First AIAA Sonic Boom Prediction Workshop Summary

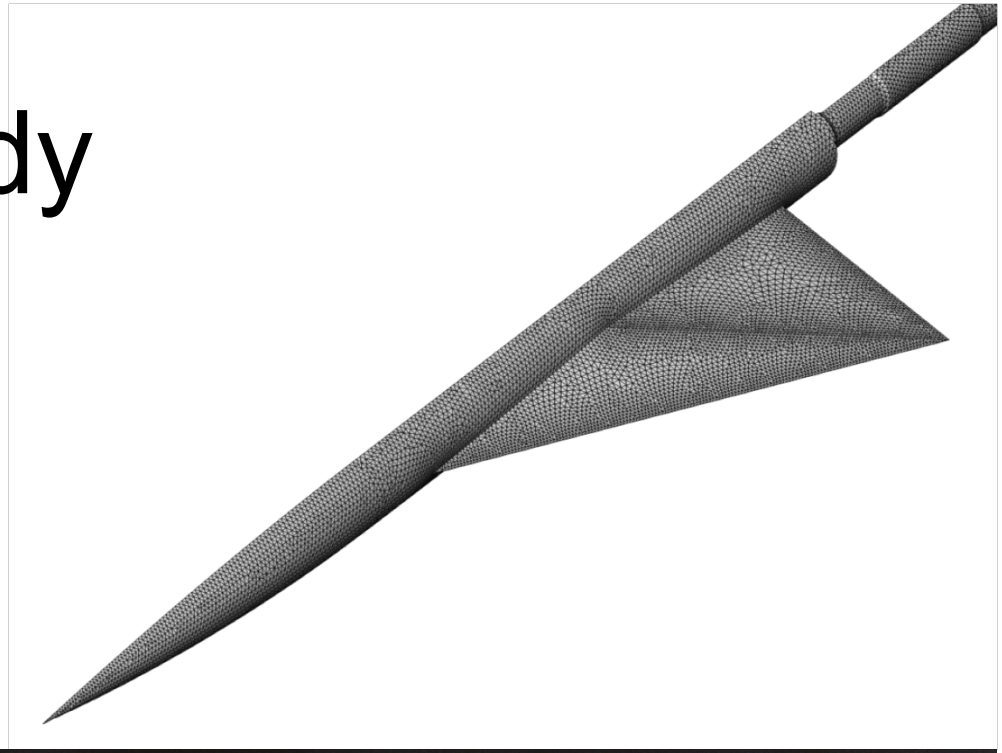
Mike Park
Computational AeroSciences Branch
NASA Langley Research Center

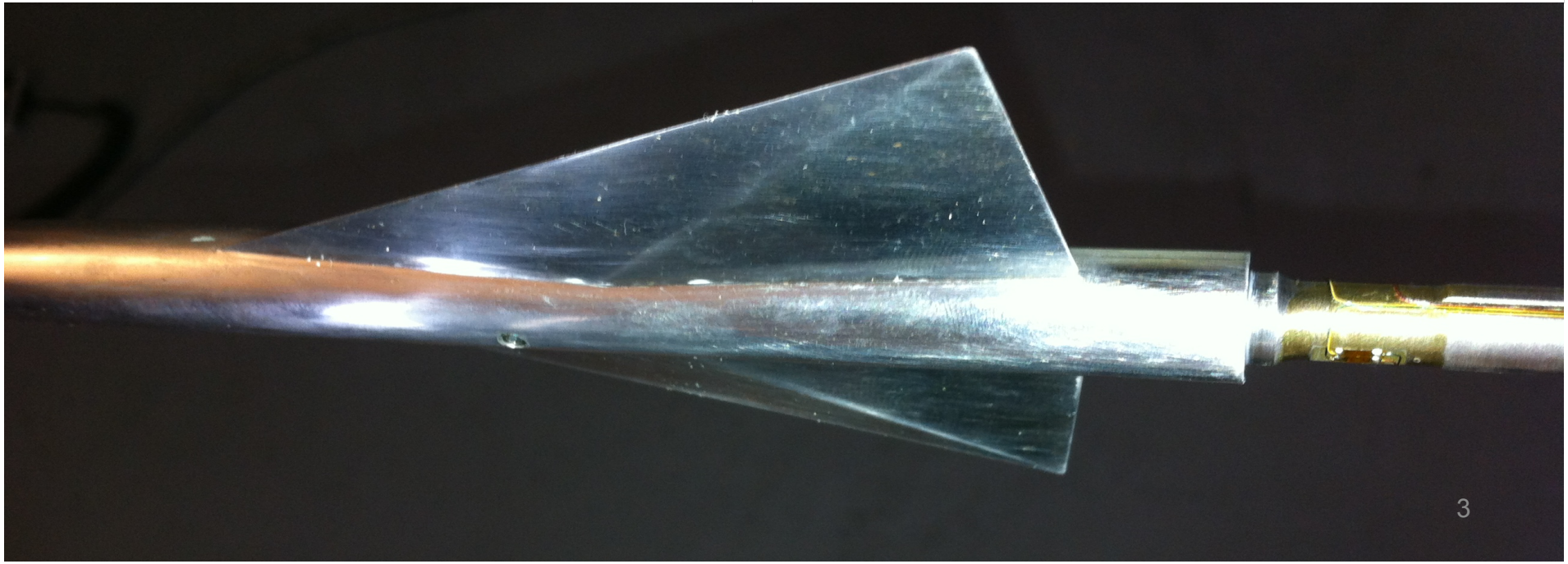
SEEB-ALR

- Axisymmetric body designed by Lockheed Martin for the validation of a flat-top signature design method
  - Seebass and George with aft lift relaxation
- 18in long, examining at H=21.2in, 42.0in
- Mach 1.6

Delta Wing Body

- 6.9 inches long
- Mach 1.7, zero degrees angle of attack





Tecplot Extraction Macro

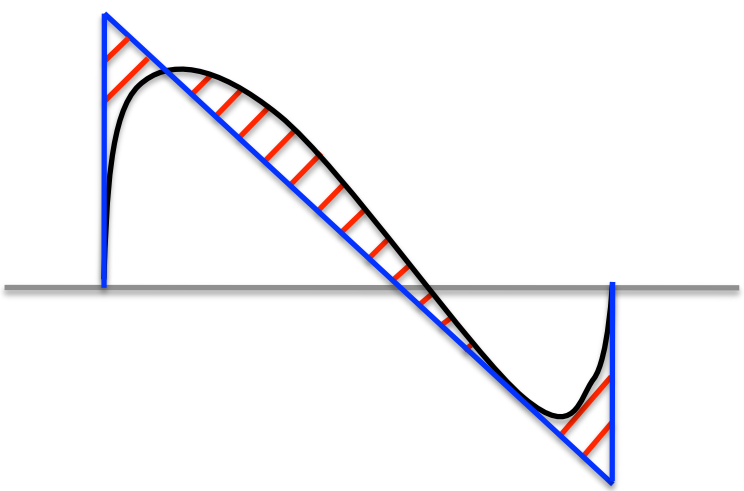
- Consistent method to extract signatures from a volume solution (**available measurements are bold**)
  - SEEB-ALR (18in length)
    - Centerline H=**21.2in** and 42.0in
  - Delta Wing Body (6.9in length)
    - Centerline H=0.5in and 21.2in
    - **0**, **30**, **60**, and **90** degree off-track H=**24.8in**
    - **0**, **30**, **60**, and **90** degree off-track H=**31.8in**

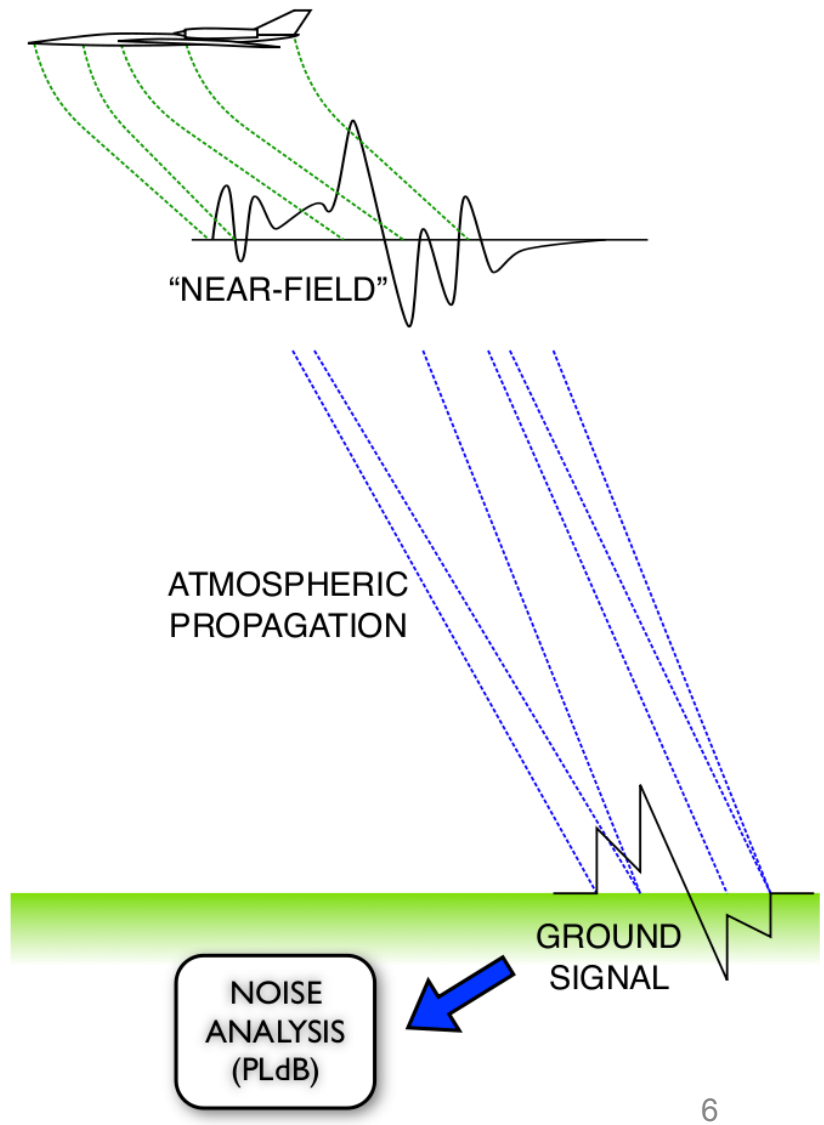
Data Processing and Quality

- Received signatures via FTP or email
- Some were converted to plain text, scaled, or reformatted
- Plotted
- Contacted participants for clarification when
  - Incorrect location or incomplete signature
  - Significant differences between submissions of same participant

Method

- Impartially compare signatures by uniform application of
  - Loudness measures
  - Validation metrics



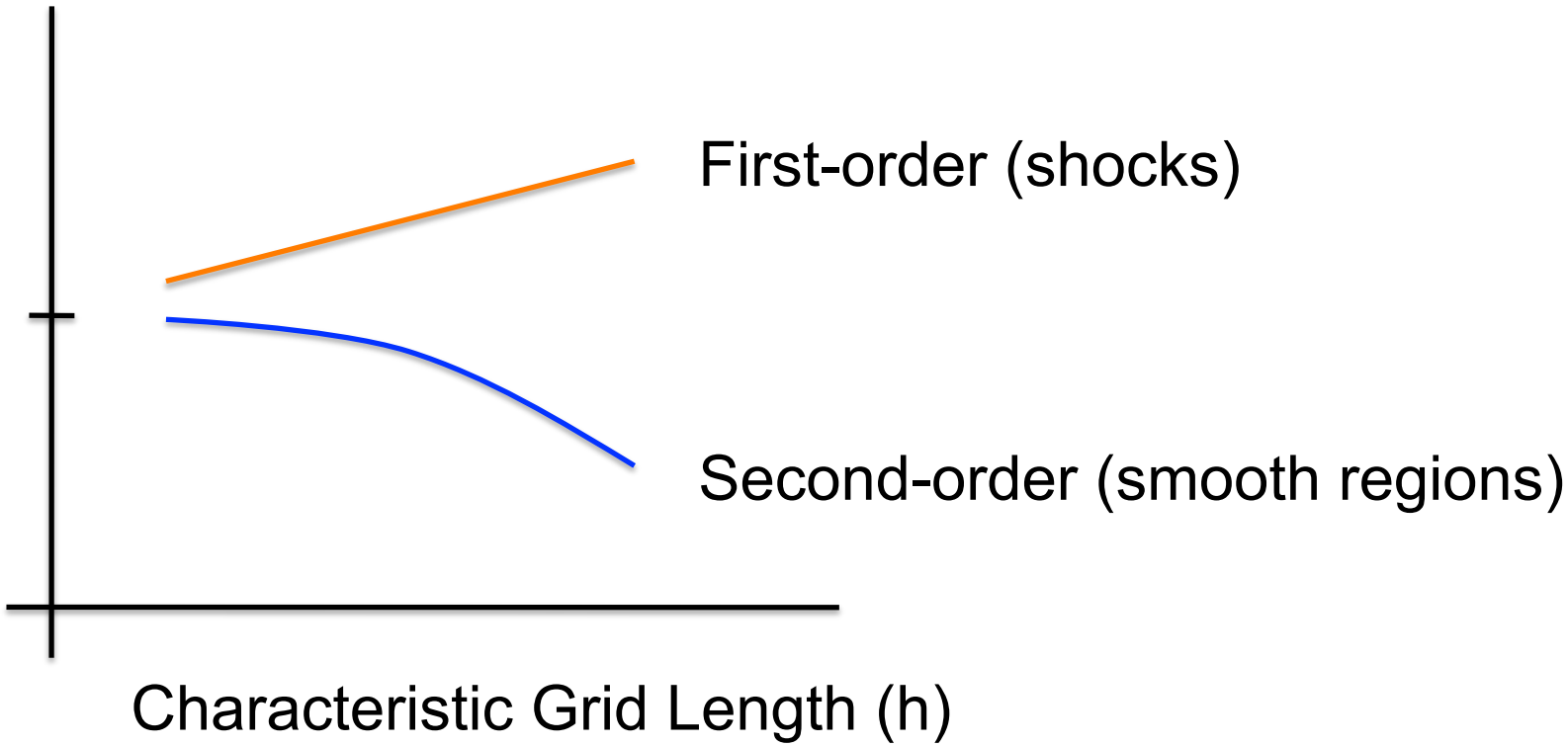


Statistical Method

- Goal is to identify “different” results, not “correct” or “wrong”
- Median +/- (coverage factor)*(std. dev.)
  - Assume a uniform distribution, sqrt(3)
- Small sample size with correlated results (same person, same code, refined grids)
- Used by other workshops

Expected Grid Convergence

- Consistent methods should approach a value as the grid is refined to “zero”



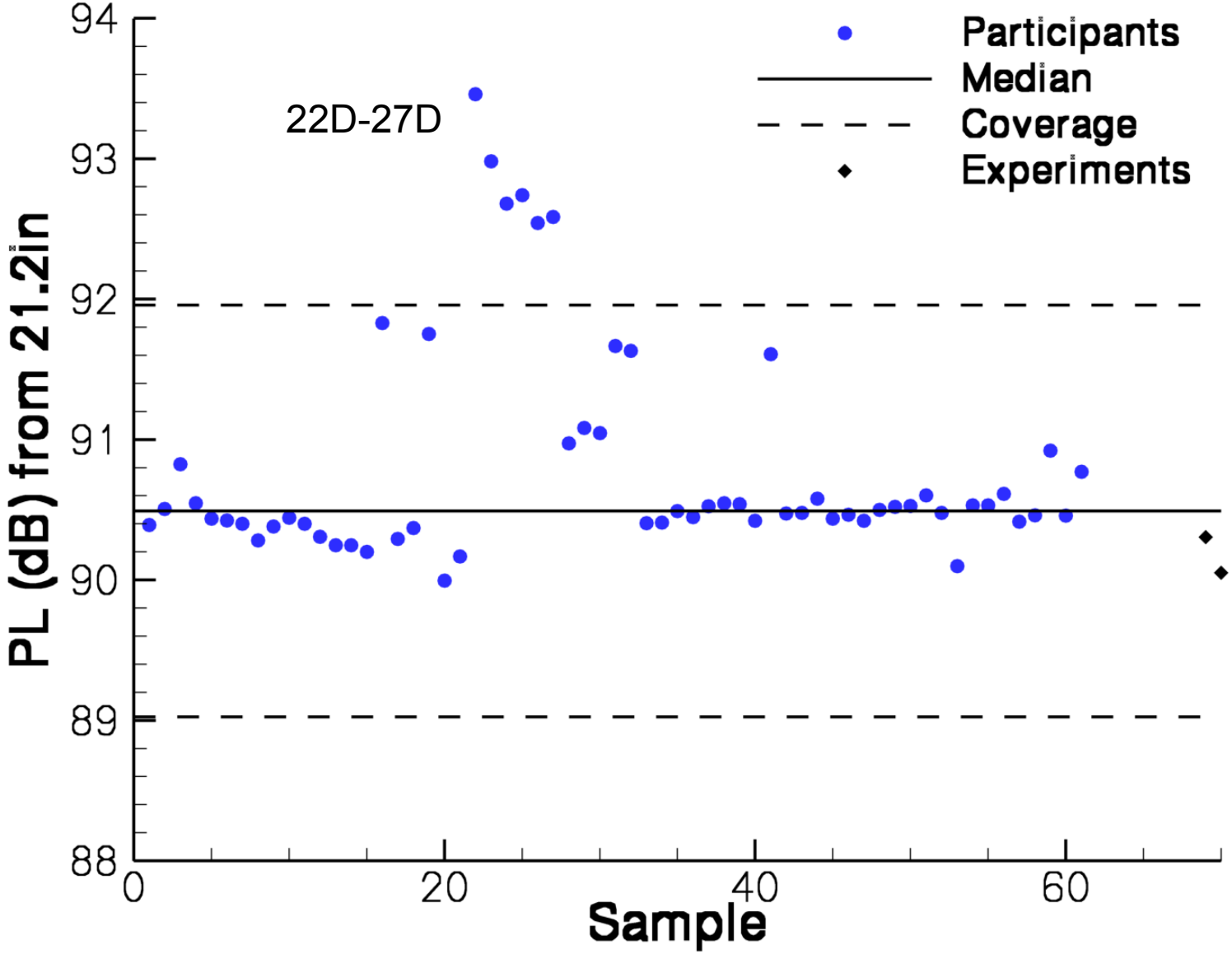
SEEB-ALR Submissions

#	Group	Phys	Type	Grid	ControlVol
1	A	Euler	Struct	S1	7323648
2	A	Euler	Struct	S2	915456
3	A	Euler	Struct	S3	114432
4	A	Euler	Struct	S4	14304
5	A	Euler	Mixed	M080	10159421
6	A	Euler	Mixed	M100	5252466
7	A	Euler	Mixed	M125	2537977
8	A	Euler	Mixed	M156	1165851
9	A	Euler	Mixed	M200	674734
10	A	Euler	Tet	T080	10159421
11	A	Euler	Tet	T100	5252466
12	A	Euler	Tet	T125	2537977
13	A	Euler	Tet	T156	1165851
14	A	Euler	Tet	T200	674734
15	B	Euler	Tet	VGRID	21519091
16	C	Euler	Tet	T100	30647394
17	C	Euler	Tet	T156	6662284
18	C	Euler	Tet	T200	3840249
19	C	Euler	Tet	PW/MCAP	2236059
20	C	Laminar	Tet	PW/MCAP	6196118
21	C	SA	Tet	PW/MCAP	6196118
22	D	Euler	Tet	Adapted-Adj	208280
23	D	Euler	Tet	Adapted-LP	875511
24	D	Euler	Tet	T080	10159421
25	D	Euler	Tet	T100	5252466
26	D	Euler	Tet	T156	1165851
27	D	Euler	Tet	T200	674734
28	E	Euler	Tet	T080	10159421
29	E	Euler	Tet	T100	5252466
30	E	Euler	Tet	T125	2537977
31	E	Euler	Tet	T156	1165851
32	E	Euler	Tet	T200	674734
33	F	Euler	Tet	T100	30647394
34	F	Euler	Tet	T156	6662284
35	F	Euler	Tet	T200	3840249
36	G	Euler	Struct	Fixed	7323648
37	H	Euler	Mixed	M080	10159421
38	H	Euler	Mixed	M100	5252466
39	H	Euler	Mixed	M156	1165851
40	H	Euler	Mixed	M200	674734
41	I	Linear	Linear	Linear	1
42	J	Euler	Mixed	M080	27865176
43	J	Euler	Mixed	M100	14325194
44	J	Euler	Mixed	M200	1793549
45	J	Euler	Struct	S1	7323648
46	J	Euler	Overset	Fixed	27646000
47	K	Euler	Struct	S1	7986107
48	L	Euler	Mixed	M100	10159421
49	L	Euler	Mixed	M125	5252466
50	L	Euler	Mixed	M156	1165851
51	L	Euler	Mixed	M200	674734
52	M	Euler	Cart	Adapted-Adj	2012184
53	N	Euler	Cart	Fixed	11147363
54	N	Euler	Overset	PW	26309760
55	O	Euler	Hybrid	Fixed	73000000
56	P	Euler	Cart	Fixed	18096942
57	Q	SA	Struct	Gridgen	2000000
58	R	Euler	Overset	Fixed	21800000
59	R	SA	Overset	Fixed	21800000
60	R	Euler	Struct	Axi	330000
61	R	SST	Struct	Axi	330000

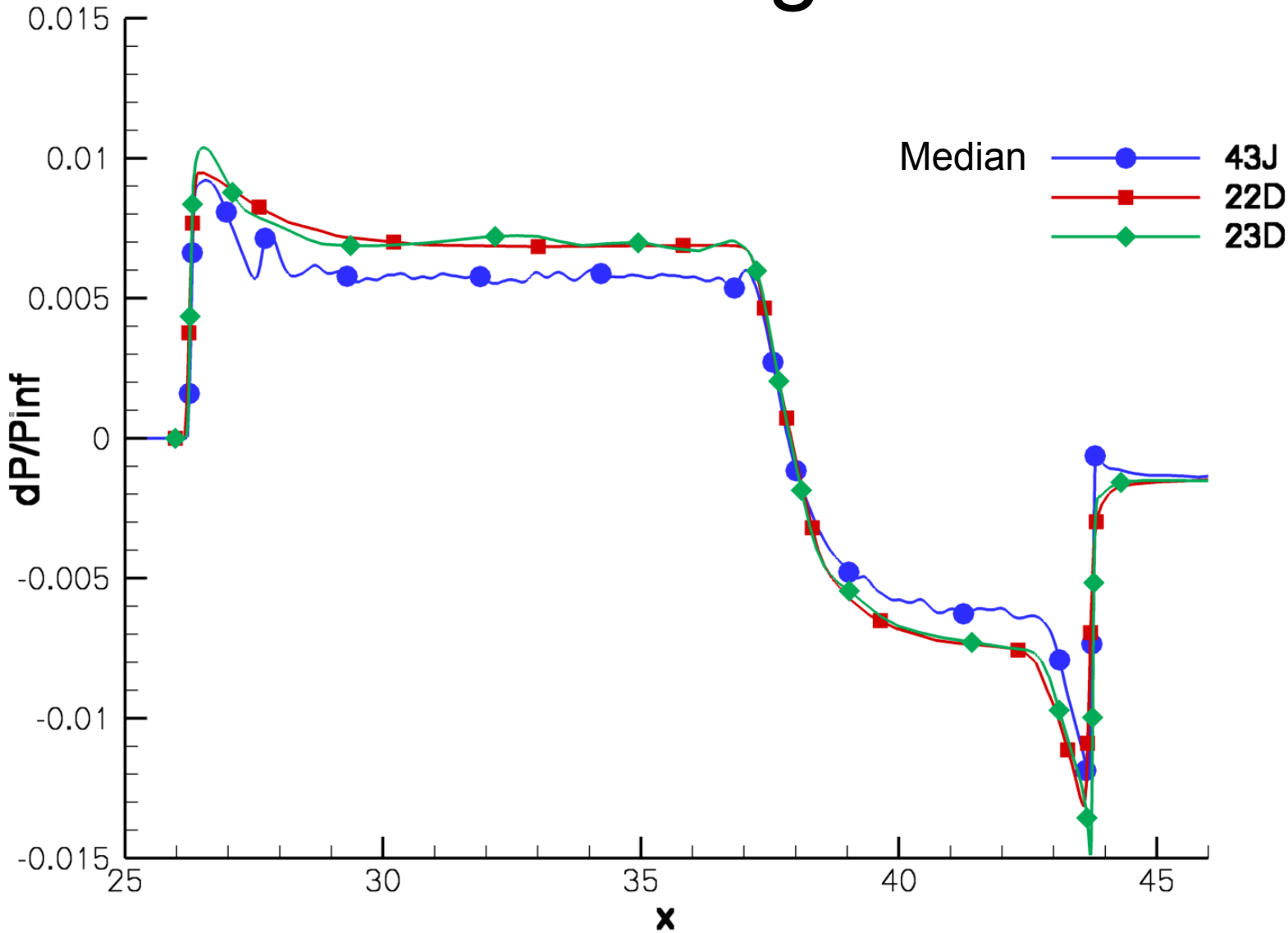
SEEB-ALR Perceived Level

- Examine the median signature with signatures identified as different
  - Statistics of PL
  - Convergence of PL with grid refinement
  - Change in PL with extraction location

