Towards Multi-Factor Noise Assessment in Automotive CFD Using Design of Experiments

Noise Factor TFG

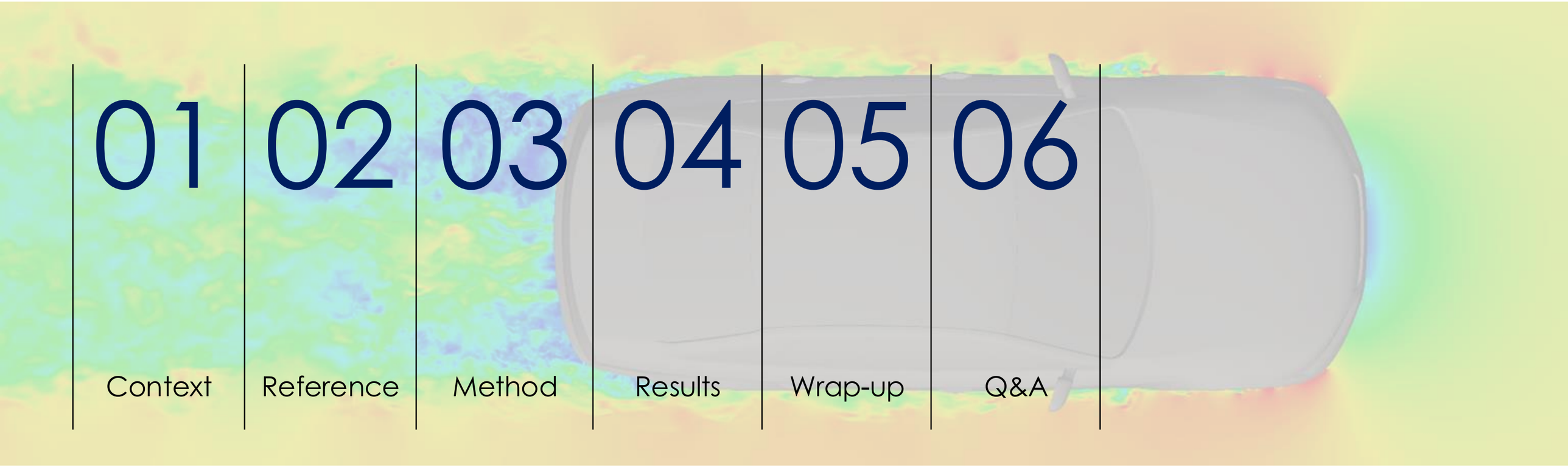
5th Automotive CFD Prediction Workshop · Bologna · Oct 8–9, 2026

ICON Technology & Process Consulting

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Agenda



01	02	03	04	05	06
Context	Reference	Method	Results	Wrap-up	Q&A

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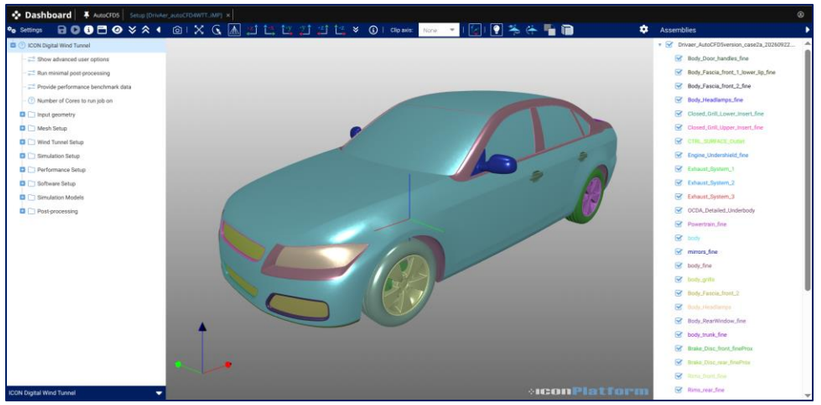
Context : iconCFD & iconPlatform

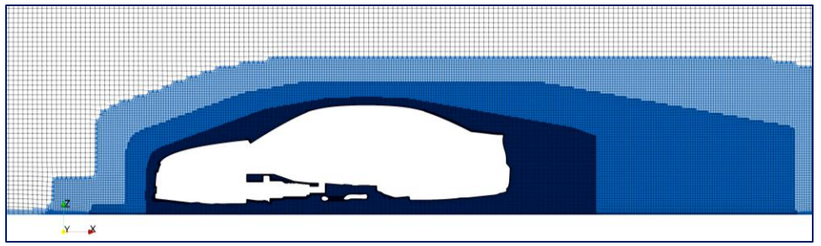
Workflow setup in minutes on iconPlatform using Digital Wind Tunnel App

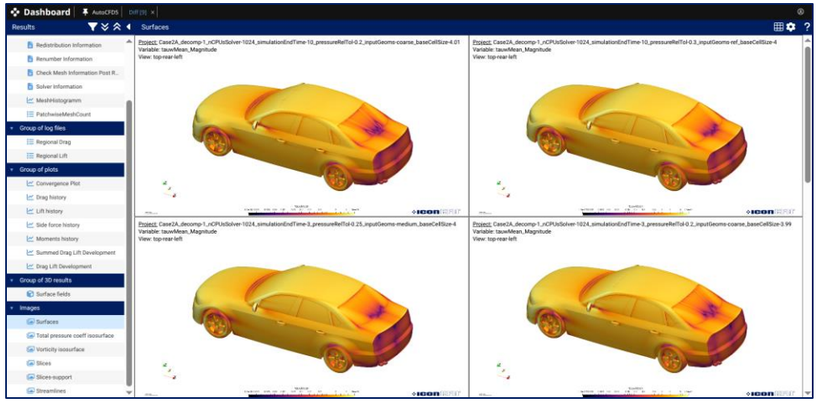
- iconCFD Mesh full layer meshing automated grid generation, high y+ (~100M cells) or low y+ (~120M cells)
- iconCFD SEAMLESS solver
- Automated post-processing
- Comparison of the CFD and experimental results on iconPlatform

