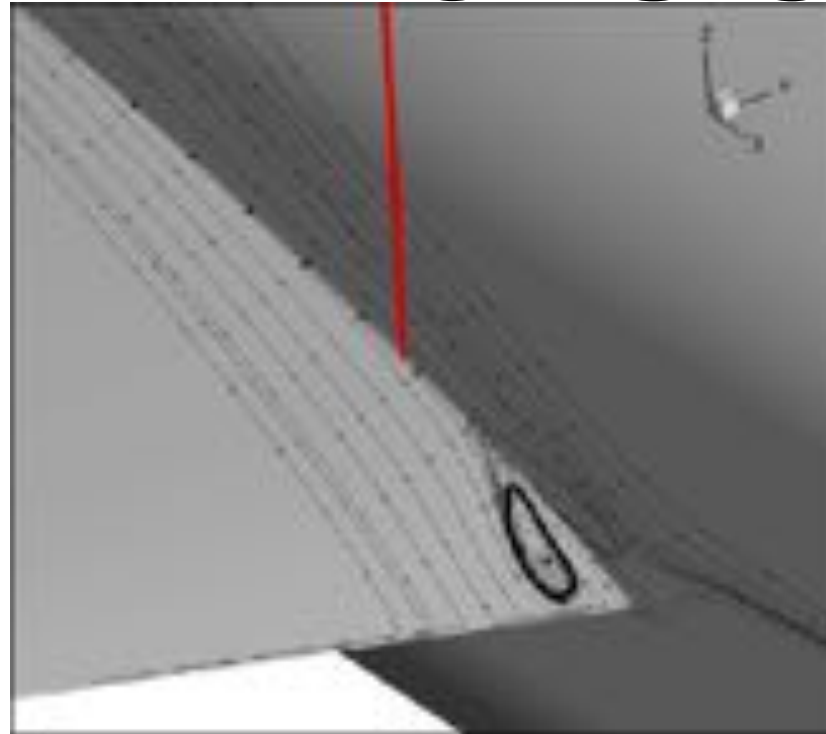
Upstream of Separation, 1 mm from fuselage