SEEB-ALR Perceived Level



SEEB-ALR Signature



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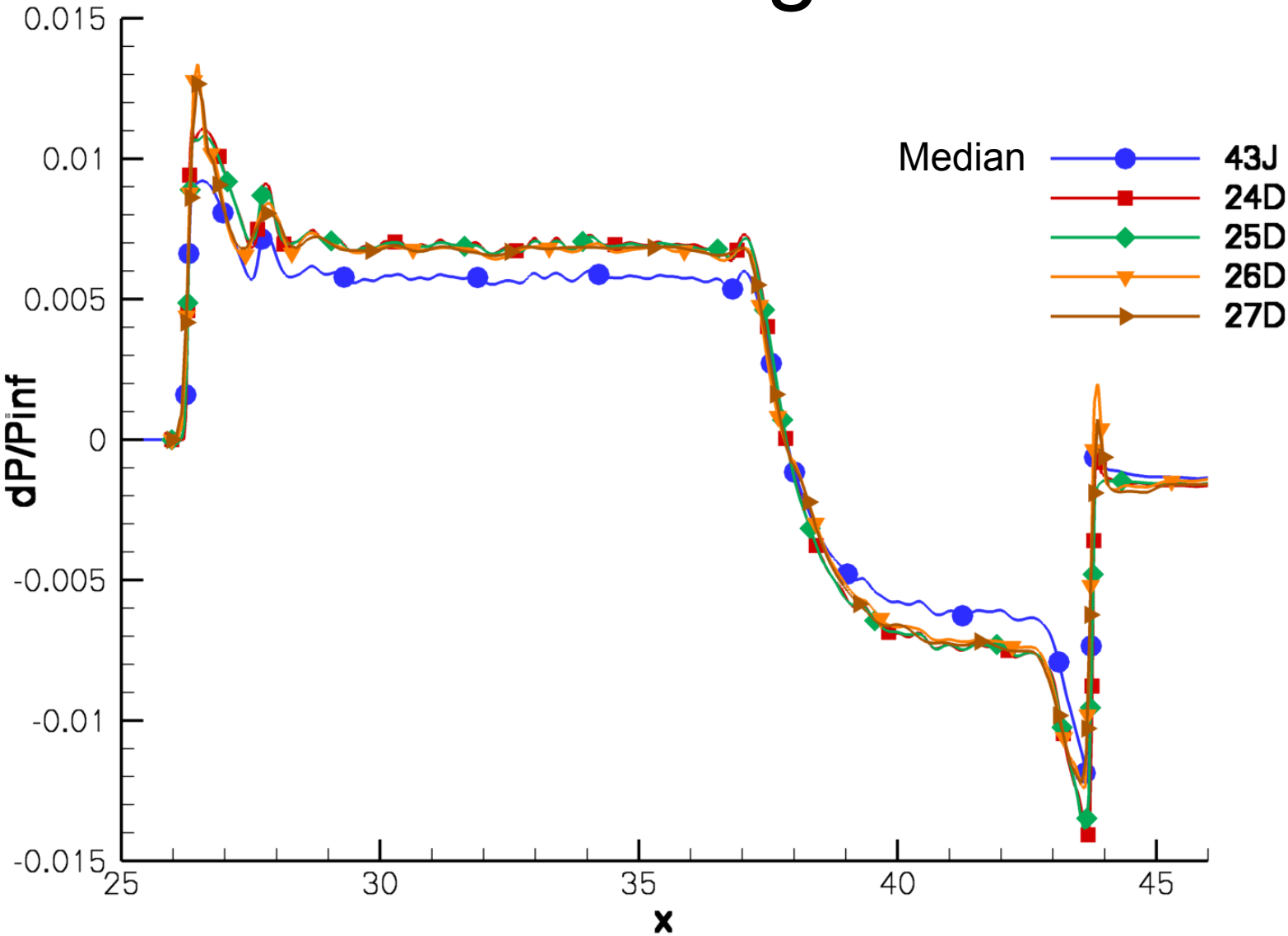

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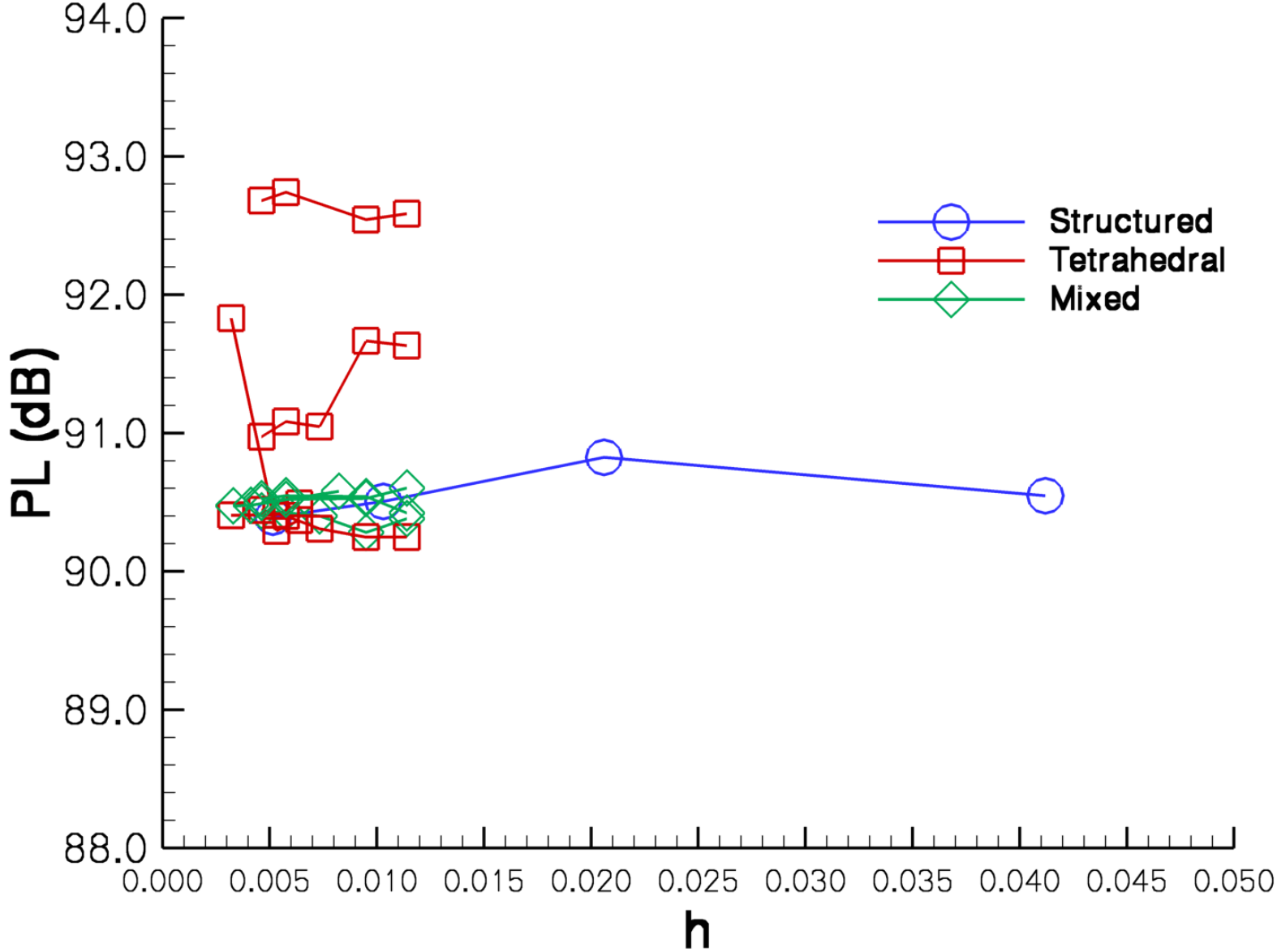
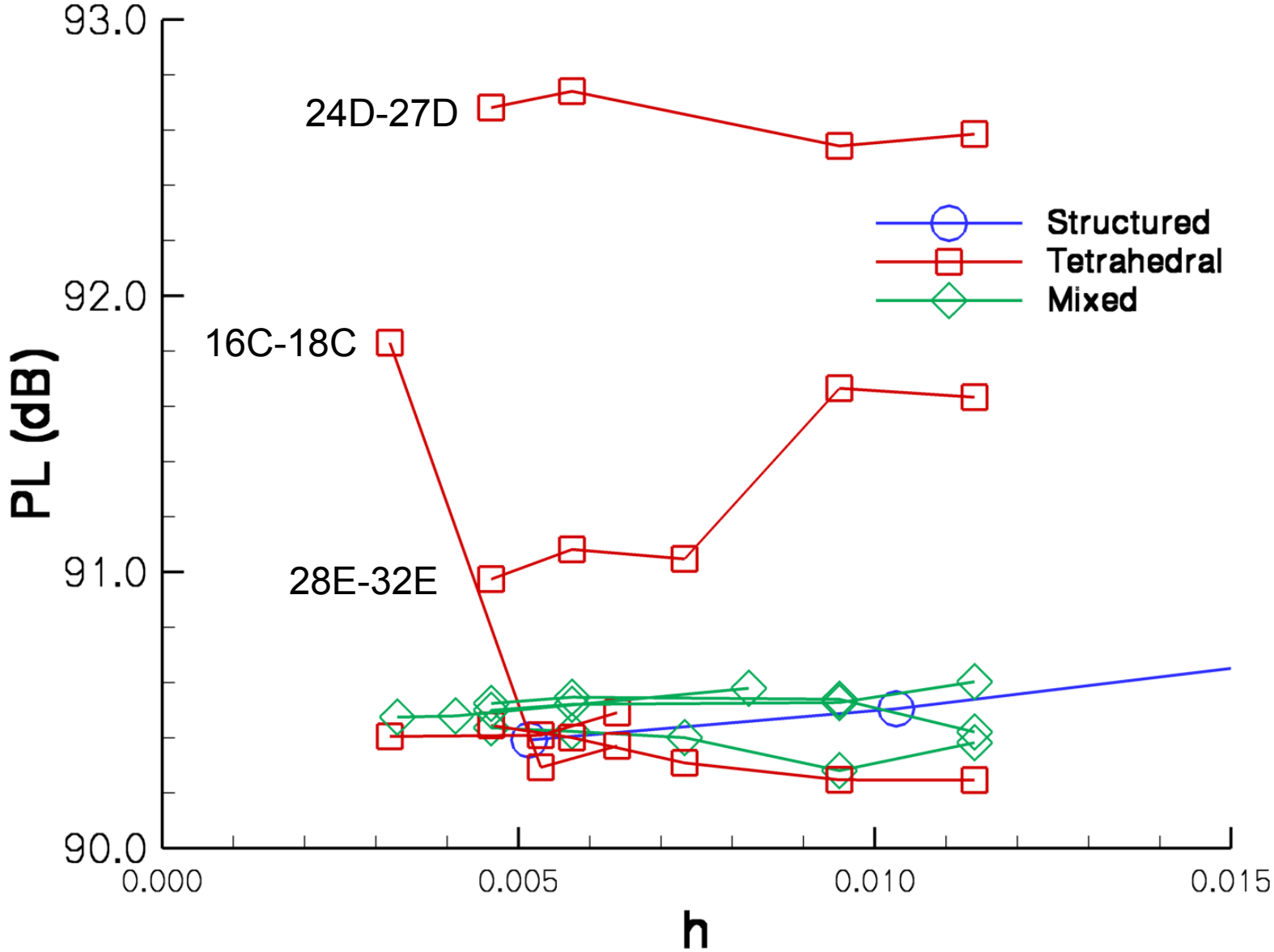


SEEB-ALR Perceived Level



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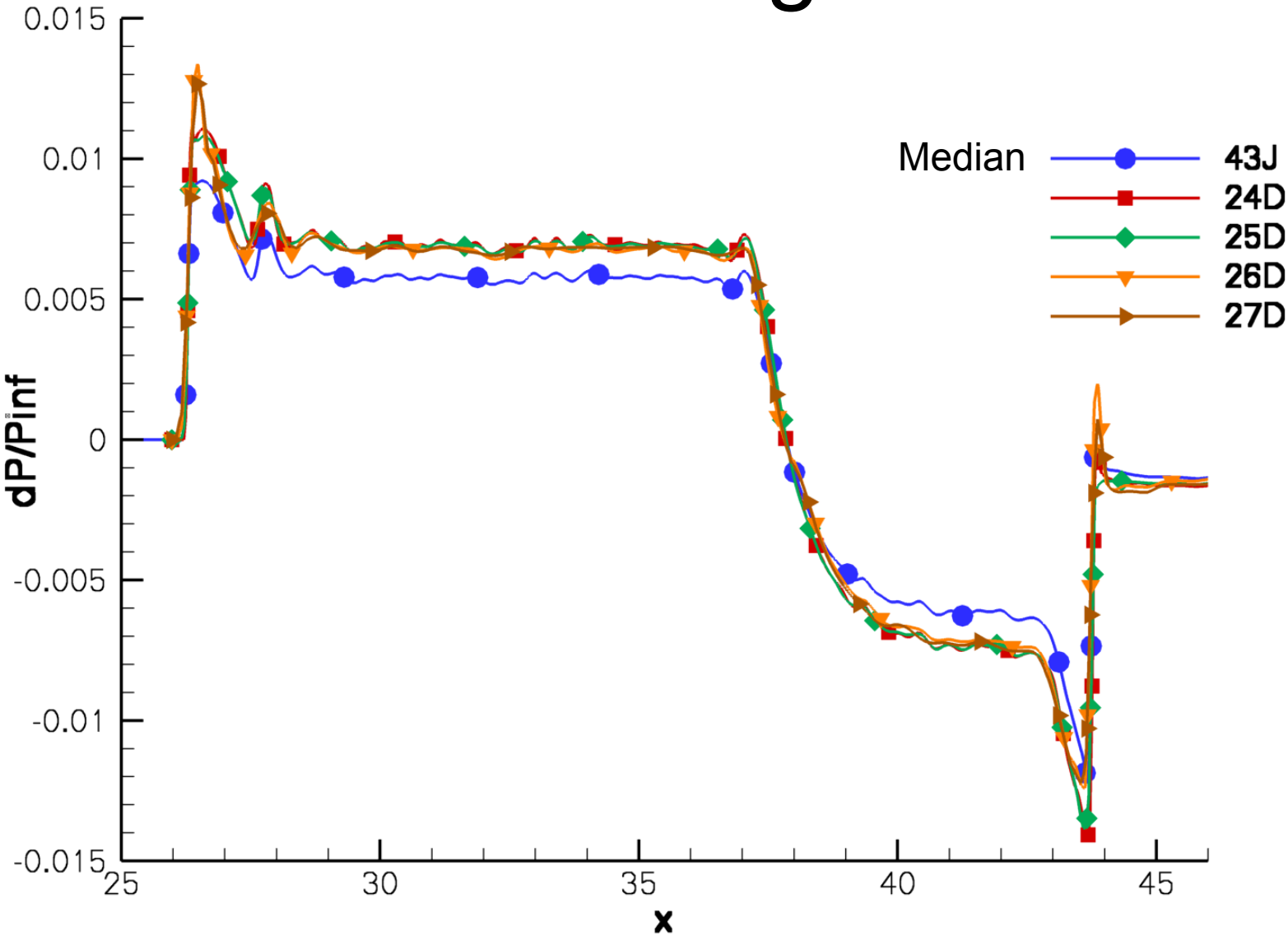

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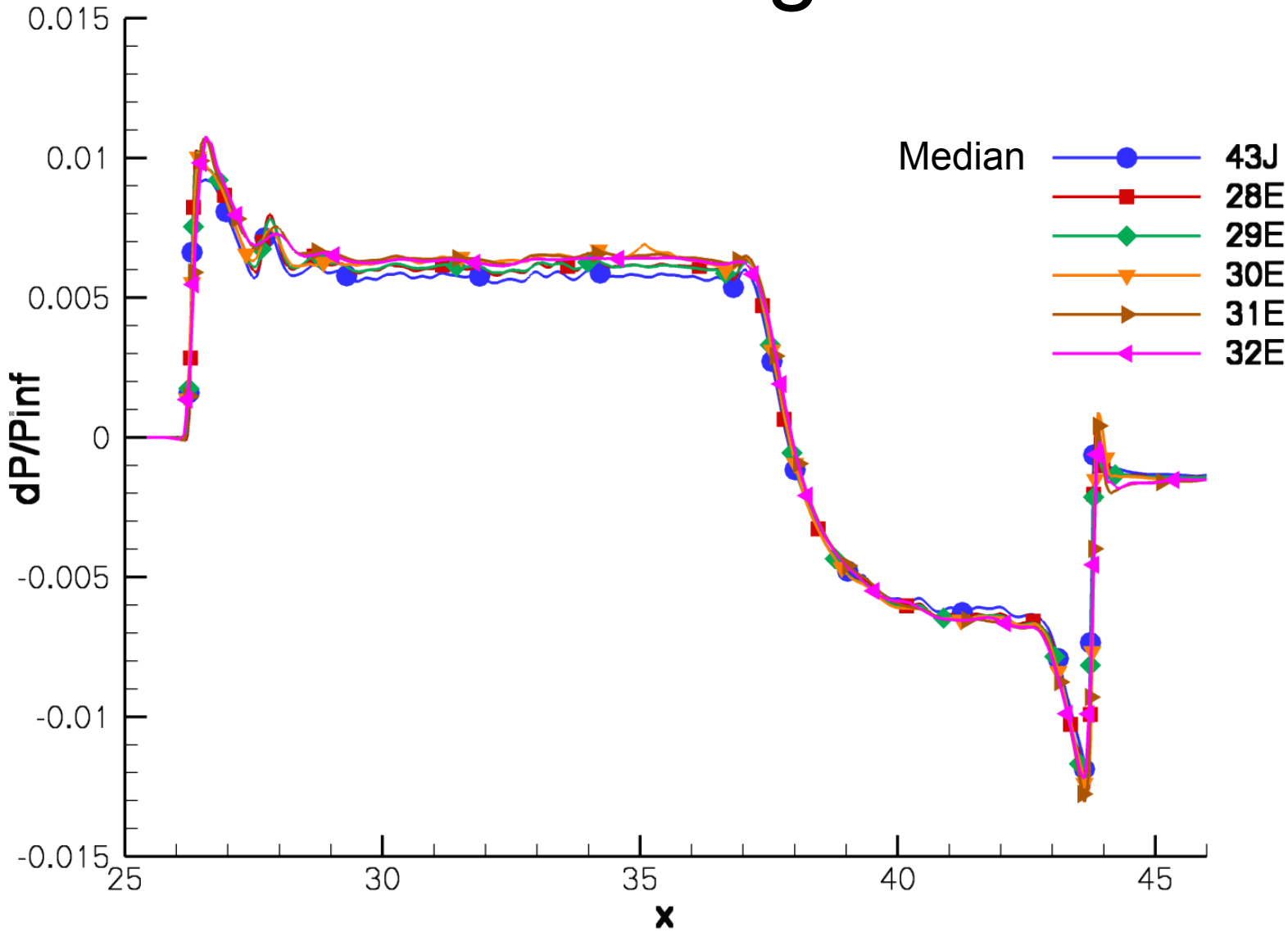