In this study:

- Set-up, runs and post-processing of the simulations with **iconPlatform DoE**
- Analysis of the results leveraging **iconPlatform MCP**



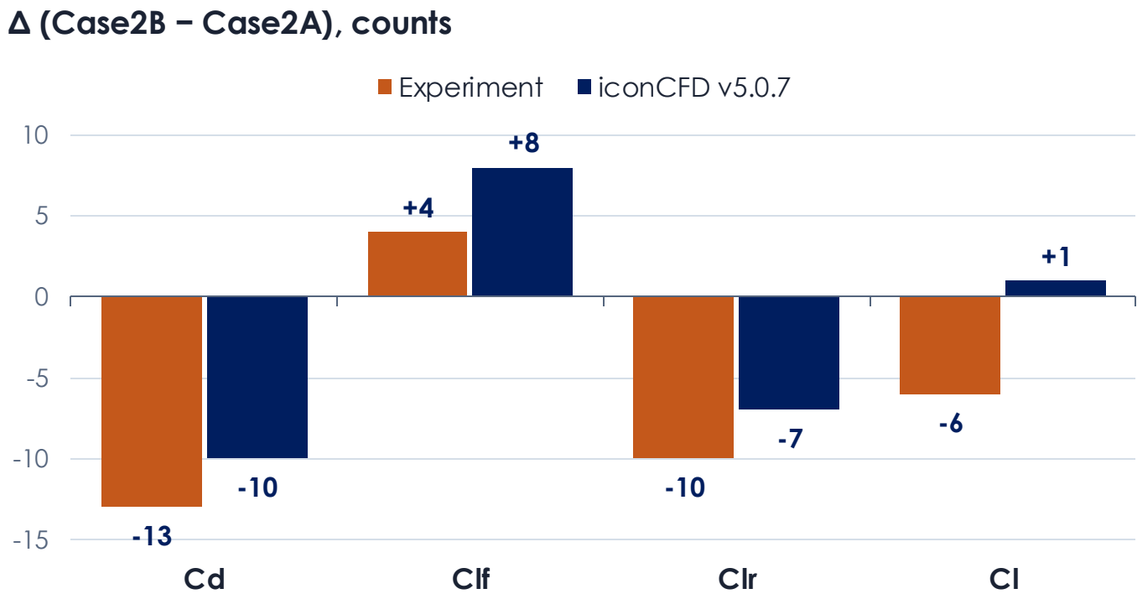




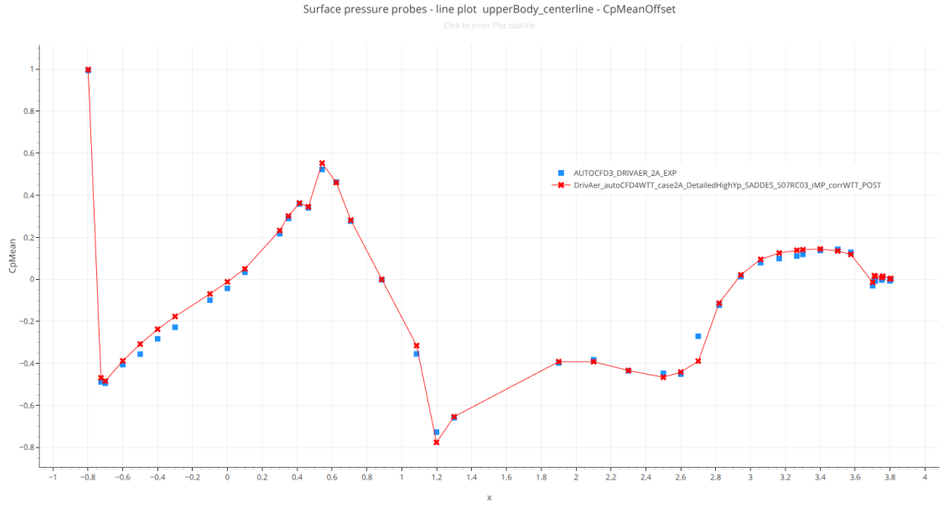
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Reference Results

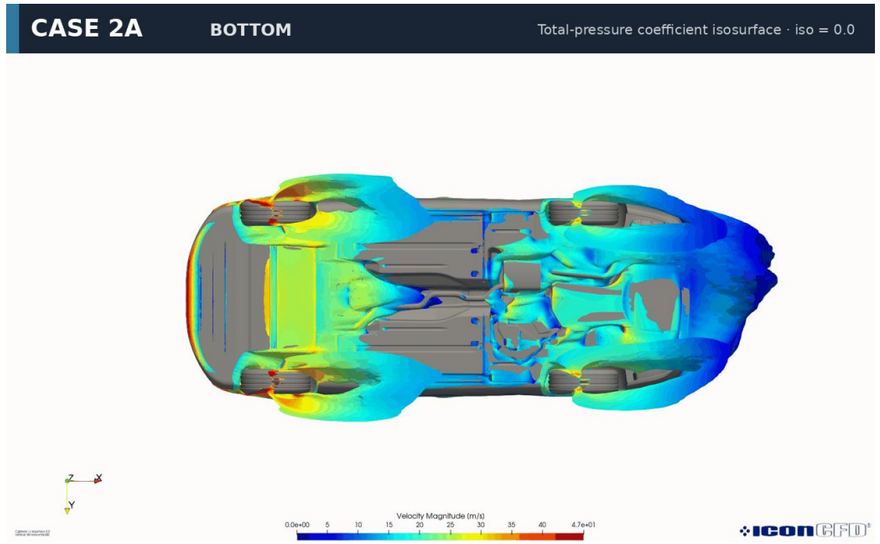
Some offset to experiment, but common to both cases: the deltas are reproduced



1 count = 0.001. Single iconCFD v5.0.7 SADDES reference run vs experiment.