AOA = 5 deg

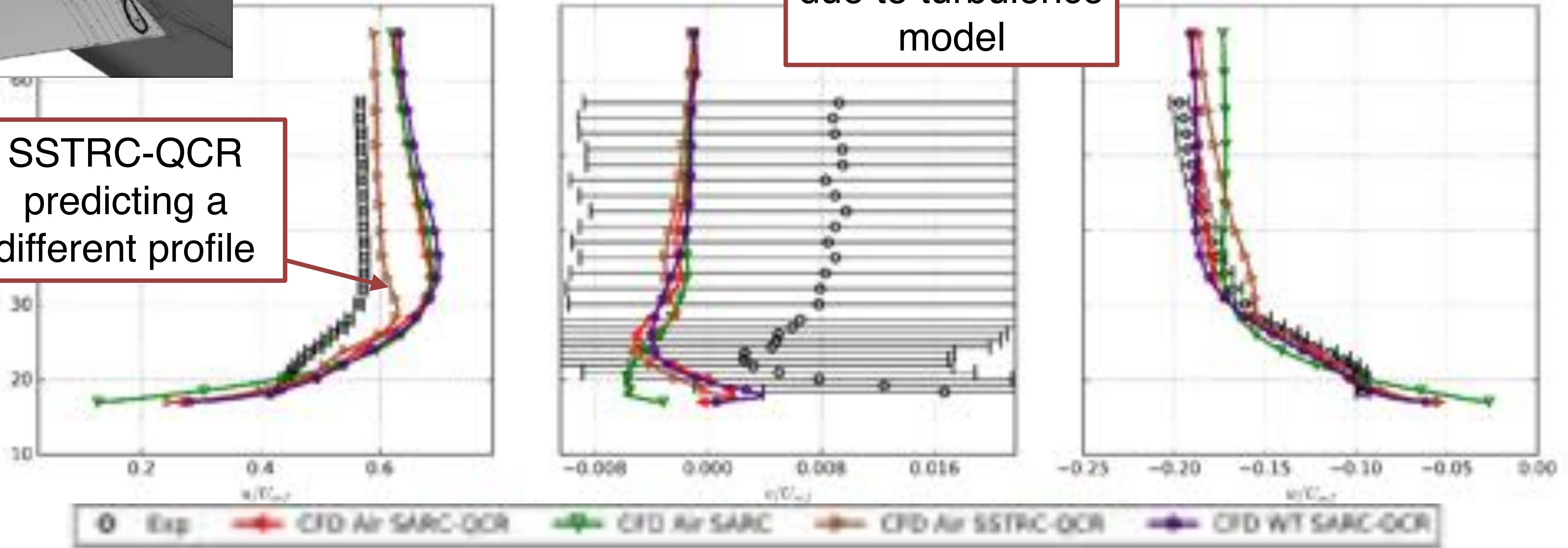
Velocity Profiles: Turbulence Model

Upstream of Separation, 1 mm from fuselage



More variation due to turbulence model

SSTRC-QCR predicting a different profile

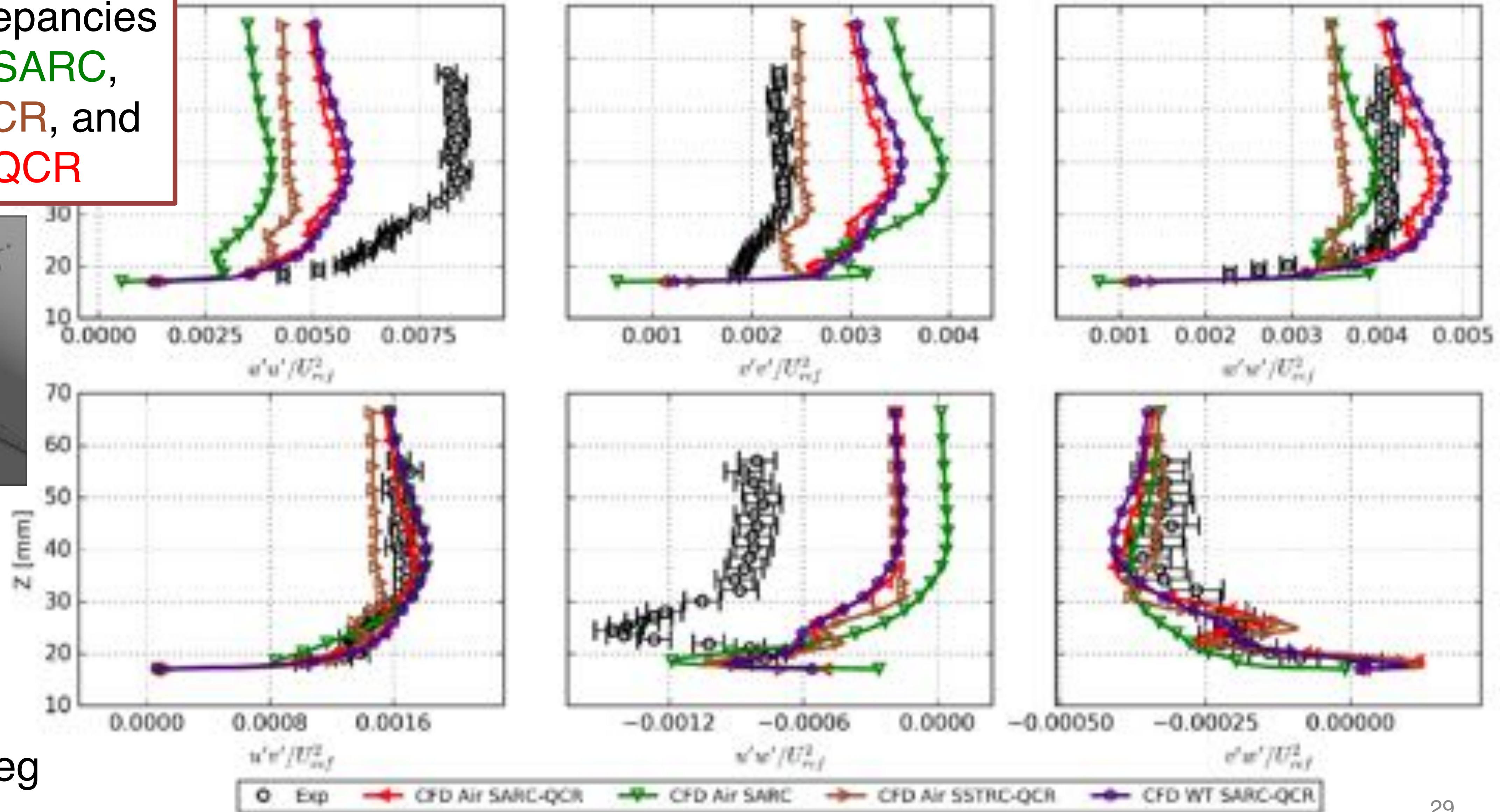
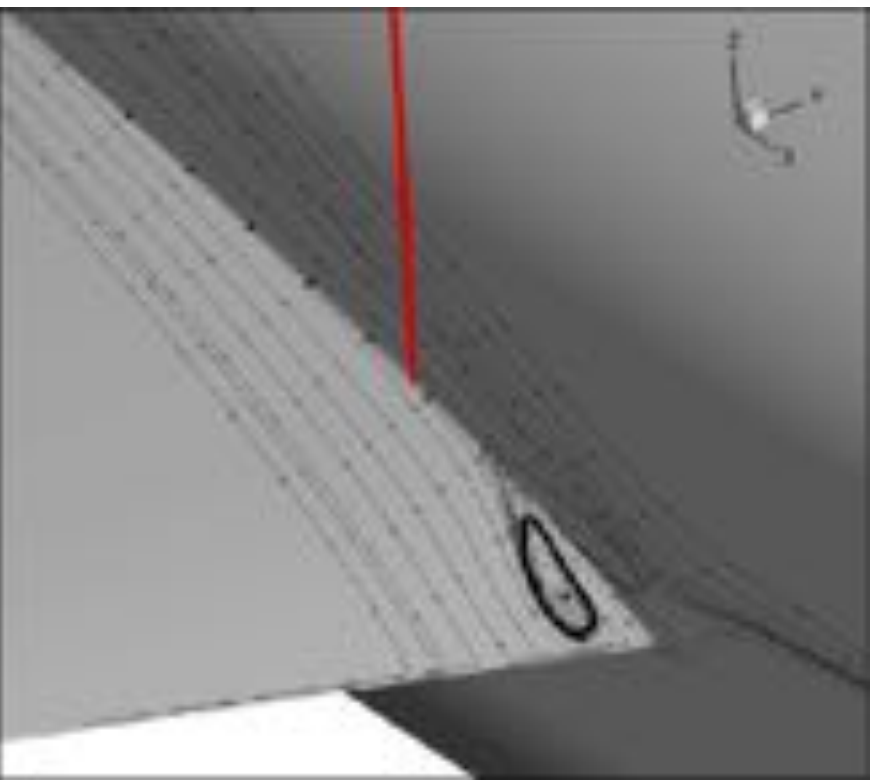


