Collaborative Testing Challenge
Plots of Collective Results

2022 Symposium on Turbulence Modeling: Roadblocks, and the Potential for Machine Learning

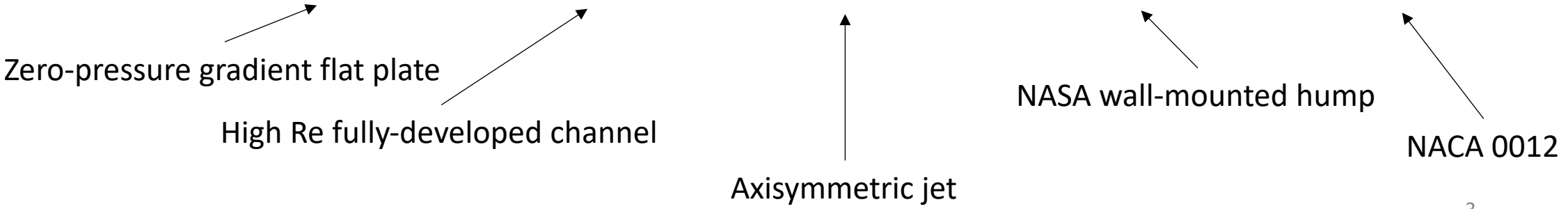
Introduction

- This collaborative challenge was intended as a friendly learning exercise, not a competition
- Here all results are identified and plotted together; this helps provide a feel for the quality of the collective results
  - For comparison against a “standard” model, they are also plotted against SA results
- Everyone had difficulties – there are no winners or losers
- There’s much to learn – both from successes and “failures”

Challenge Participants – what was submitted

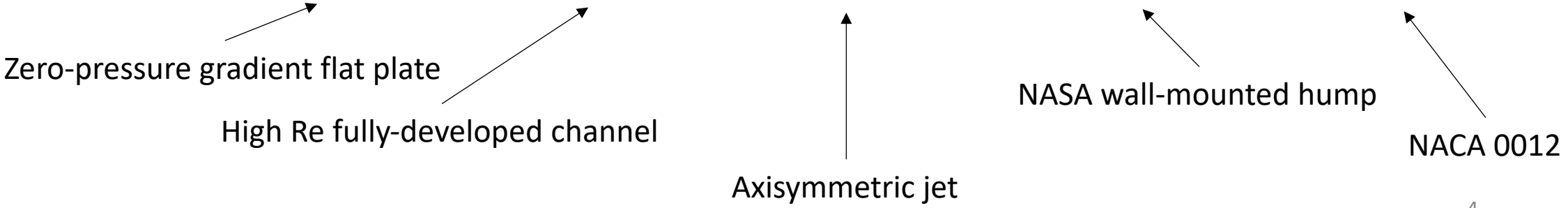
(Green=submitted ; Red = not submitted)

Participant	2DZP	2DFDC	ASJ	2DWMH	2DN00
Fang (exp)					
Fang (theory)					
Bin					
Cherroud					
Dwight					
Parish					
Stoellinger					
Viswanathan					
Marepally					

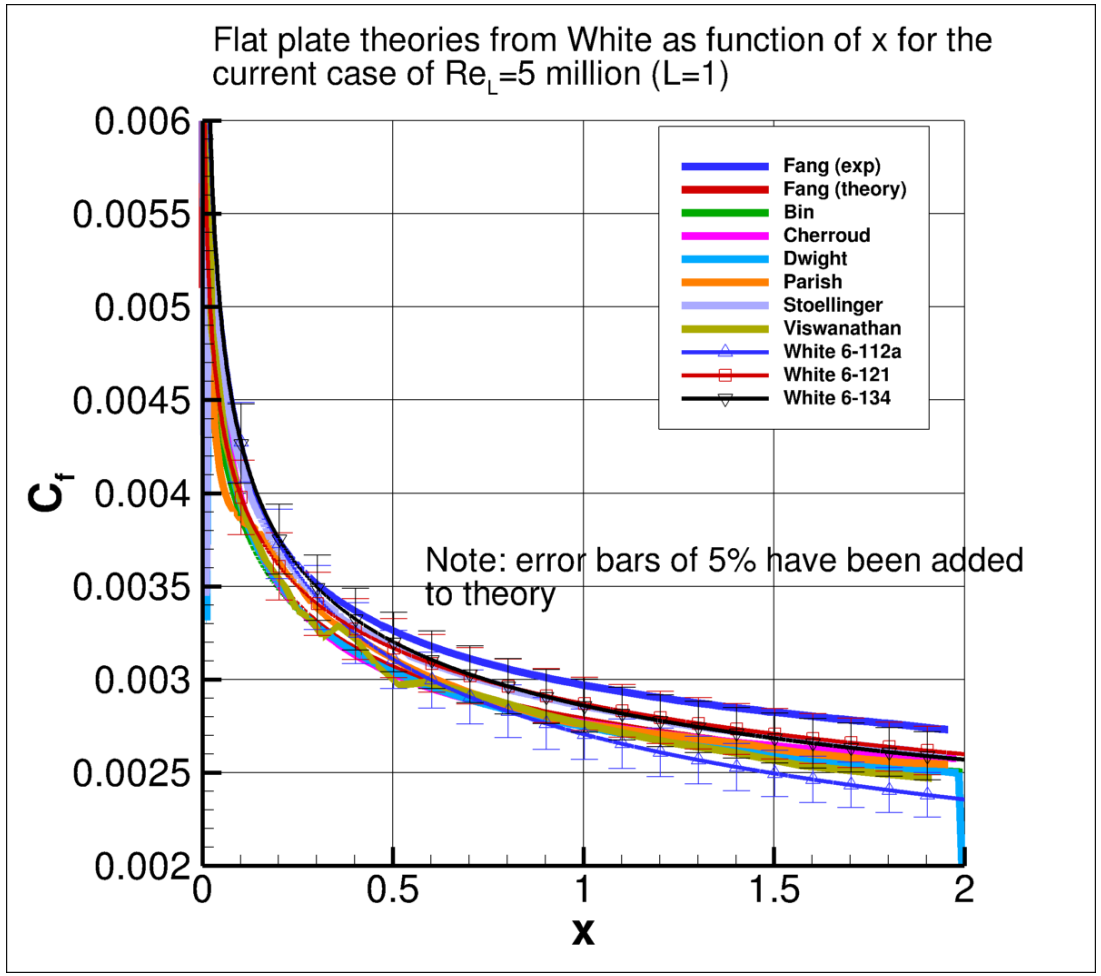


Challenge Participants – very brief summary of methods

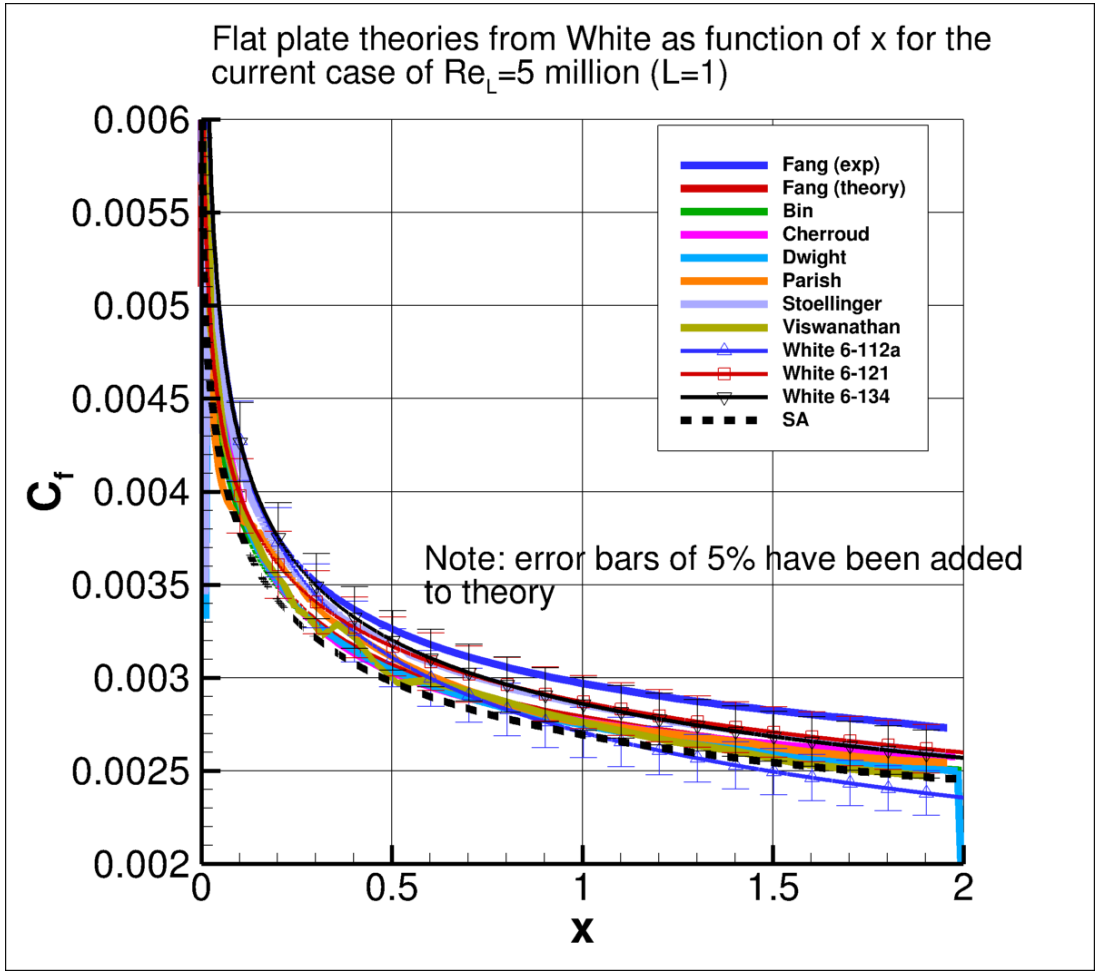
Participant	2DZP	2DFDC	ASJ	2DWMH	2DN00
Fang (exp)	GEP optimized	based on exp			
Fang (theory)	GEP optimized	based on theory			
Bin	DD fix of SA	(do no harm…	protect LOTW)		
Cherroud	Separately	trained EARSM	models	aggregated	
Dwight	Baseline SST	… then train a	classifier model		
Parish	Ensemble of NNs	with training on	data other than	challenge cases	
Stoellinger	Human-trained	model			
Viswanathan	Ground truth:	SA model itself			
Marepally	FIML on SA	(S809 for training)			



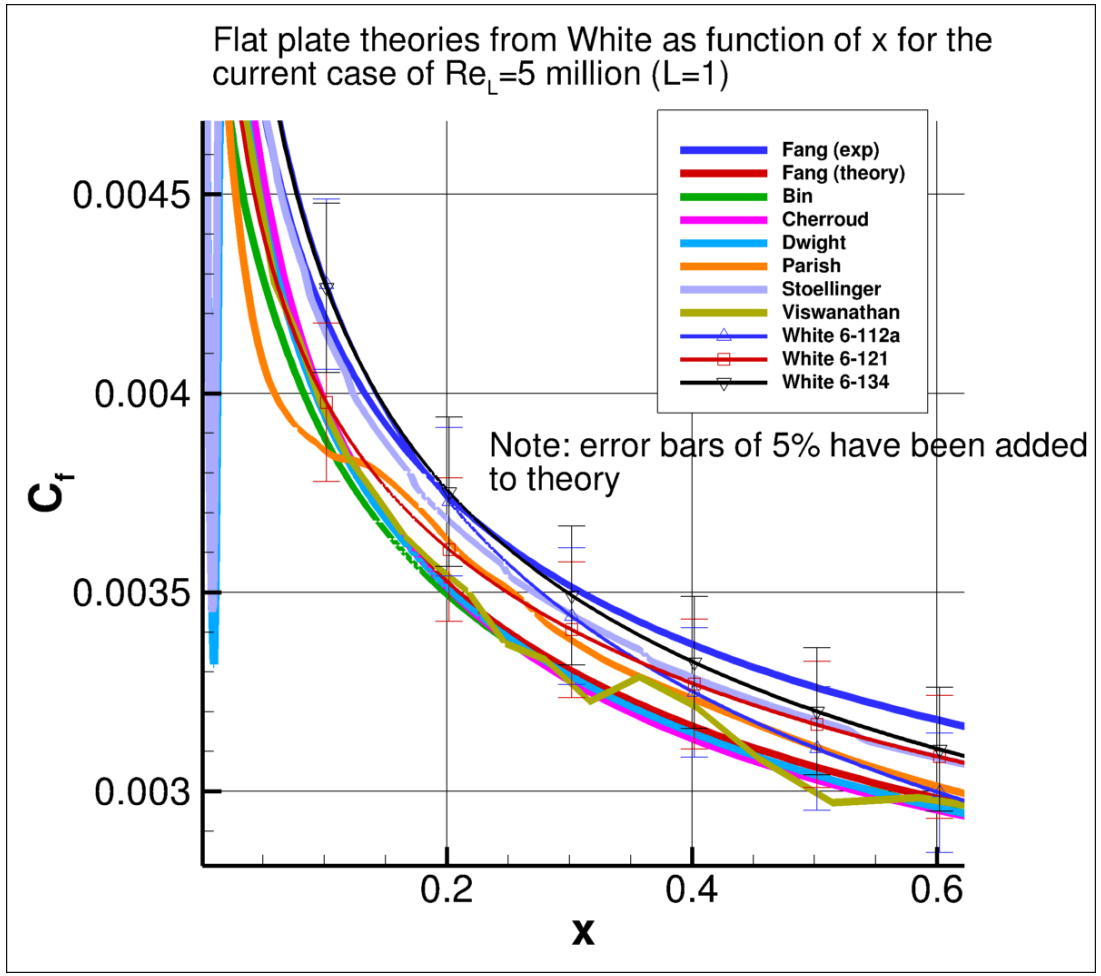
2DZP


Flat plate theories from White as function of x for the current case of Re$_L$=5 million (L=1)
0.006
0.0055
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
C_f
0
0.5
1
1.5
2
x
Fang (exp)
Fang (theory)
Bin
Cherroud
Dwight
Parish
Stoellinger
Viswanathan
White 6-112a
White 6-121
White 6-134
Note: error bars of 5% have been added to theory

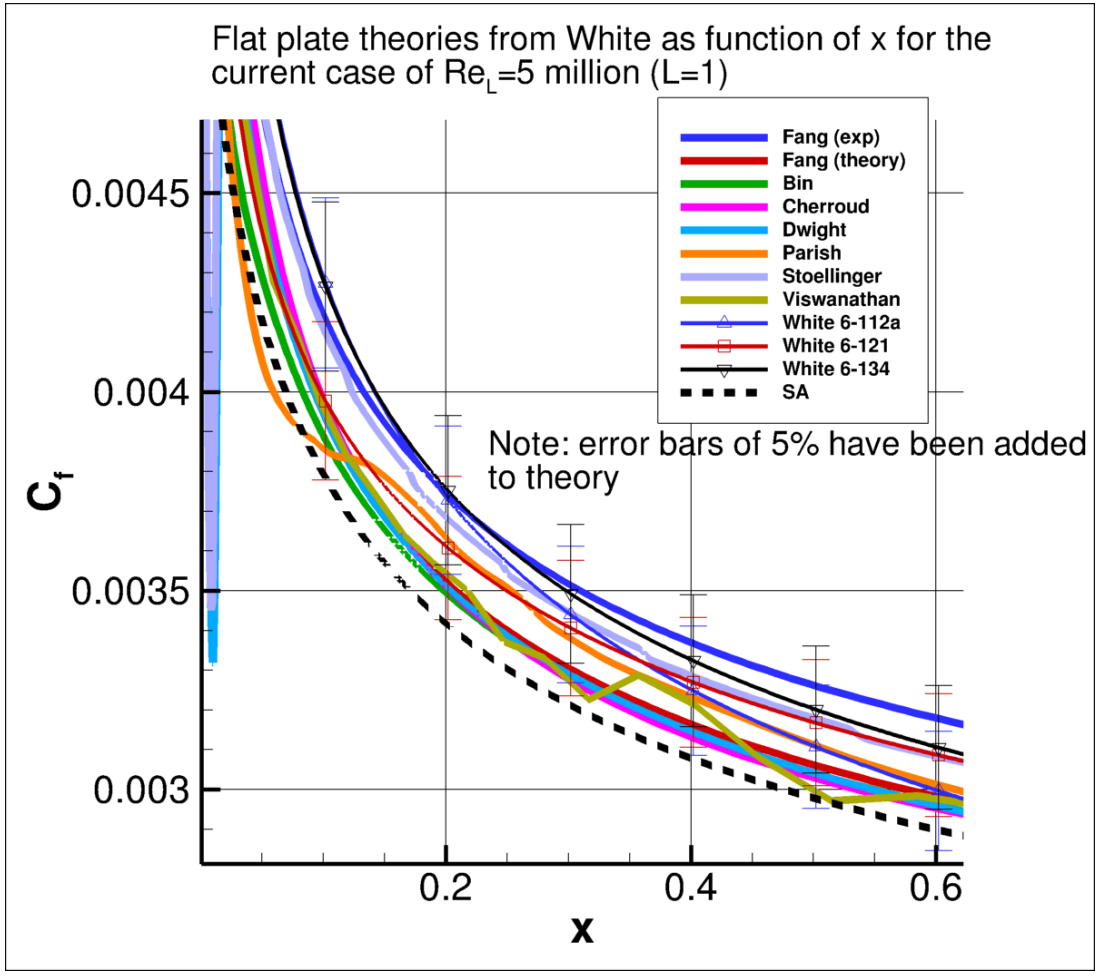
Zoom


Flat plate theories from White as function of x for the current case of Re$_L$=5 million (L=1)
0.006
0.0055
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
C_f
0
0.5
1
1.5
2
x
Fang (exp)
Fang (theory)
Bin
Cherroud
Dwight
Parish
Stoellinger
Viswanathan
White 6-112a
White 6-121
White 6-134
SA
Note: error bars of 5% have been added to theory