Centerline Cp, Case2A: iconCFD (red) vs experiment (blue)



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Context: from single factors to combined noise

What the TFG established

Noise factors studied one at a time:

- Hardware architecture, CPU partitioning
- Physical averaging time, timestep size
- CAD part ordering, geometric details
- Surface and volume mesh generation

Result: individual impact on Cd, Cl and side force is quantified

Missing: their combined effect and eventual interactions

Objective, build a method and tools which can be reapplied:

- Prepare, run and post-process dozens of simulations with **iconPlatform DoE**
- Analyse the data leveraging **iconPlatform MCP**
- Later, use the results to improve iconCFD tool chain by reducing the noise factors sensitivity

What we ask here

Q1

How large is the overall variability envelope when factors are varied together?

Q2

Which factors dominate it?

Q3

Do factors interact: amplification or compensation, in absolute values and in deltas?

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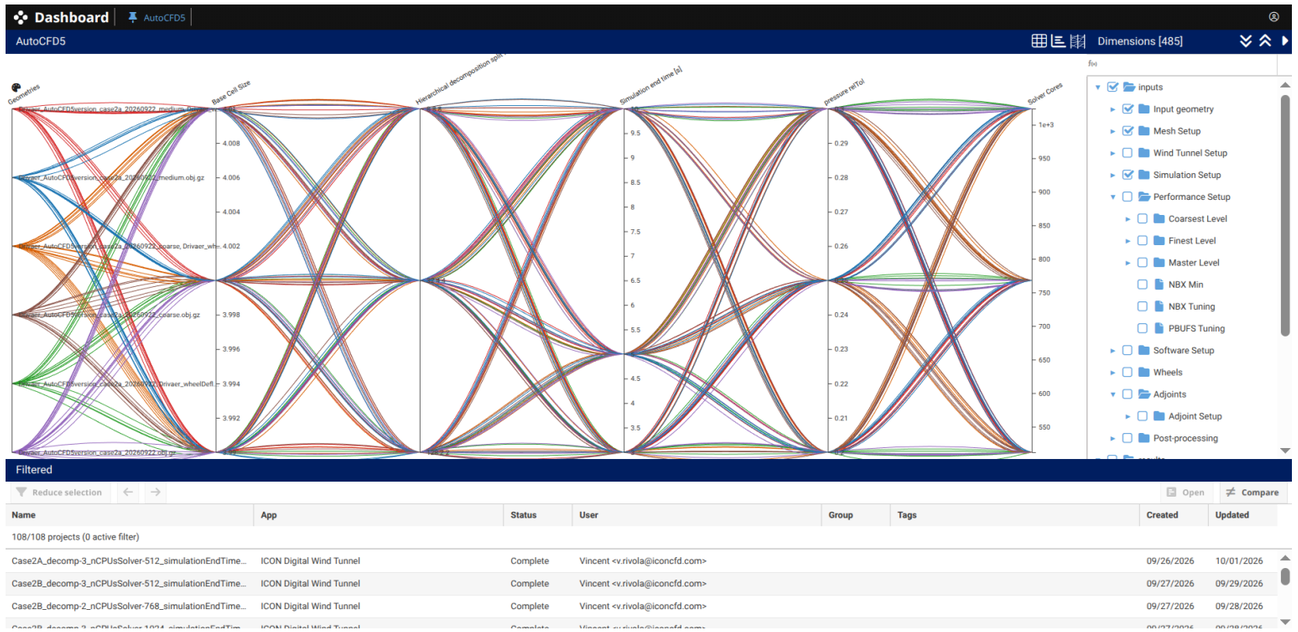
DOE set-up: six factors varied simultaneously

54 runs over 729 (full factorial) setup on iconPlatform, each computed on Case2A and Case2B (108 simulations), balanced and orthogonal

Factor	Levels
Mesher CPU partitioning	[128 2 2] · [32 4 4] · [8 8 8]
Solver CPU count	512 · 768 · 1024
Physical run time [s]	3 · 5 · 10 s
Pressure solver tolerance	0.20 · 0.25 · 0.30
Input geometry set	coarse · medium · ref
Background mesh size [m]	3.99 · 4.00 · 4.01

54
paired runs

18
Occurrences of each pair of parameters



Setting up the 108 cases takes a few minutes on **iconPlatform** and the distribution of cases can be easily analysed before running the simulations