AOA = 5 deg

Reynolds Stress Profiles: Turbulence Model

Upstream of Separation, 1 mm from fuselage

Large discrepancies between **SARC**, **SSTRC-QCR**, and **SARC-QCR**

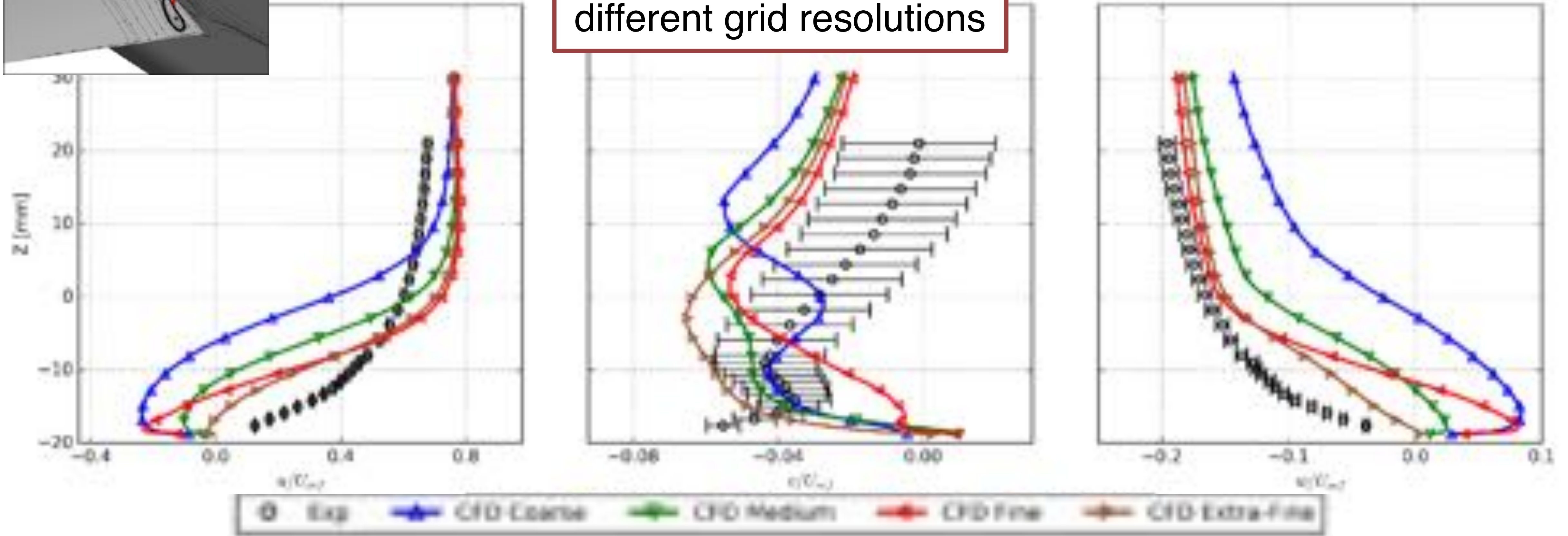
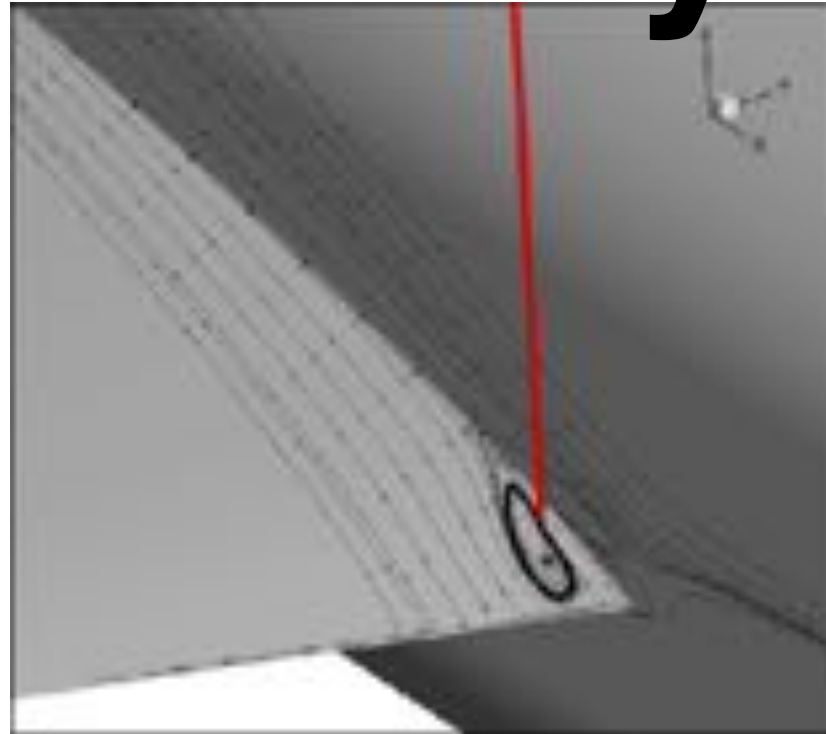


AOA = 5 deg

Velocity Profiles: Grid Resolution (Free Air)