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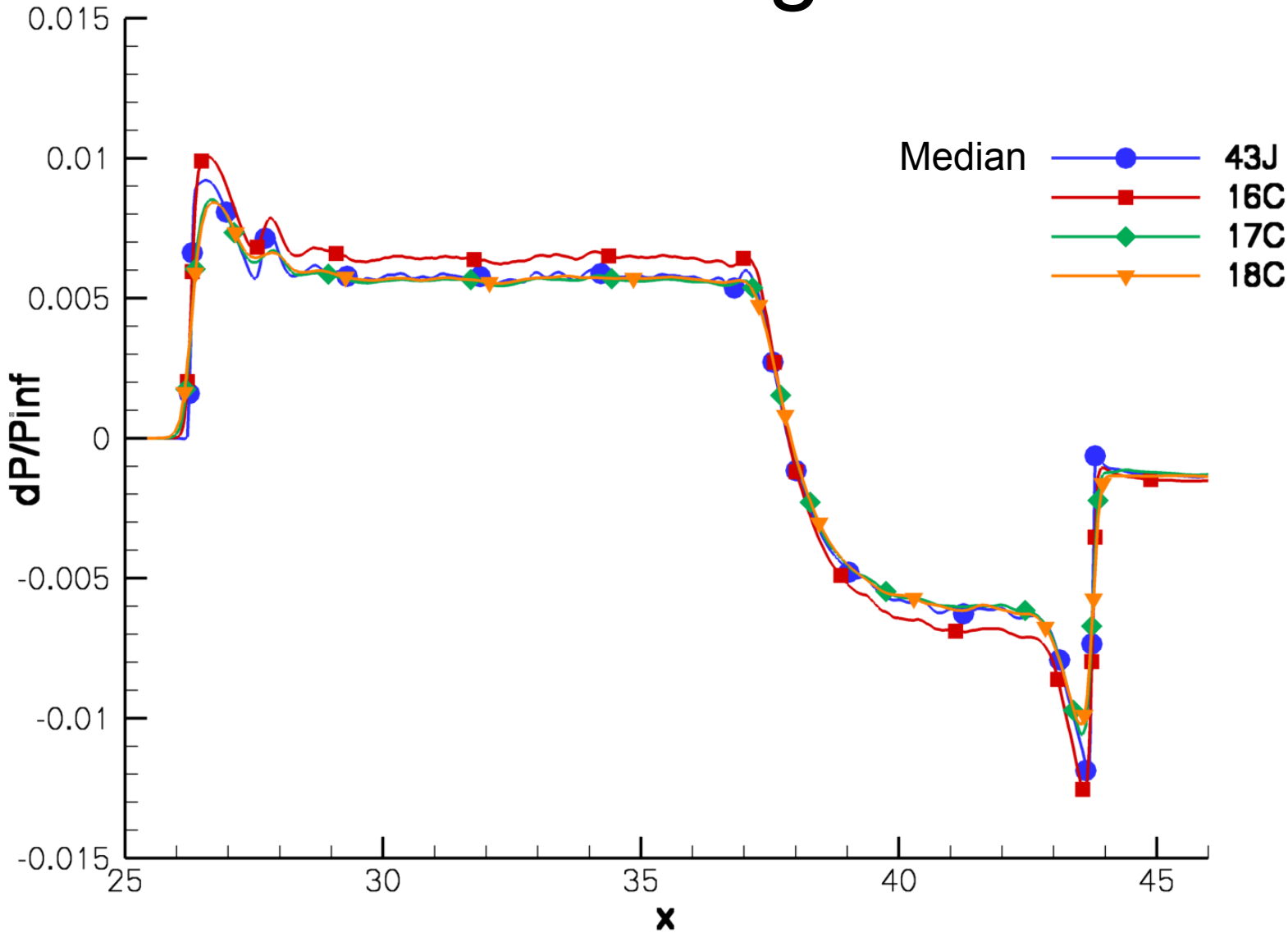
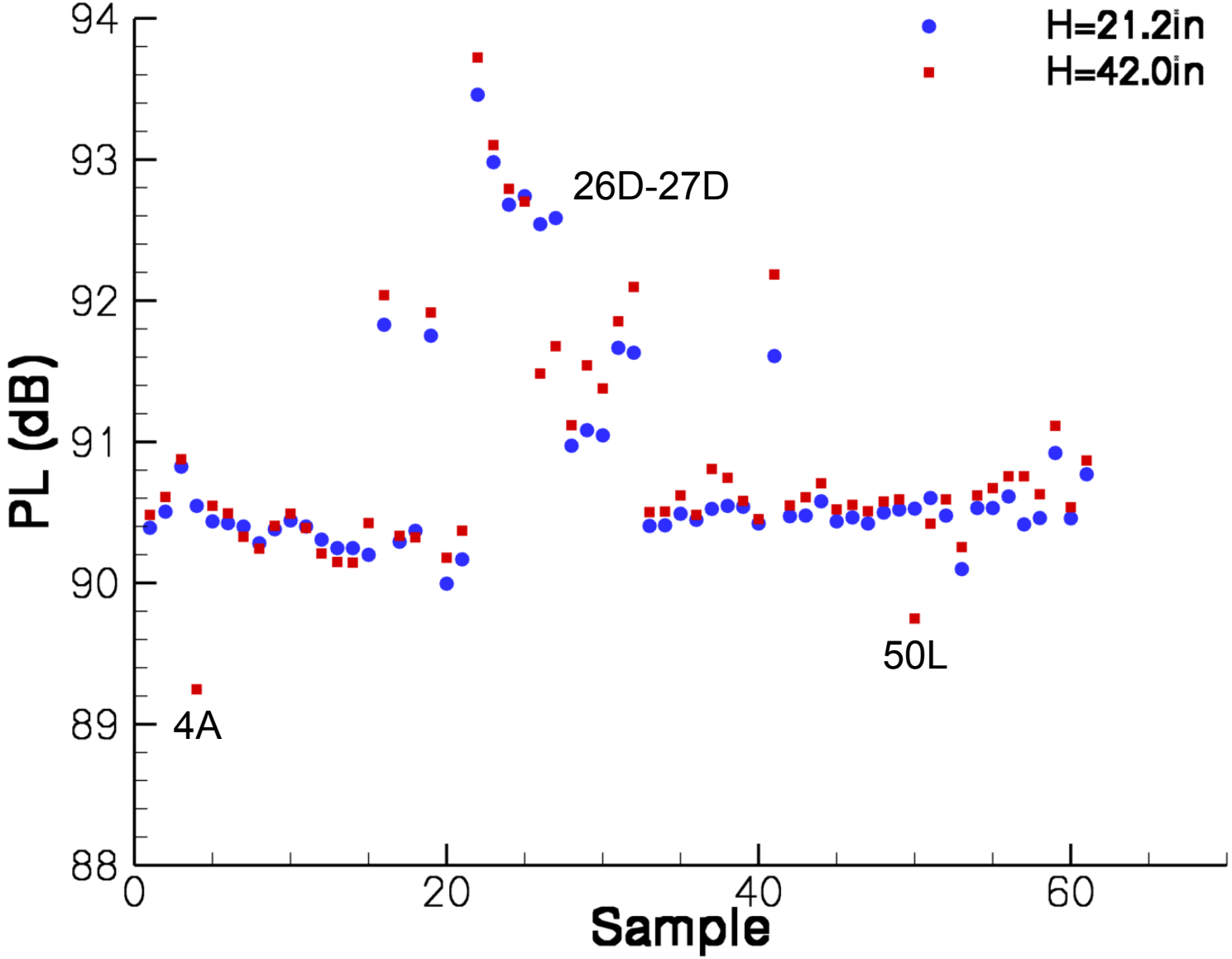
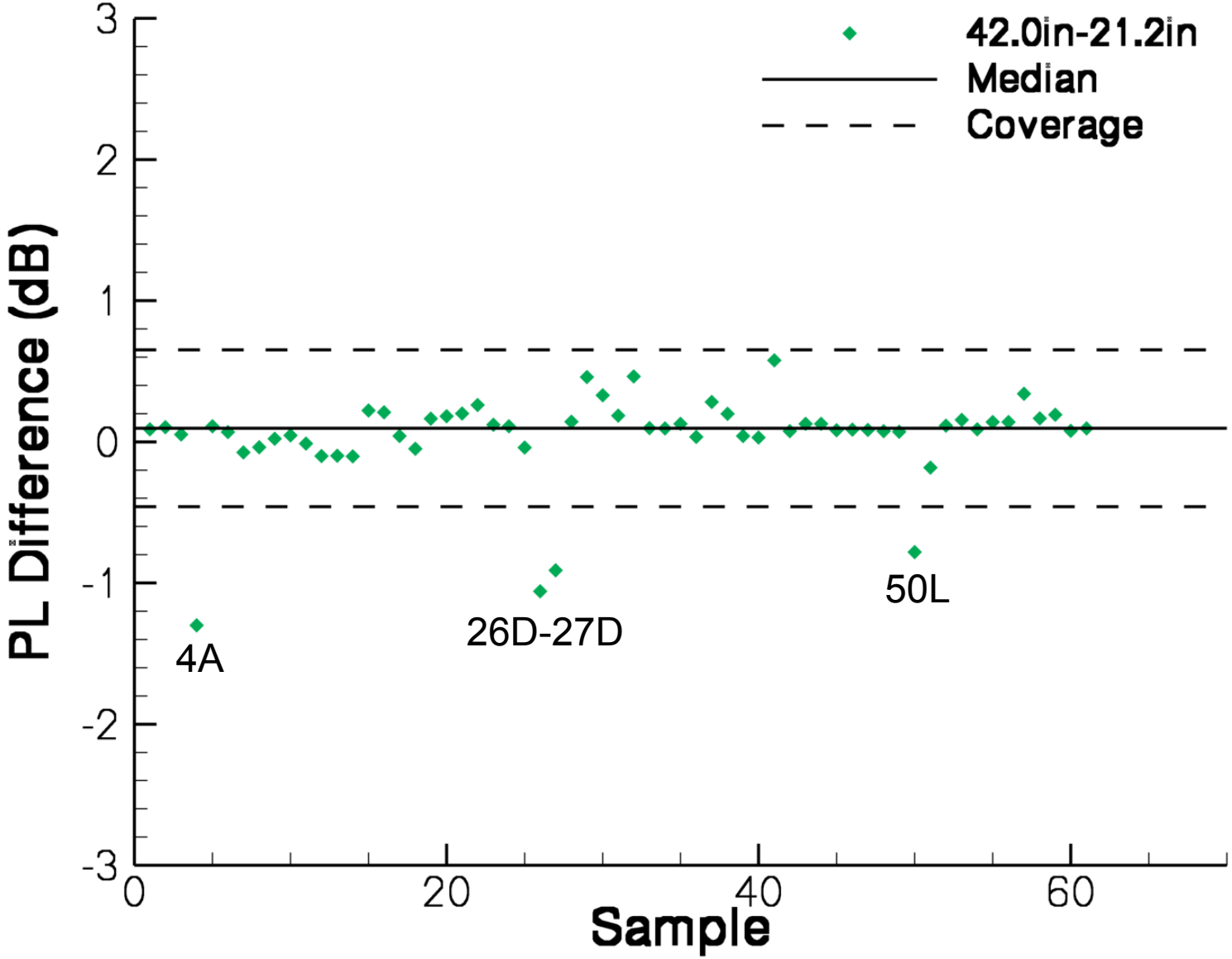


SEEB-ALR Perceived Level



SEEB-ALR Perceived Level



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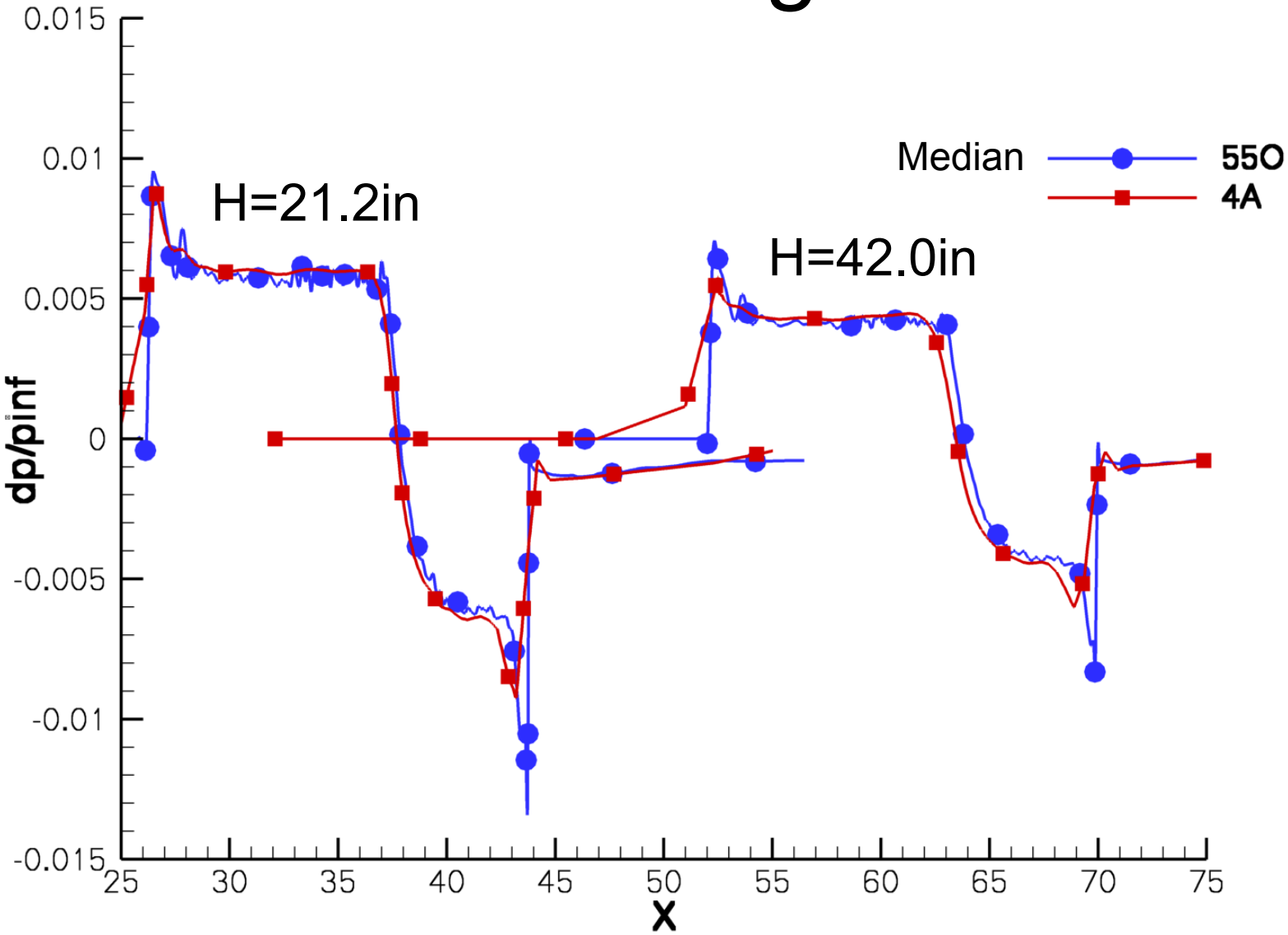

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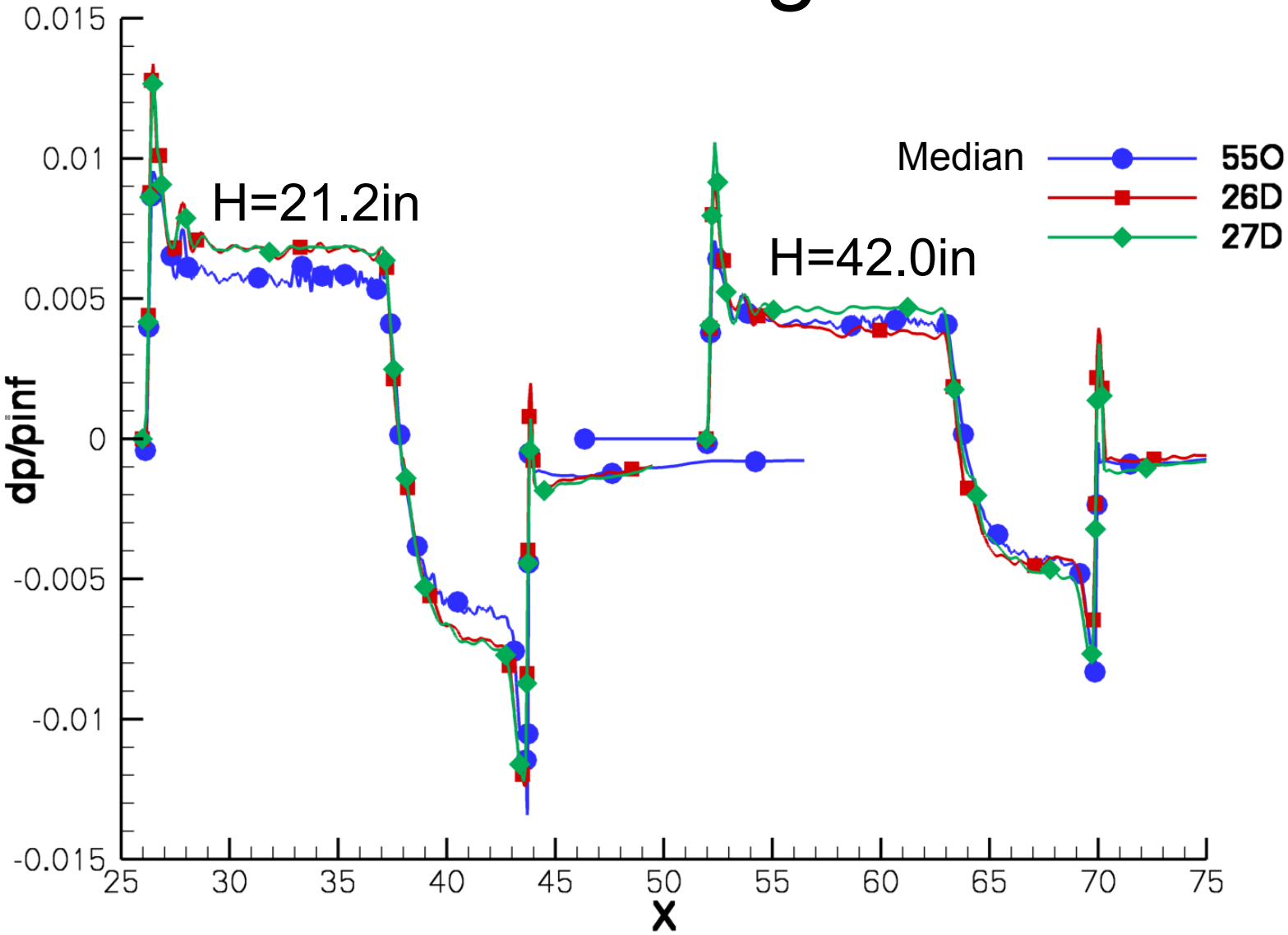

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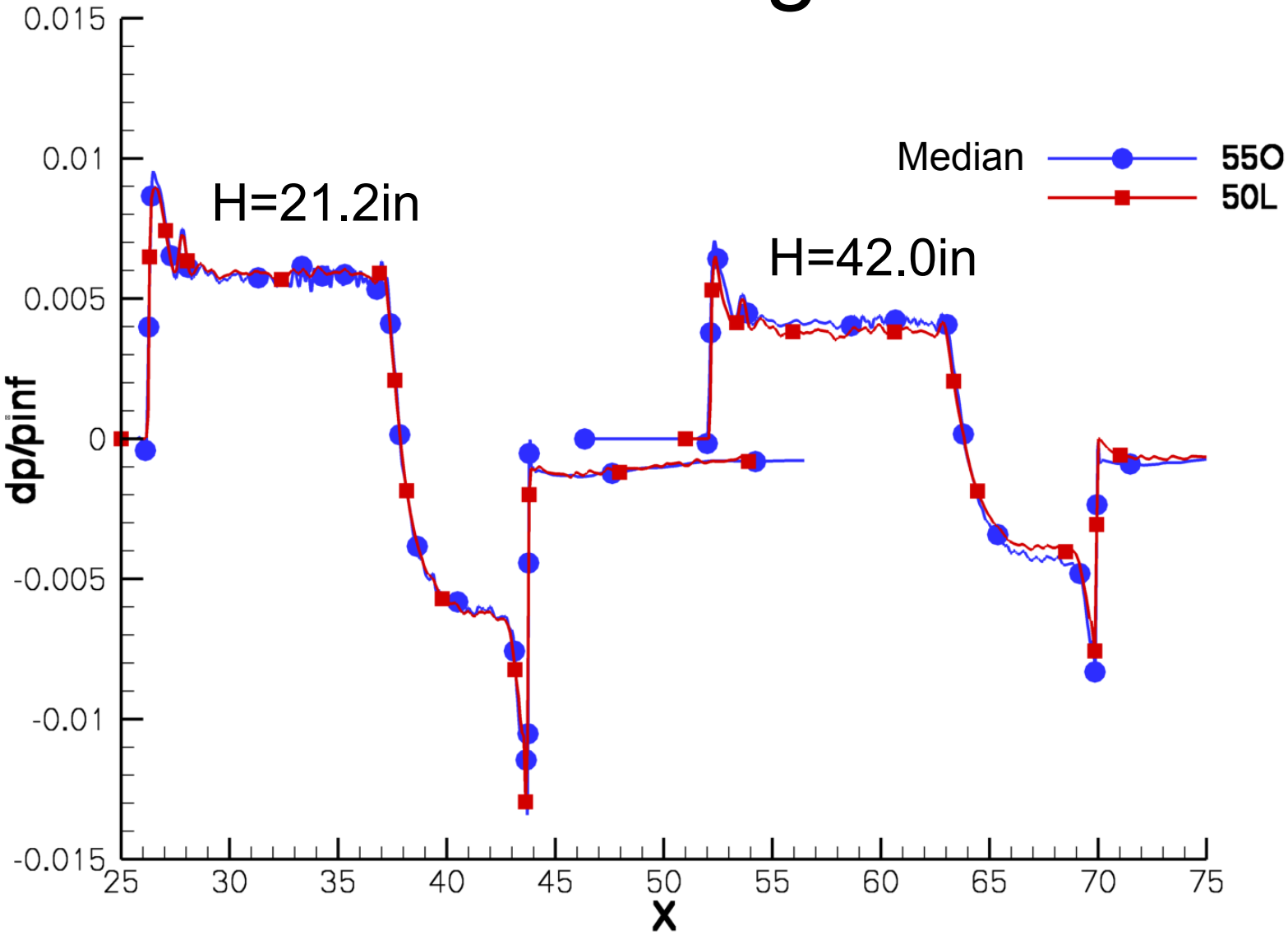
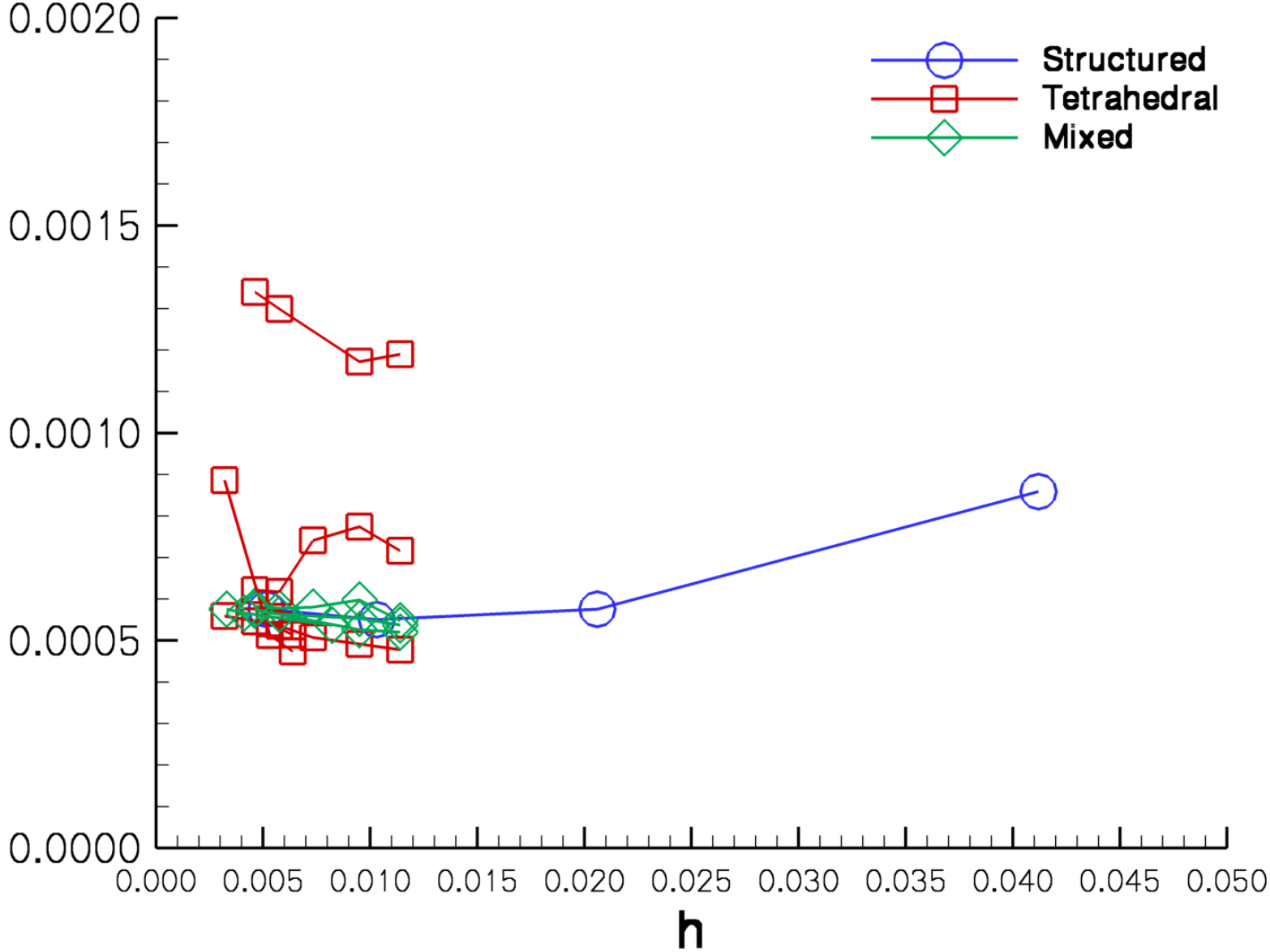


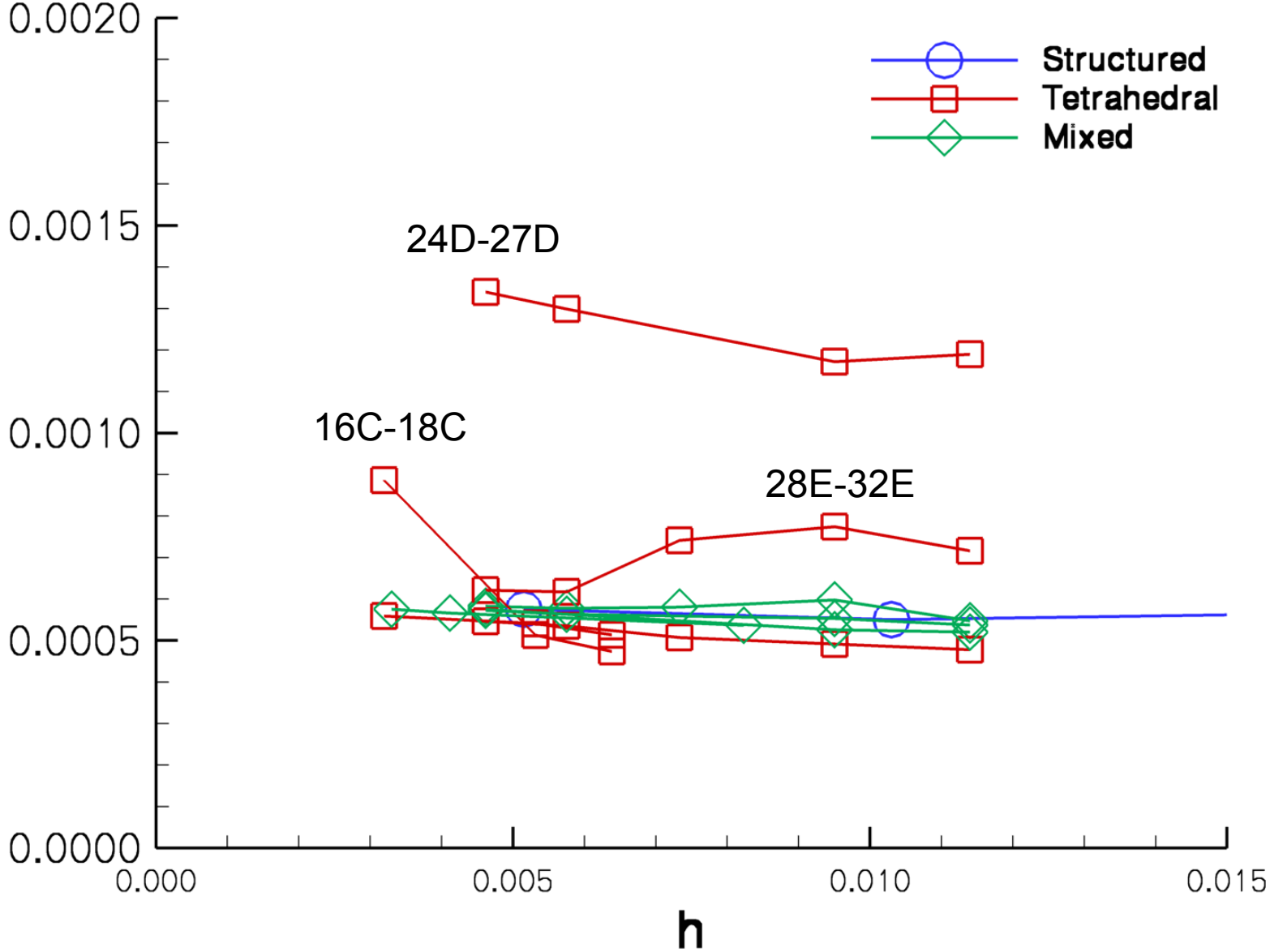
SEEB-ALR Validation Metric

- Examine the wind tunnel measurement with signatures identified as different
  - Convergence of the validation metric with grid refinement
  - Largest and smallest validation metric