2DZP



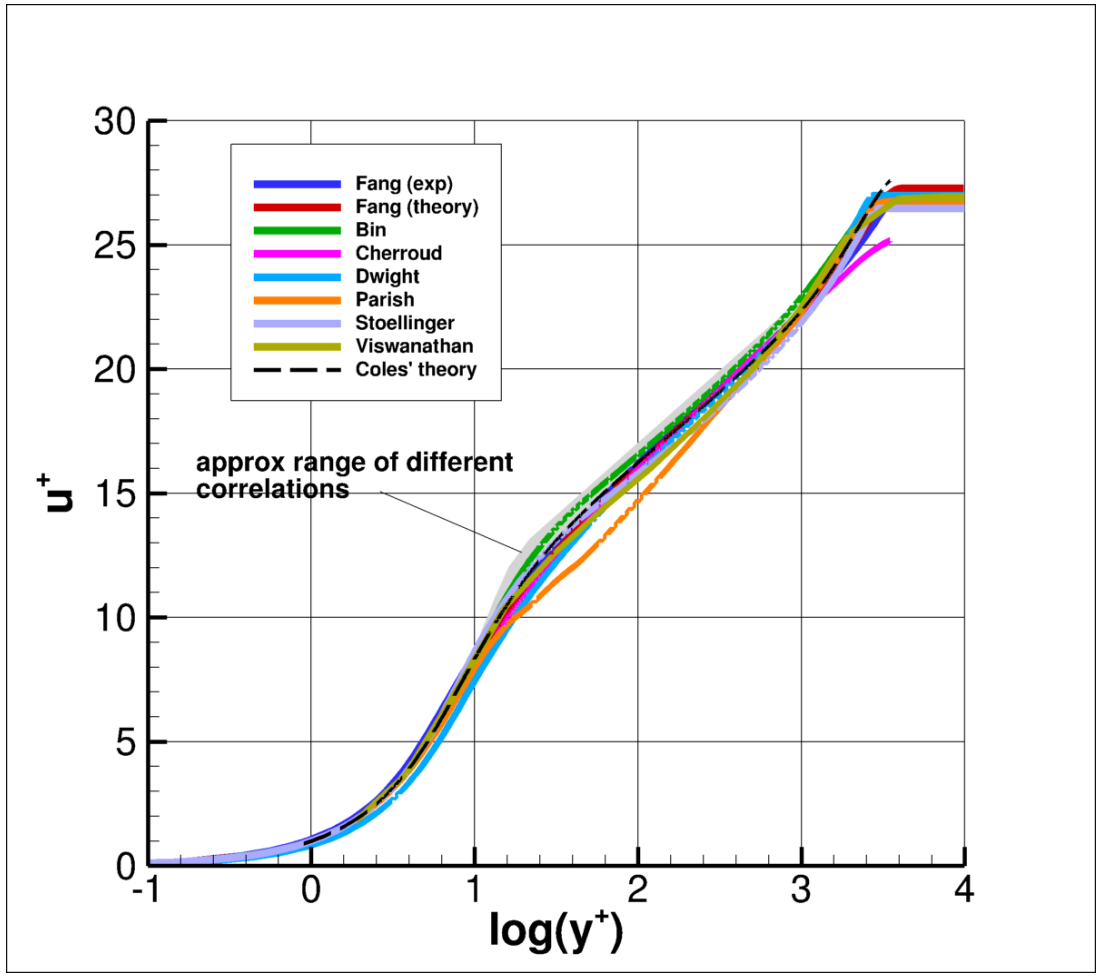
Zoom

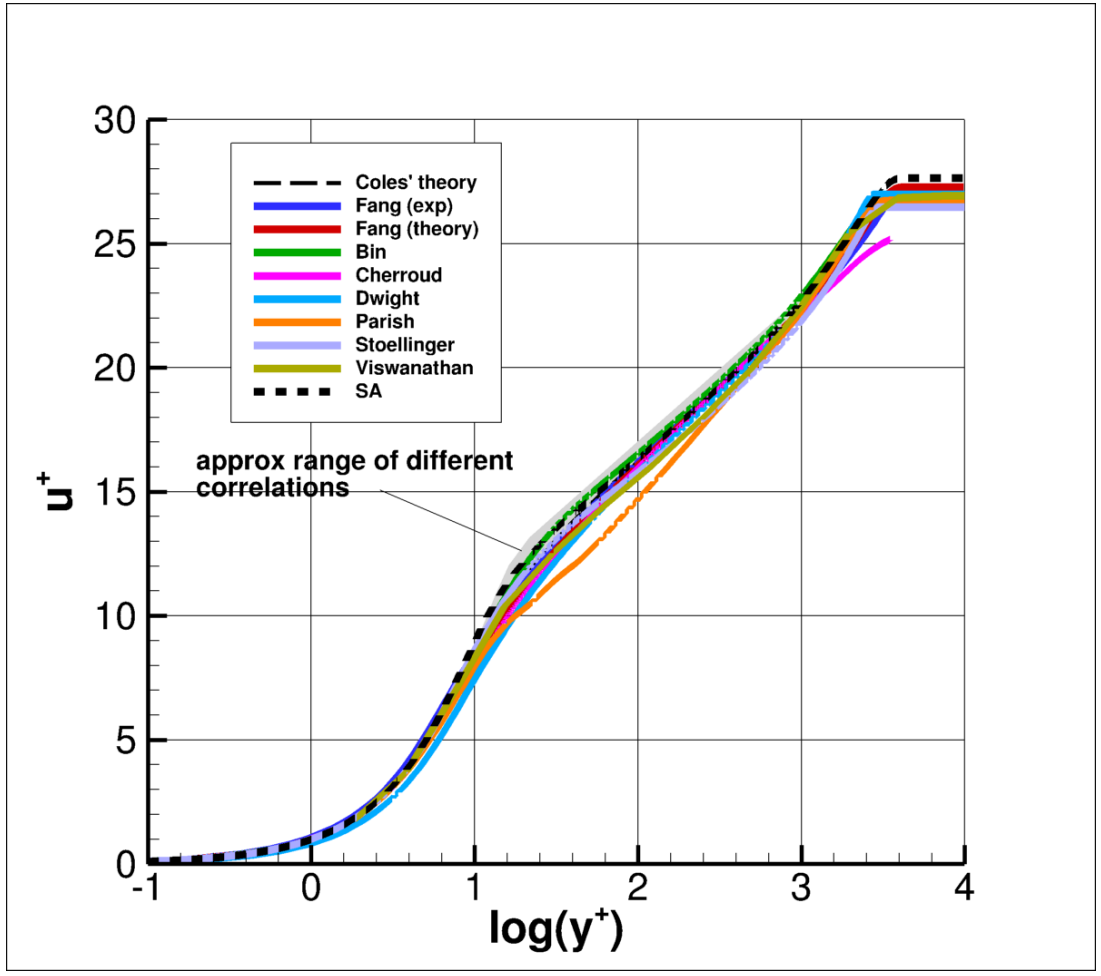


A few of the CFD results are “wavy”