In the Separated Region, 10 mm from fuselage

Large variation in velocity profiles across different grid resolutions

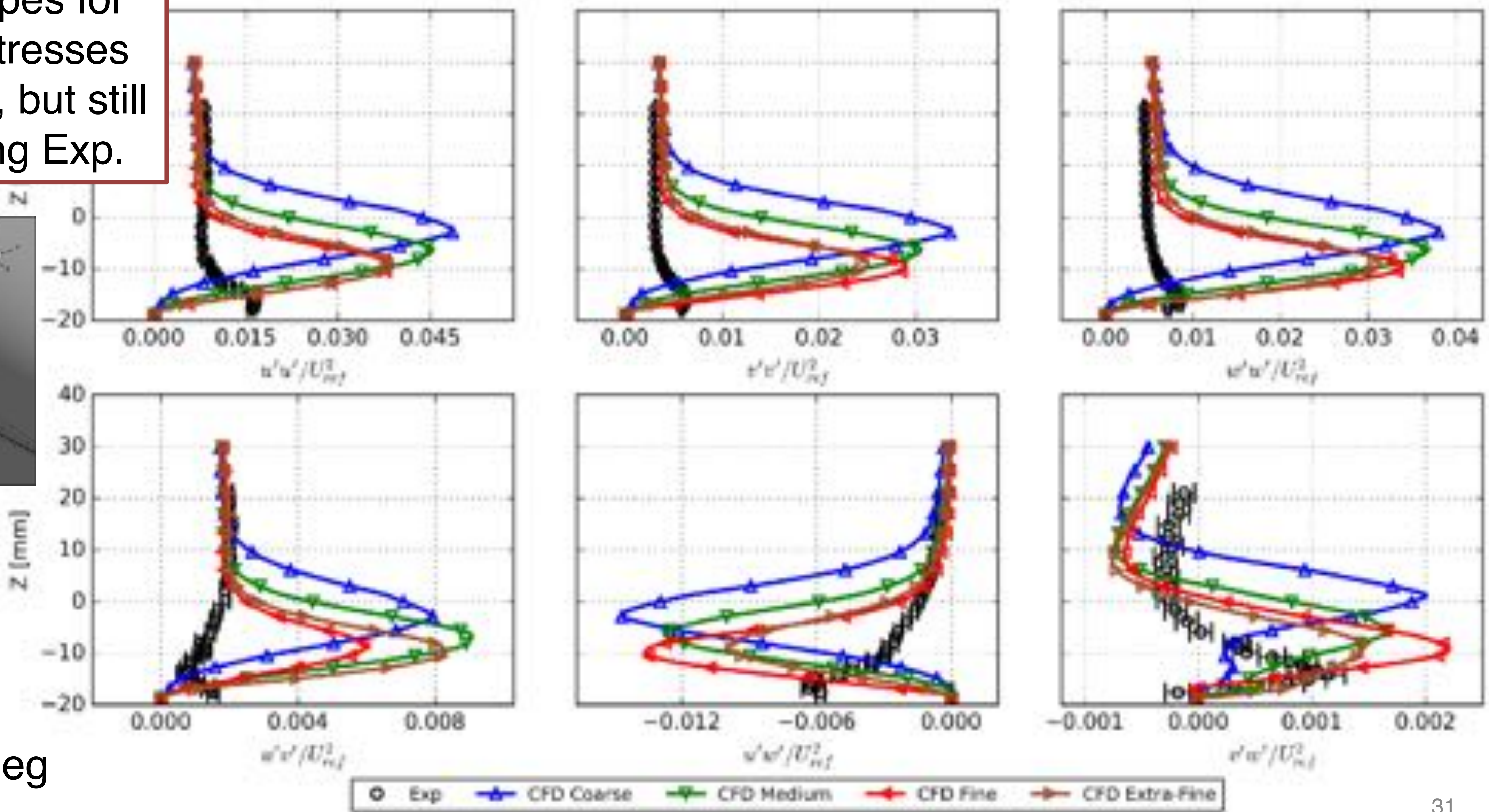
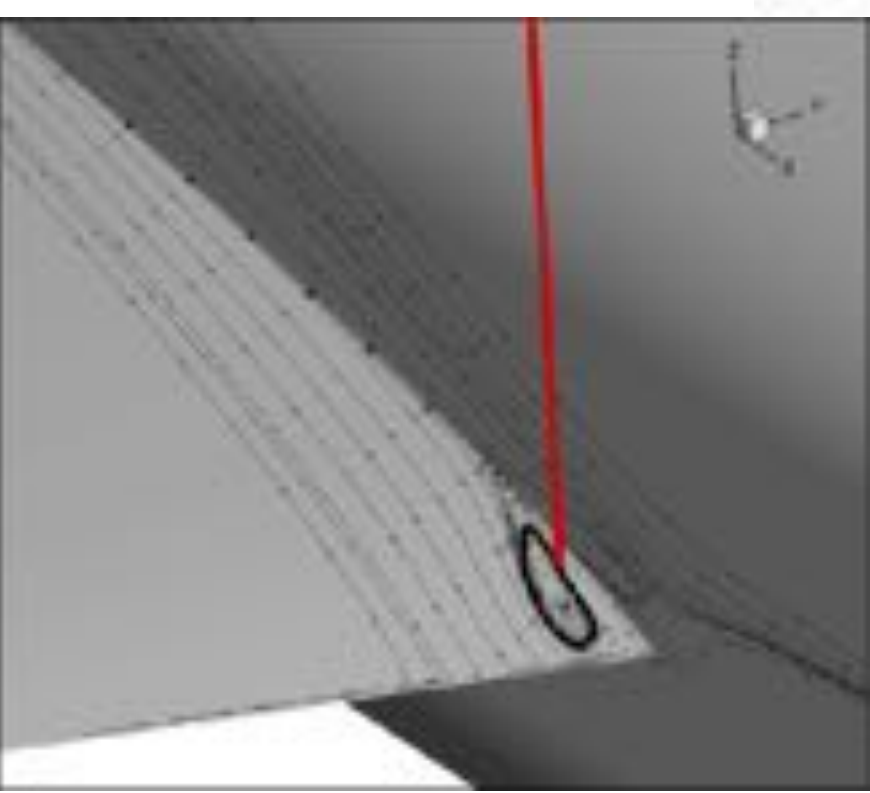


AOA = 5 deg

Reynolds Stress Profiles: Grid Resolution (Free Air)

Similar shapes for Reynolds stresses across grids, but still not matching Exp.