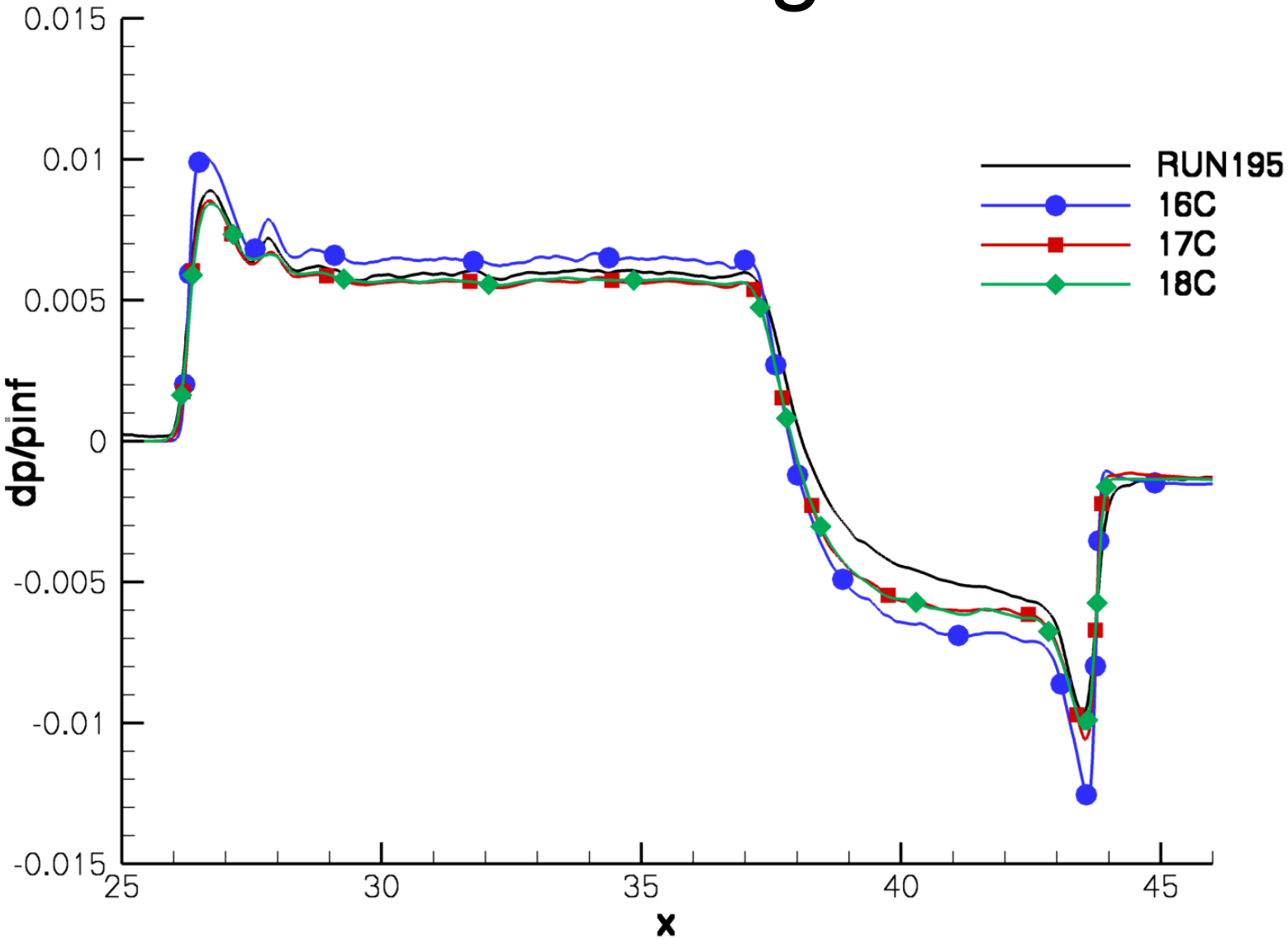
SEEB-ALR Validation Metric



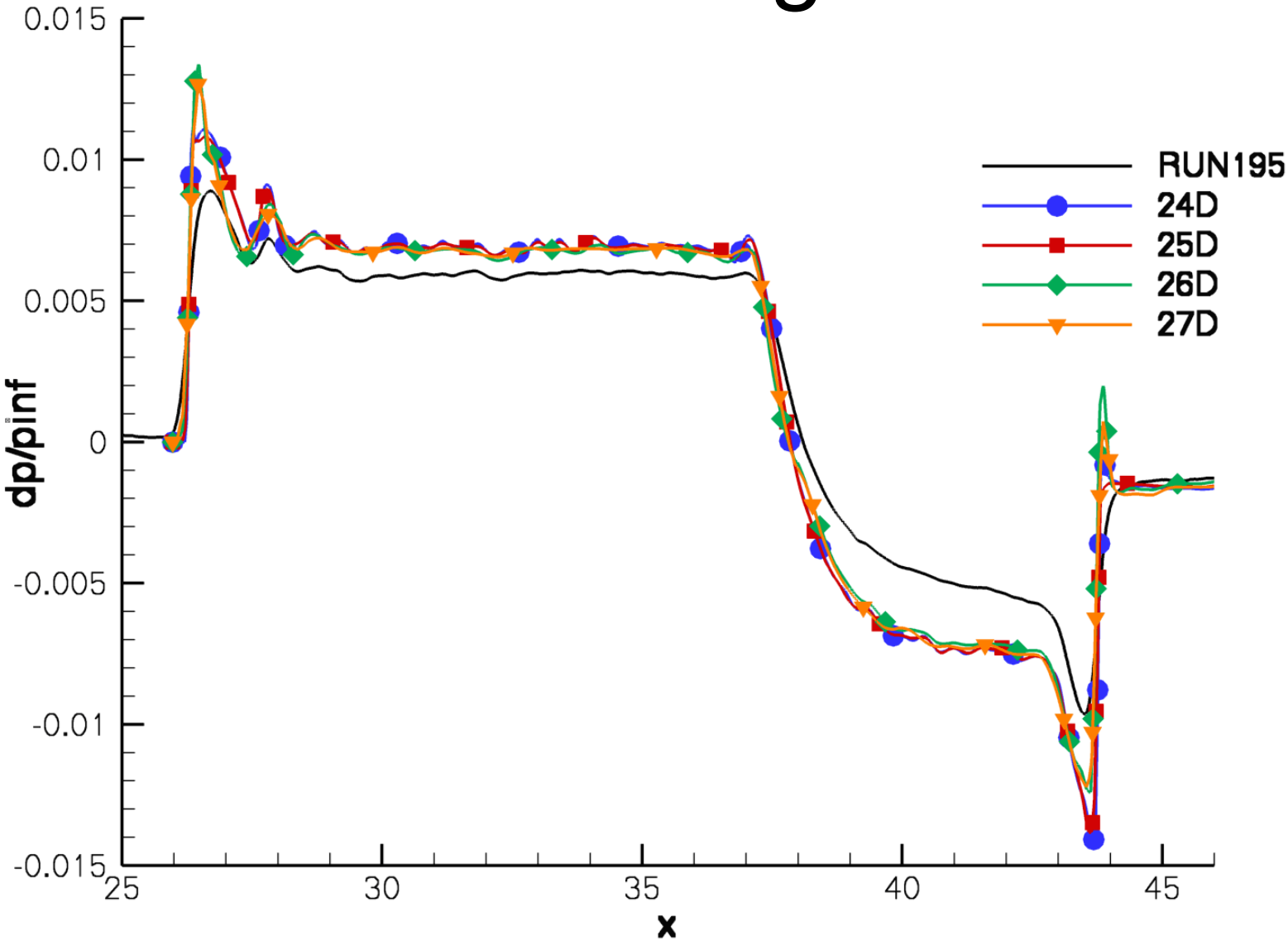
SEEB-ALR Validation Metric



SEEB-ALR Signature



SEEB-ALR Signature



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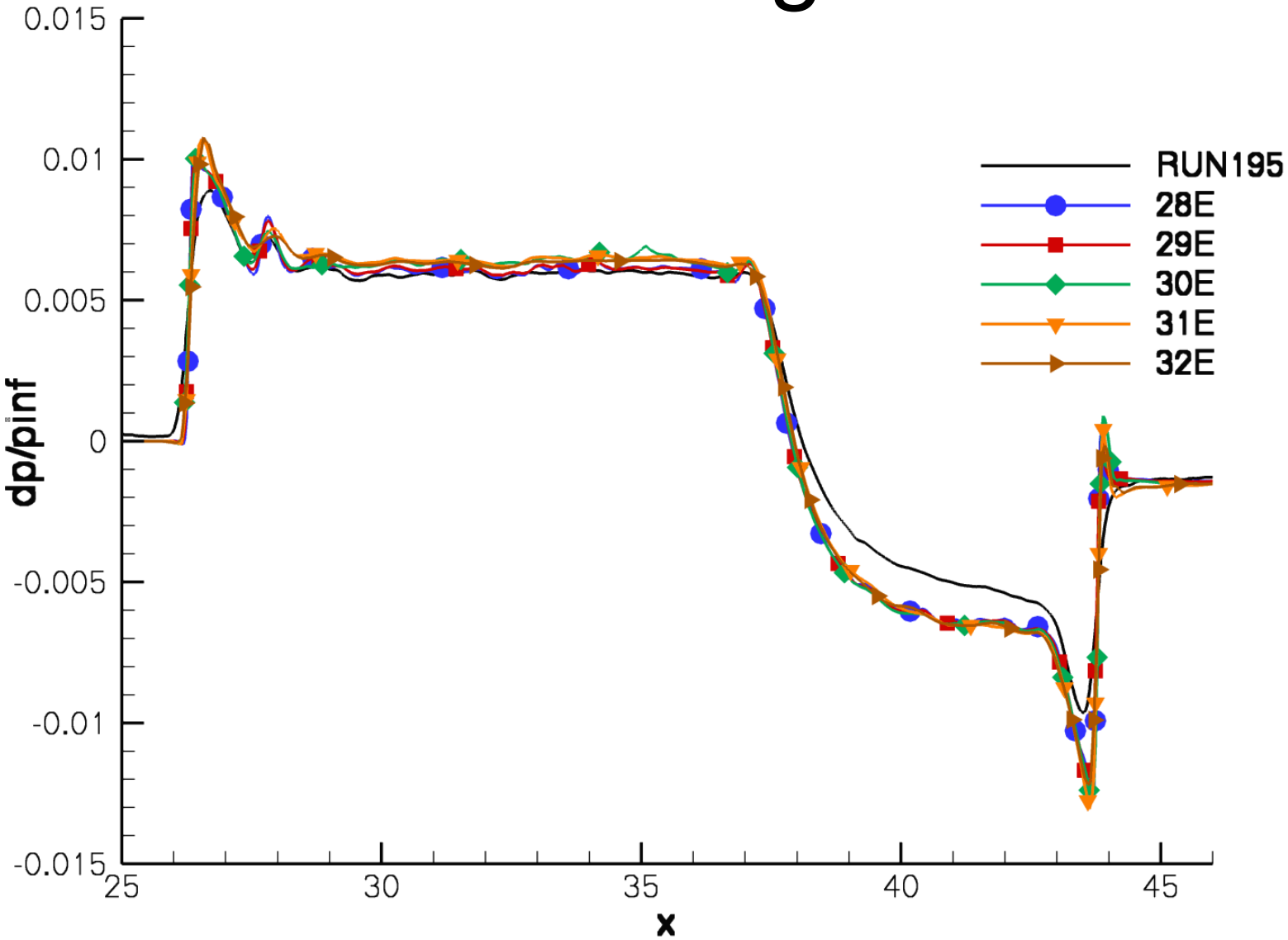
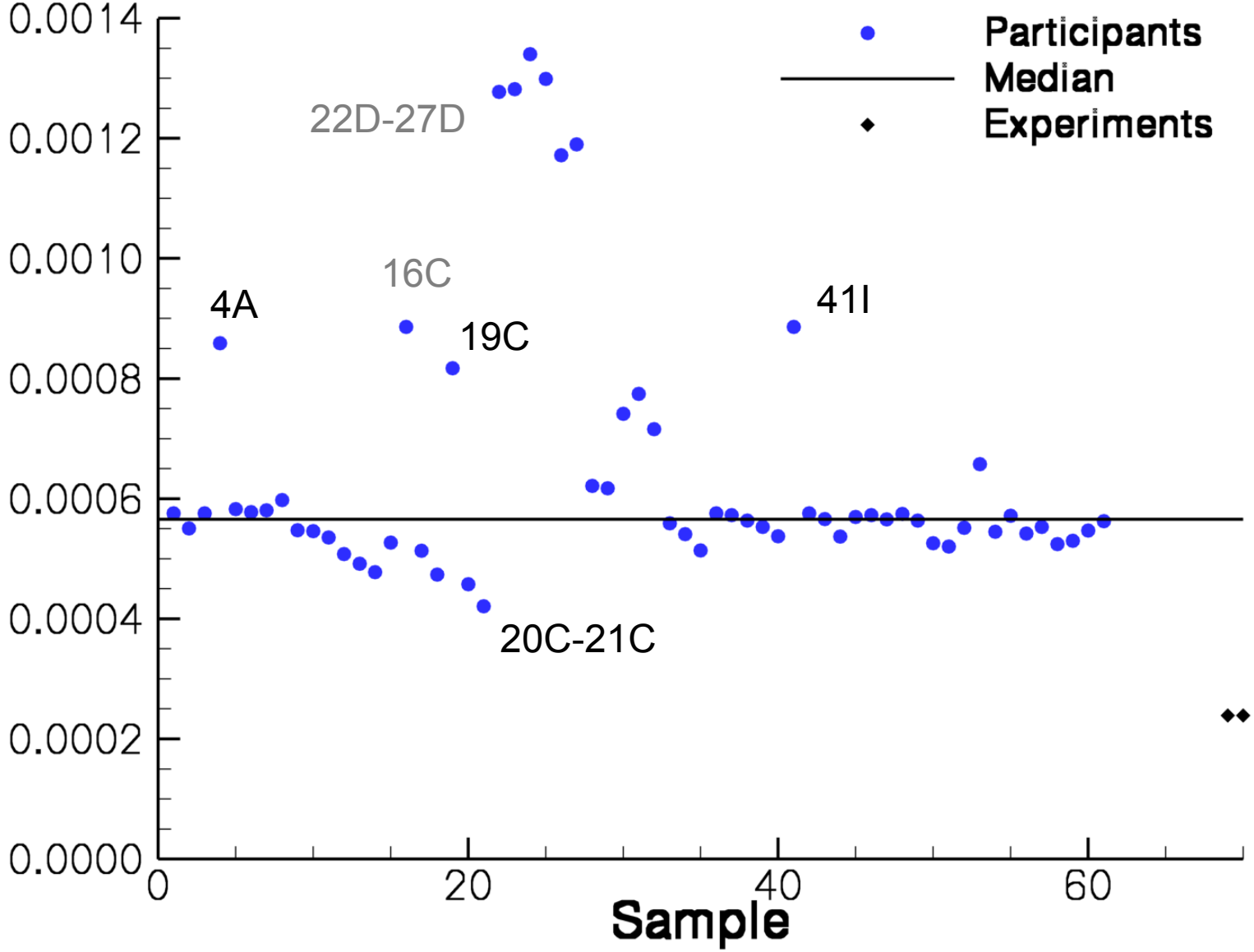
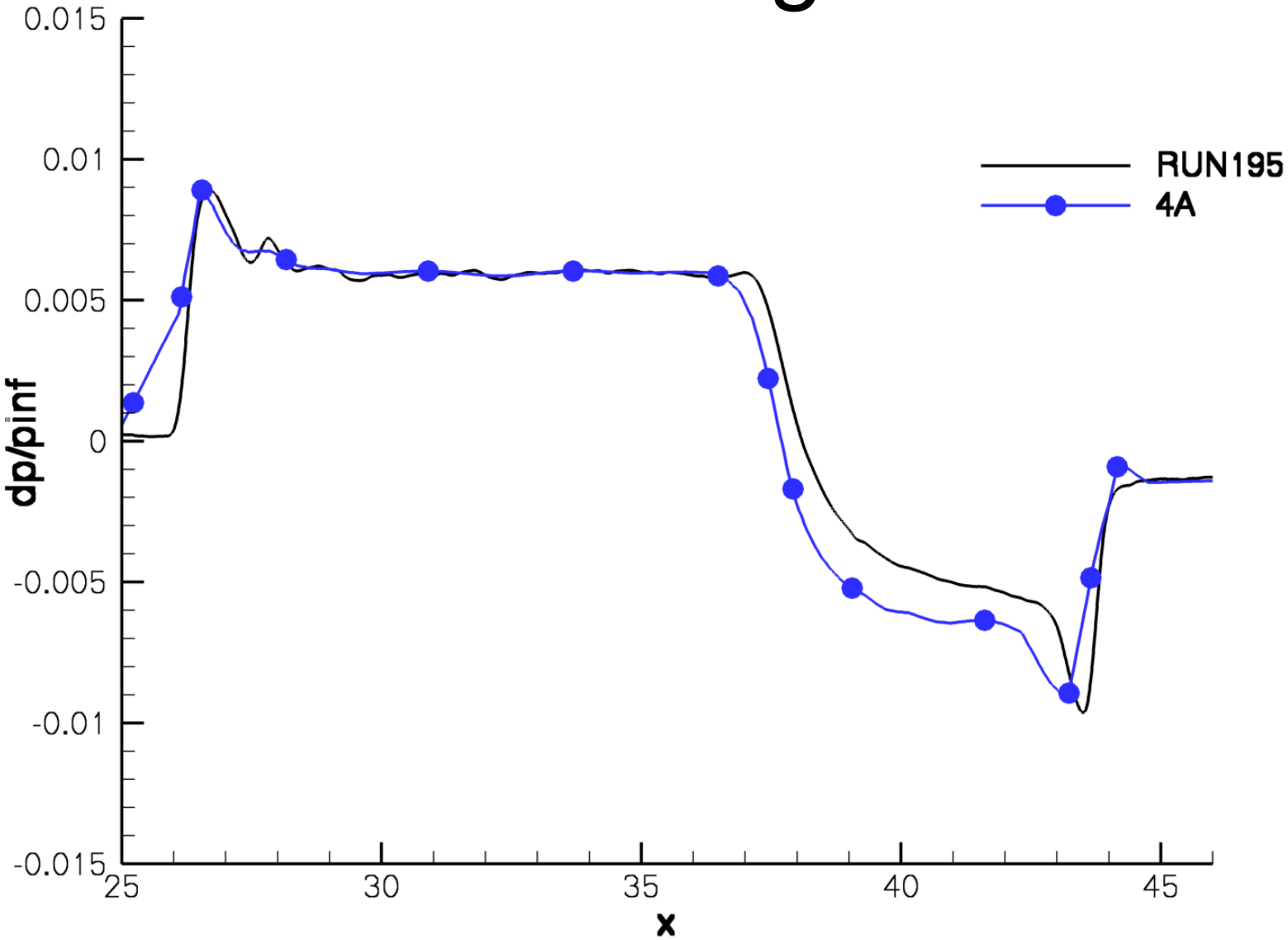


SEEB-ALR Validation Metric



SEEB-ALR Signature



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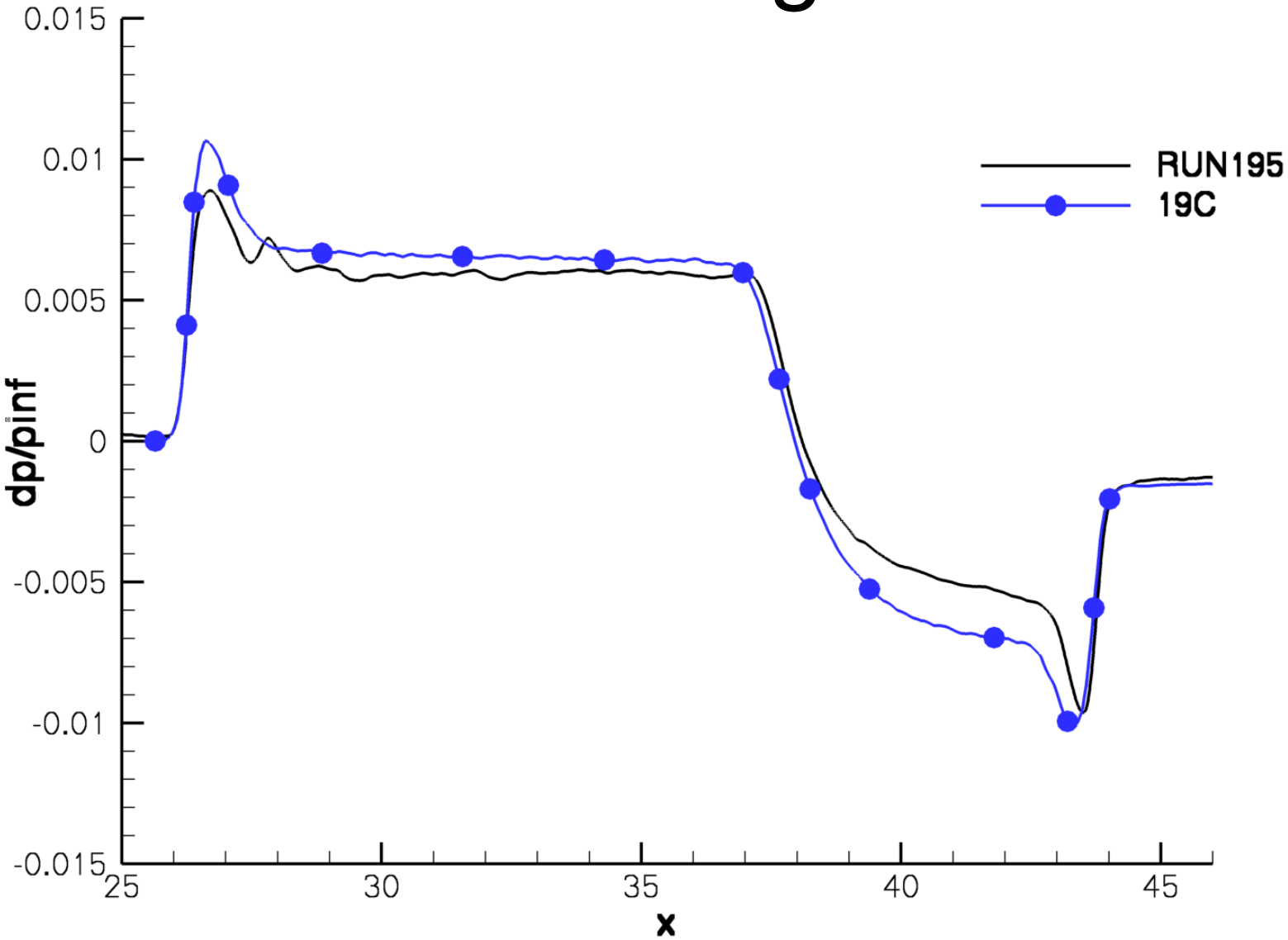