2DZP

How new results stack up against standard SA model

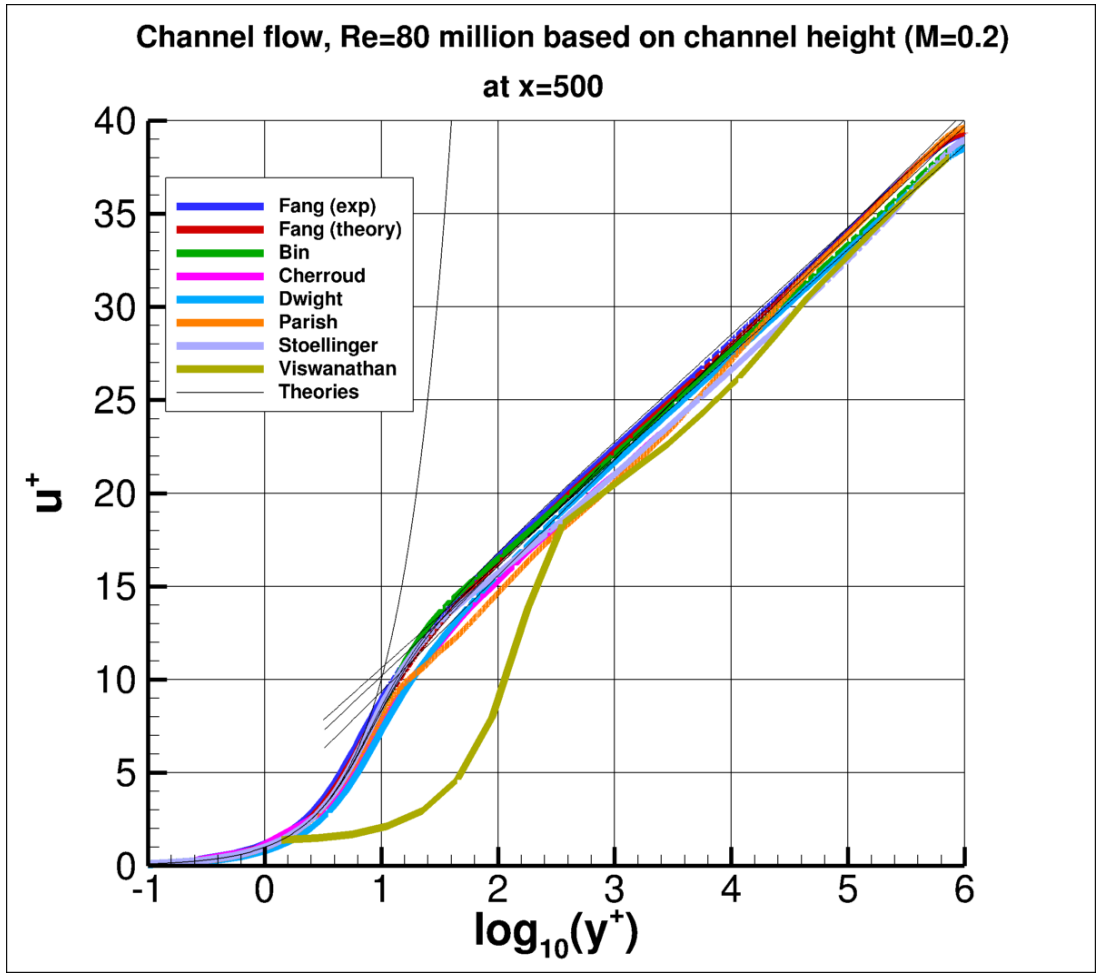


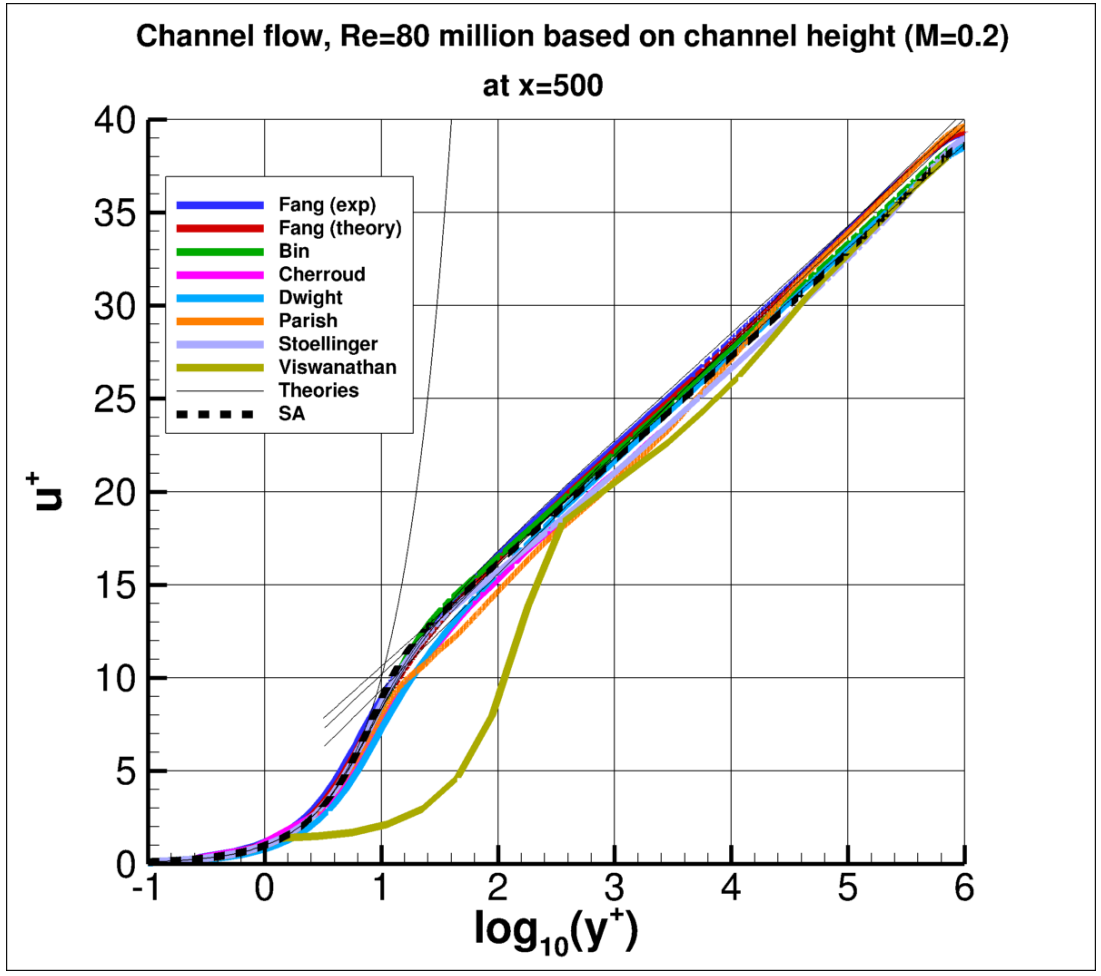


Parish departs from standard LOTW behavior

2DFDC

How new results stack up against standard SA model

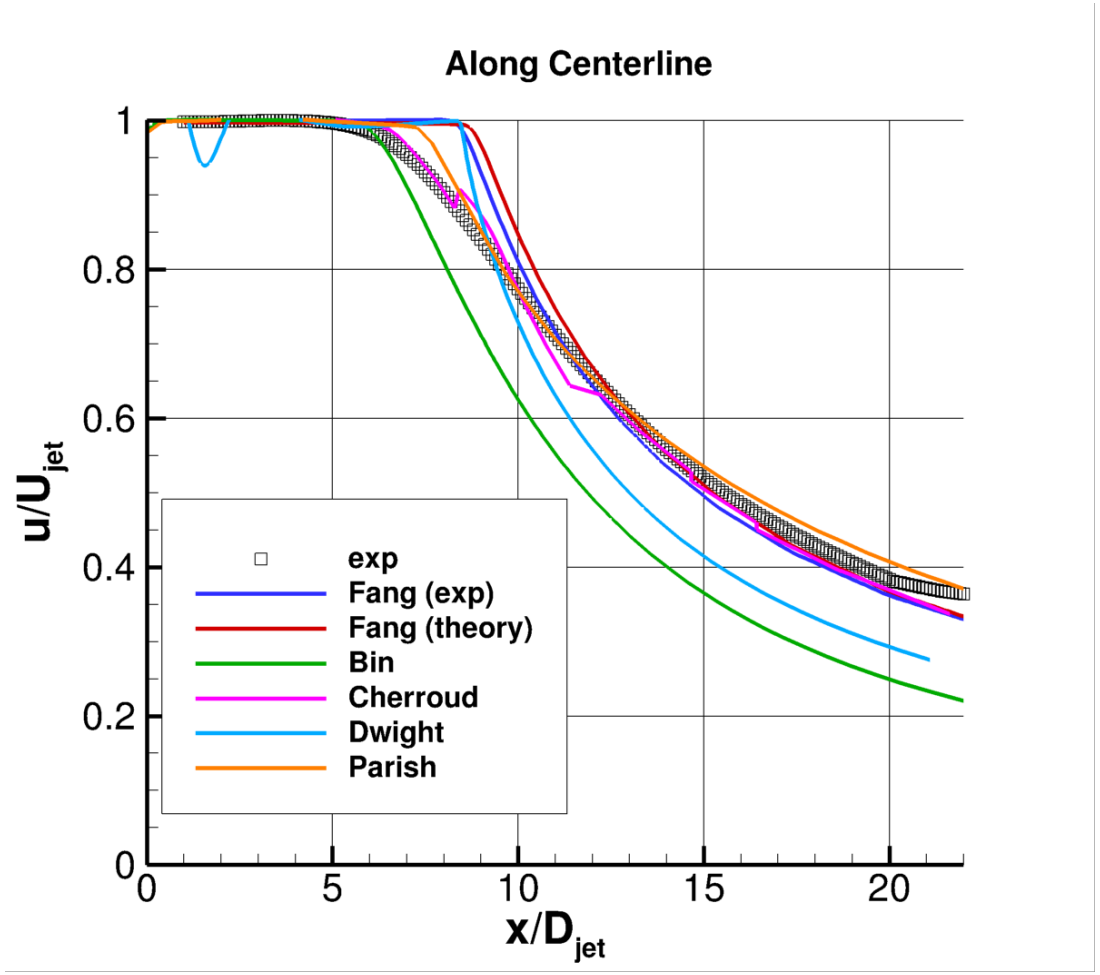


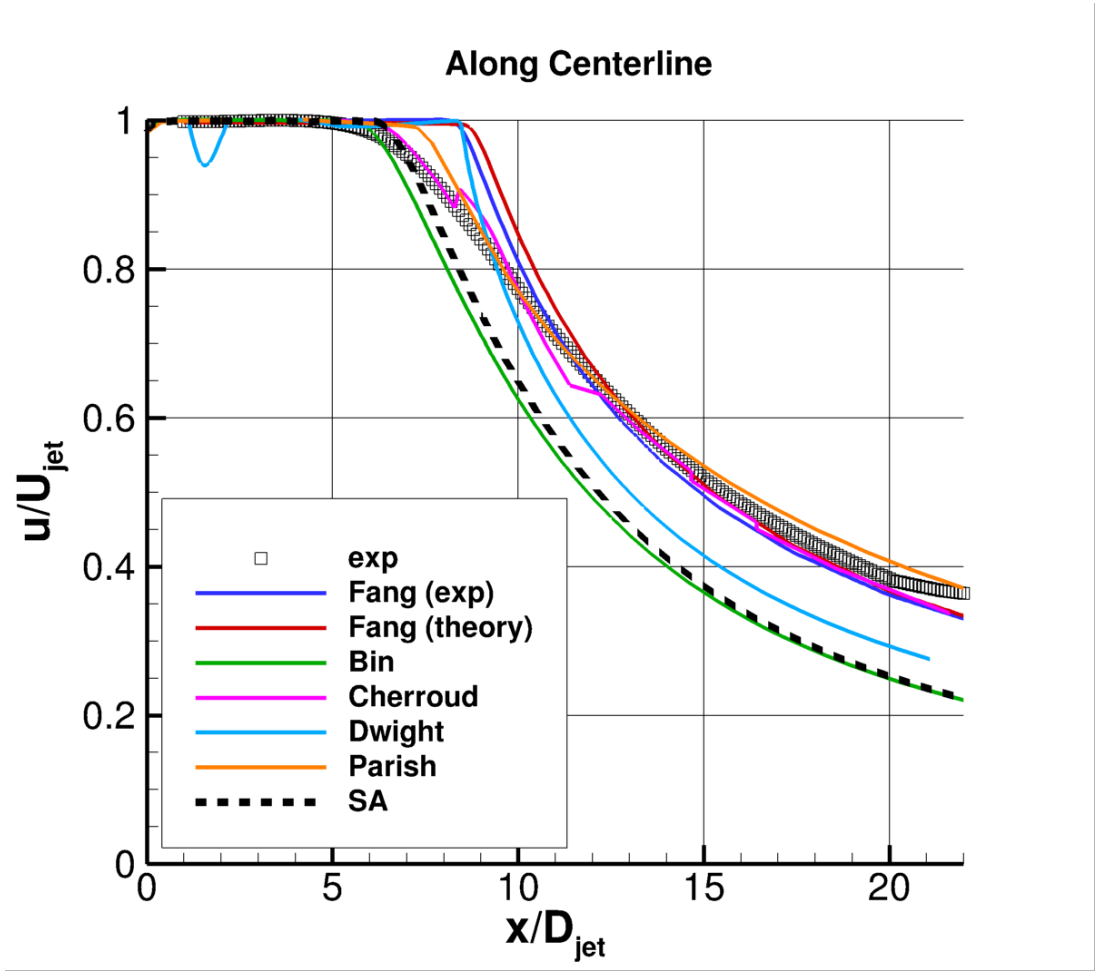


Parish (slightly) and Viswanathan depart from standard LOTW behavior

ASJ

How new results stack up against standard SA model

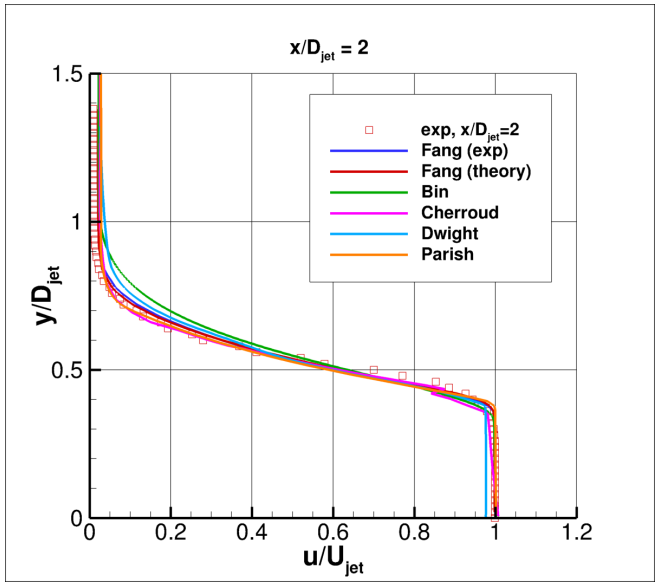


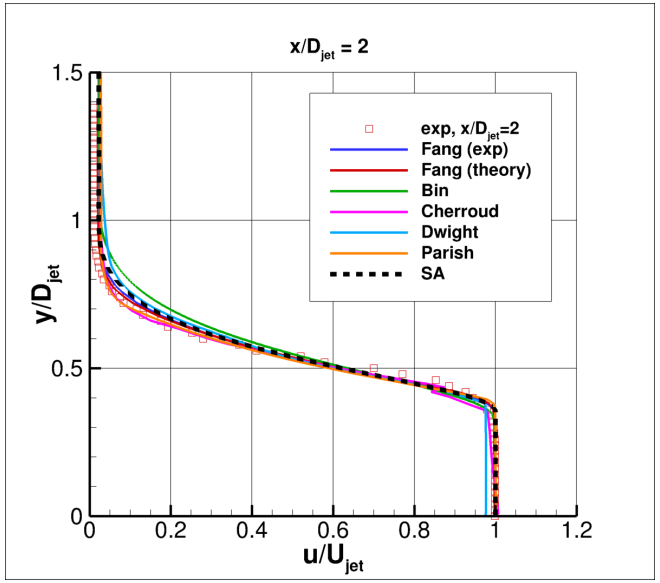


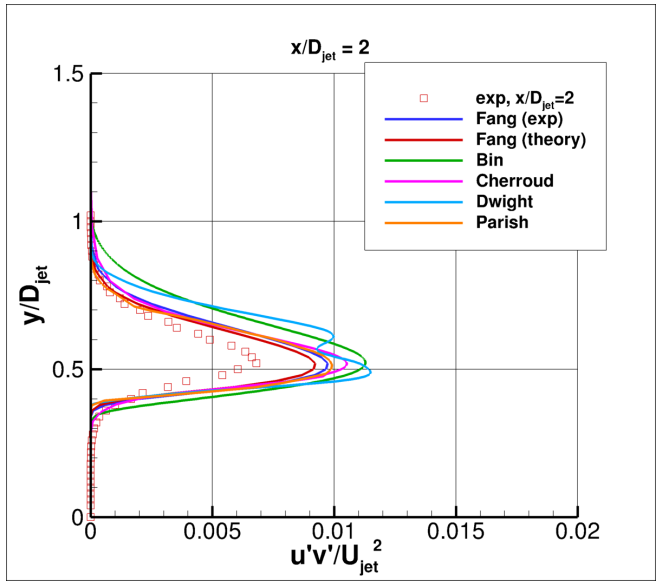
Parish and Cherroud are closest to data
(Cherroud has some “kinks”); Fang (exp) and Fang (theory) are both close beyond $x/D_{jet}=12$

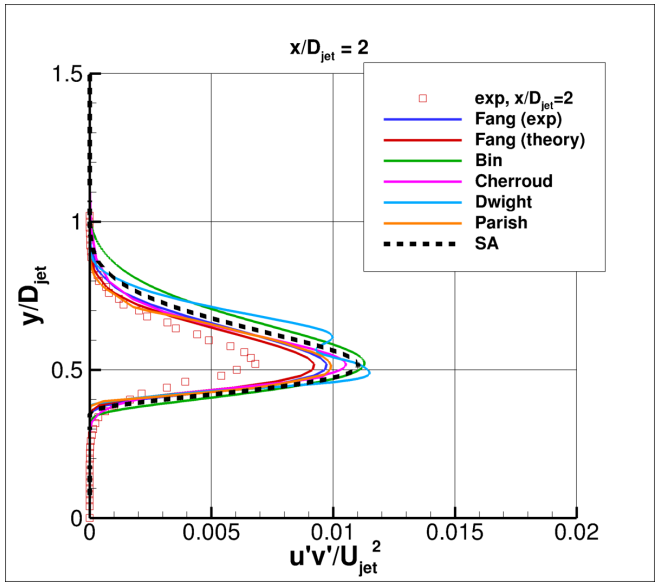
ASJ, at $x/D_{jet}=2$

How new results stack up against standard SA model





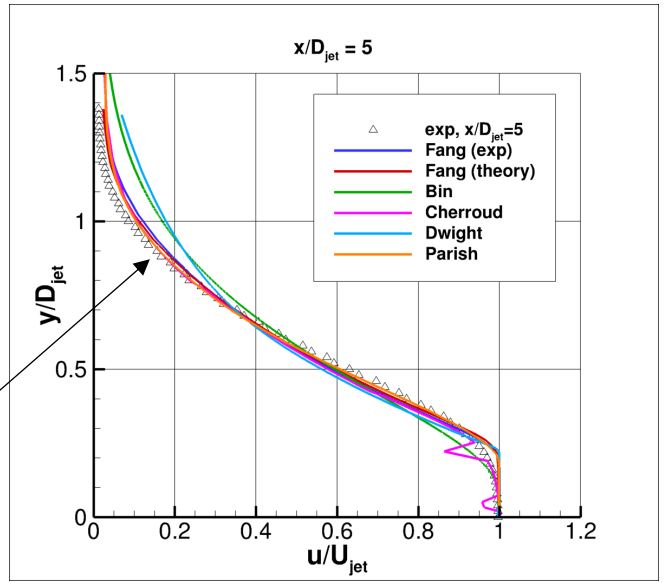


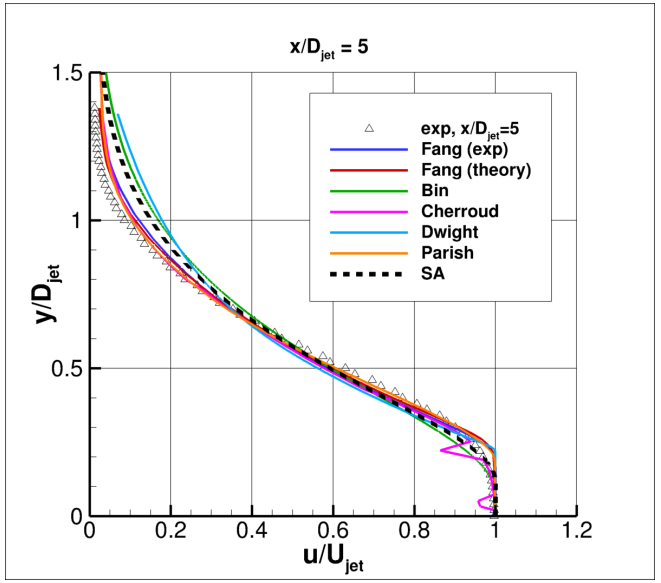


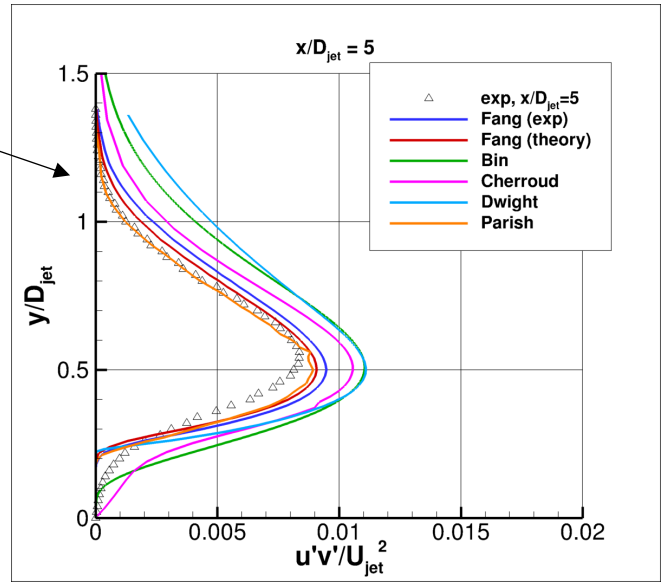
ASJ, at $x/D_{jet}=5$

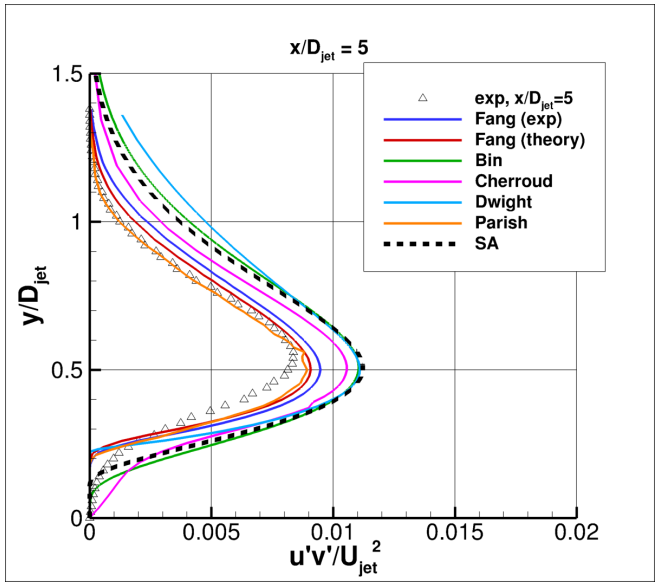
How new results stack up against standard SA model

Fang (exp), Fang (theory), Cherroud, and Parish are all close to exp (some kinks in Cherroud, and Cherroud's u'v' is too large)





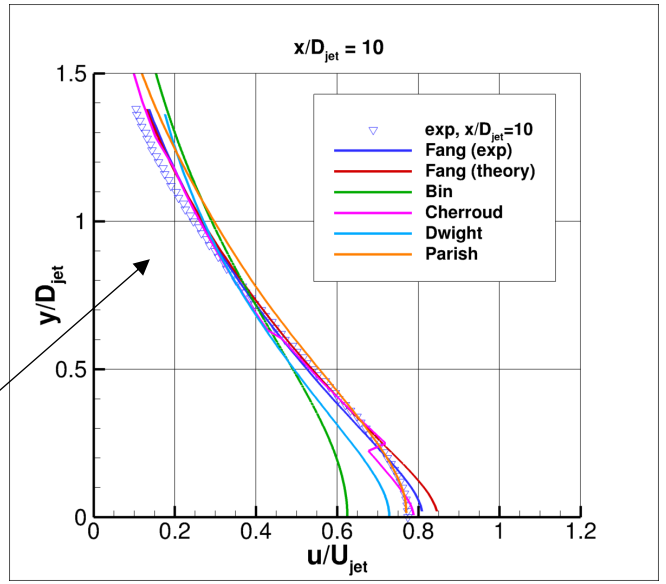


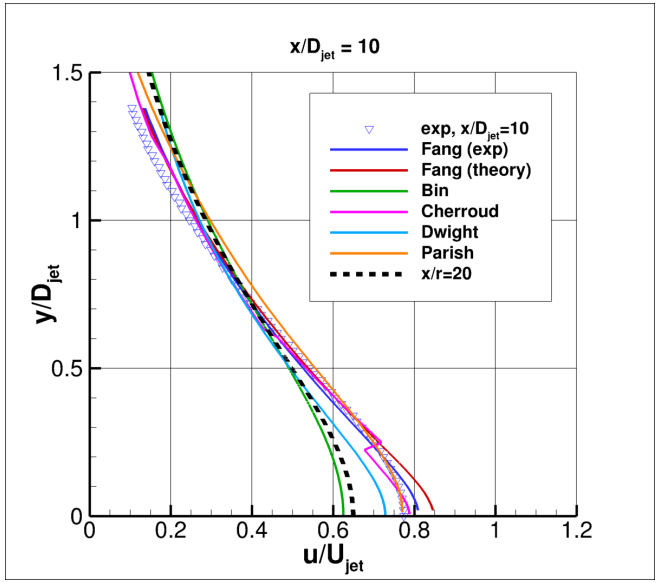


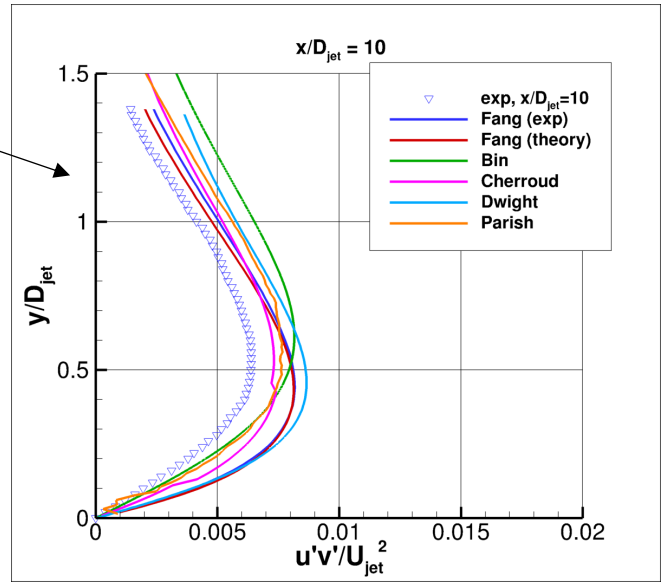
ASJ, at x/D_{jet}=10

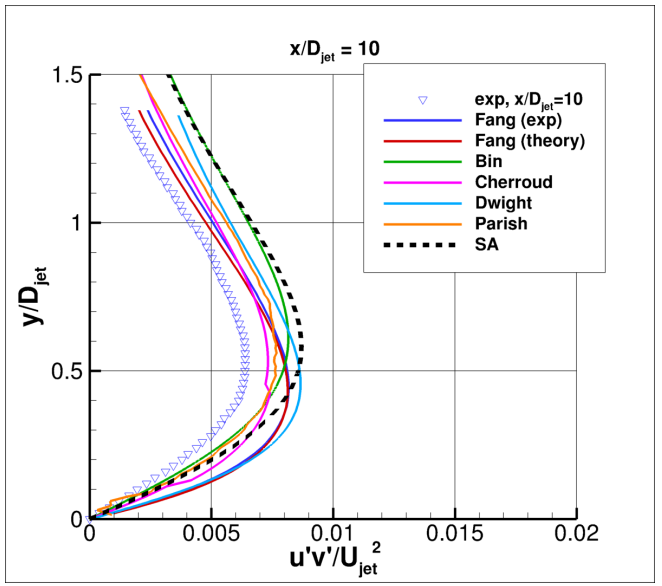
How new results stack up against standard SA model

Fang (exp) and Cherroud are closest to exp (some kinks in Cherroud); Parish is close near y=0