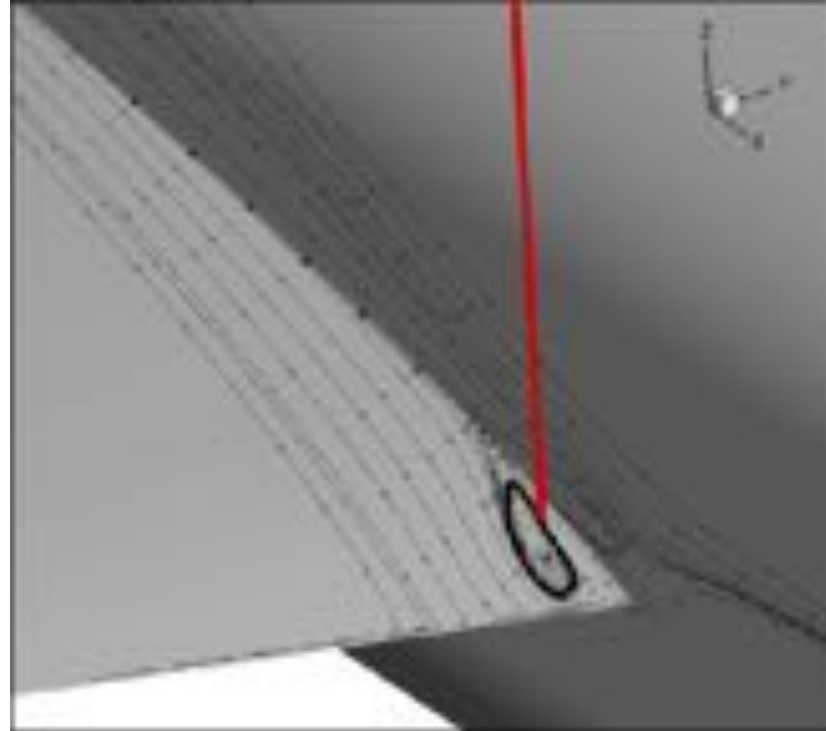
In the Separated Region, 10 mm from fuselage