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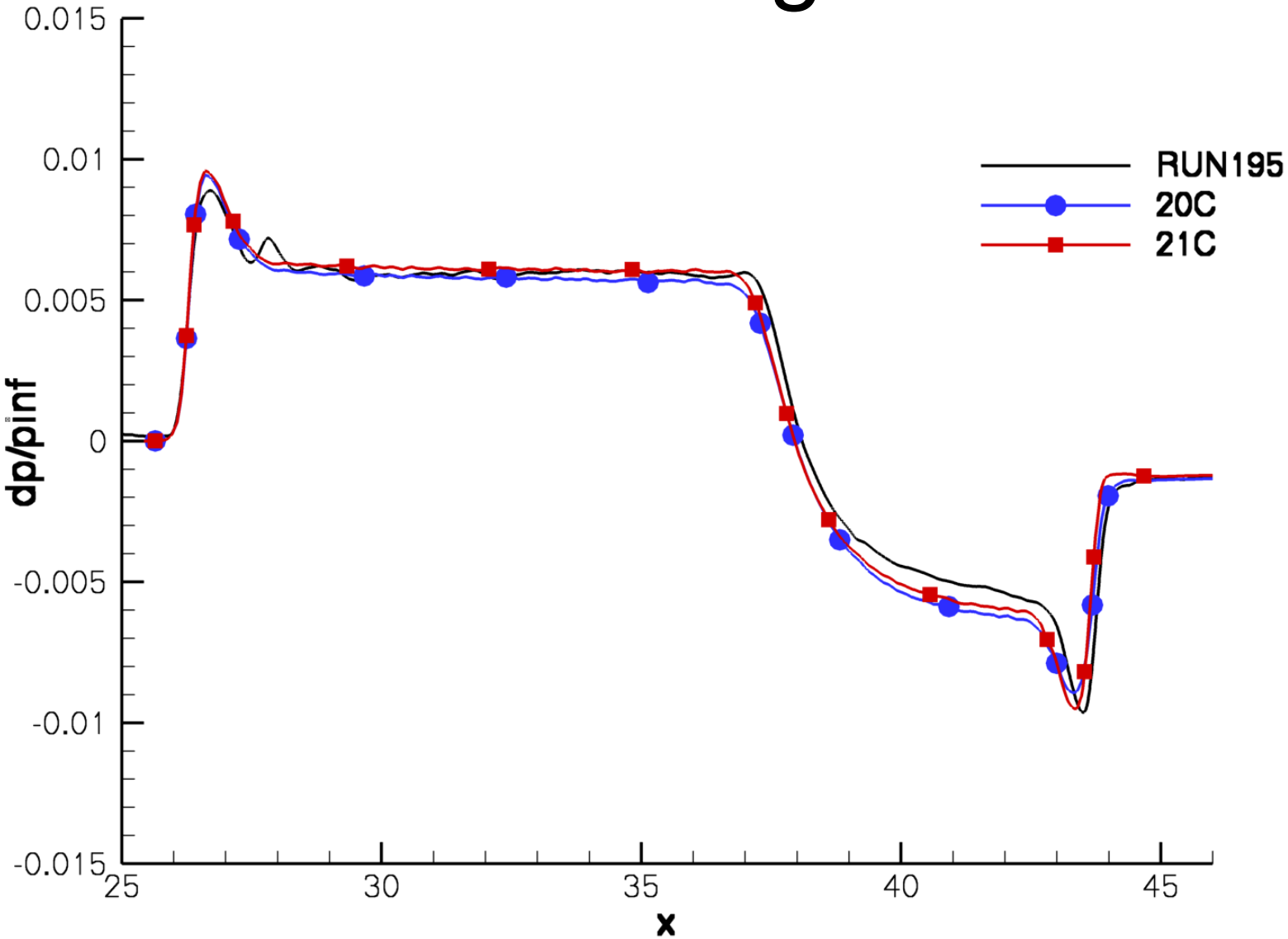
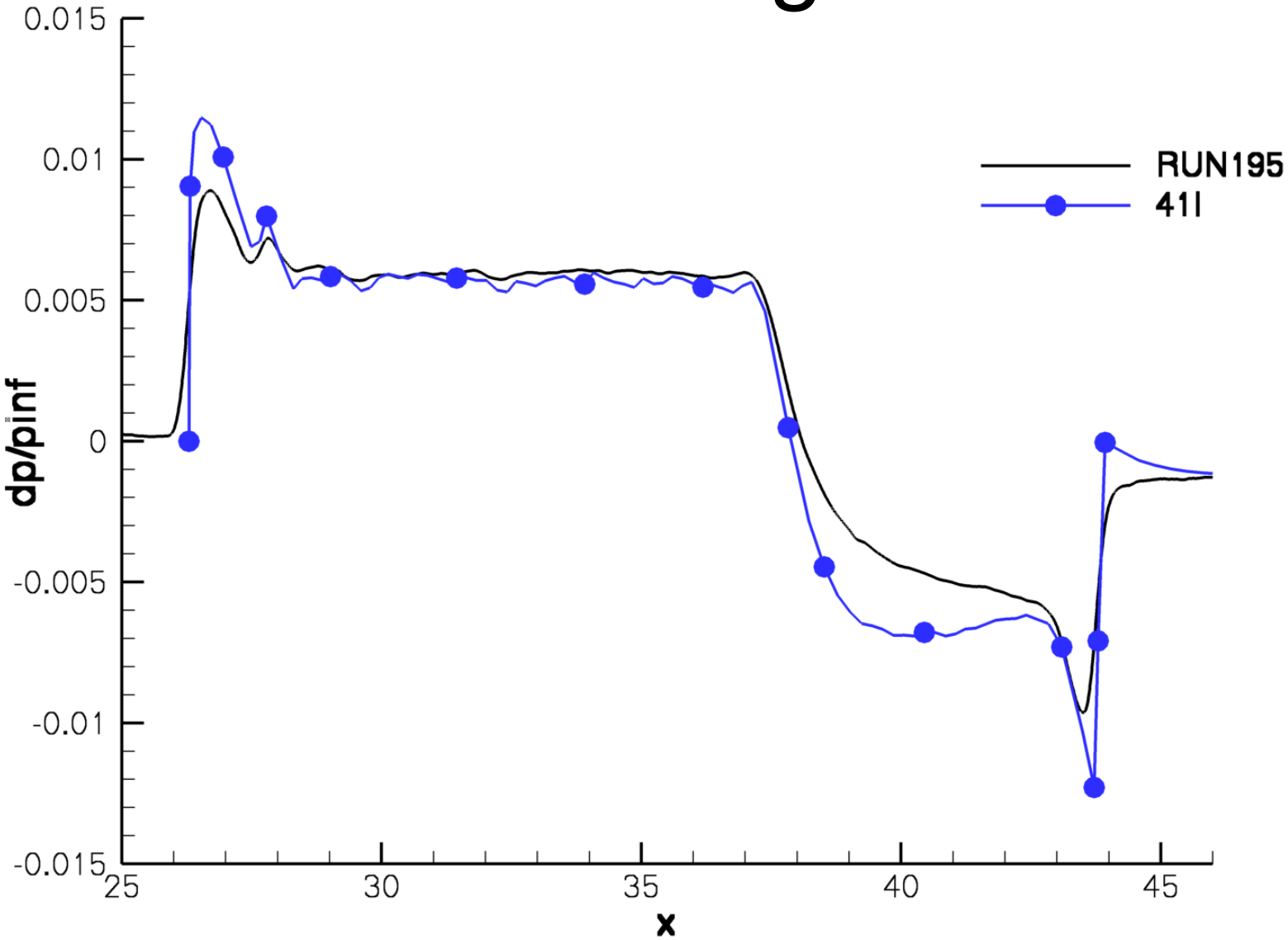


SEEB-ALR Signature



SEEB-ALR

- Outliers in PL are often outliers in the validation metric
  - These outliers generally had higher flat top pressure and lower expansion pressure than median
- The larger extraction distance was quieter in PL amongst outliers
- Laminar (20C) and SA (21C) had the smallest validation metric

SEEB-ALR

- Eight of ten grid refinement submissions appear to be heading to same value near median
- 24D-27D appear to be heading to a different PL and validation metric than others with grid refinement
- 16C does not follow the trends of the 17C and 18C with grid refinement
- 28E-32E appear to be heading to the same value as the collective, but less smoothly

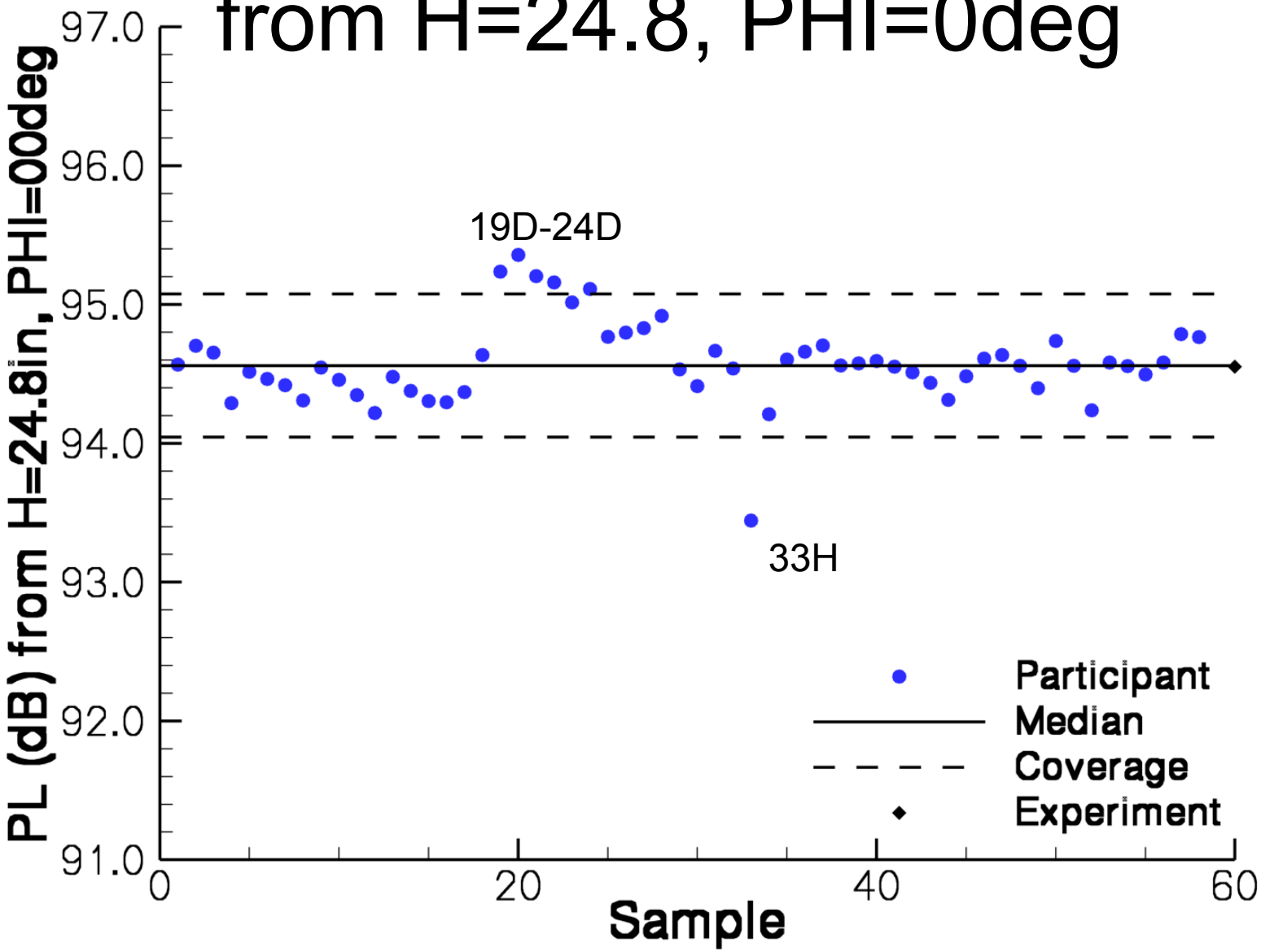
Delta Wing Body Submissions

#	Group	Phys	Type	Grid	ControlVol
1	A	Euler	Struct	S1	10141696
2	A	Euler	Struct	S2	1267712
3	A	Euler	Struct	S3	158464
4	A	Euler	Struct	S4	19808
5	A	Euler	Mixed	M100	5363065
6	A	Euler	Mixed	M125	2742341
7	A	Euler	Mixed	M156	1411515
8	A	Euler	Mixed	M200	695709
9	A	Euler	Tet	T100	5363065
10	A	Euler	Tet	T125	2742341
11	A	Euler	Tet	T156	1411515
12	A	Euler	Tet	T200	695709
13	B	Euler	Tet	VGRID	16700946
14	C	Euler	Tet	T125	16191339
15	C	Euler	Tet	T156	8288192
16	C	Euler	Tet	T200	4056575
17	C	Euler	Tet	PW/MCAP	6033621
18	C	SA	Tet	PW/MCAP	7864672
19	D	Euler	Tet	Adapted-Adj	759048
20	D	Euler	Tet	Adapted-LP	860010
21	D	Euler	Tet	T100	5363065
22	D	Euler	Tet	T125	2742341
23	D	Euler	Tet	T156	1411515
24	D	Euler	Tet	T200	695709
25	E	Euler	Tet	T100	5363065
26	E	Euler	Tet	T125	2742341
27	E	Euler	Tet	T156	1411515
28	E	Euler	Tet	T200	695709
29	F	Euler	Tet	T100	31801283
30	F	Euler	Tet	T200	4056575
31	F	Euler	Struct	S1	10141696
32	G	Euler	Struct	Gridgen	9848768
33	H	Euler	Tet	Adapted-Adj	229000
34	H	Euler	Tet	Adapted	1197548
35	H	Euler	Mixed	M100	5363065
36	H	Euler	Mixed	M125	2742341
37	H	Euler	Mixed	M156	1411515
38	H	Euler	Mixed	M200	695709
39	J	Euler	Struct	S1	10141696
40	J	Euler	Overset	Fixed	27646000
41	J	Euler	Mixed	M100	22423283
42	J	Euler	Mixed	M125	11451499
43	J	Euler	Mixed	M156	5877312
44	J	Euler	Mixed	M200	2830575
45	K	Euler	Struct	Gridgen	10640580
46	L	Euler	Mixed	M100	5363065
47	L	Euler	Mixed	M125	2742341
48	L	Euler	Mixed	M156	1411515
49	L	Euler	Mixed	M200	695709
50	M	Euler	Cart	Adapted-Adj	15885435
51	N	Euler	Cart	Adapted	49000000
52	N	Euler	Cart	Fixed	75000000
53	N	Euler	Mixed	M100	22423283
54	O	Euler	Hybrid	Fixed	108000000
55	P	Euler	Cart	Fixed	54466264
56	Q	Euler	Mixed	M100	22423283
57	R	SA	Overset	Fixed	21300000
58	R	SA	Mixed	Fixed	12100000

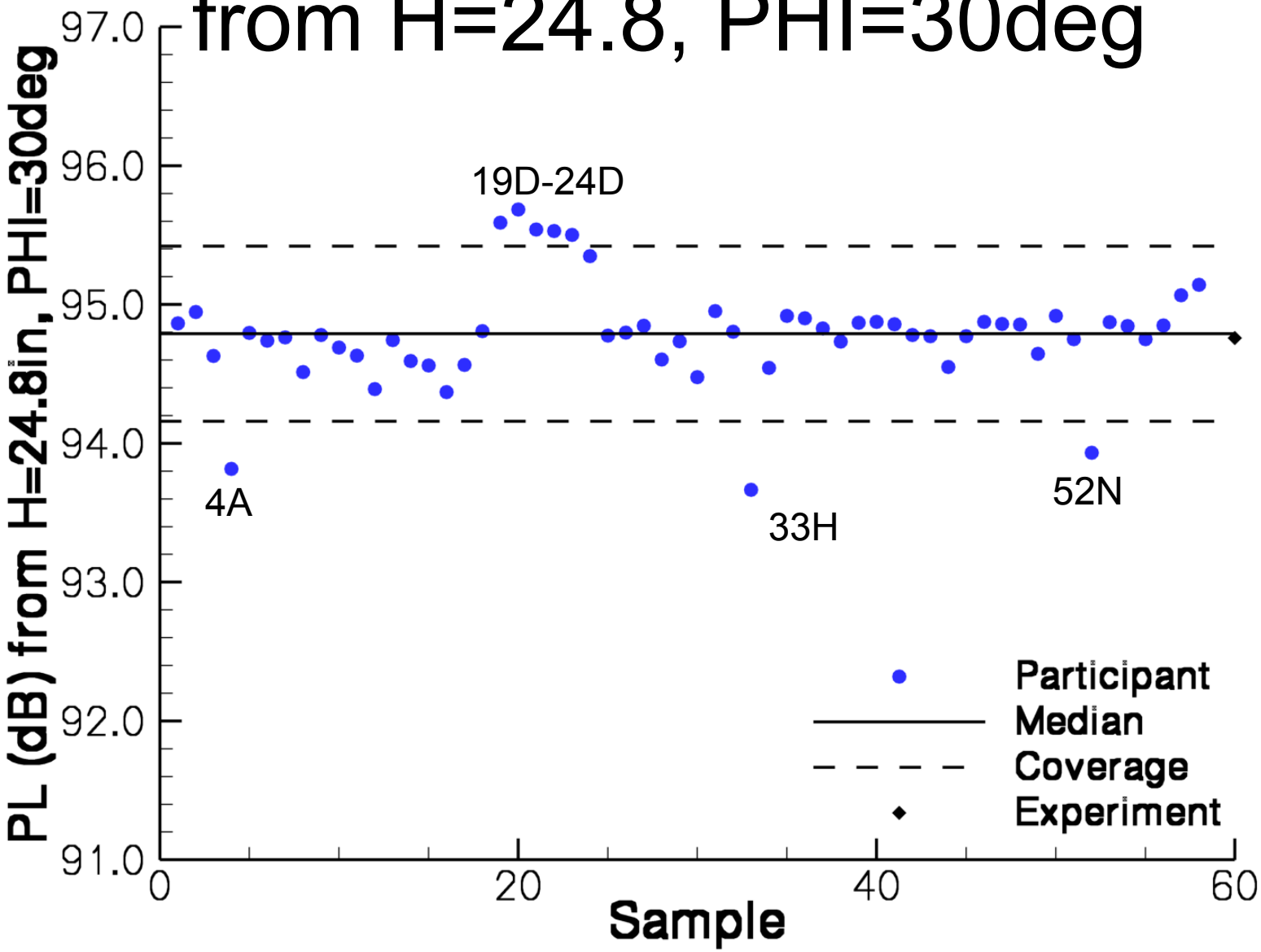
Delta Wing Body Perceived Level

- Examine the median signature with signatures identified as different
  - Statistics of PL for PHI=0, 30, 60, and 90 degrees
    - The on- and off-track signatures are propagated in the same manner for statistics (not a boom carpet)
  - Convergence of PL with grid refinement at PHI=0 degrees
  - Change in PL with extraction location at PHI=0 degrees

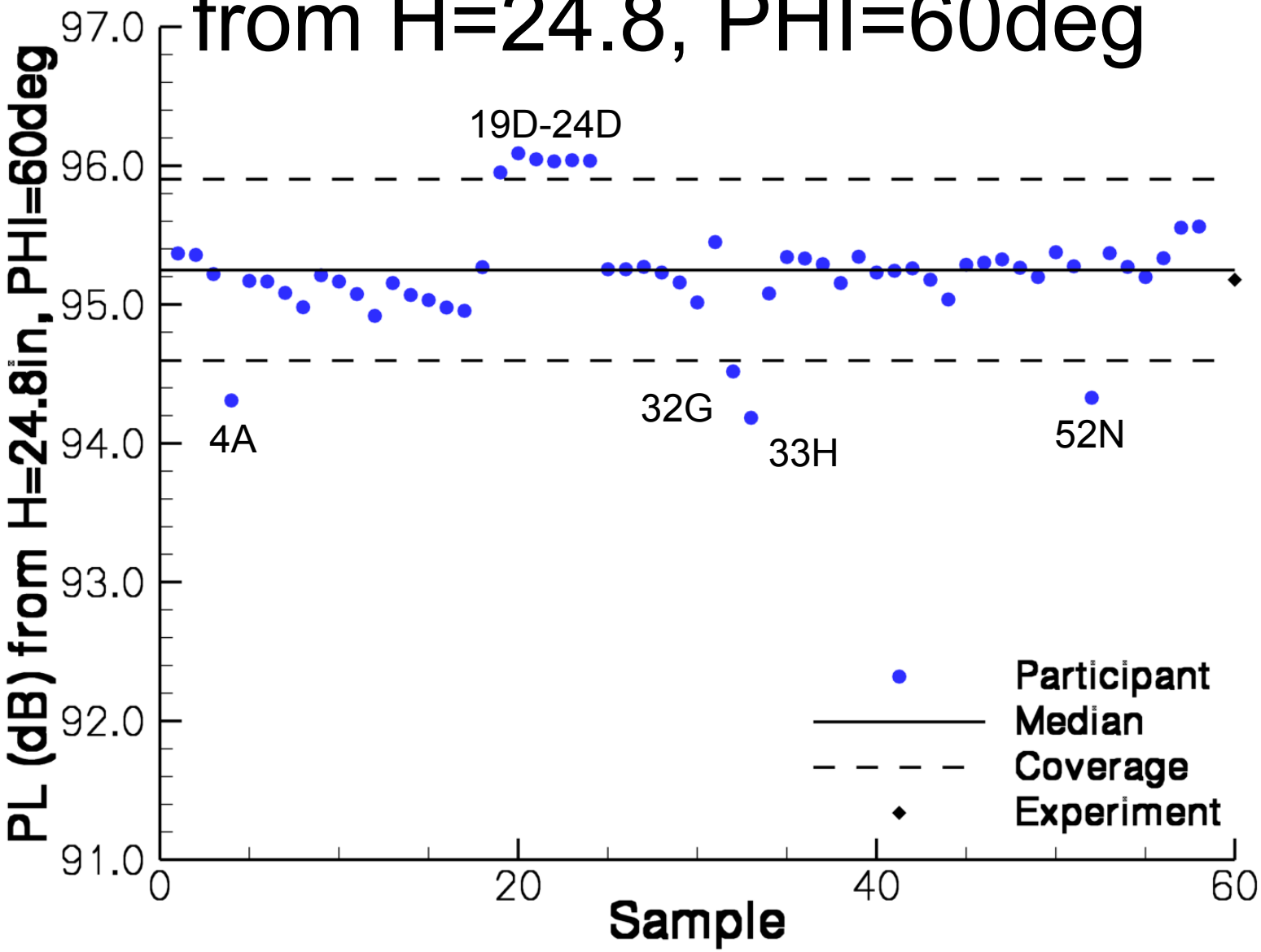
Delta Wing Body Perceived Level from H=24.8, PHI=0deg



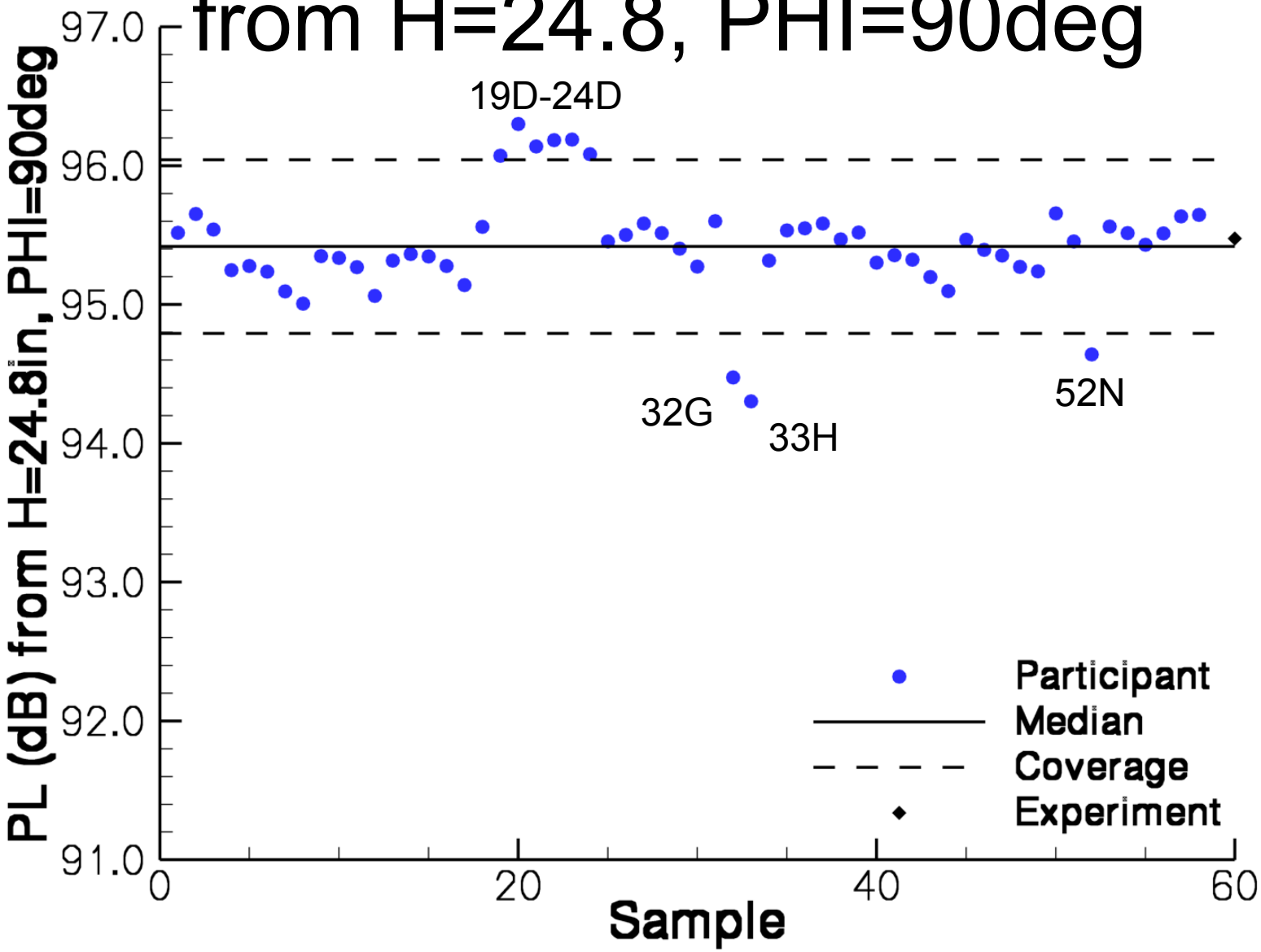
Delta Wing Body Perceived Level from H=24.8, PHI=30deg