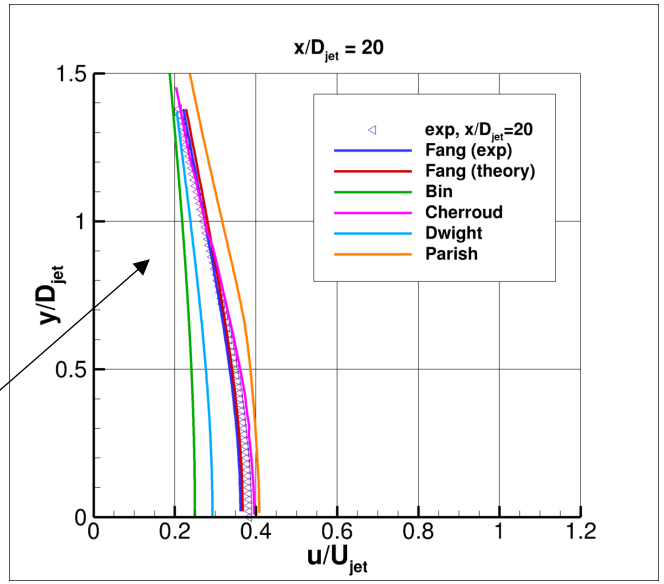


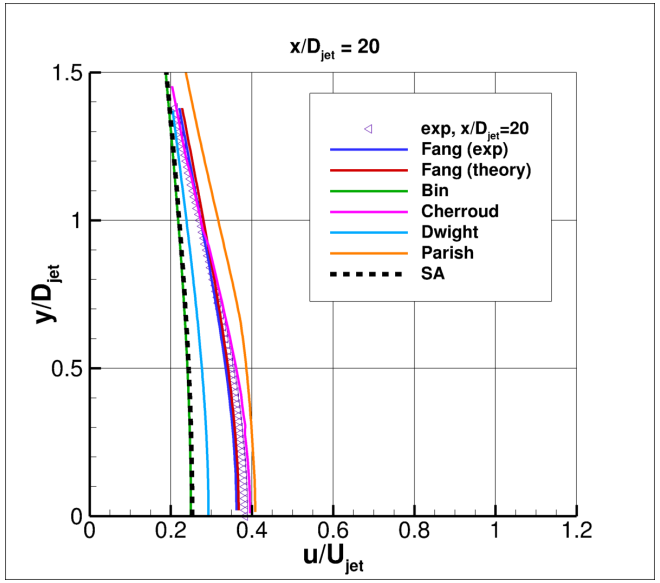


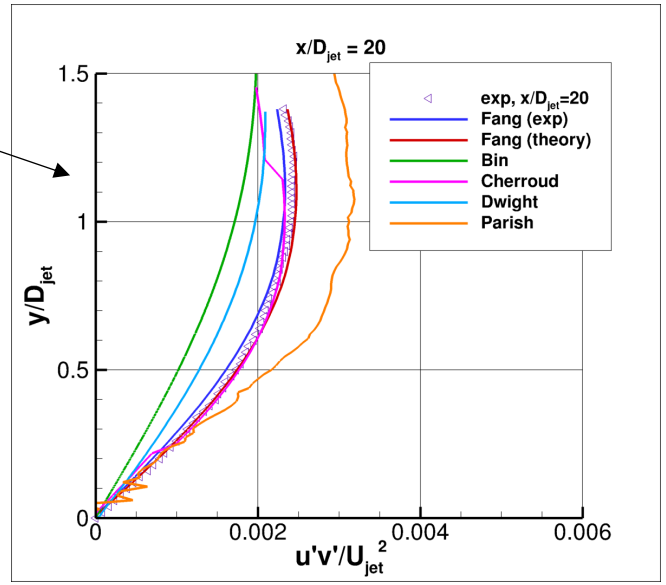
ASJ, at $x/D_{jet}=20$

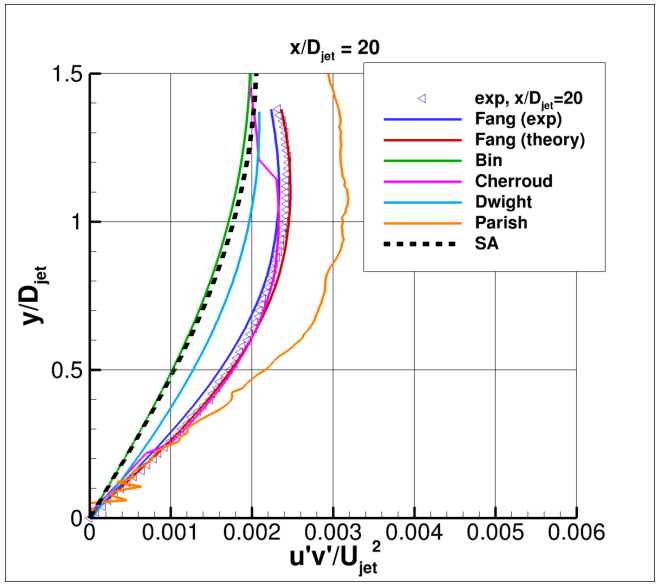
How new results stack up against standard SA model

Fang (exp), Fang (theory), and Cherroud are closest to exp); Parish is close near y=0 (but nonsmooth in u'v')

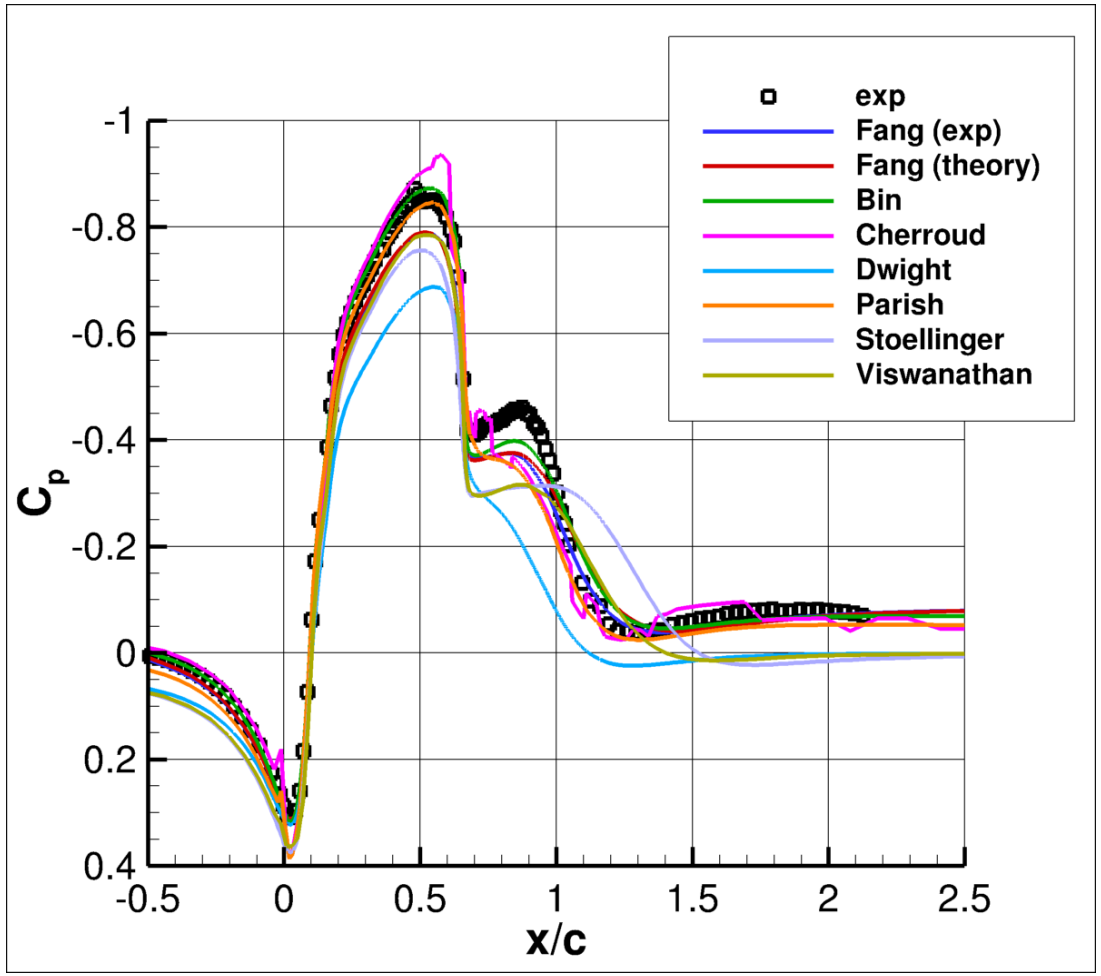




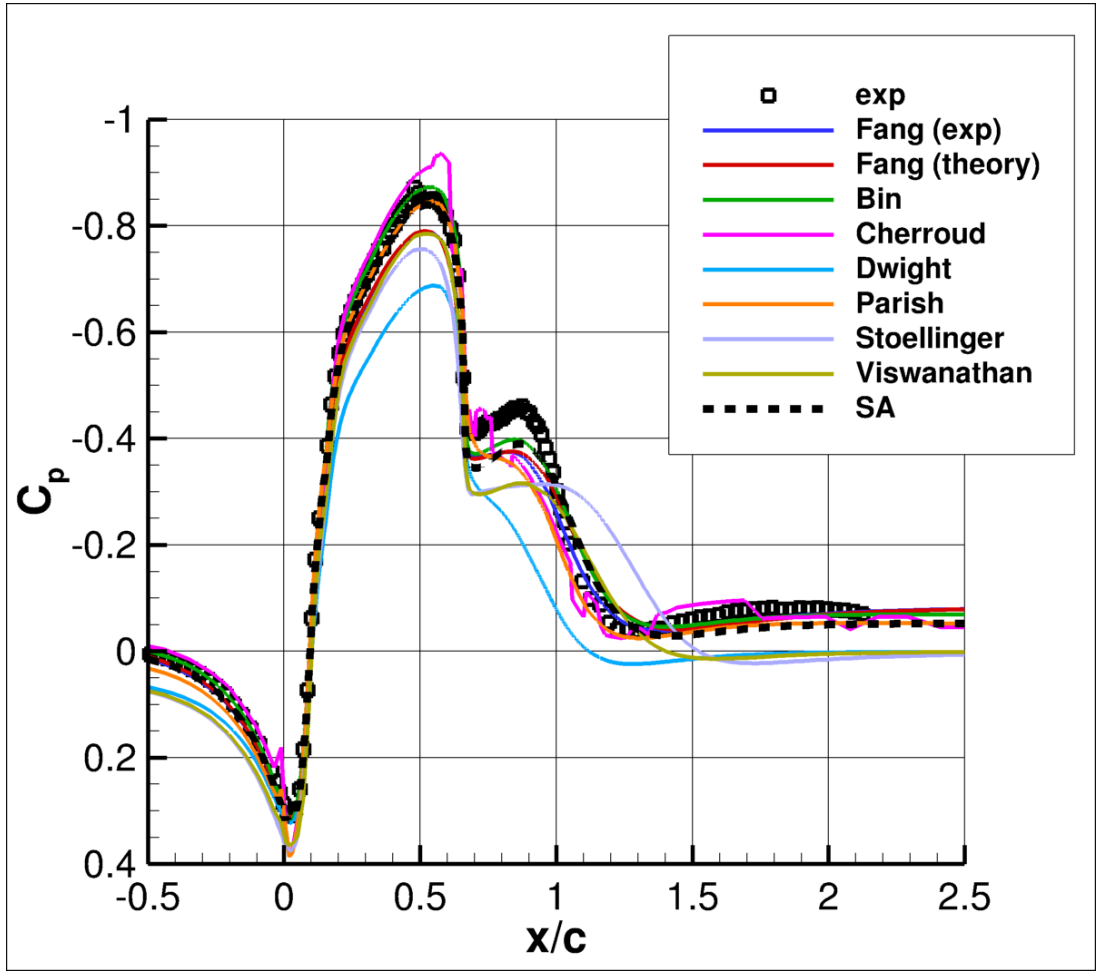




2DWMH



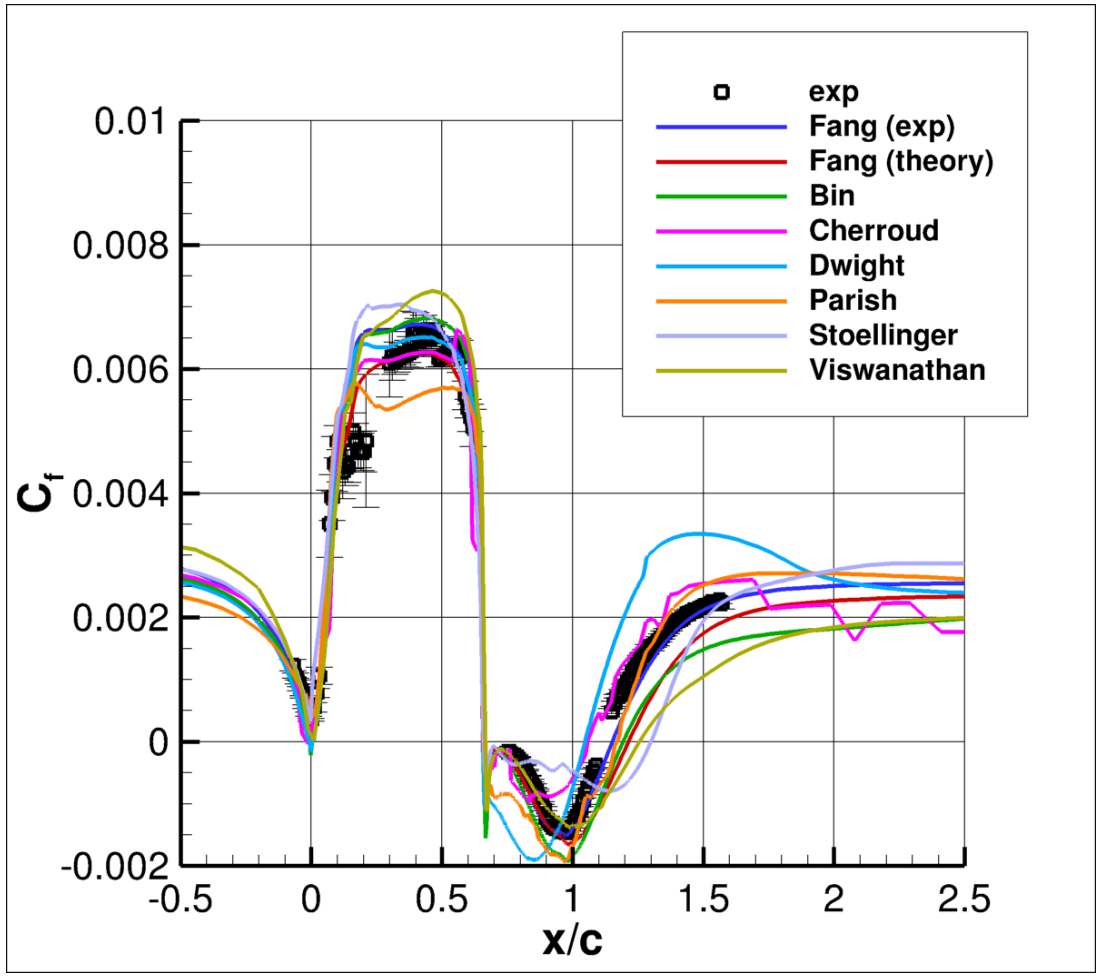
How new results stack up against standard SA model