AOA = 5 deg

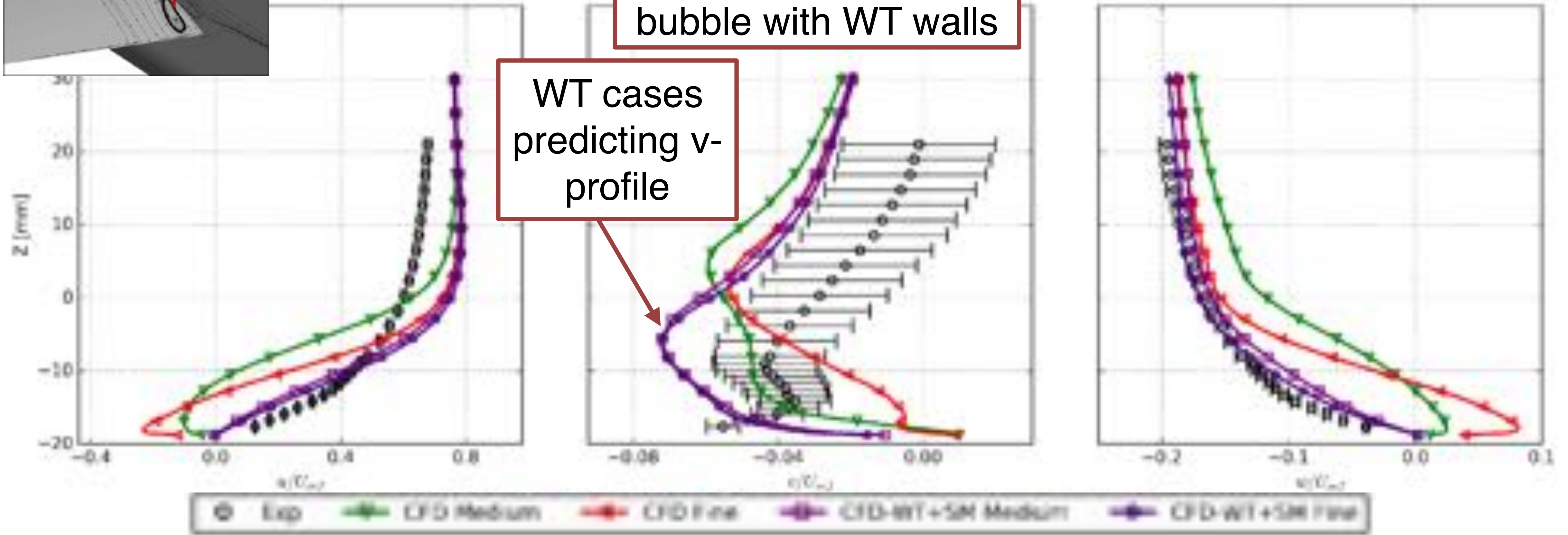
Velocity Profiles: Wall Effect

In the Separated Region, 10 mm from fuselage



Separated flow predictions different in bubble with WT walls

WT cases predicting v-profile