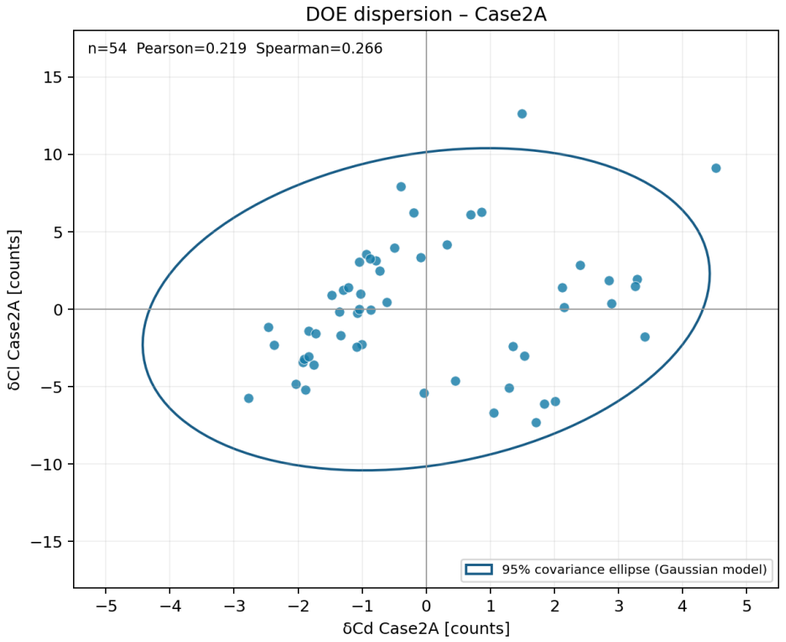
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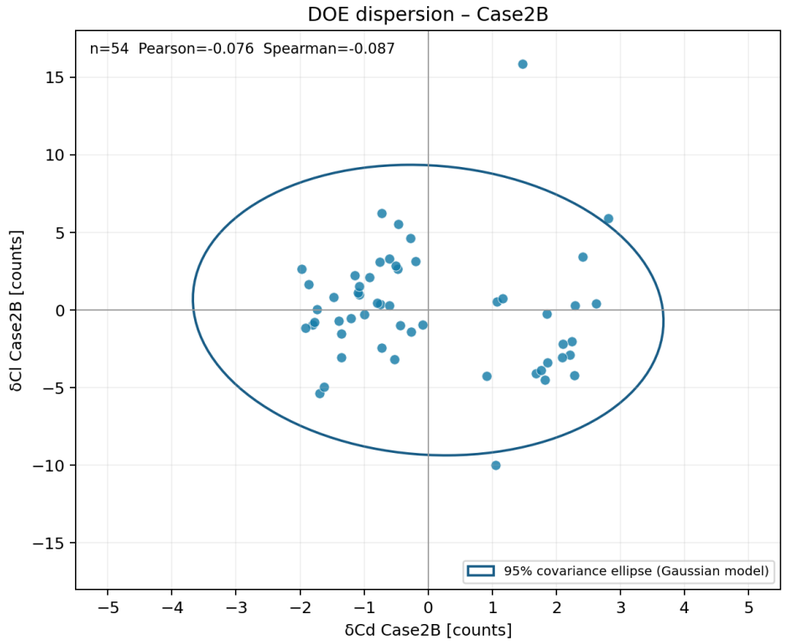
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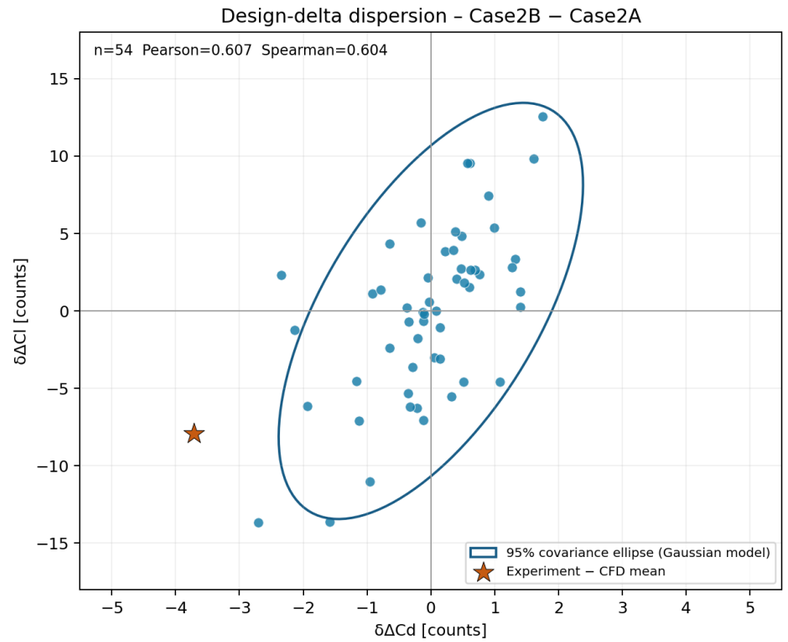
Q1 · Overall variability envelope

All the results presented are either analysed on **iconPlatform** or extracted and post-processed with i**conPlatform MCP**

Q1 **Combined noise: σ ≈ 1.5–1.8 counts on Cd and ≈ 3-4 counts on Cl**







1.81 / 4.25

σ Cd/Cl for Case2A

1.50 / 3.82

σ Cd/Cl for Case 2B

0.97 / 5.49

σ Cd/Cl for Δ(2B-2A)

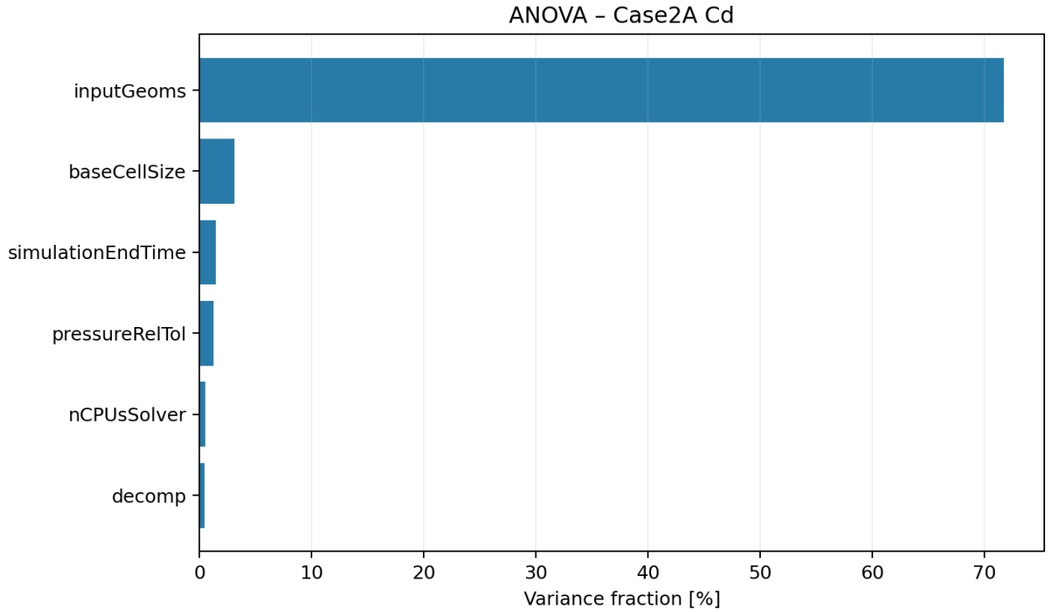
Cd/Cl are quite independent on absolute values but ΔCd / ΔCl move together (Pearson = 0.61)