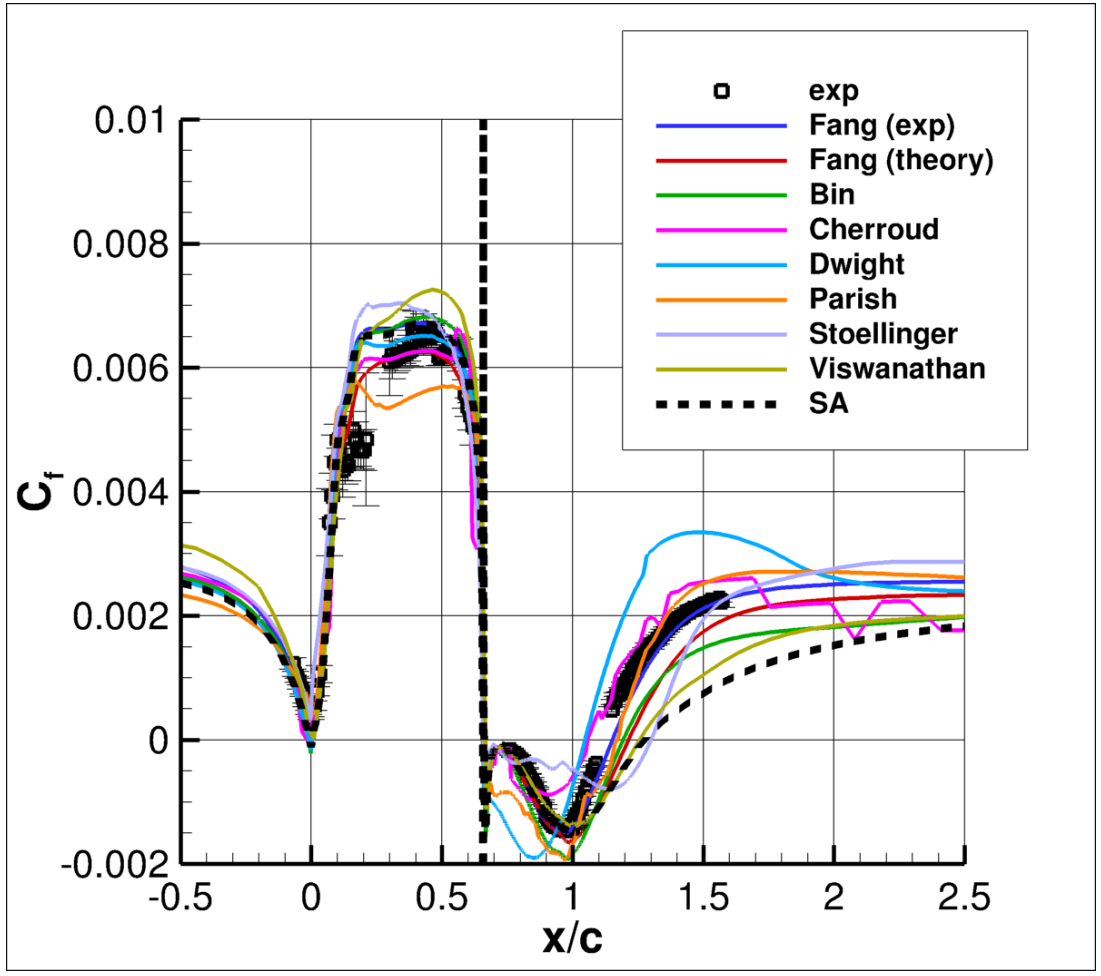


SA and Bin results look best

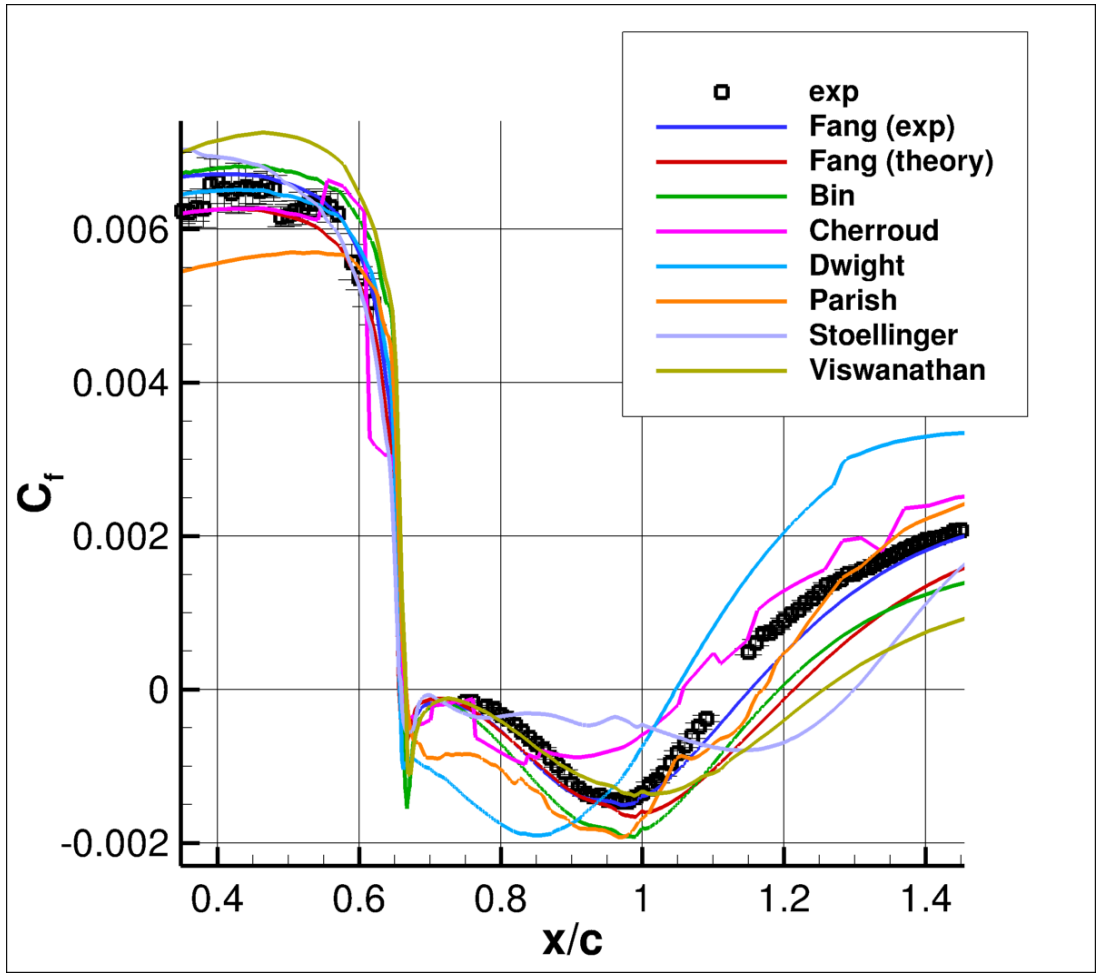
2DWMH

How new results stack up against standard SA model

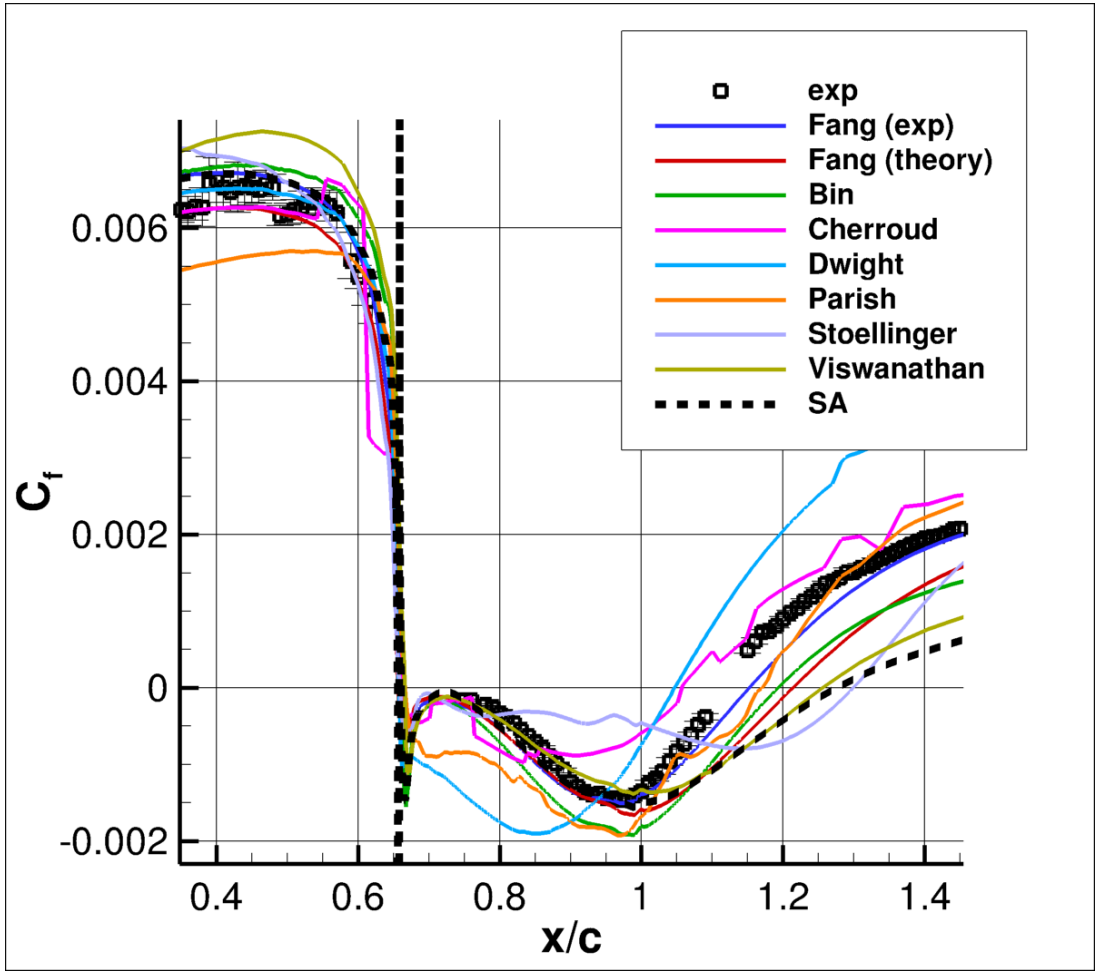




2DWMH



How new results stack up against standard SA model

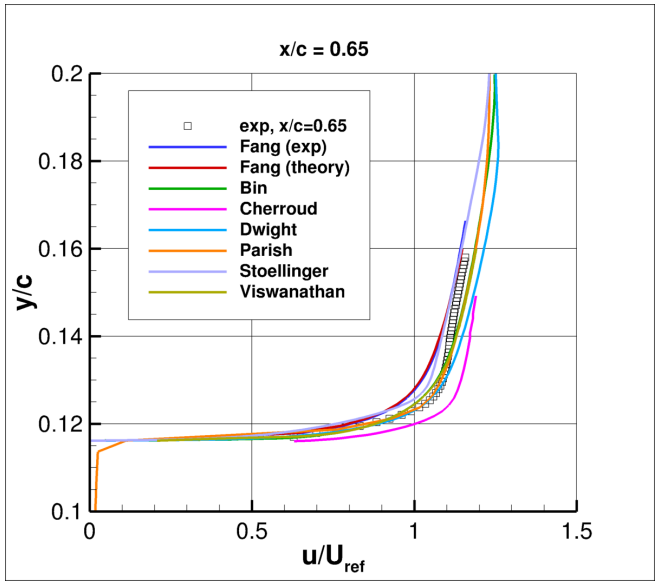


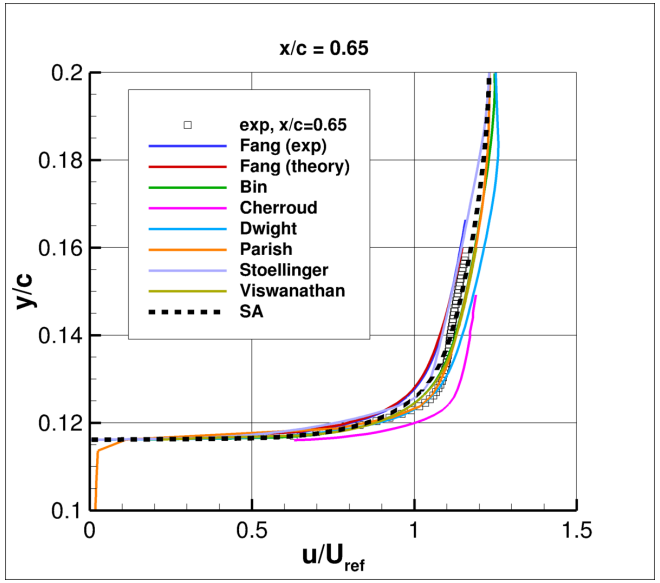
Fang (exp) shows best reattachment result
Dwight & Cherroud reattach too early

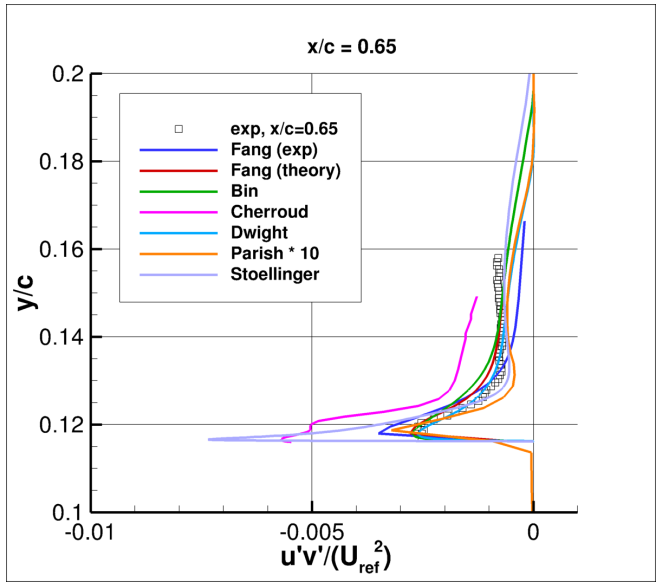
2DWMH, at x/c=0.65

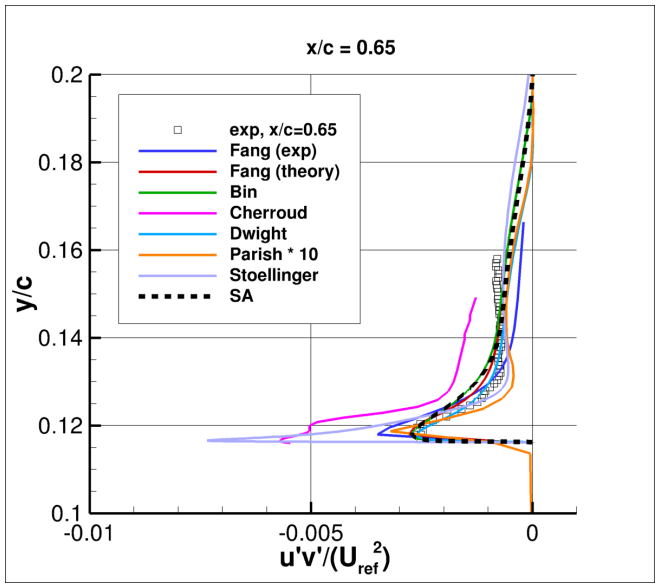
How new results stack up against standard SA model

Cherroud and Stoellinger are furthest off in u'v'







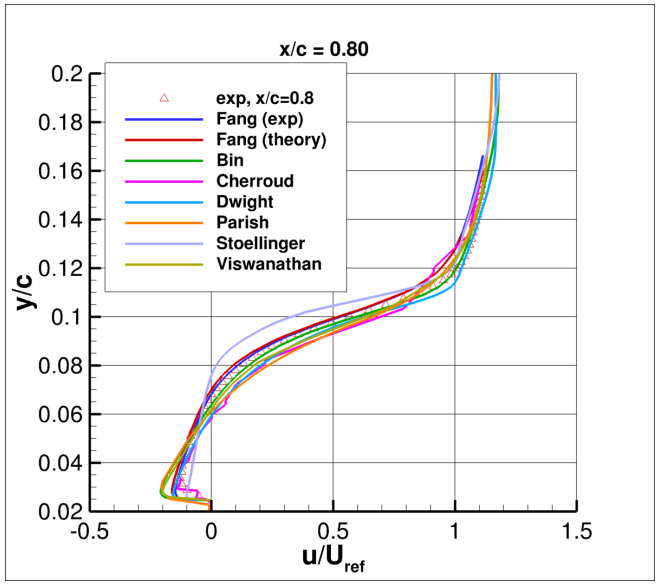


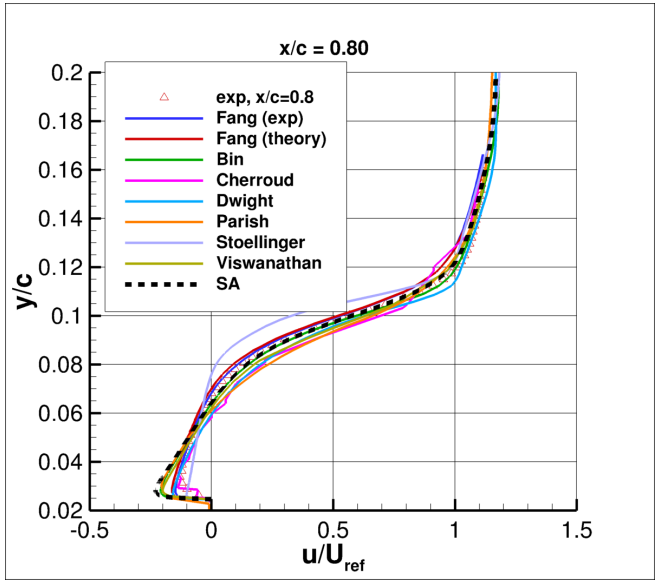
2DWMH, at x/c=0.80

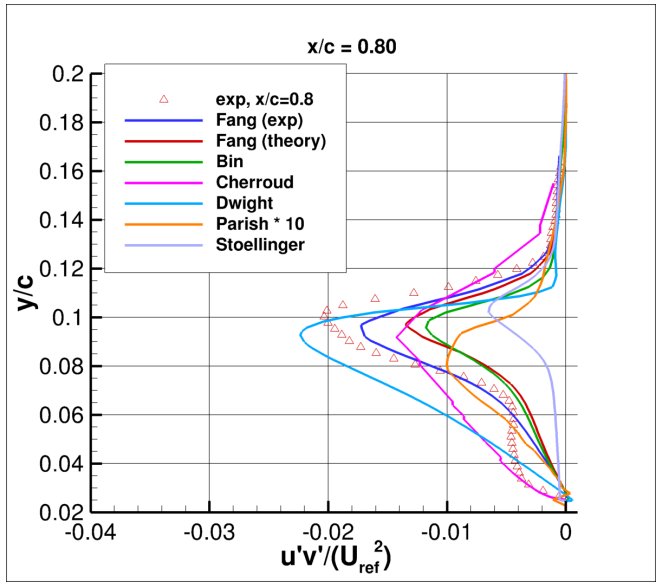
How new results stack up against standard SA model

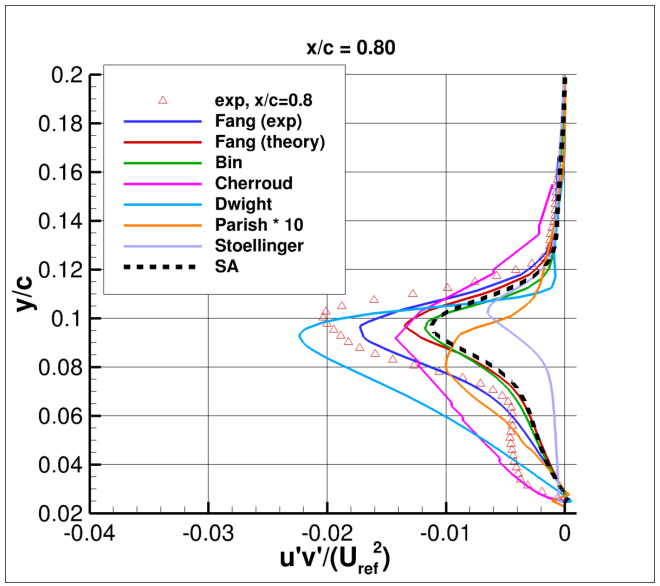
Stoellinger furthest from u profile

Fang (exp) and Dwight are closest to peak u'v'