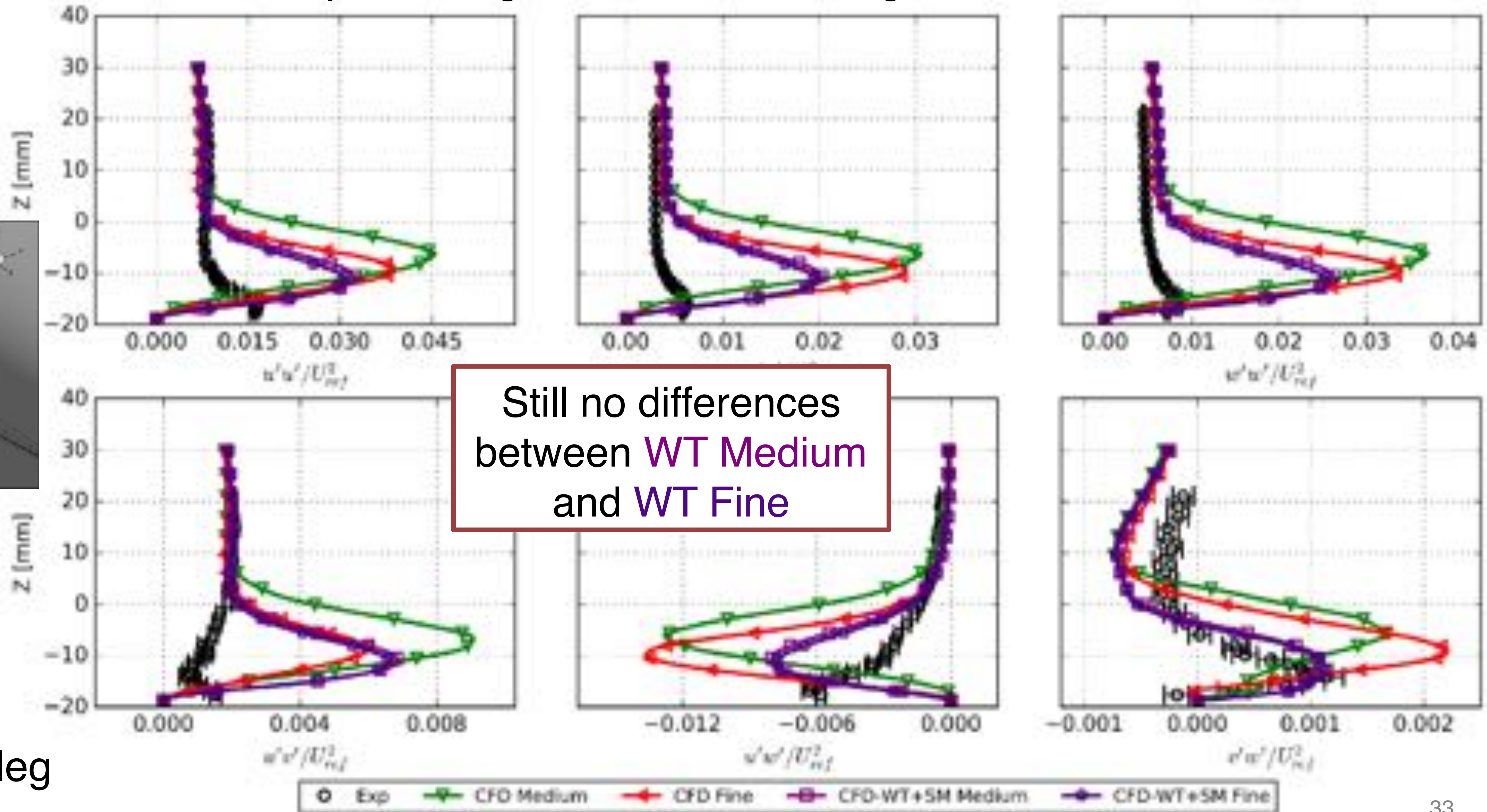
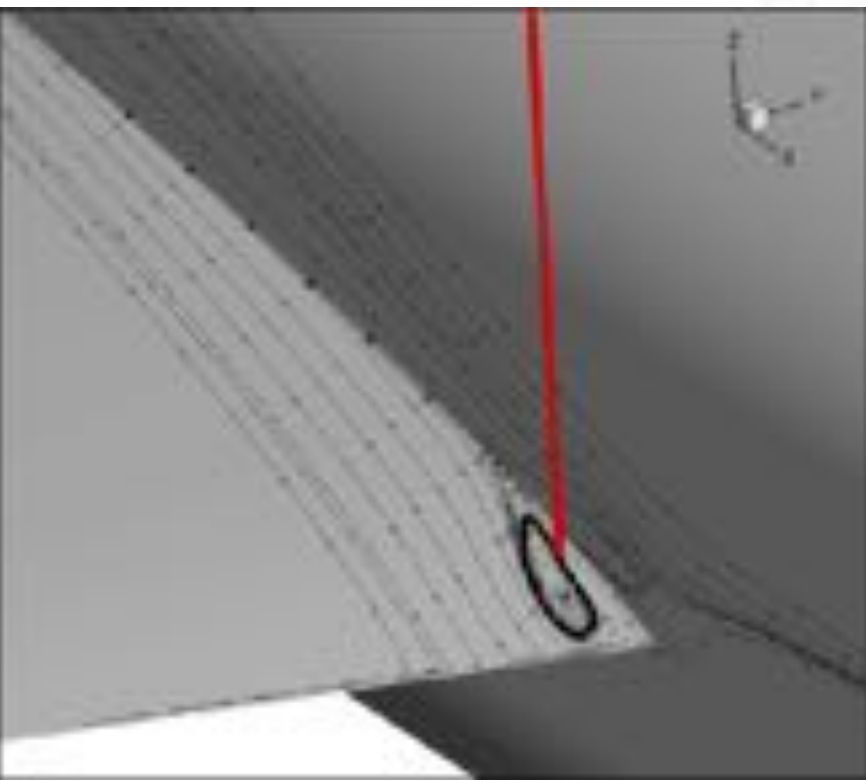


AOA = 5 deg

Reynolds Stress Profiles: Wall Effect



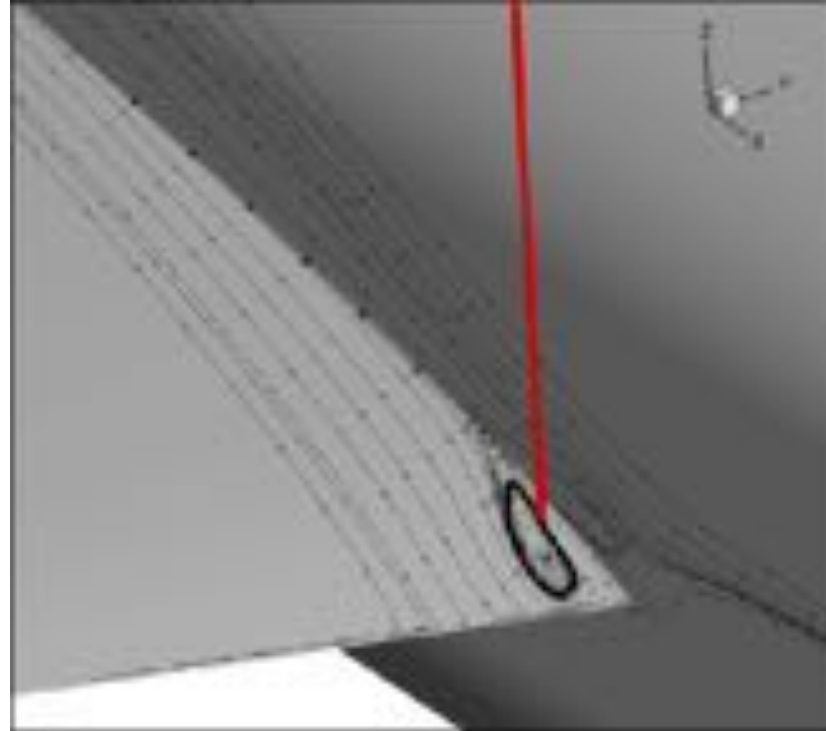
In the Separated Region, 10 mm from fuselage