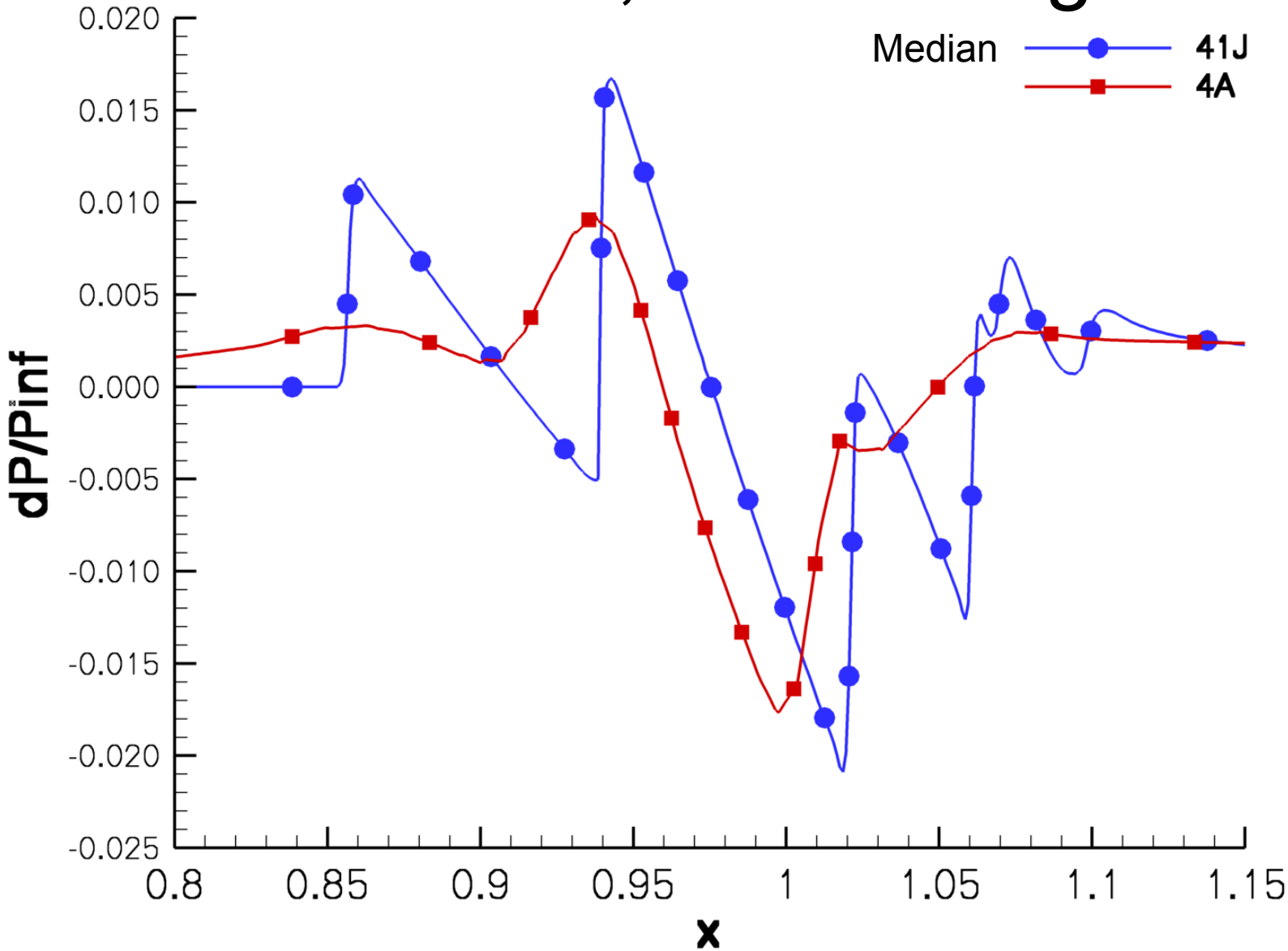
Delta Wing Body Perceived Level from H=24.8, PHI=60deg



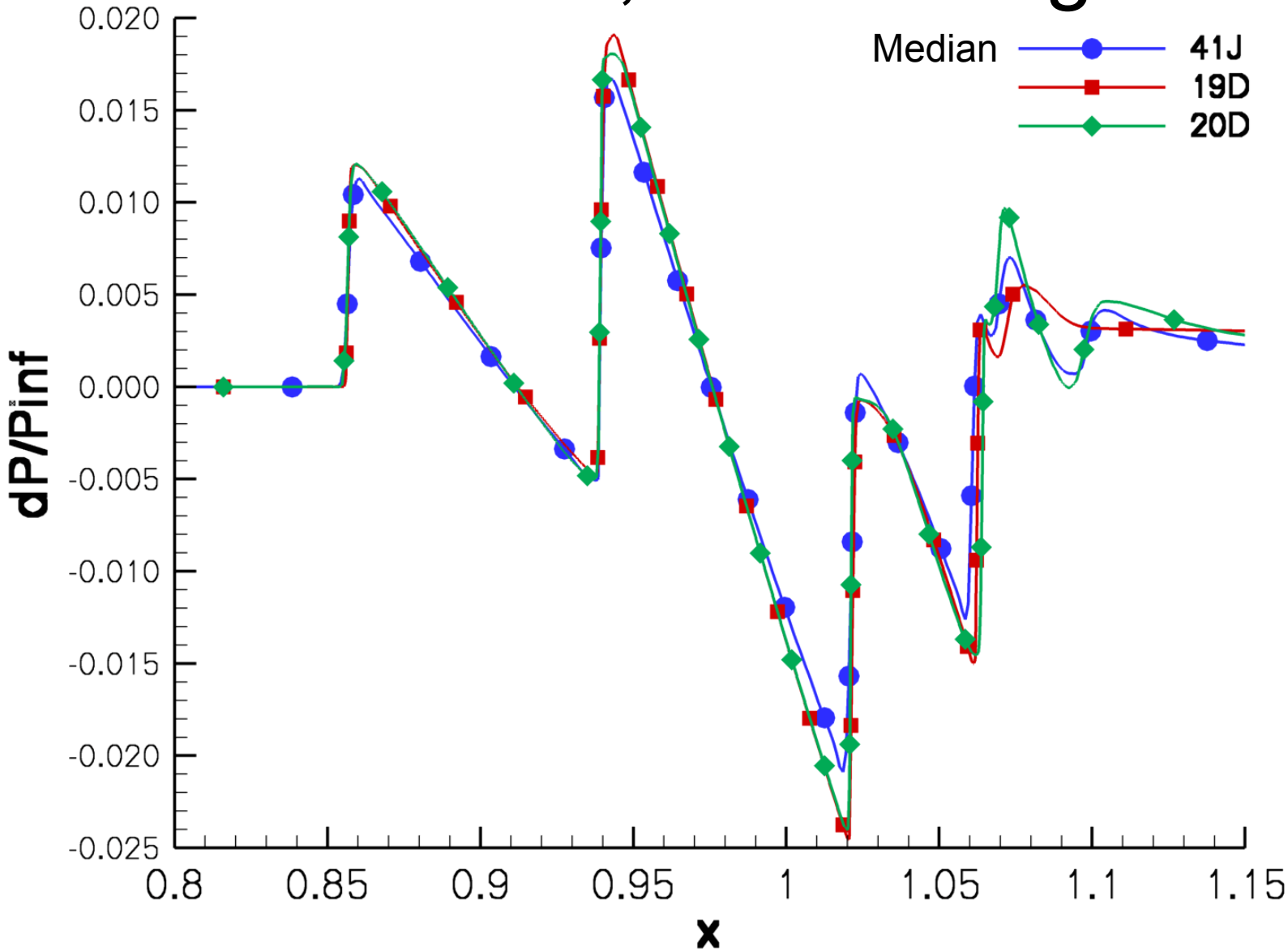
Delta Wing Body Perceived Level from H=24.8, PHI=90deg



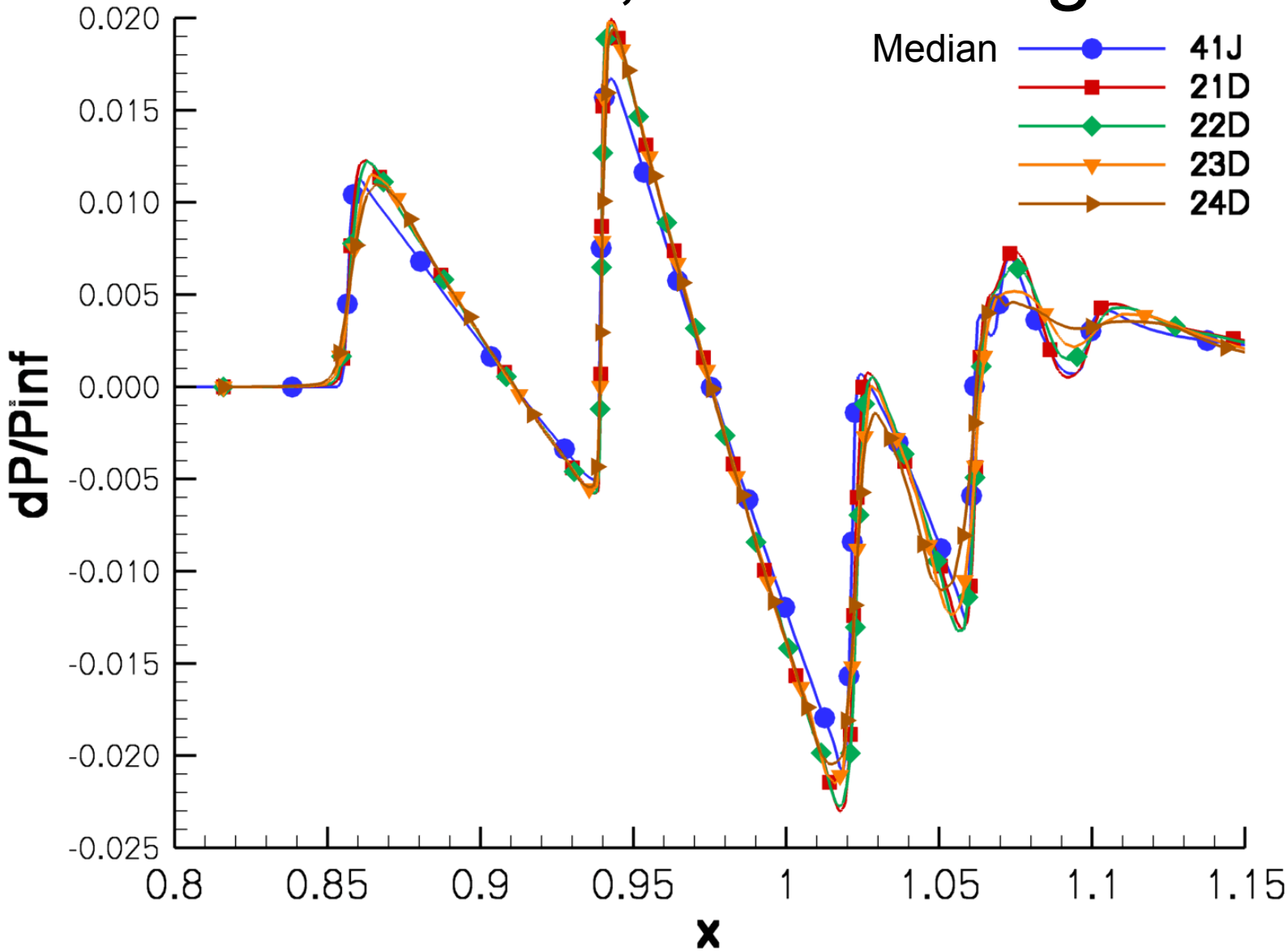
Delta Wing Body Signature
H=24.8in, PHI=90deg



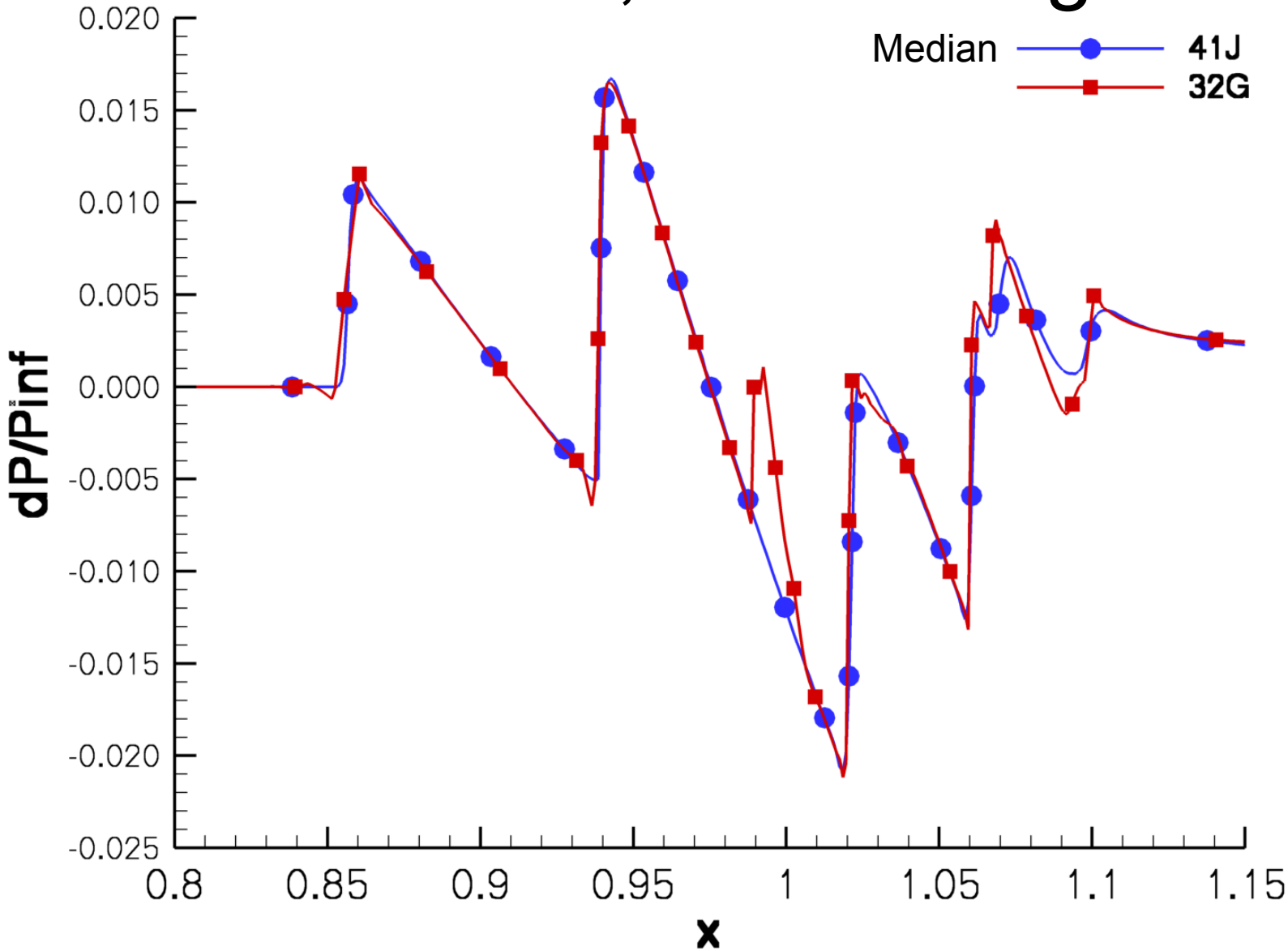
Delta Wing Body Signature
H=24.8in, PHI=90deg



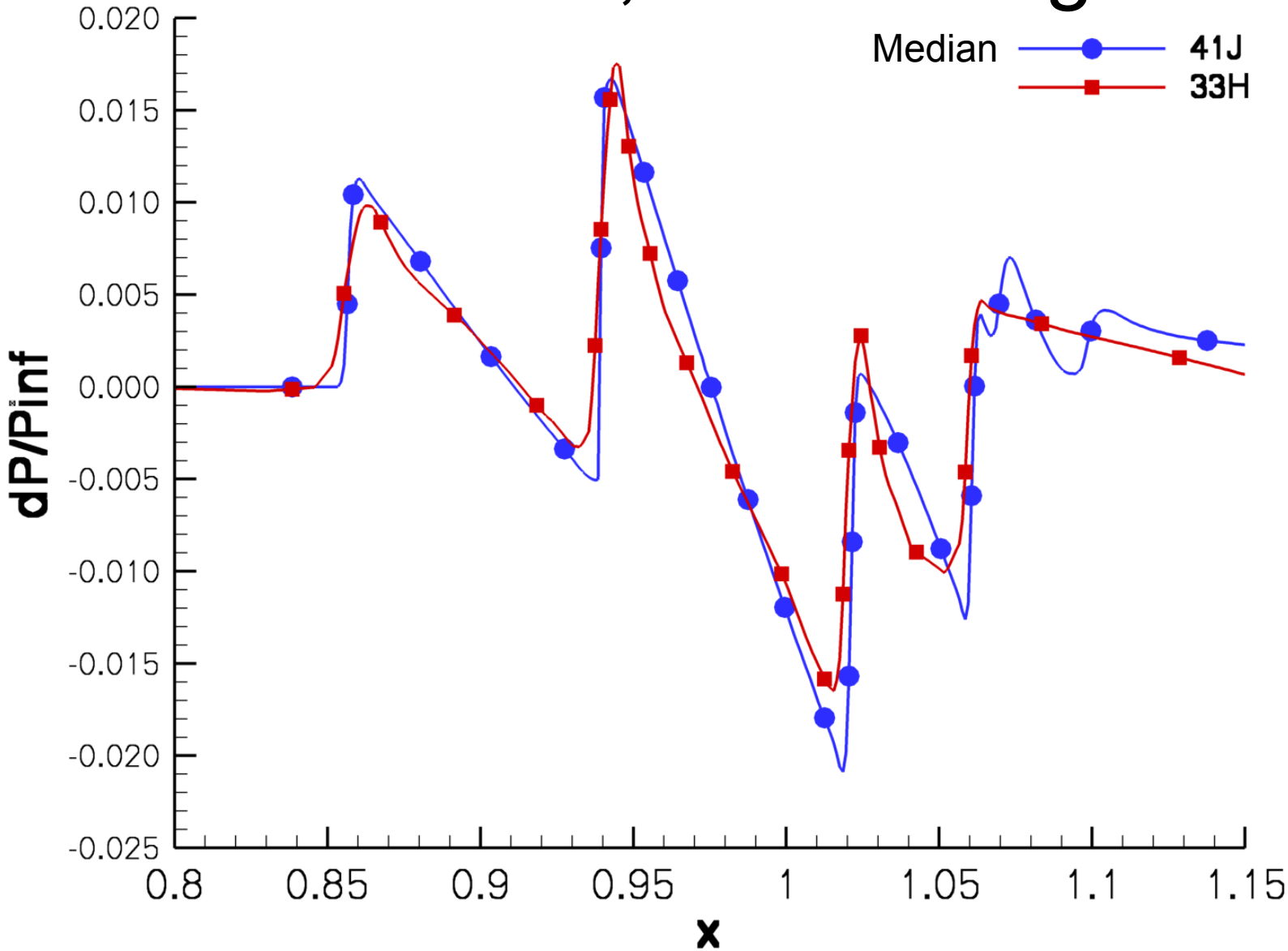
Delta Wing Body Signature
H=24.8in, PHI=90deg



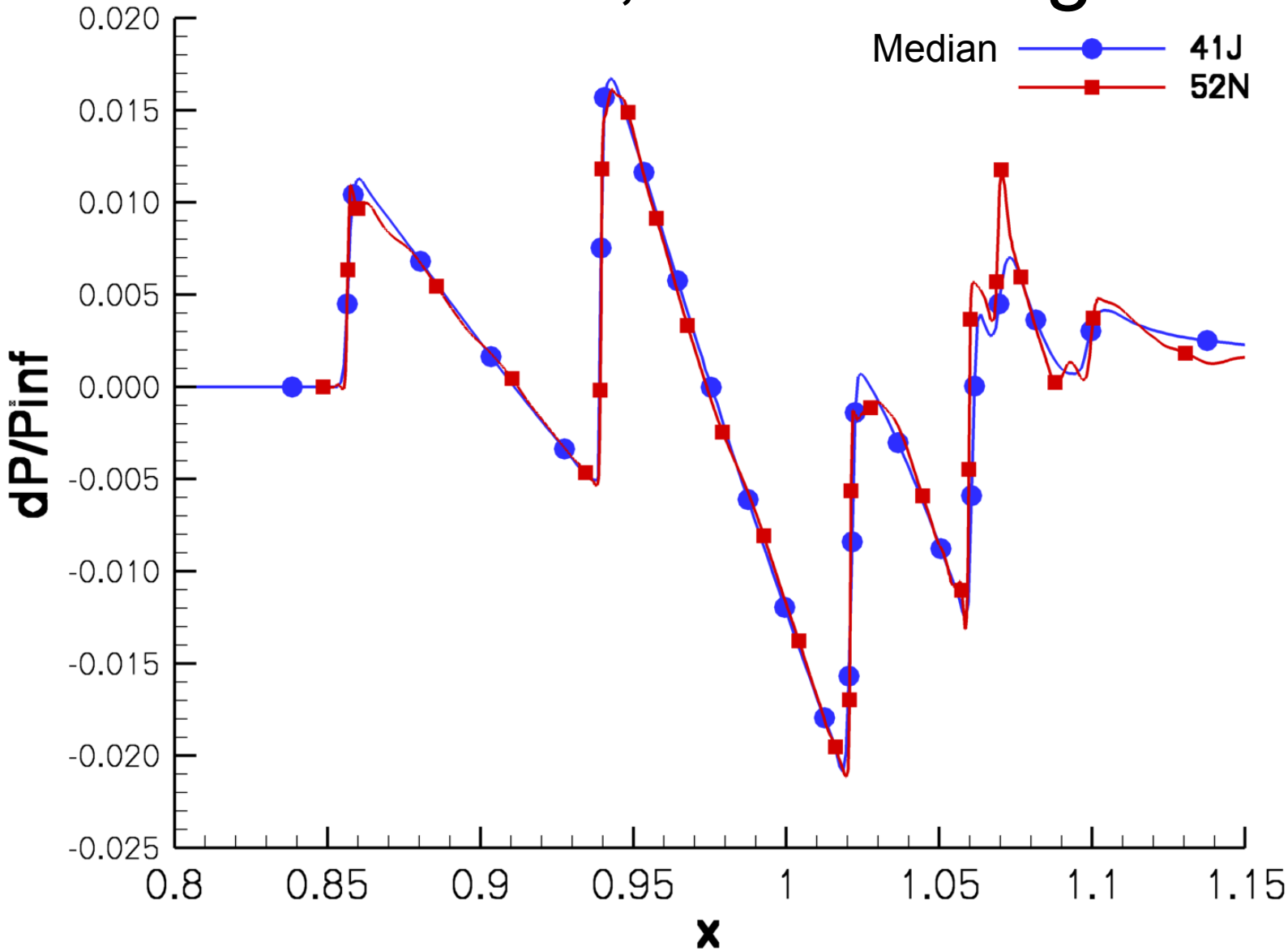
Delta Wing Body Signature
H=24.8in, PHI=90deg



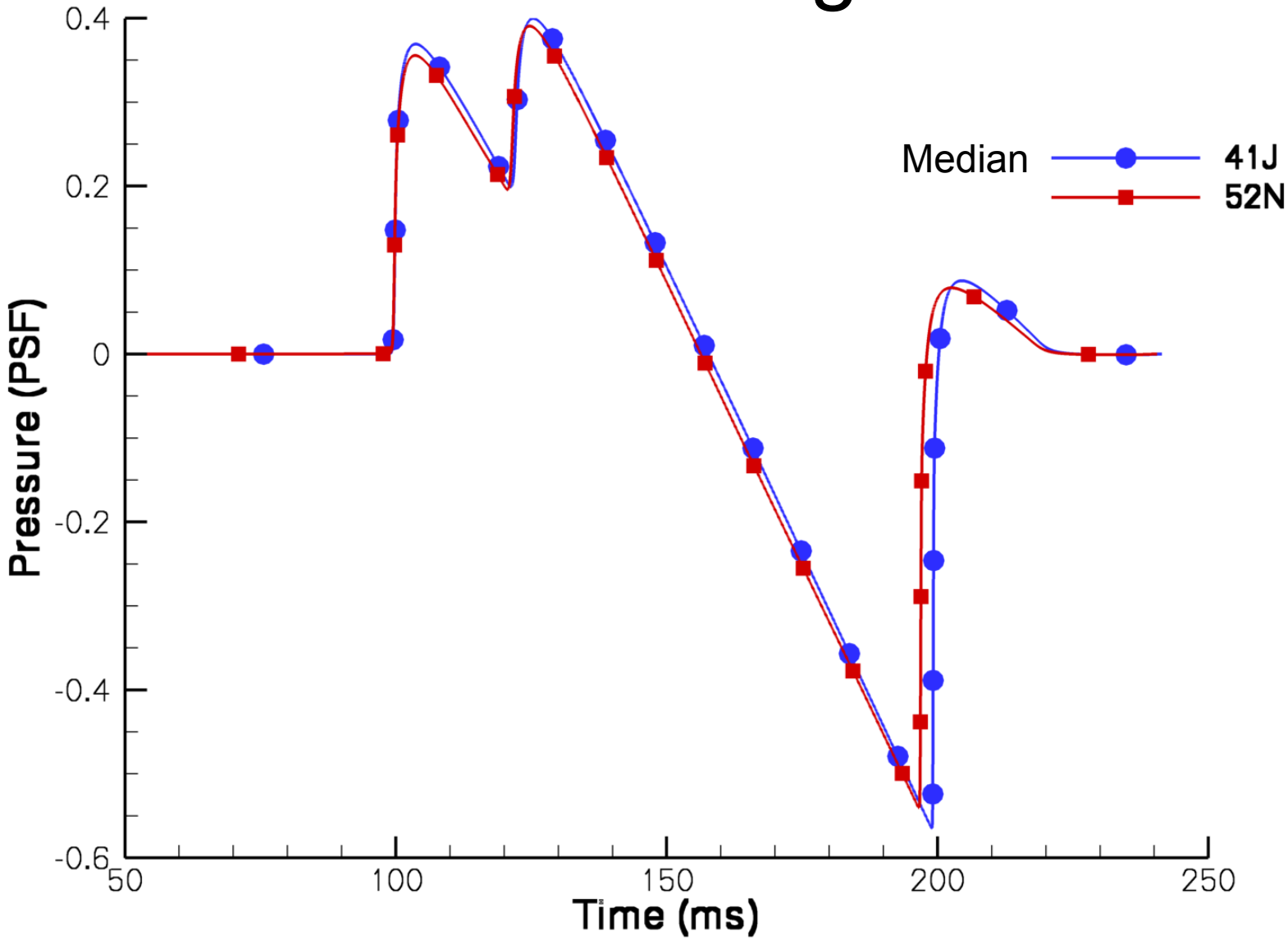
Delta Wing Body Signature
H=24.8in, PHI=90deg