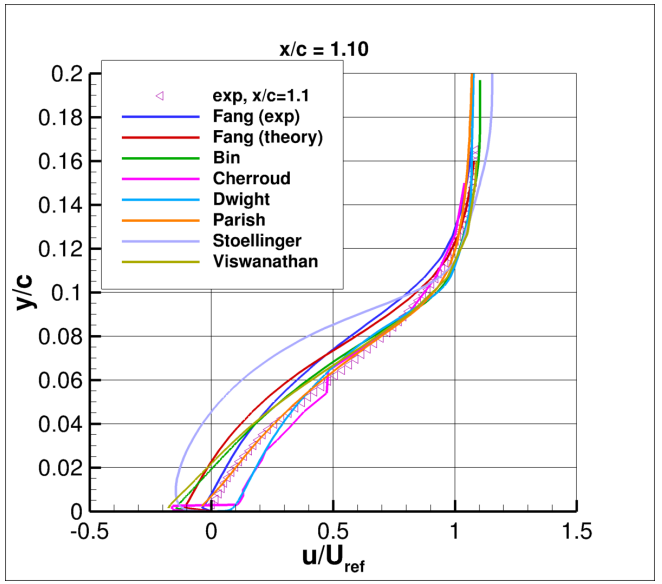


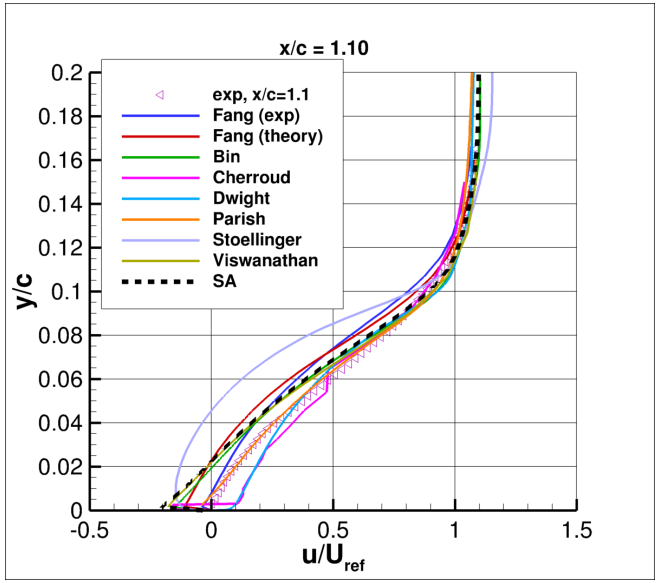
2DWMH, at x/c=1.10

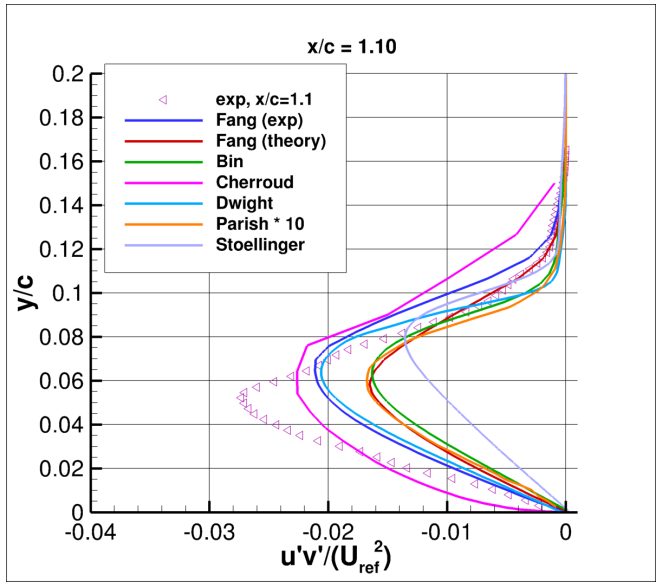
How new results stack up against standard SA model

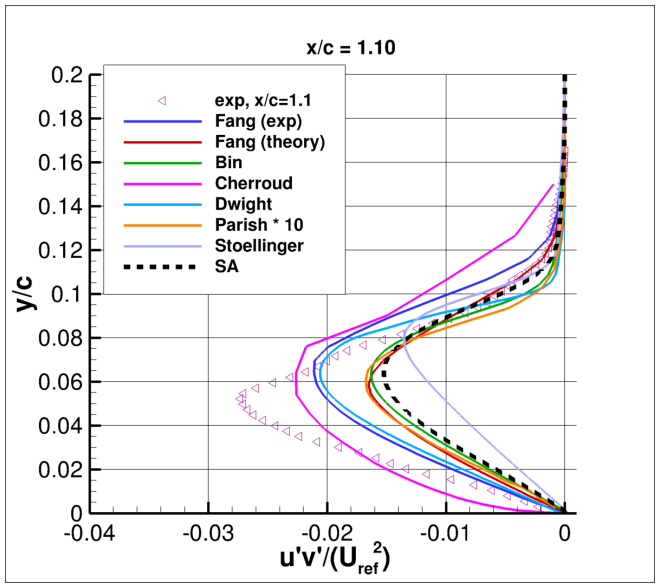
Stoellinger furthest from u profile; Parish matches profile well

Fang (exp), Dwight, and Cherroud are closest to peak u'v'





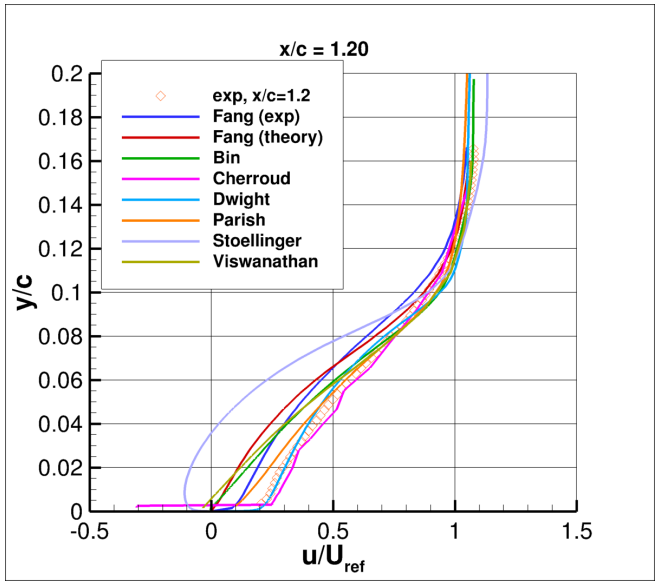


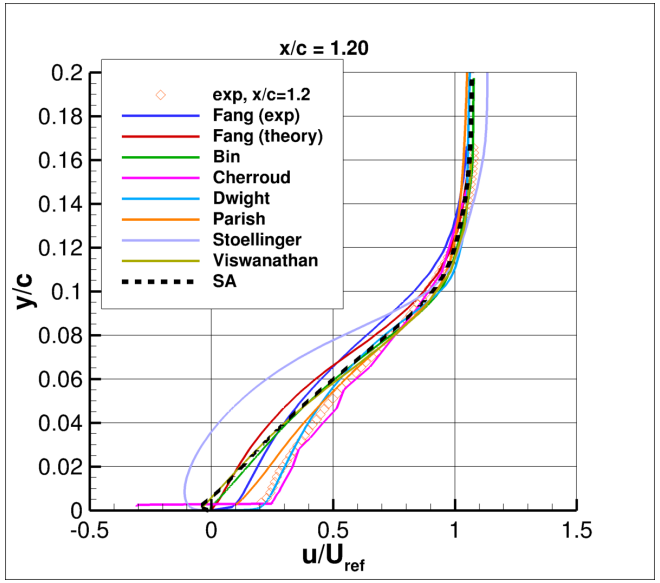


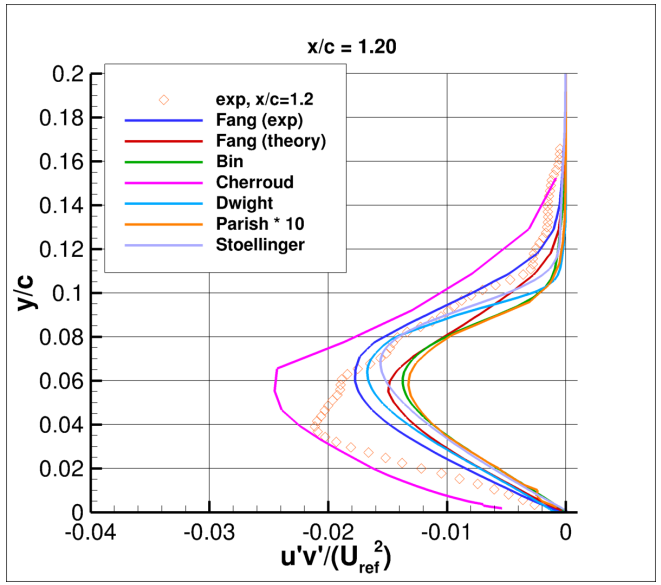
2DWMH, at x/c=1.20

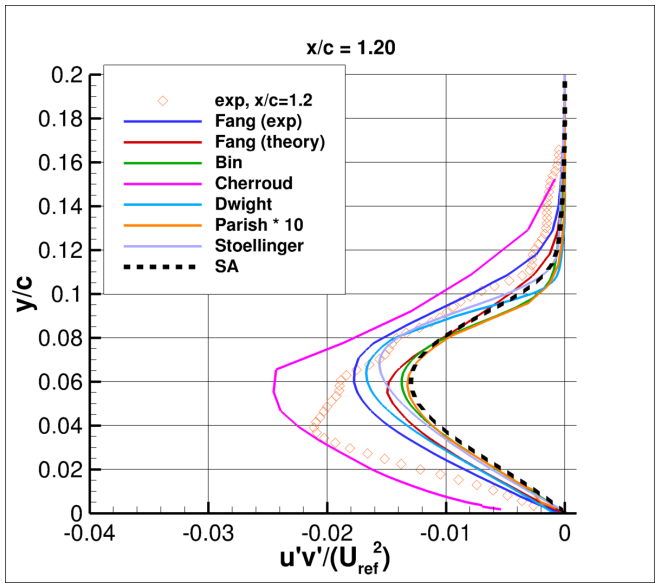
How new results stack up against standard SA model

Stoellinger furthest from u profile; Dwight and Cherroud (nonsmooth) match profile best





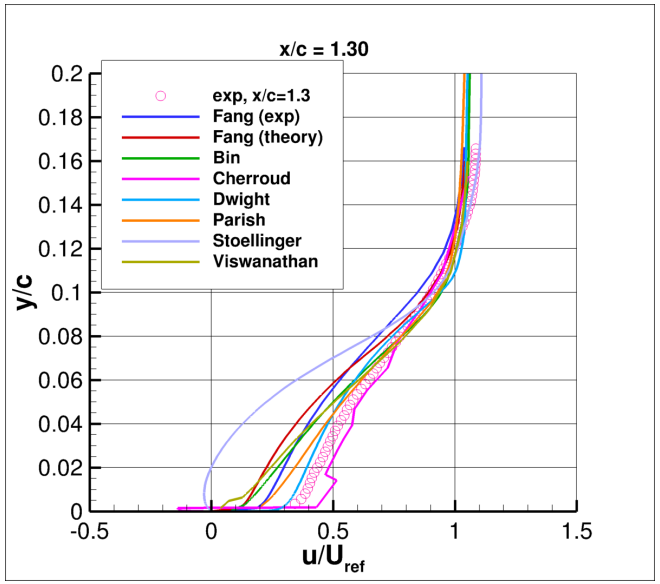


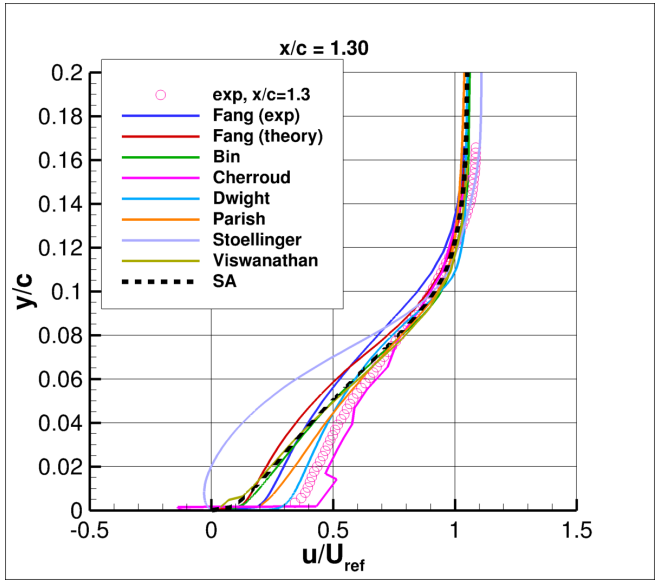


2DWMH, at x/c=1.30

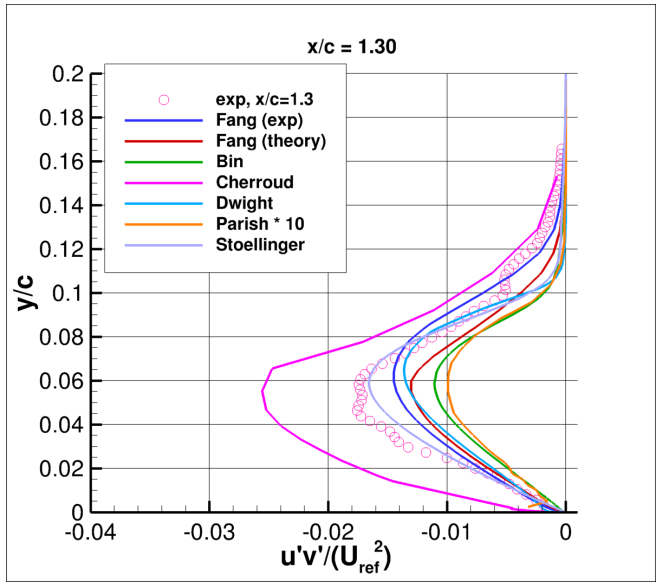
How new results stack up against standard SA model

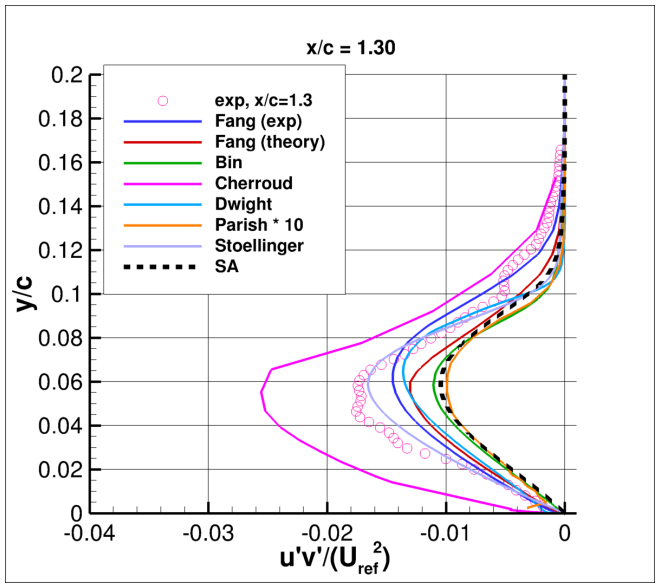
Stoellinger furthest from u profile; Dwight and Cherroud (nonsmooth) match profile best