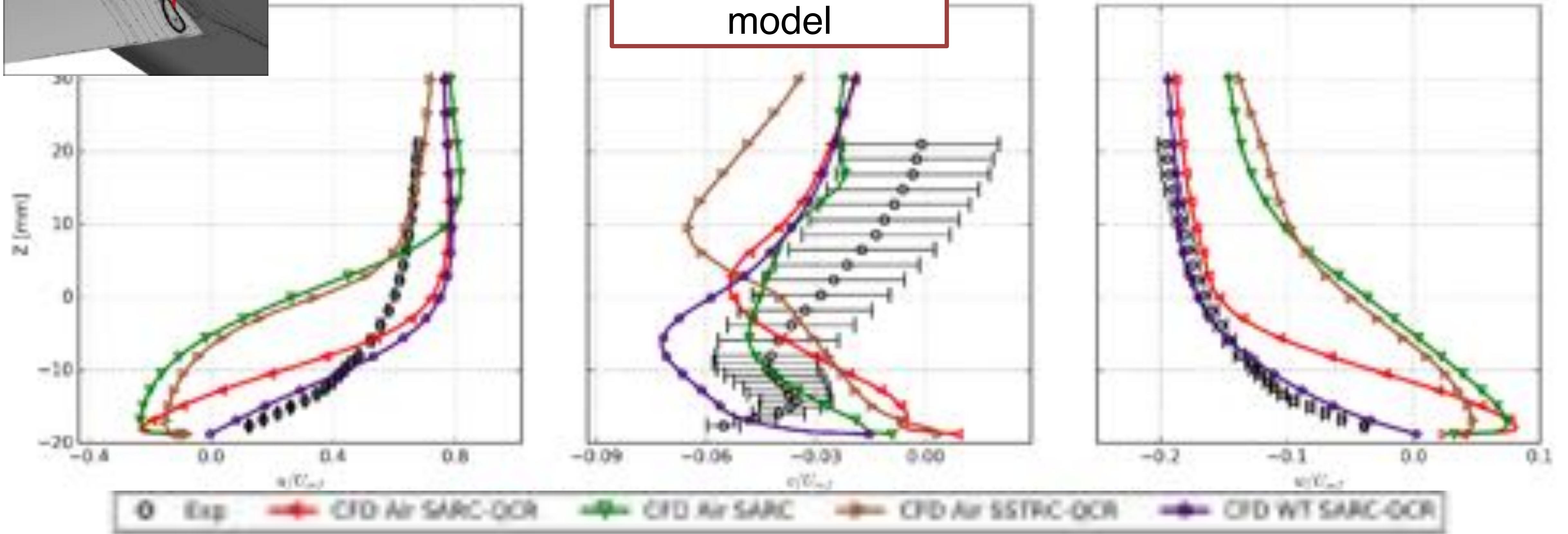
AOA = 5 deg

Velocity Profiles: Turbulence Model

In the Separated Region, 10 mm from fuselage



Large variation for each turbulence model

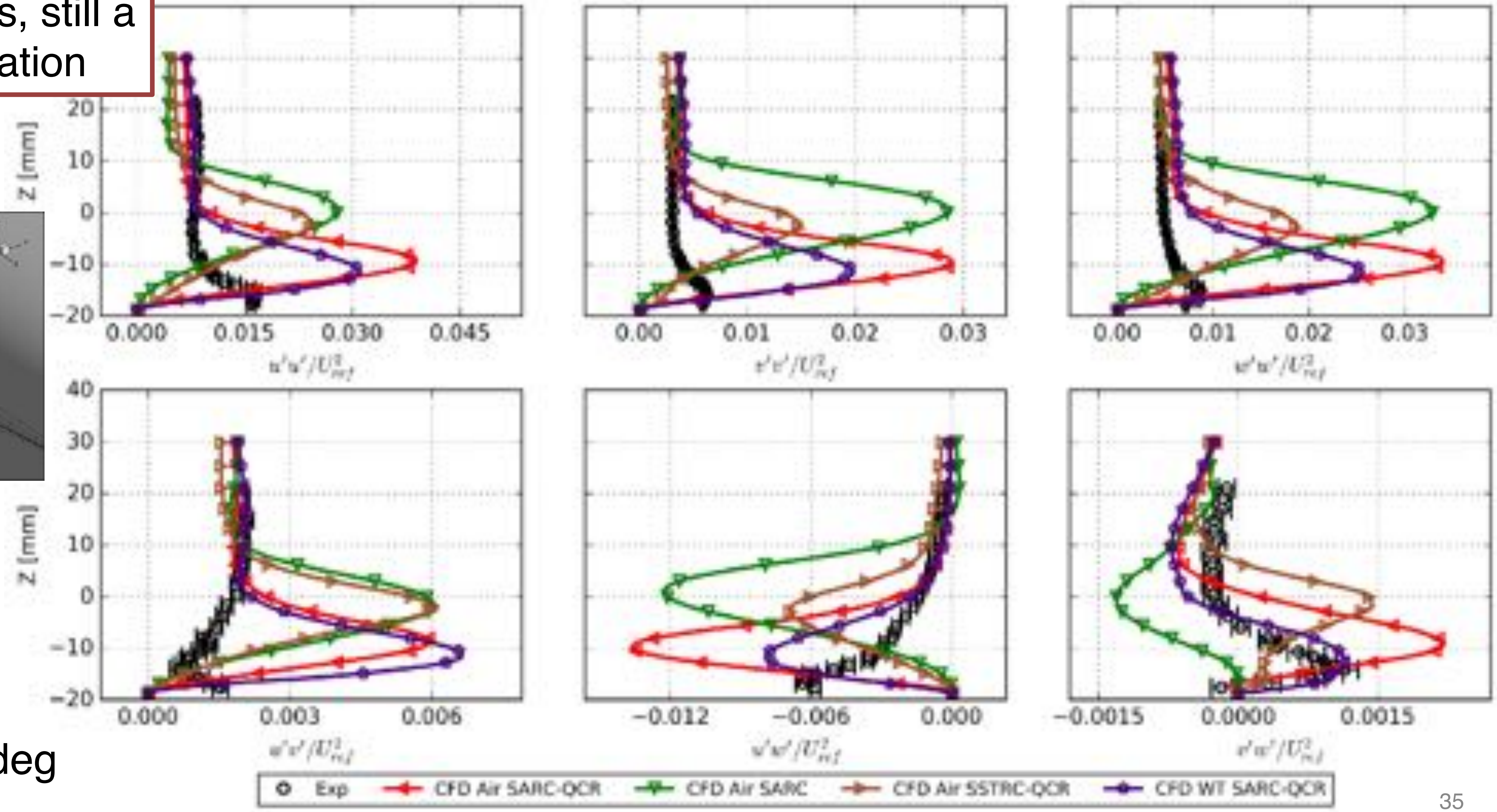
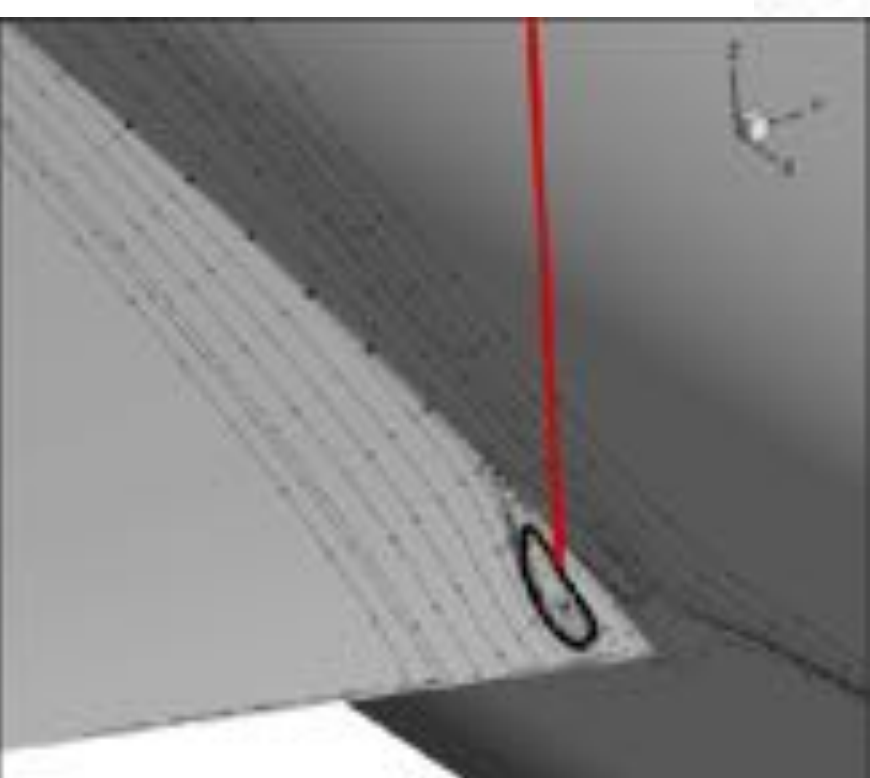


AOA = 5 deg

Reynolds Stress Profiles: Turbulence Model

In the Separated Region, 10 mm from fuselage

Turb. models, still a large variation



AOA = 5 deg



Summary

- Preliminary evaluations of OVERFLOW CFD “RANS” on Juncture Flow region
 - Solutions compare well before separation
 - Some sensitivity to grid resolution in free air
 - Less sensitive to grid resolution with wind tunnel walls
 - CFD in tunnel simulations predicted smaller separations
 - Turbulence Model variations the largest
- Turbulence Model predicted largest differences
 - No “trend” on which model matches the best
 - Wide variation across models
- CFD is doing a decent job at the broader quantities (pressures, velocities), but predictions break down in the separated regions.



Future Work

- No significant indication in the computation of unsteady nature to the flow
- Preliminary time accurate computations do not show any major effects of unsteadiness
- Need a bit more guidance about the time scales
- Further explore effects of resolution (grid adaption) and turbulence model variations
- Possible corrections for AOA?

Acknowledgements



NASA's Transformational Tools and Technologies Project

NAS Supercomputing Division for Pleiades & Electra

Chris Rumsey and the Juncture Flow committee:

NASA Langley: P. Balakumar, Mark Cagle, Dick Campbell, Jan-Renee Carlson, Andy Davenport, Kevin Distill, Judy Hannon, Luther Jenkins, Bil Kleb, Mujeeb Malik, Cathy McGinley, Joe Morrison, Frank Quinto, Don Smith, Sandy Webb

NASA Ames: Henry Lee, Thomas Pulliam, James Bell, Nettie Roozeboom, Laura Simurda, Greg Zilliac

Boeing: Mike Beyer, Neal Harrison, Peter Hartwich, Philippe Spalart, Tony Sclafani, John Vassberg

AUR: Gwibo Byun and Roger Simpson

Virginia Tech: Aurelien Borgoltz and Todd Lowe

University of Kentucky: Jim Coder

Bill Oberkampf

Questions?