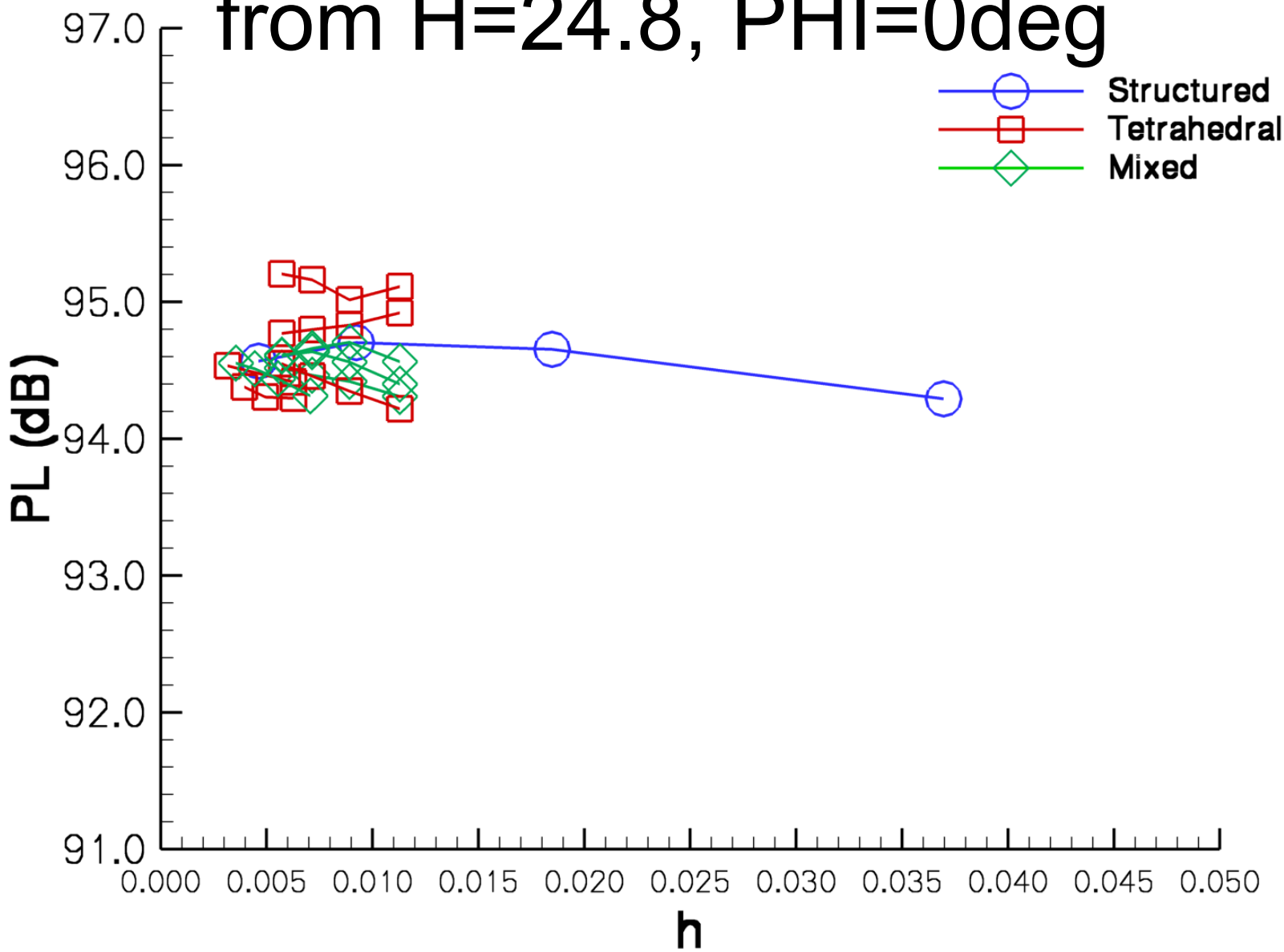
Delta Wing Body Signature
H=24.8in, PHI=90deg



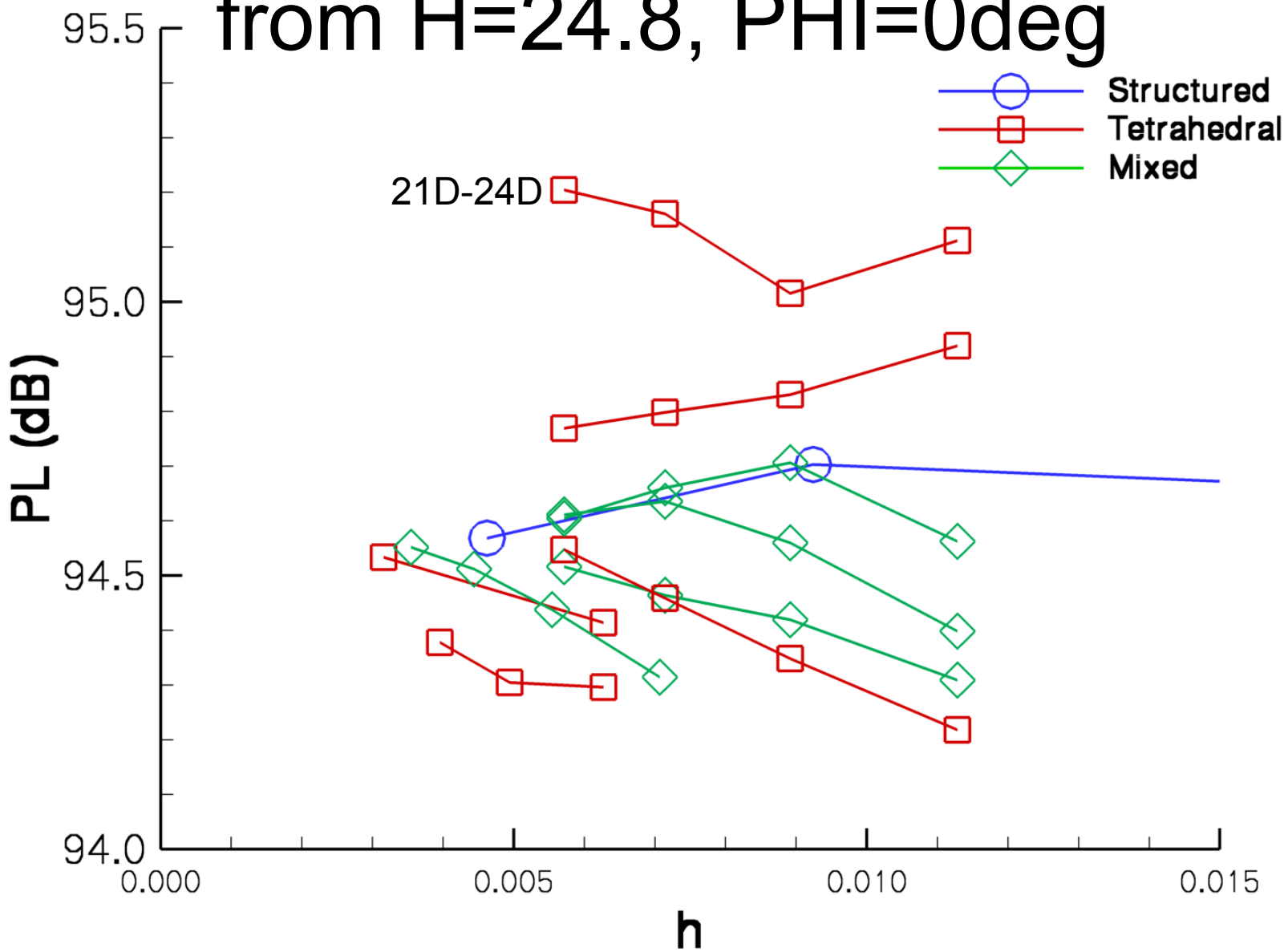
Delta Wing Body Ground H=24.8in, PHI=90deg



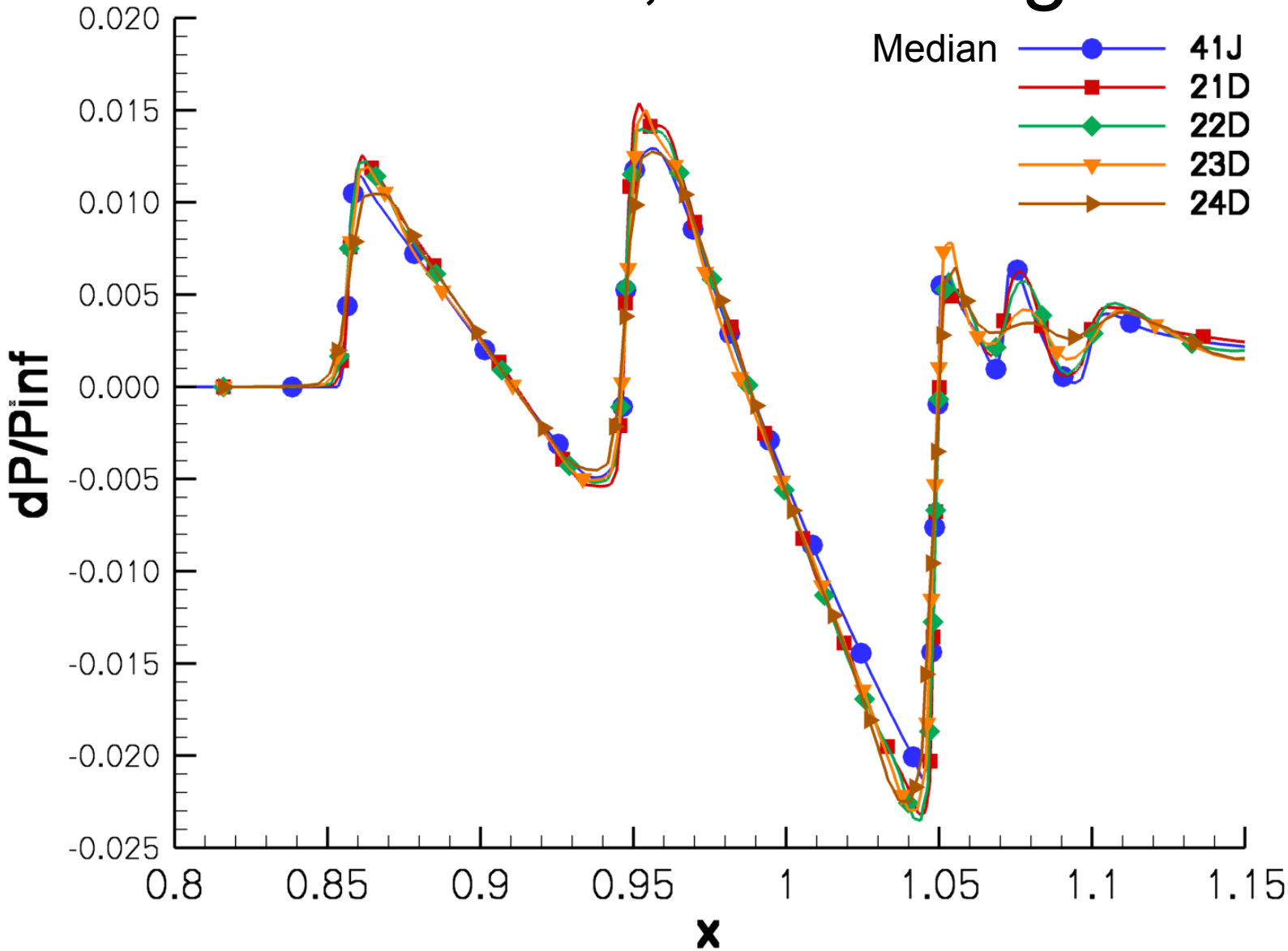
Delta Wing Body Perceived Level from H=24.8, PHI=0deg



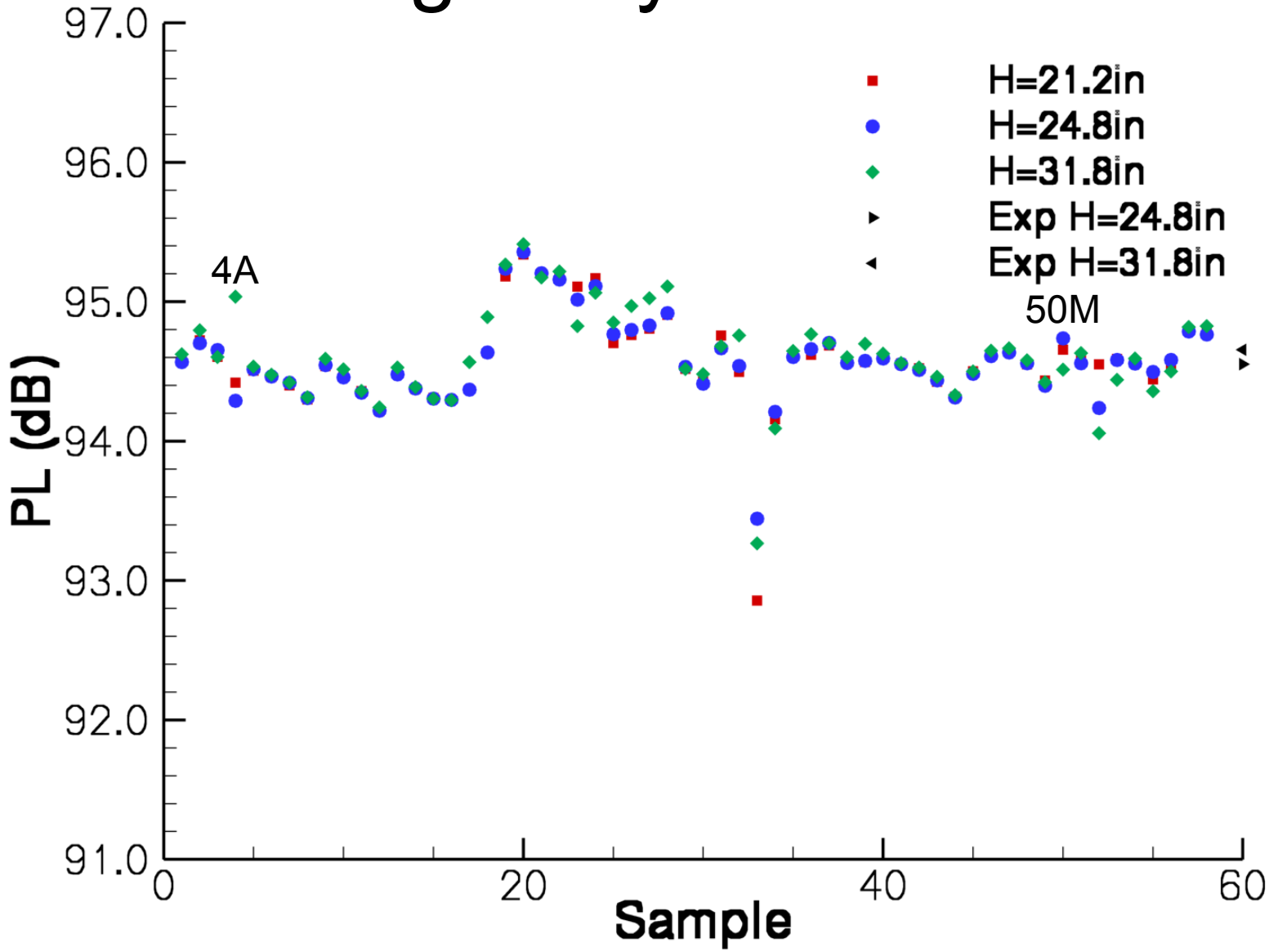
Delta Wing Body Perceived Level from H=24.8, PHI=0deg



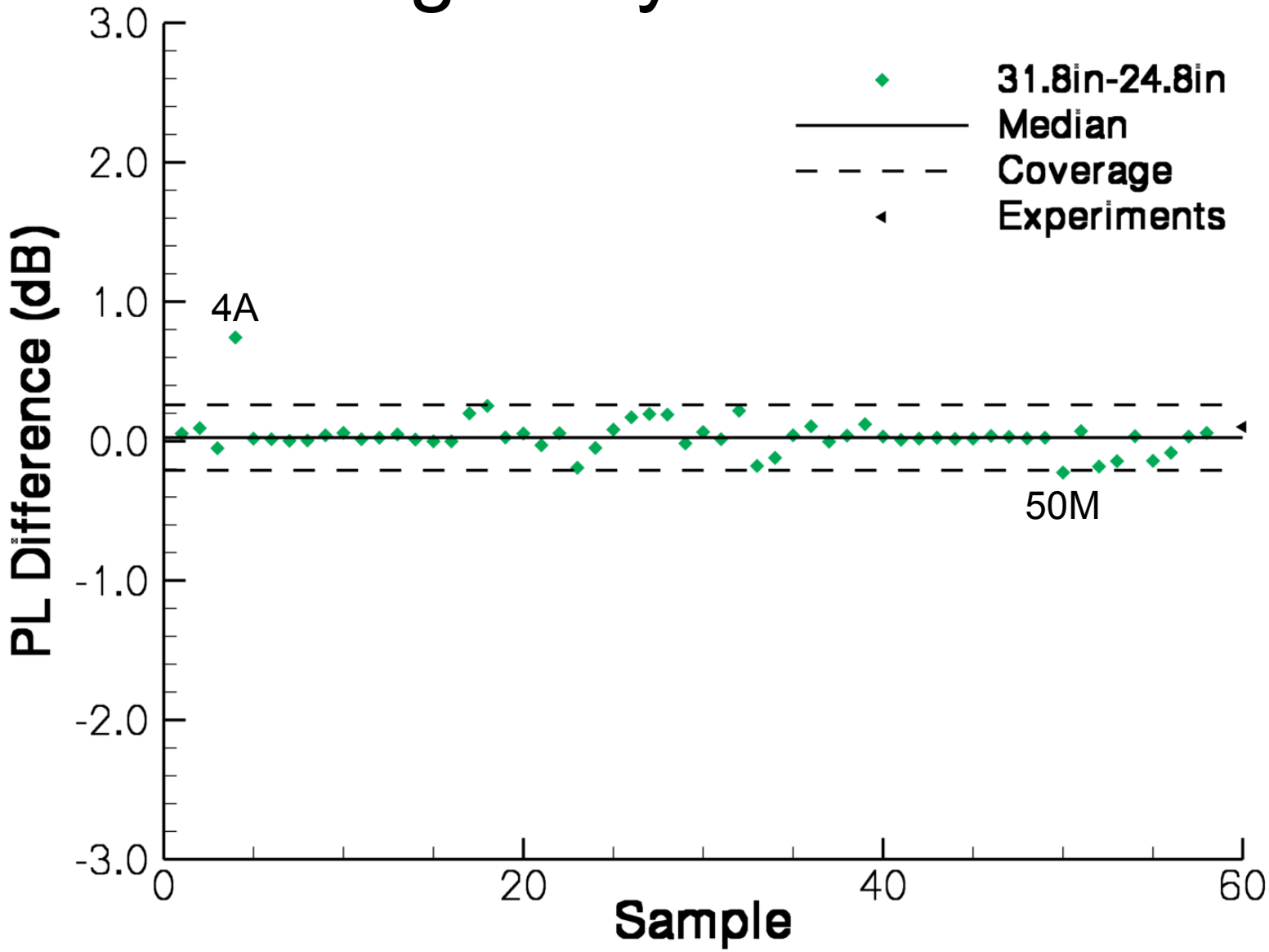
Delta Wing Body Signature
H=24.8in, PHI=0deg