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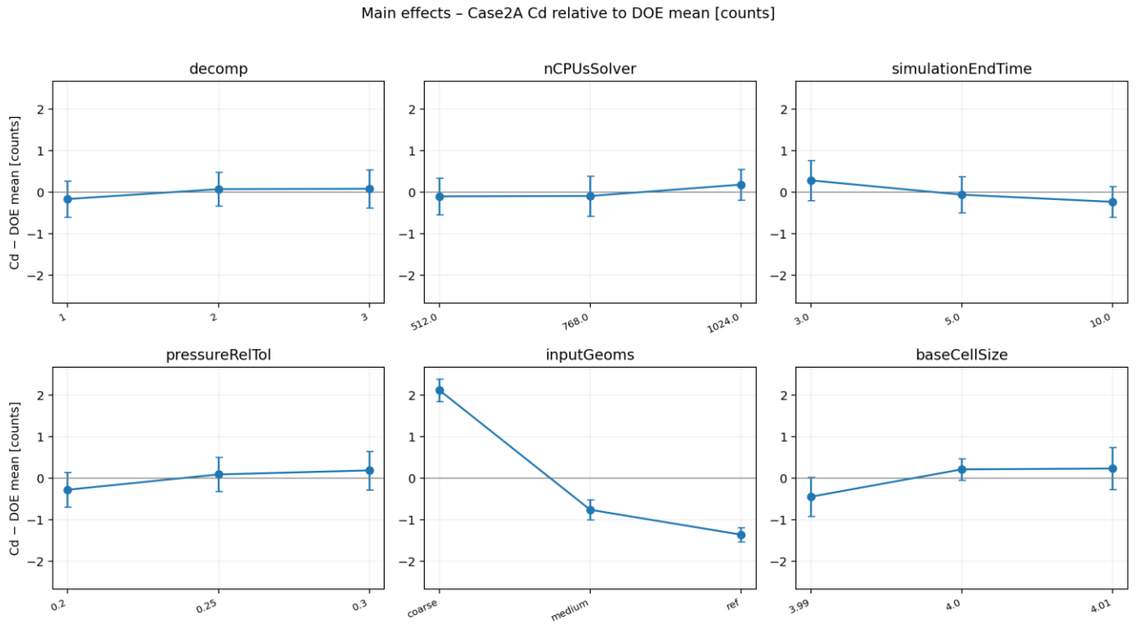
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Q2 · Dominant contributors (absolute Cd)

Q2 **inputGeoms explains 70–80 % of the absolute Cd variance; all other factors are below 4 %**



71.7 % / 83.3 % of Cd variance from inputGeoms (Case2A / Case2B)



≈ 3.5 counts

Cd swing between coarse and ref geometry (3.48 / 3.07)

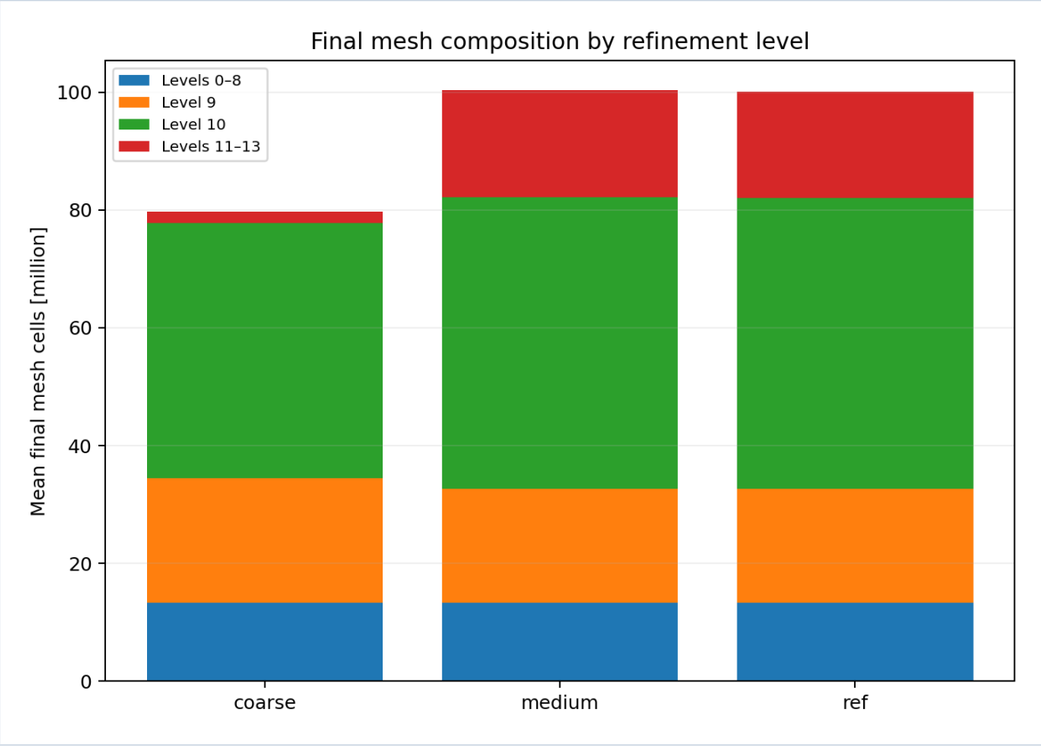
*ANOVA (ANalysis Of VAriance) splits the total variance of a result into the share explained by each factor and the share left unexplained.