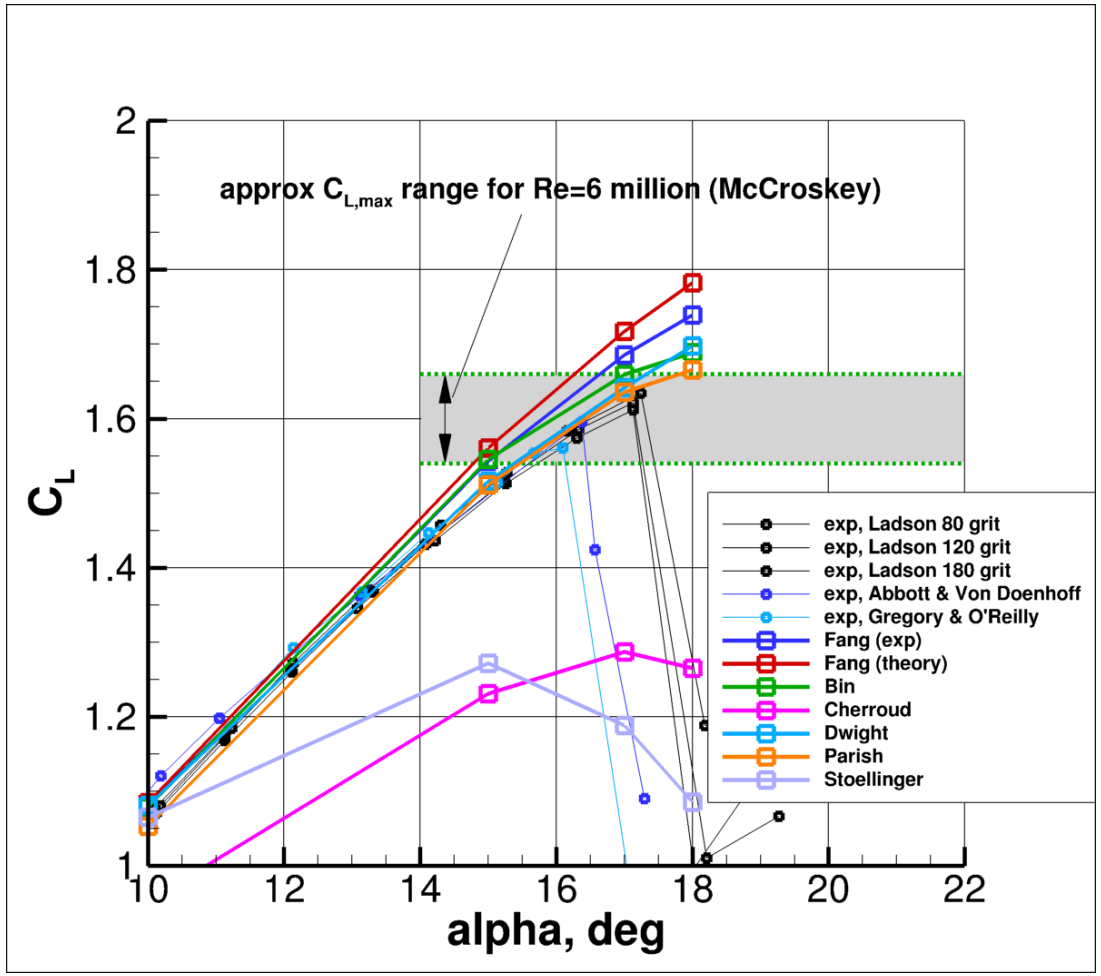
Stoellinger matches u'v' peak best

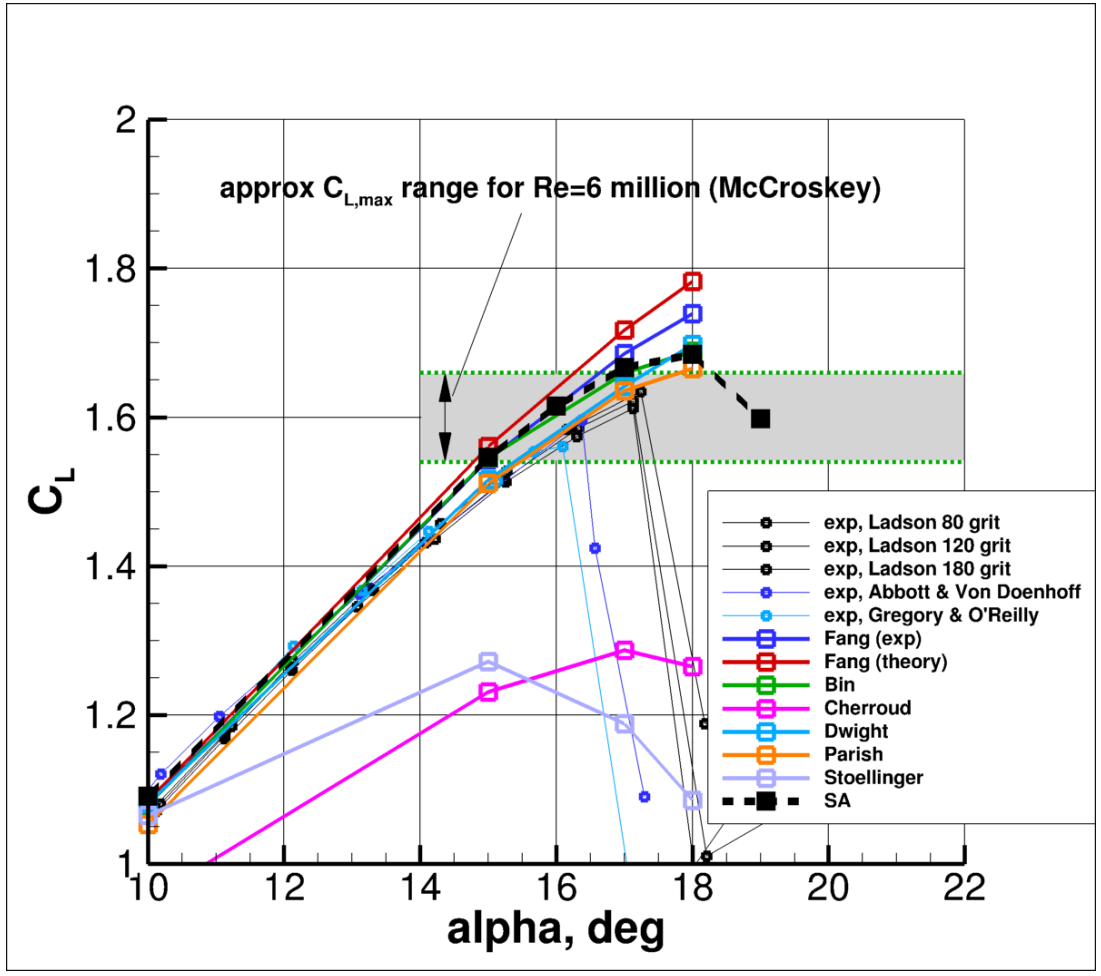




2DN00

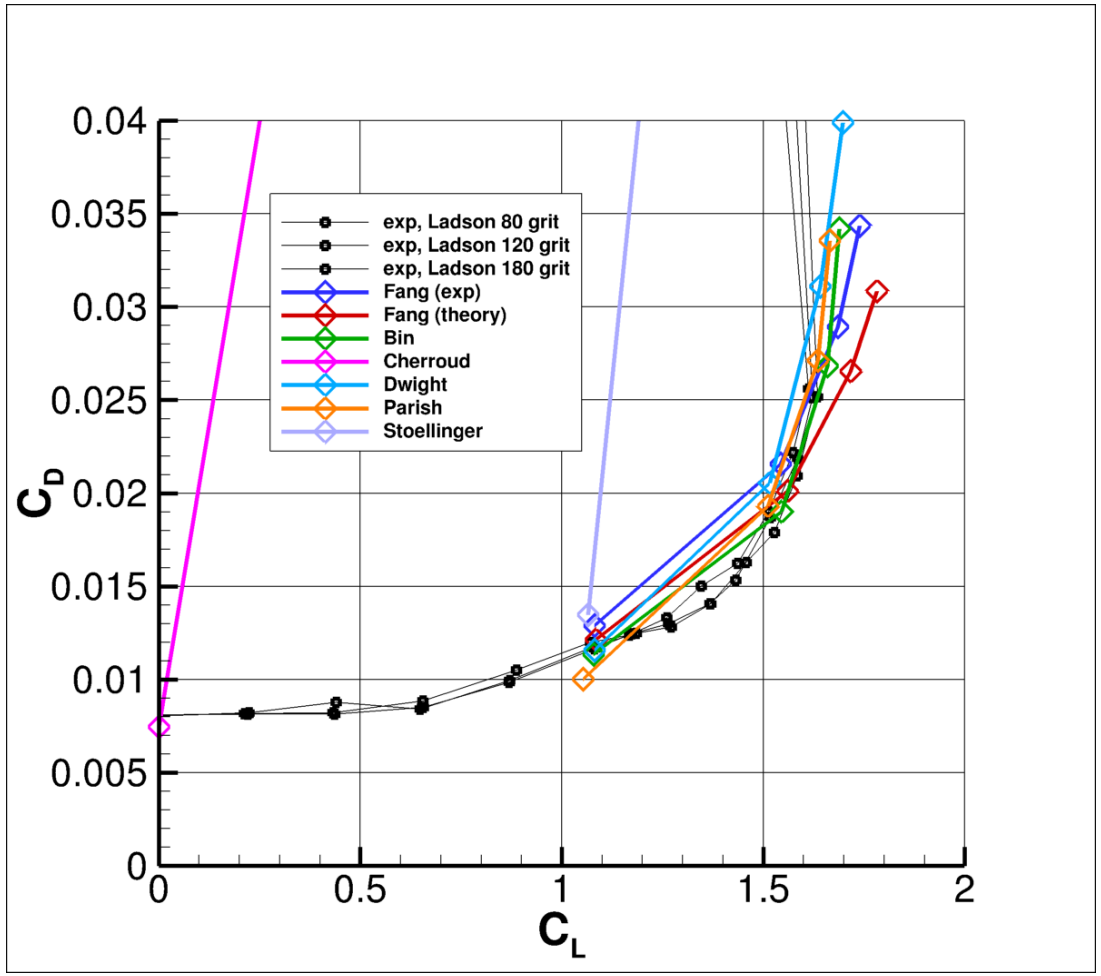
How new results stack up against standard SA model





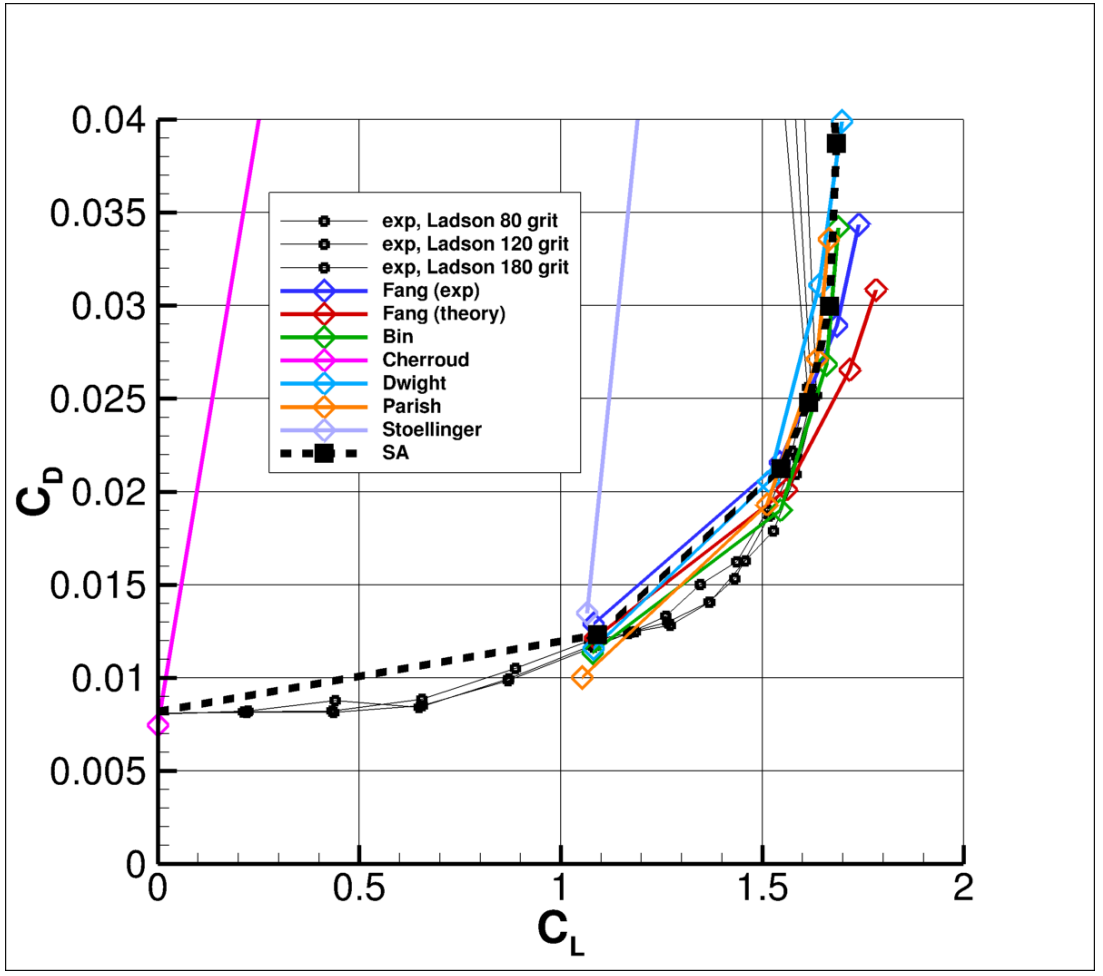
Stoellinger and Cherroud give very low CL

2DN00



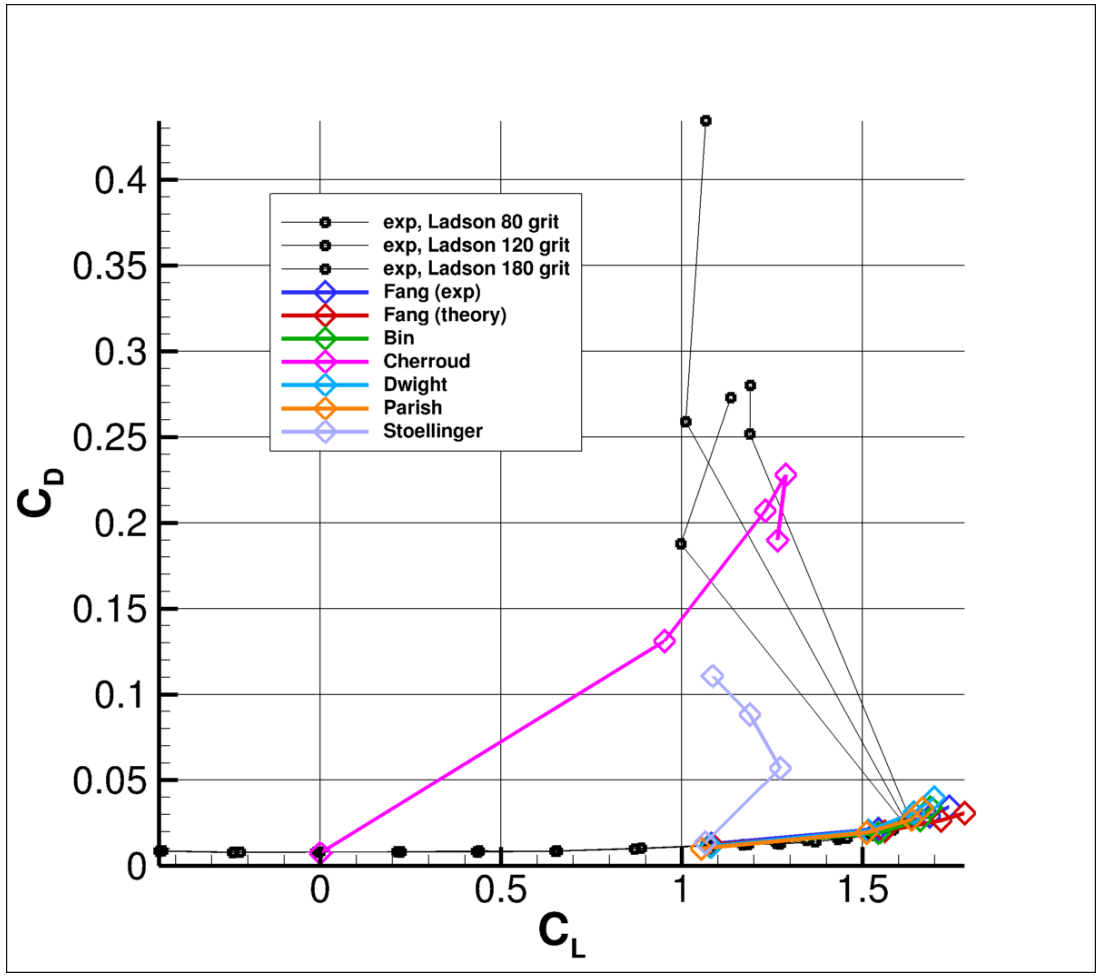
Stoellinger and Cherroud give very high CD

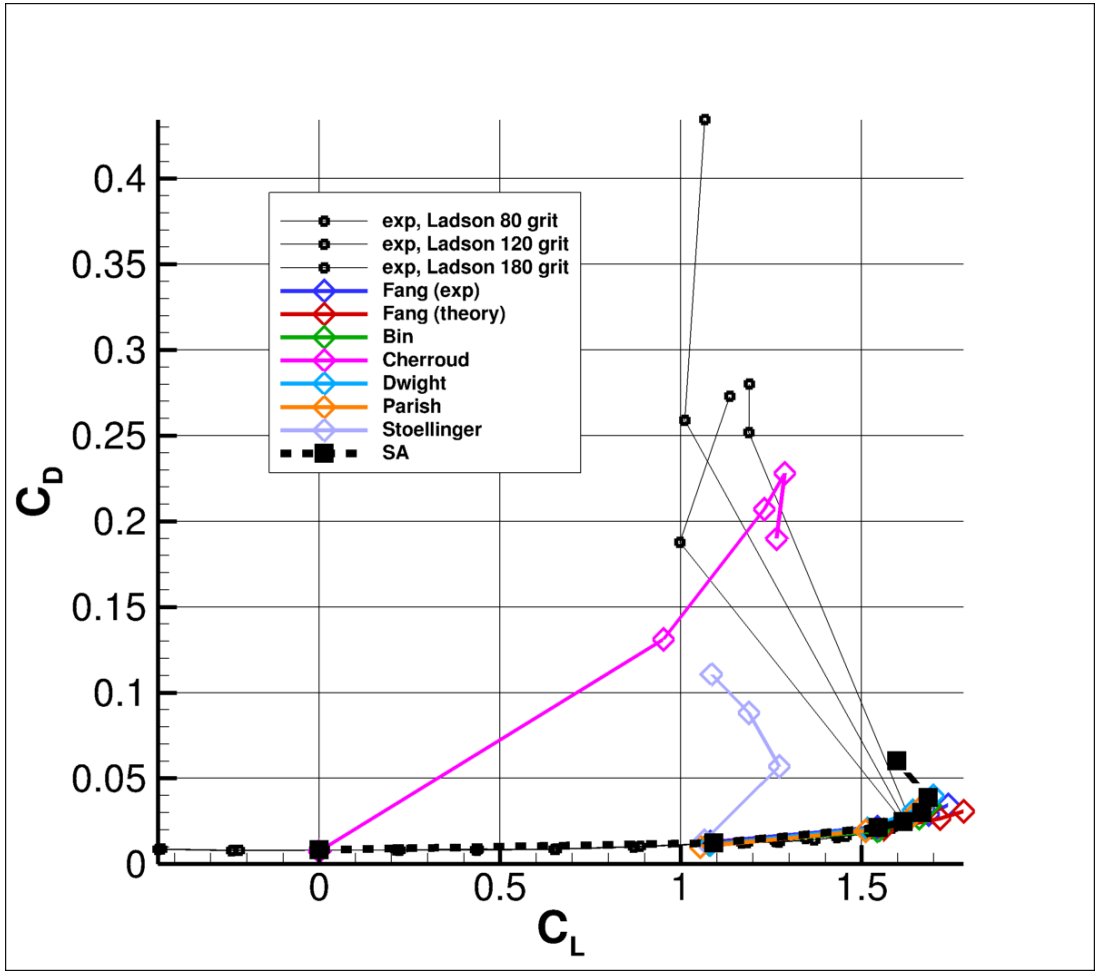
How new results stack up against standard SA model



2DN00

How new results stack up against standard SA model



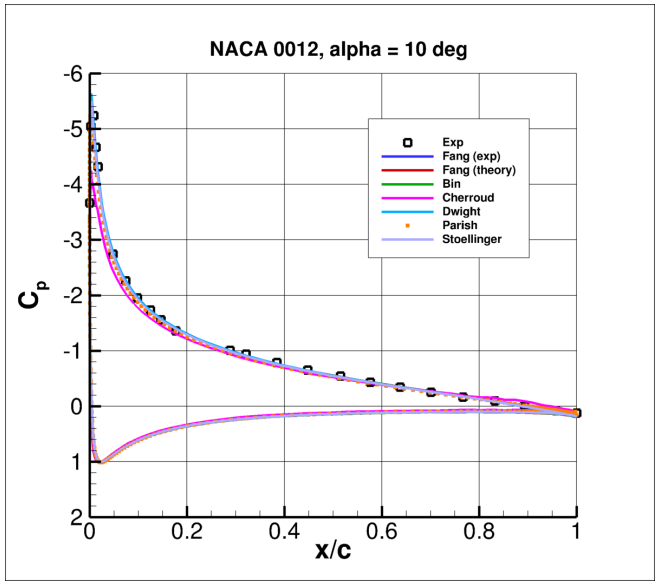


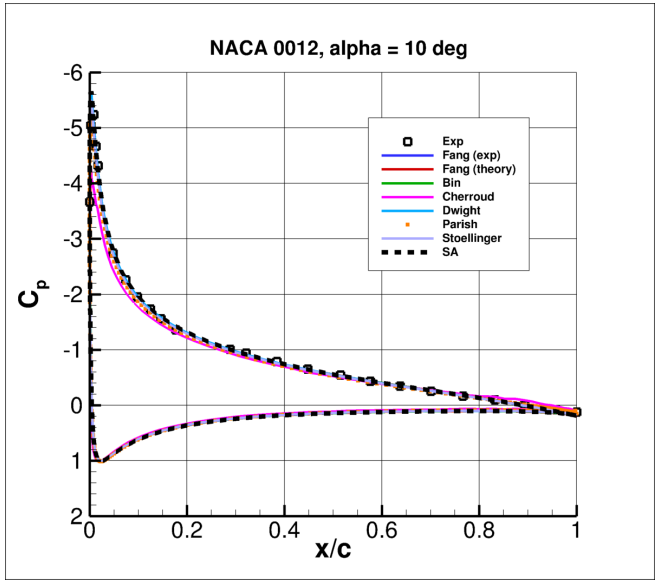
Stoellinger and Cherroud give very high CD

2DN00, AoA=10 deg.