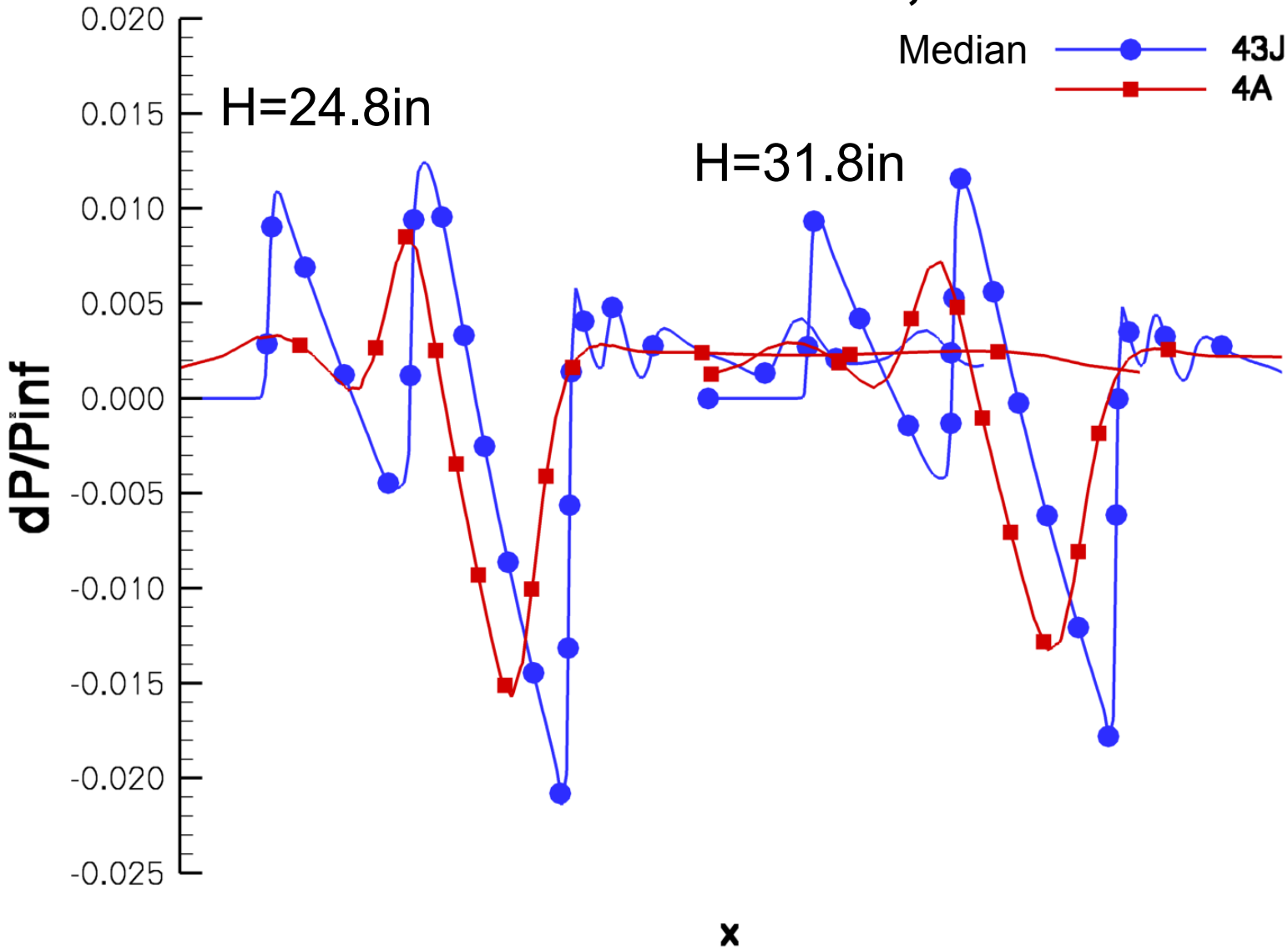
Delta Wing Body Perceived Level



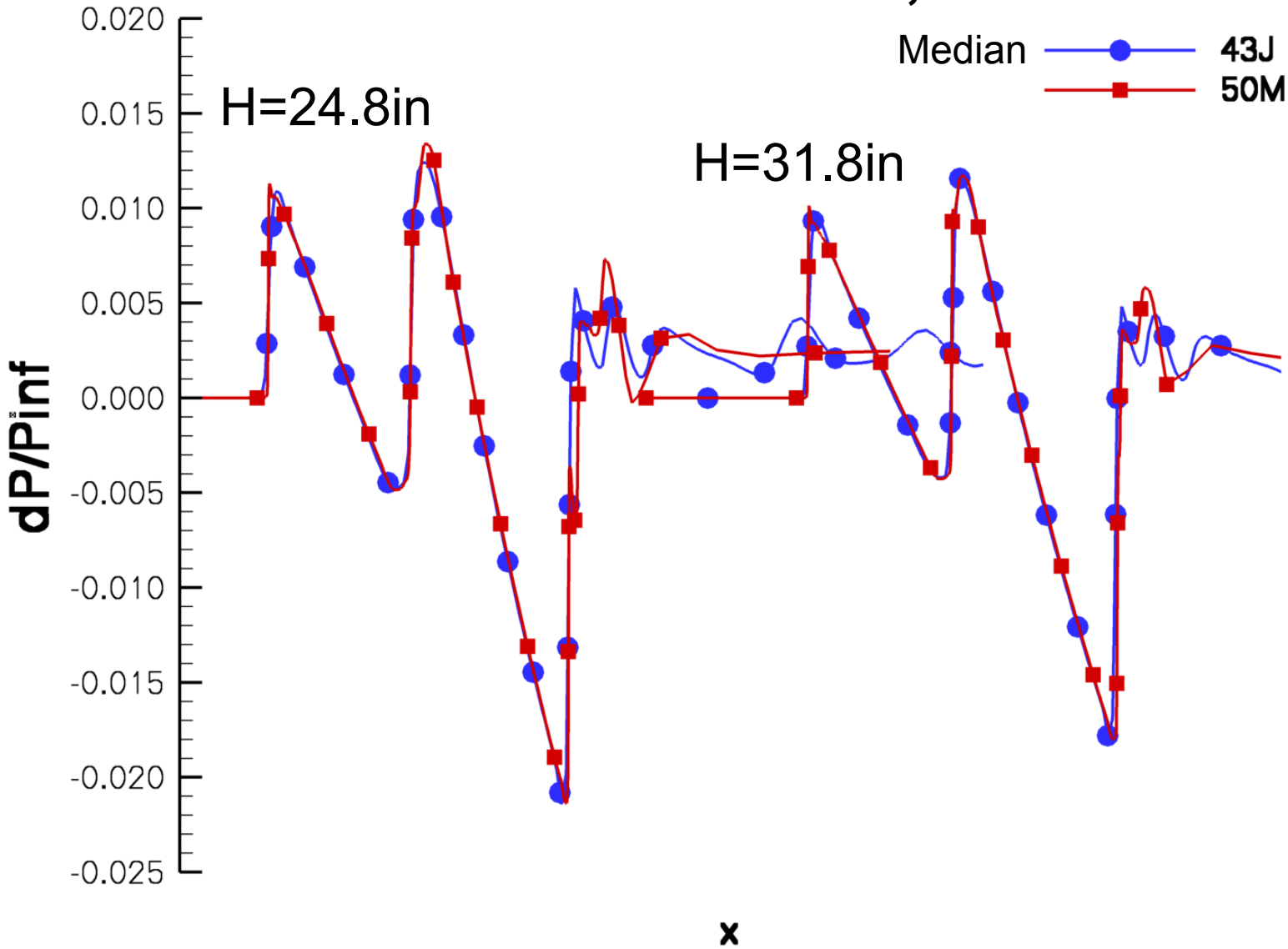
Delta Wing Body Perceived Level



Delta Wing Body Signature H=24.8in and H=31.8, PHI=0deg



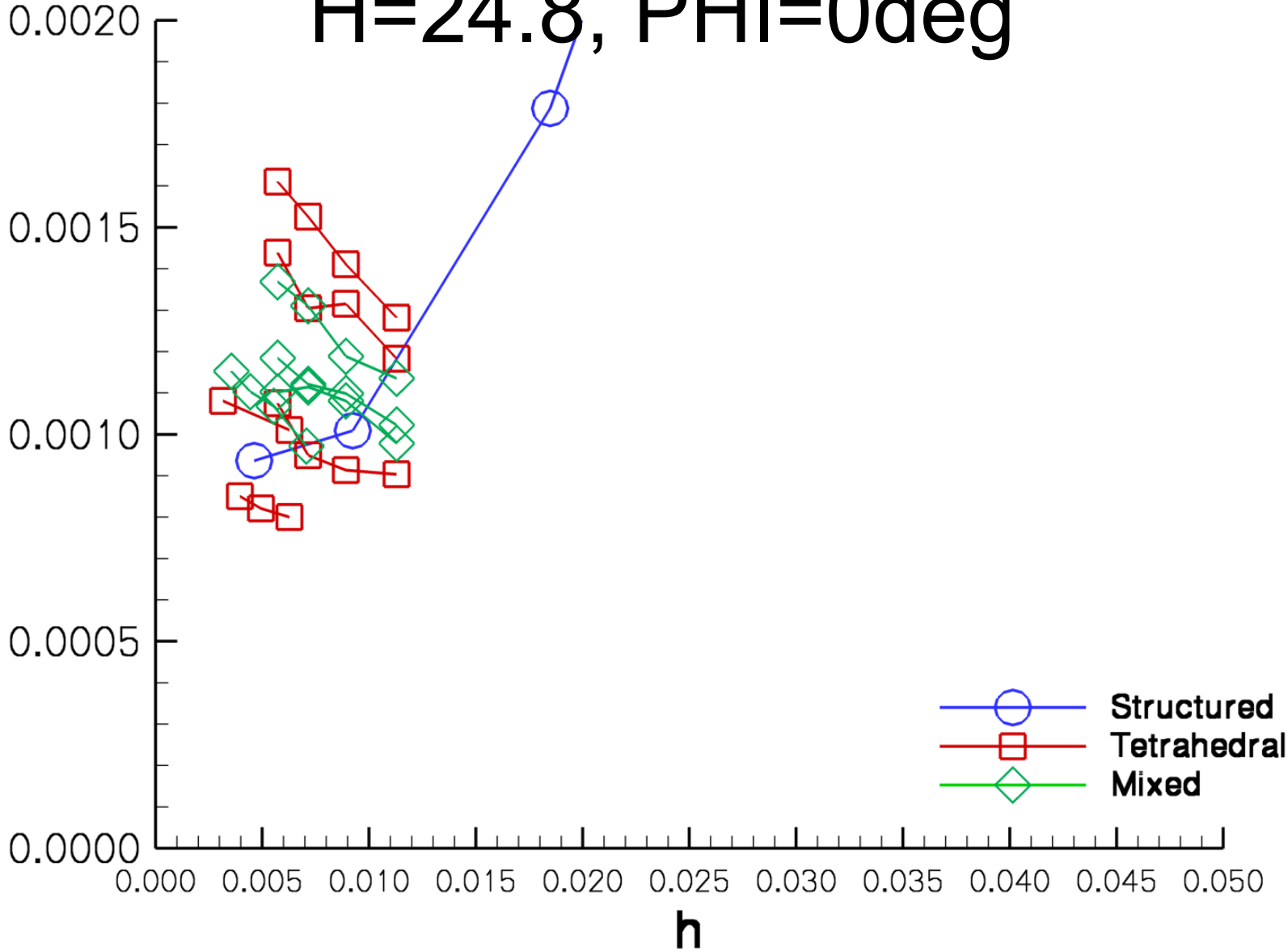
Delta Wing Body Signature H=24.8in and H=31.8, PHI=0deg



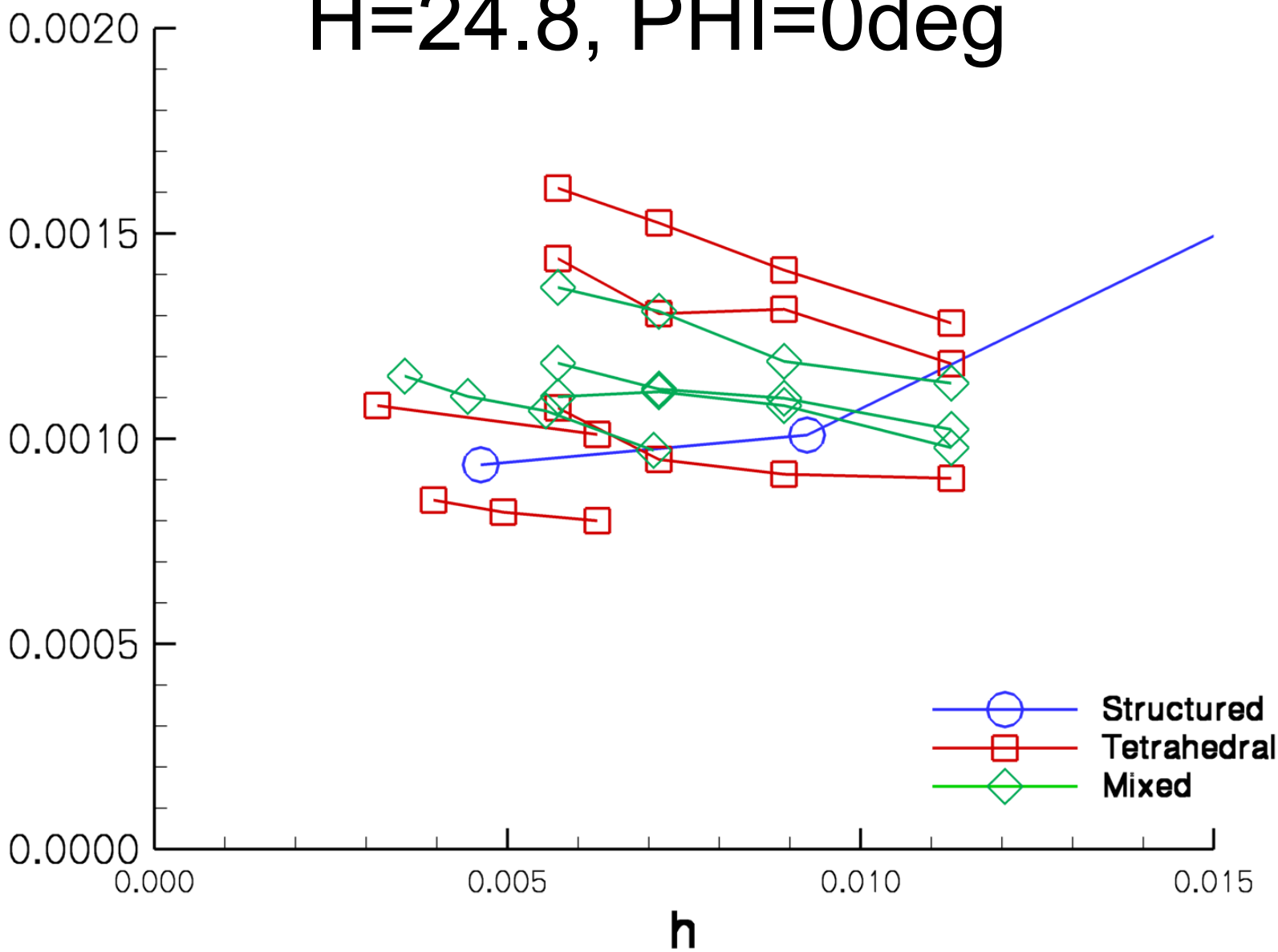
Delta Wing Body Validation Metric

- Examine the wind tunnel measurement with signatures identified as different
  - Convergence of the validation metric with grid refinement
  - Largest and smallest validation metric

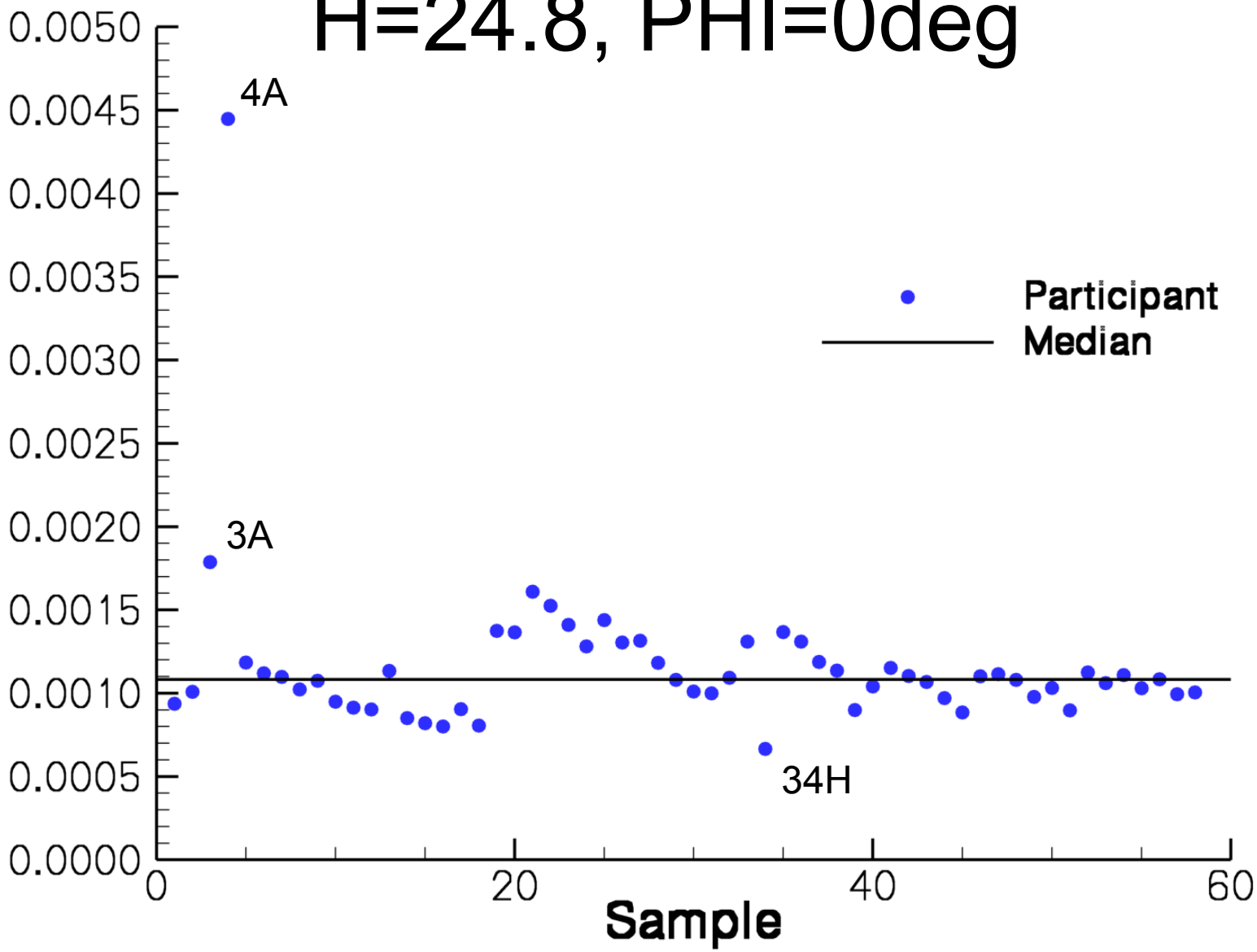
Delta Wing Body Validation Metric
H=24.8, PHI=0deg



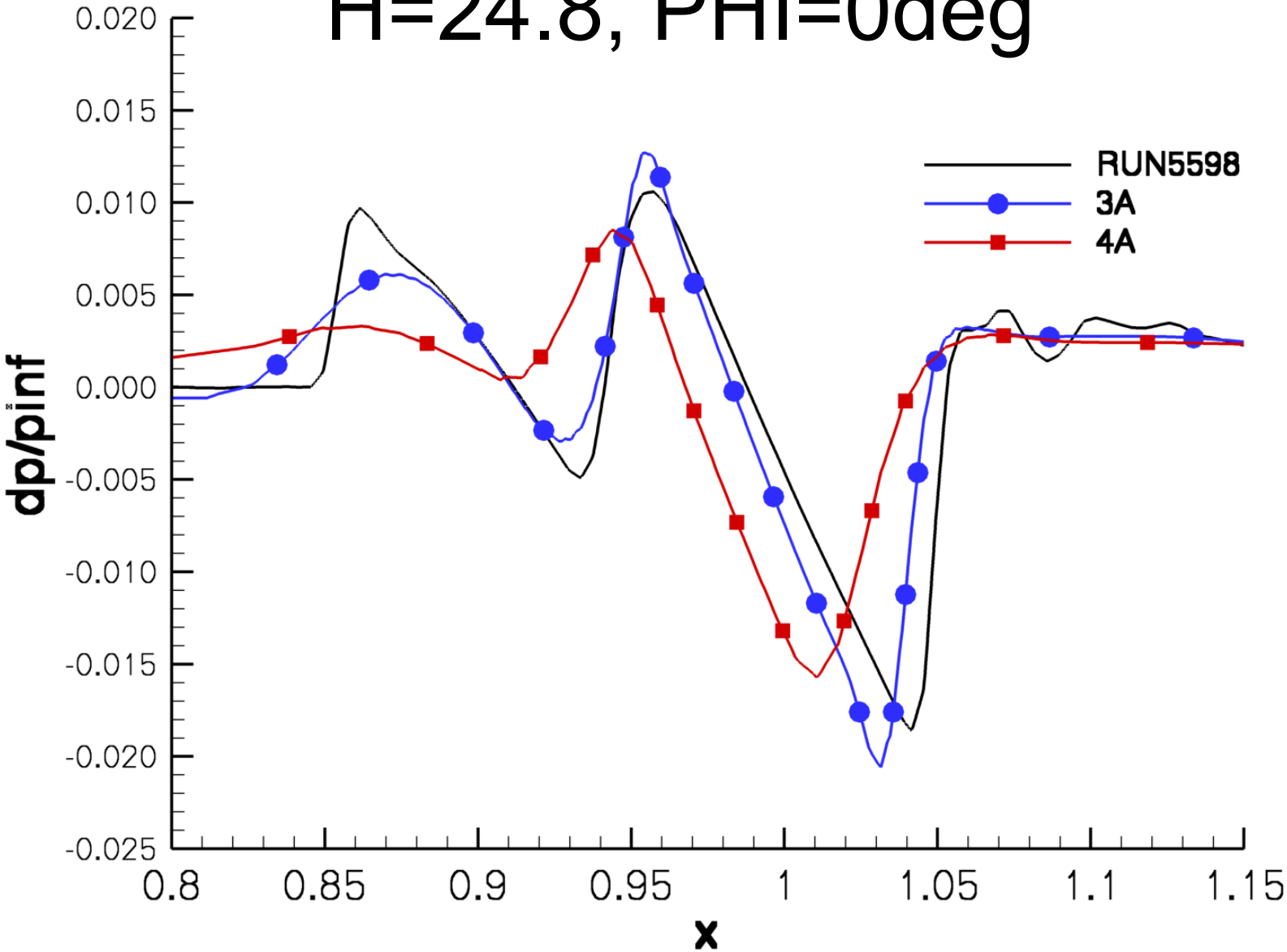
Delta Wing Body Validation Metric
H=24.8, PHI=0deg



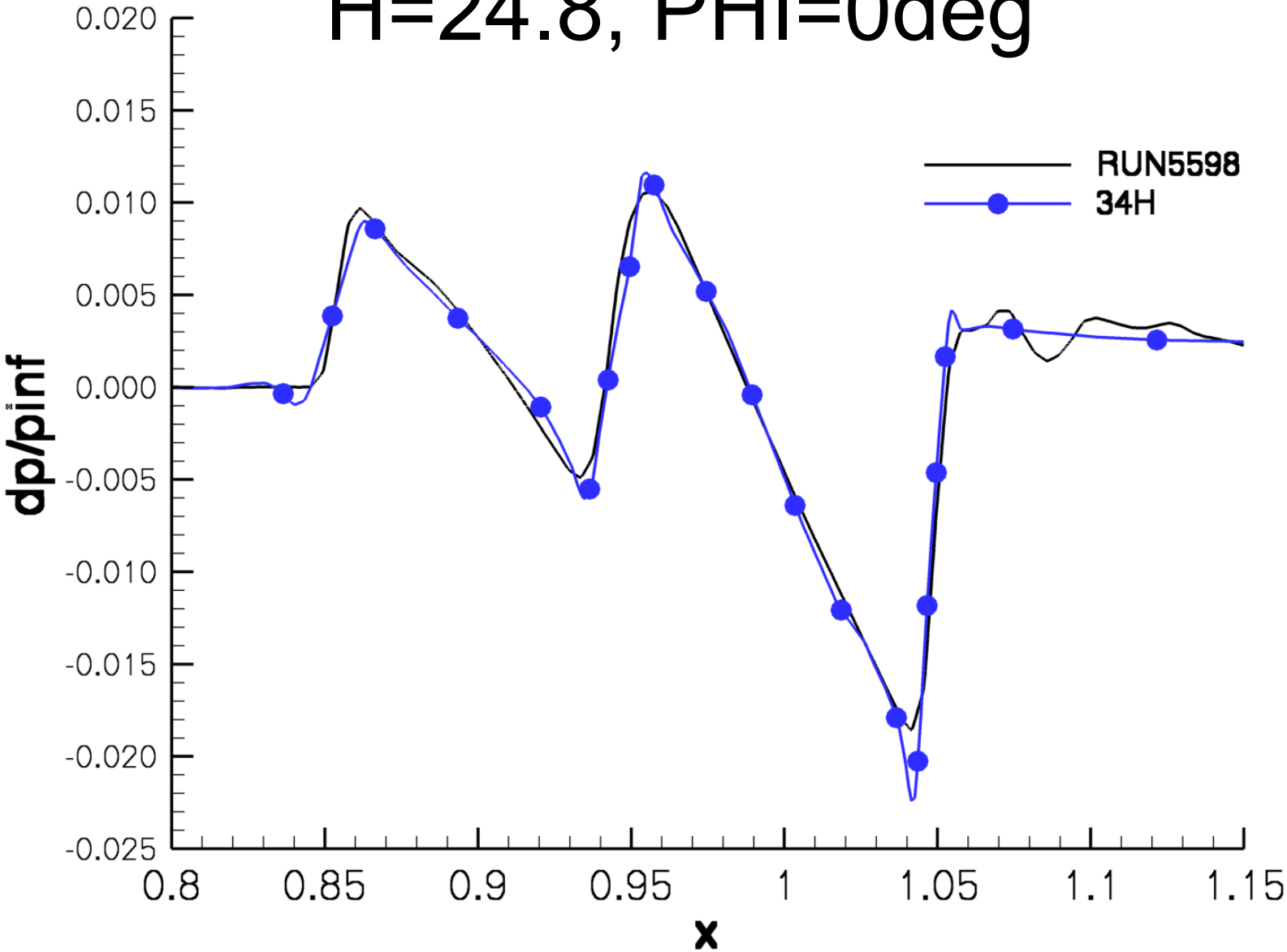
Delta Wing Body Validation Metric H=24.8, PHI=0deg



Delta Wing Body Validation Metric
H=24.8, PHI=0deg



Delta Wing Body Validation Metric
H=24.8, PHI=0deg



Delta Wing Body

- Statistics showed an increase in mean PL with off-track angle with a similar standard deviation
- Most outliers at 60deg off-track angle
- Many outliers were present at multiple off-track angles

Delta Wing Body

- Loudest signatures had a steeper nose and wing expansions than median signature
- Quieter signatures had an extra shock or weaker expansion that moved final shock forward on ground

Delta Wing Body

- The participants showed little agreement on the grid refined PL and the validation metric
  - Lacked a clear majority opinion, especially for the validation metric
  - Stronger shocks and separated “wake” region may illustrate differences in Euler methods

Summary

- SEEB-ALR had a median PL of 90.5 dB with 0.8 dB standard deviation
- Delta Wing Body had a median PL of 94.6 dB with 0.3 dB standard deviation for the centerline
- Study by Bretl and Walker propagated wind tunnel measure measurement uncertainty to 0.4-4.1dB uncertainty in PL

Summary

- Propagating ground signatures from different locations had 0.5 dB standard deviation for SEEB-ALR and 0.2 dB for Delta Wing Body standard deviation
  - Most methods are doing an excellent job of maintaining signatures in the near-field

Summary

- SEEB-ALR had a tight grouping of PL and validation metric near the median values
- Delta Wing Body lacked an obvious grouping with grid refinement
  - Exacerbated by strong shocks and separated “wake” region?

Summary

- Statistics of validation metric and PL were used to discriminate methods
- Computational uncertainty appears to be on the same level as wind tunnel measurements for the these simple geometries

Future/Discussions

- Submissions can be updated until 07-FEB-2014 (for release and summary paper)
- Workshop data made available by 14-FEB-2014 to enable independent analysis
  - Extracted signatures
  - Volume grids
  - Wind tunnel data
  - Propagated ground signatures
  - Noise measures
  - Validation metrics