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Q2 · What "inputGeoms" really changes

Q2 **inputGeoms is a package (geometry + refinements levels): ~80 % of the Cd shift happens at the coarse → medium step**



Mean final mesh cells by refinement level

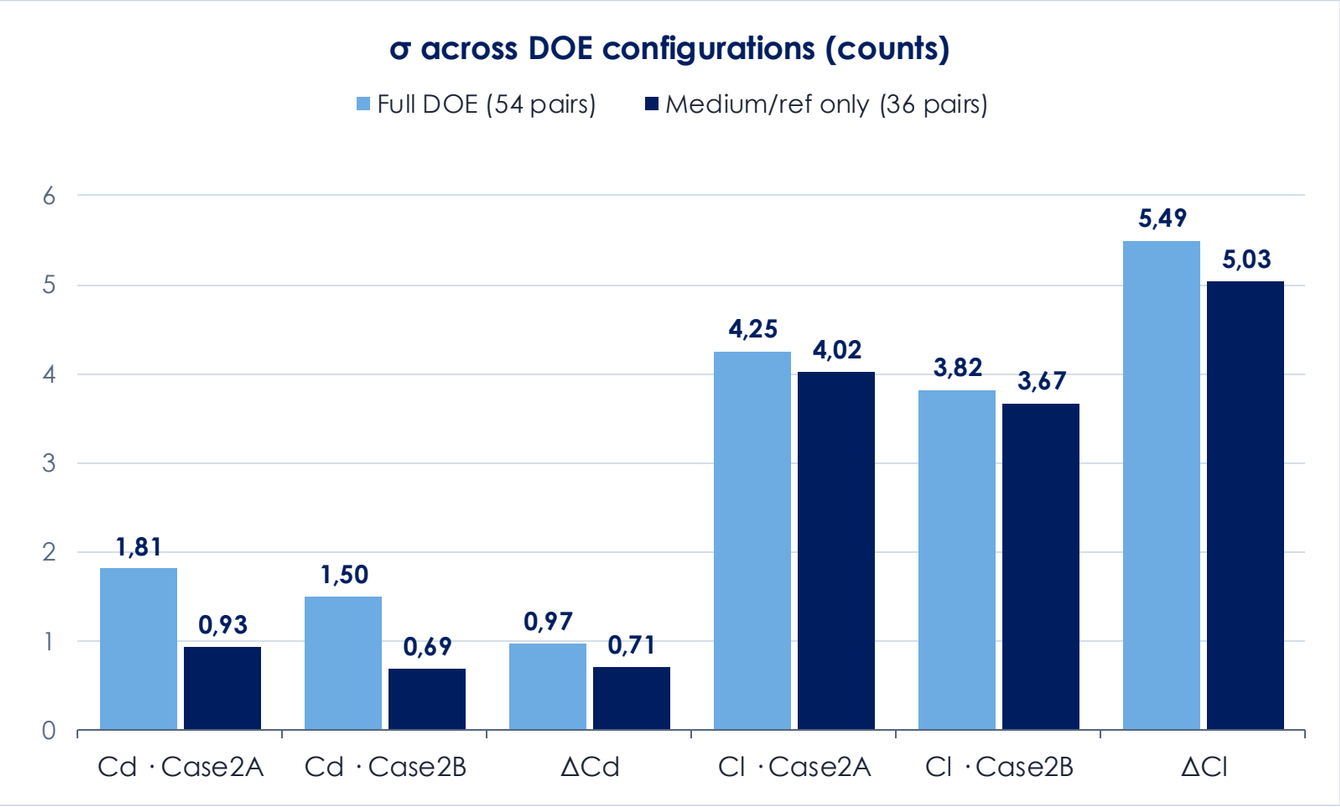
- **Final cells count:** ~80 M (coarse) vs ~100 M (medium and ref)
- **Coarse → medium:** −2.9 counts on avg Cd for Case2A, (95 % CI [−3.5; −2.2]). The coarse input surface triggers different mesh settings, so two different final meshes are compared
- **Medium → ref:** −0.6 [−1.2 / +0.04]. Nearly the same parts and cell count: as close as it can be to a pure tessellation effect

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Q1 · The envelope without the coarse input geom

Q1 **Removing the coarse recipe halves the absolute Cd spread and cuts σΔCd by 27 %**



σ across the DOE configurations (in counts): all 54 pairs vs the 36 medium/ref pairs

Cd: a clear gain

σ Case2A 1.81 → 0.93 (−49 %), Case2B 1.50 → 0.69 (−54 %)

σΔCd 0.97 → 0.71 count (−27 %, 95 % CI −9 to −44 %)

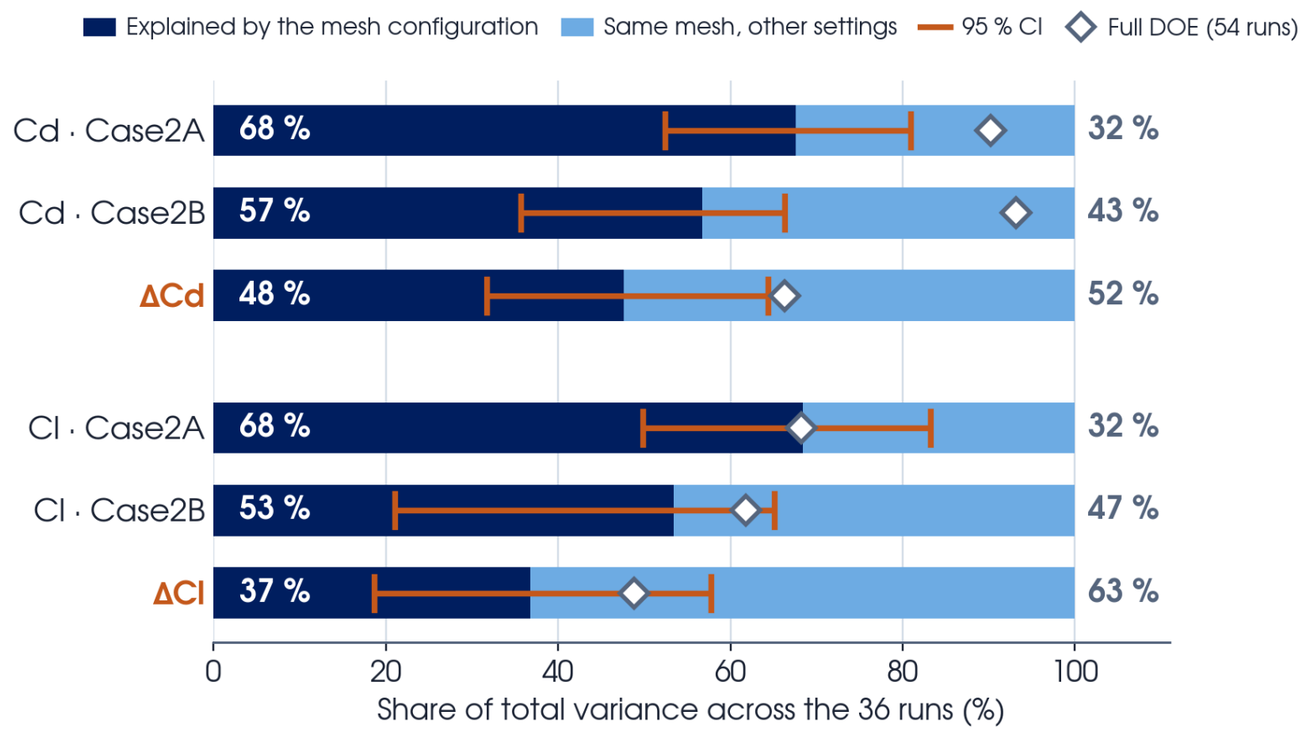
- **Cl: unchanged** within the CI (−4 to −8 %); Clf also improves (σΔ 2.74 → 1.72)
- **Read as a conditional spread:** not pure solver noise