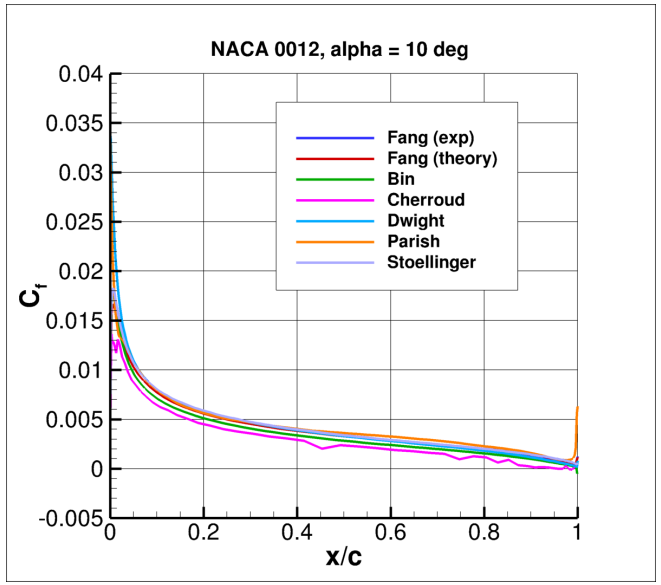
How new results stack up against standard SA model

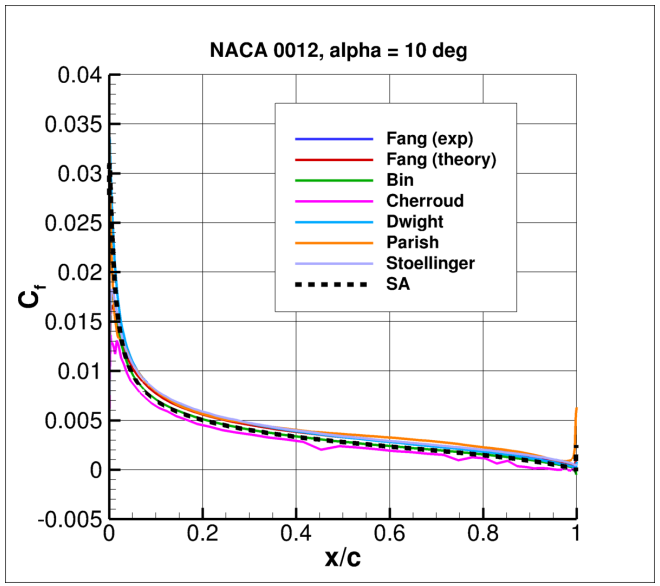
All fairly reasonably; Cherroud has lower peak Cp





Cherroud results are nonsmooth

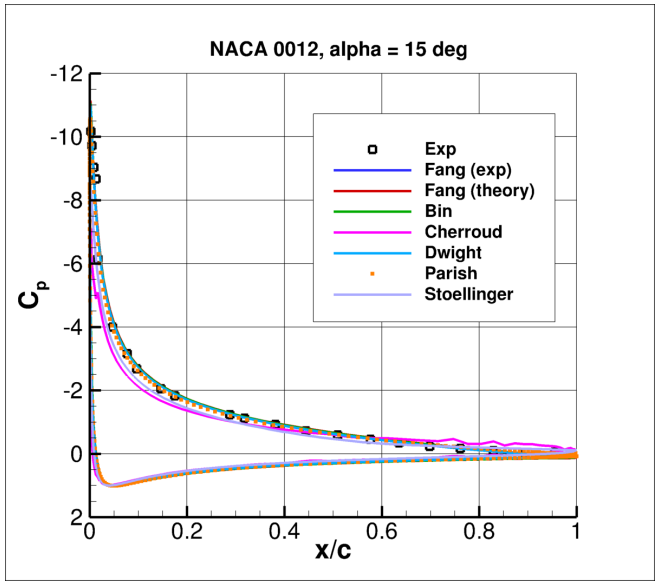


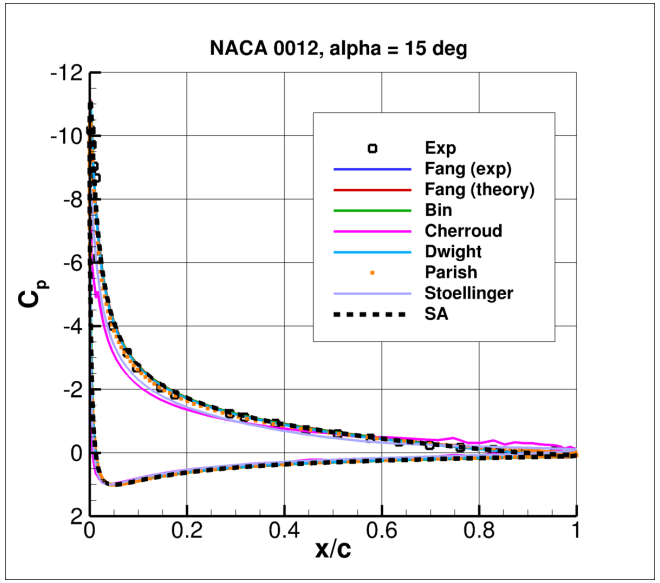


2DN00, AoA=15 deg.

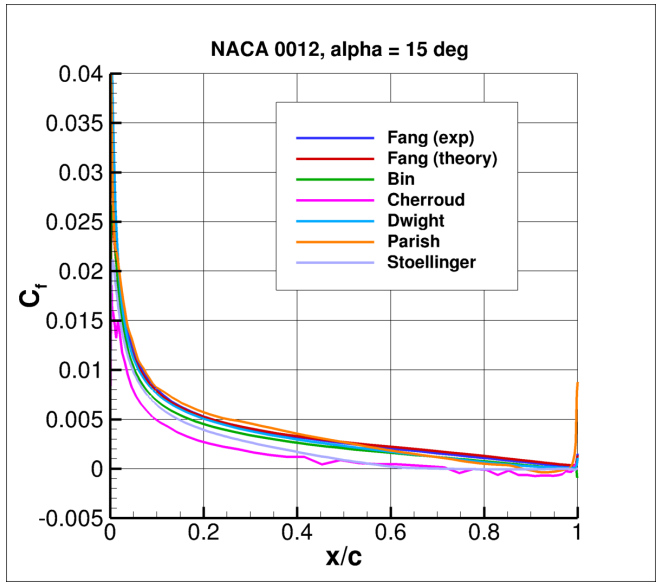
How new results stack up against standard SA model

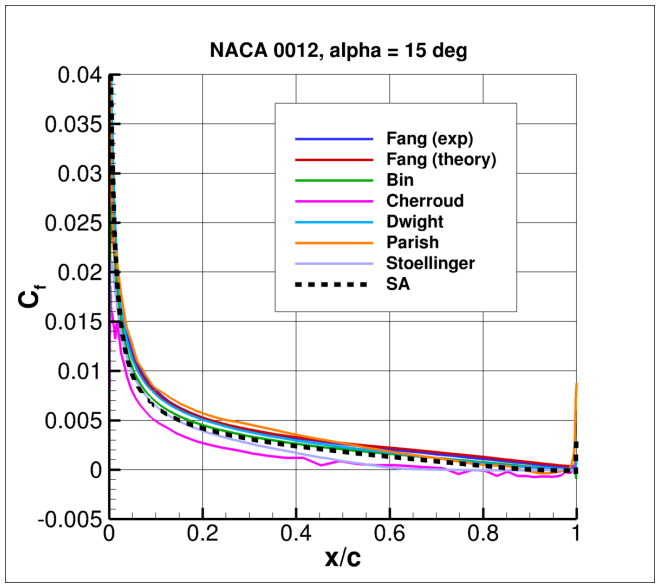
All fairly reasonably; Cherroud and Stoellinger have lower peak Cp





Cherroud results are nonsmooth; Cherroud and Stoellinger separate earlier than others

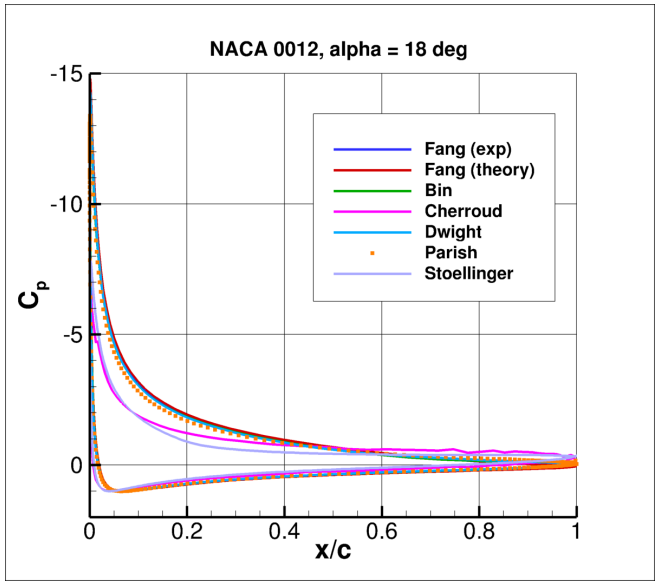


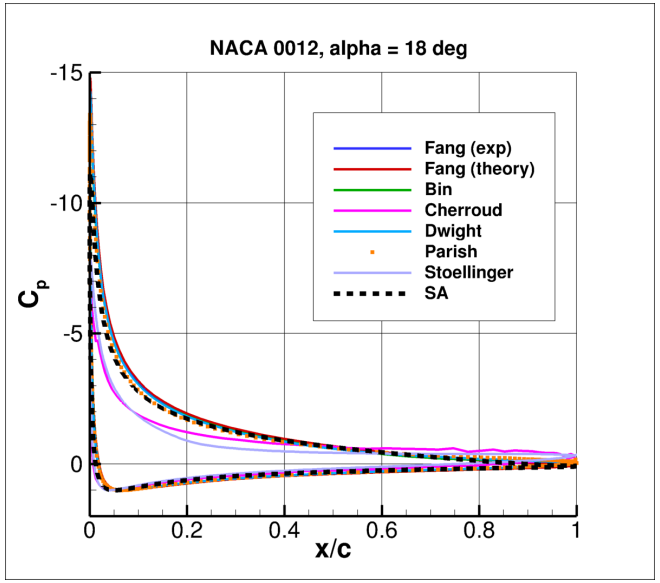


2DN00, AoA=18 deg.

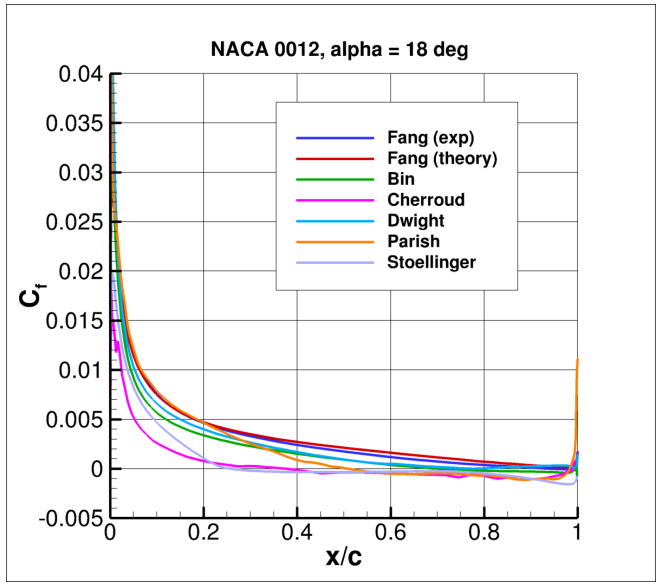
How new results stack up against standard SA model

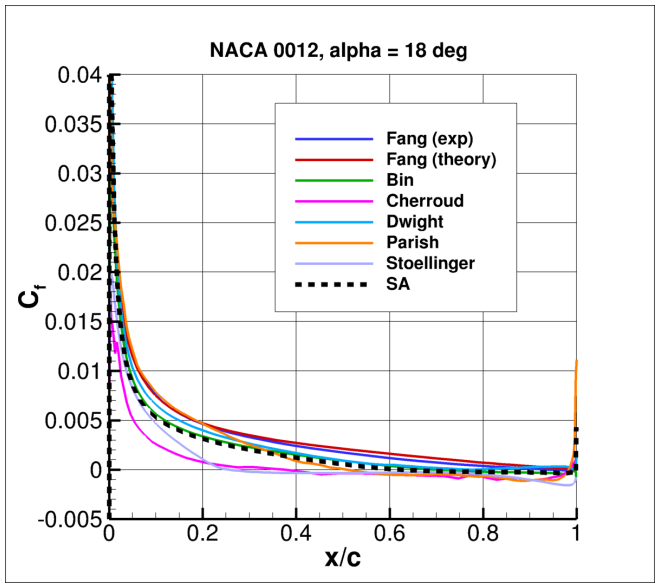
Cherroud and Stoellinger have lower peak Cp





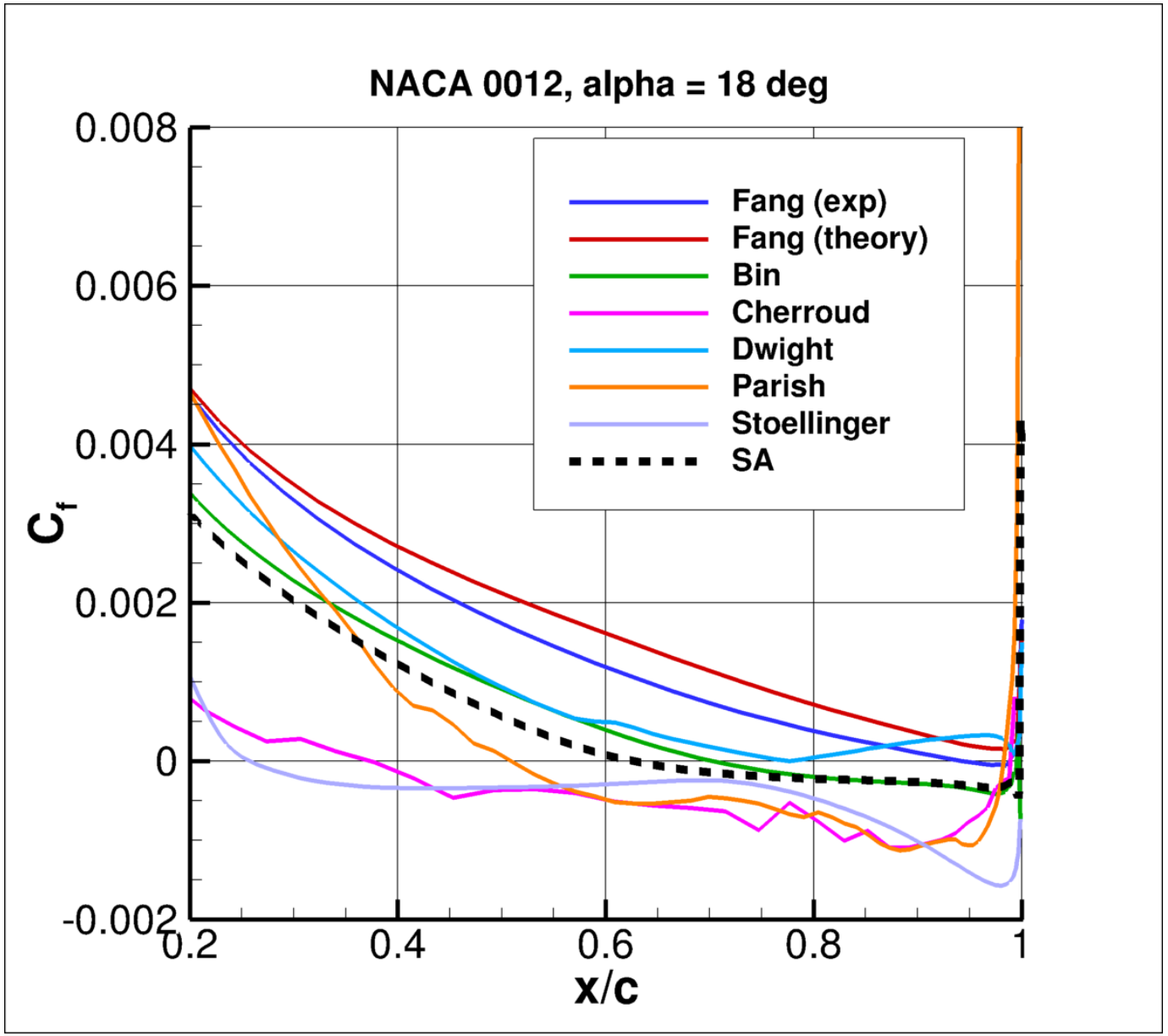
Cherroud results are nonsmooth; Cherroud, Stoellinger, and Parish separate earlier than others





2DN00, AoA=18 deg.

Participant results vary from upper surface separation at x/c=0.25 through fully attached!



Bottom Line

- The fact that the participants were able to use a “single strategy” to yield plausible results for so many diverse cases was a positive outcome
- However, despite isolated successes, it appears to be very difficult to achieve broad agreement across multiple diverse cases with a single RANS model
- Possibly carry these cases forward for future (continuing) challenge(s)