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Q2 · How much does the mesh settings contribute ?

Q2 **The mesh configuration still leads absolute Cd (57–68 %, ≈ 90 % before), and explains about half of ΔCd**



Variance across the 36 runs of each case, between and within the 18 mesh configurations

Mesh configuration

inputGeoms × baseCellSize × decomp = 2 × 3 × 3 = 18 combinations

Each one was run twice: the 2 runs share the same mesh and differ only by solver settings (CPU count, run time, pressure tolerance)

- **Absolute Cd:** the mesh still decides most of it (68 % and 57 %), less than with coarse (90 % and 93 %)
- **On Δ:** 48 % mesh (66 % before); the other half comes from solver settings, run length and time sampling

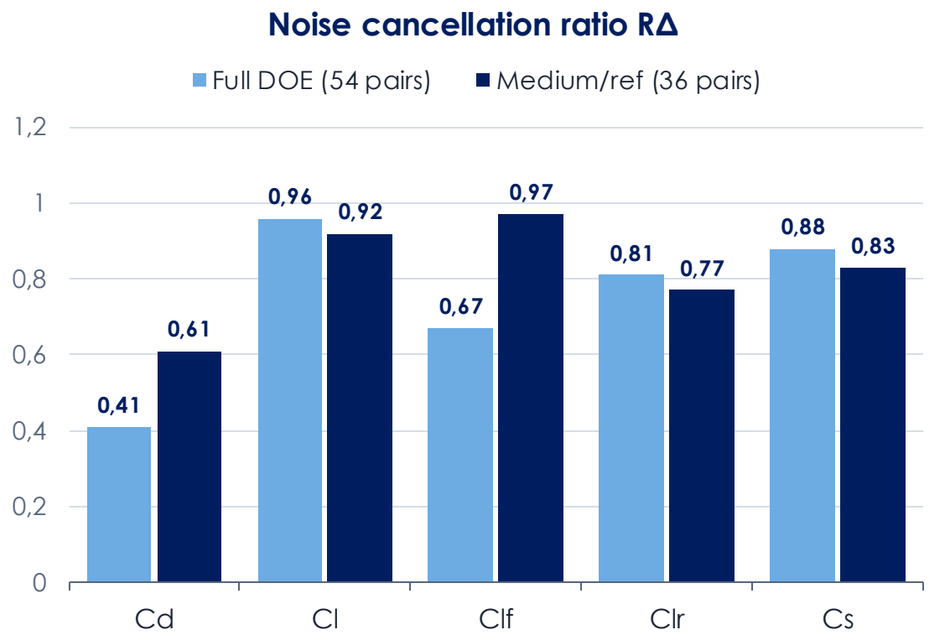
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Q3 · Noise cancellation in the delta

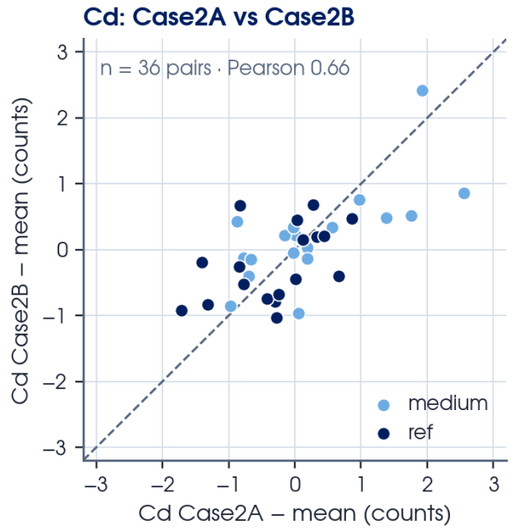
Q3

Cd noise still partly cancels in Δ, less than before; Cl noise does not



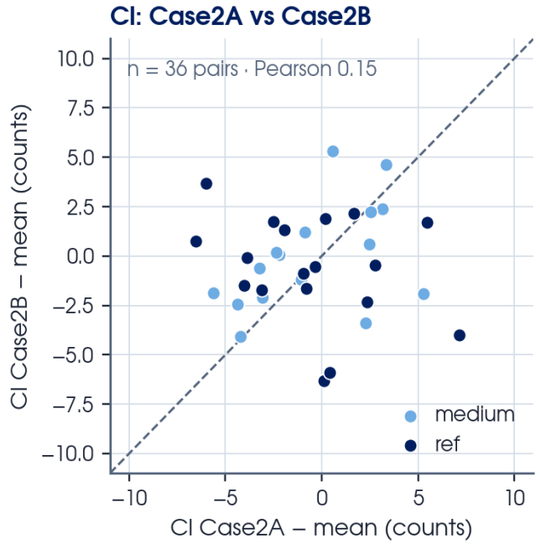
RΔ = σ(Δ) / √(σA² + σB²). Below 1: common noise cancels. At 1: none.

Medium/ref: RΔCd 0.61 [0.46–0.79], RΔCl 0.92 [0.74–1.10]; Pearson r Cd 0.66 [0.41–0.80], Cl 0.15 [−0.23–0.48] (95 % bootstrap CI, 36 pairs)



Pearson r = 0.66

Cd, Case2A and Case2B move together



Pearson r = 0.15

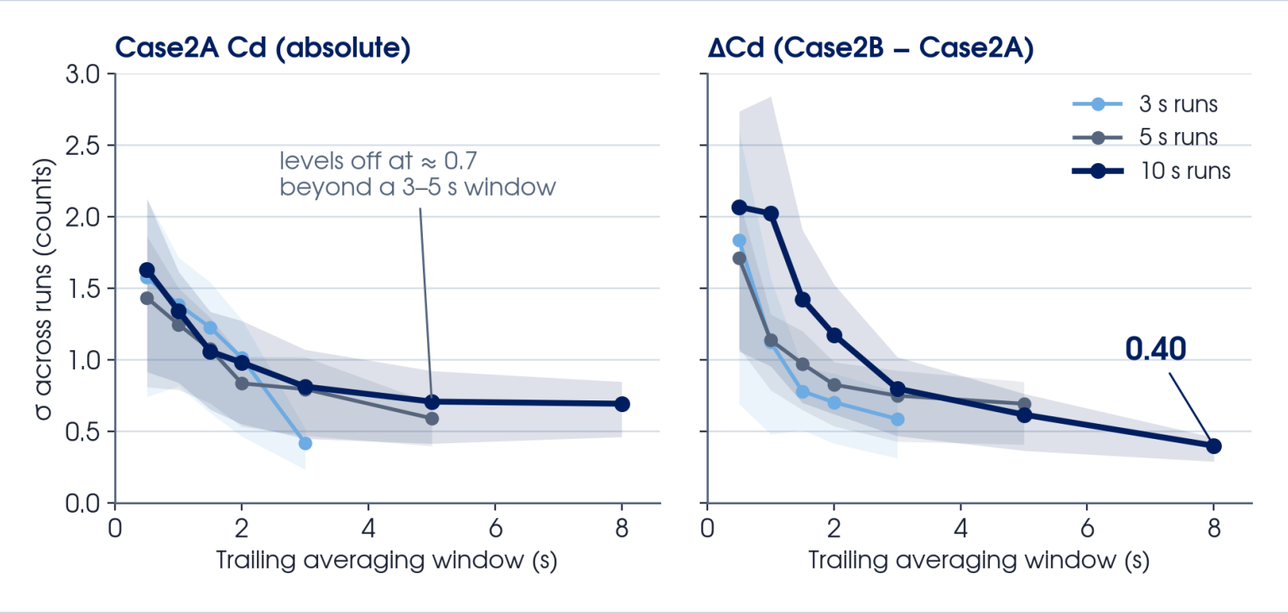
Cl, Case2A and Case2B are essentially independent

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Averaging longer pays off on the delta

On the delta, averaging still pays off: σΔCd = 0.40 count on 10 s runs, while absolute Cd levels off at ≈ 0.7



Run	Max averaging window	σΔCd max window	σΔCd 1 s	σΔCl max window	σΔCl 1 s
3 s	1.5 s	0.78	1.12	7.42	8.08
5 s	3.0 s	0.75	1.14	4.52	7.29
10 s	8.0 s	0.40	2.02	1.21	5.55

Absolute Cd (left): σ levels off at ≈ 0.7 beyond a 3–5 s window; without the coarse input geom the floor is lower (≈ 1.7 before)

Delta (right): σΔCd keeps falling with window and run length: 2.02 → 0.40 count on 10 s runs

Time sampling is not negligible: median standard error per pair is 0.62 count (Cd) and 2.41 counts (Cl), against DOE σΔ of 0.71 and 5.03

σ in counts across the 12 runs of each length (bands: 95% bootstrap CI); 1 s = fixed final 1 s window; max window = 1.5 / 3 / 8 s for 3 / 5 / 10 s runs. Medium/ref only

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Answers to the three questions

Q1 **Envelope**

σΔCd ≈ 0.7 count

Absolute Cd: 0.7–0.9 counts

Q2 **Dominant factors**

Mesh settings

baseCellSize leads absolute Cd; the mesh configuration explains 57 to 68 % of it

inputGeoms no longer drives the delta

Q3 **Interactions**

Cd cancels, Cl does not

RΔ 0.61 for Cd, 0.92 for Cl

Interactions not resolved with 36 pairs

Removing the coarse recipe halves the absolute Cd spread and cuts σΔCd by 27 %; quote the noise on the delta and size pairs to the Δ you need to resolve.

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A method you can reuse

1 Design

Vary all noise factors together in a DoE

In this study
6 factors, 36 of 486 set-ups for each case2A/2B

2 Pair

Run every set-up on both configurations, A and B

In this study
Case2A / Case2B: 72 simulations

3 Compare

Work on σ across runs and on Δ = B − A; RΔ shows how much noise cancels

In this study
RΔ 0.61 on Cd, 0.92 on Cl

4 Attribute

ANOVA and mesh variance budget: which factor is predominant and by how much

In this study
baseCellSize 24–41 %; gobal mesh configuration 57–68 %

5 Size

Choose run length, averaging window and how much it influences the deltas

In this study
Absolute σ plateaus while σ of delta still reduces after 5s

Each step runs on iconPlatform DoE and MCP: replace Case2A / Case2B with your own baseline and modification, and read the result on Δ.

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What's next ?

Conclusions

- Method: a paired DoE on iconPlatform, read on Δ, transfers to any A/B pair
- Without the coarse input geom σΔCd ≈ 0.7 count (−27 %), against a 3.8-count gap between CFD and experiment
- Mesh settings now dominate absolute Cd (baseCellSize first); inputGeoms no longer drives Δ
- Cd noise still partly cancels in Δ, Cl noise does not
- Averaging longer pays off on Δ

Proposed next steps

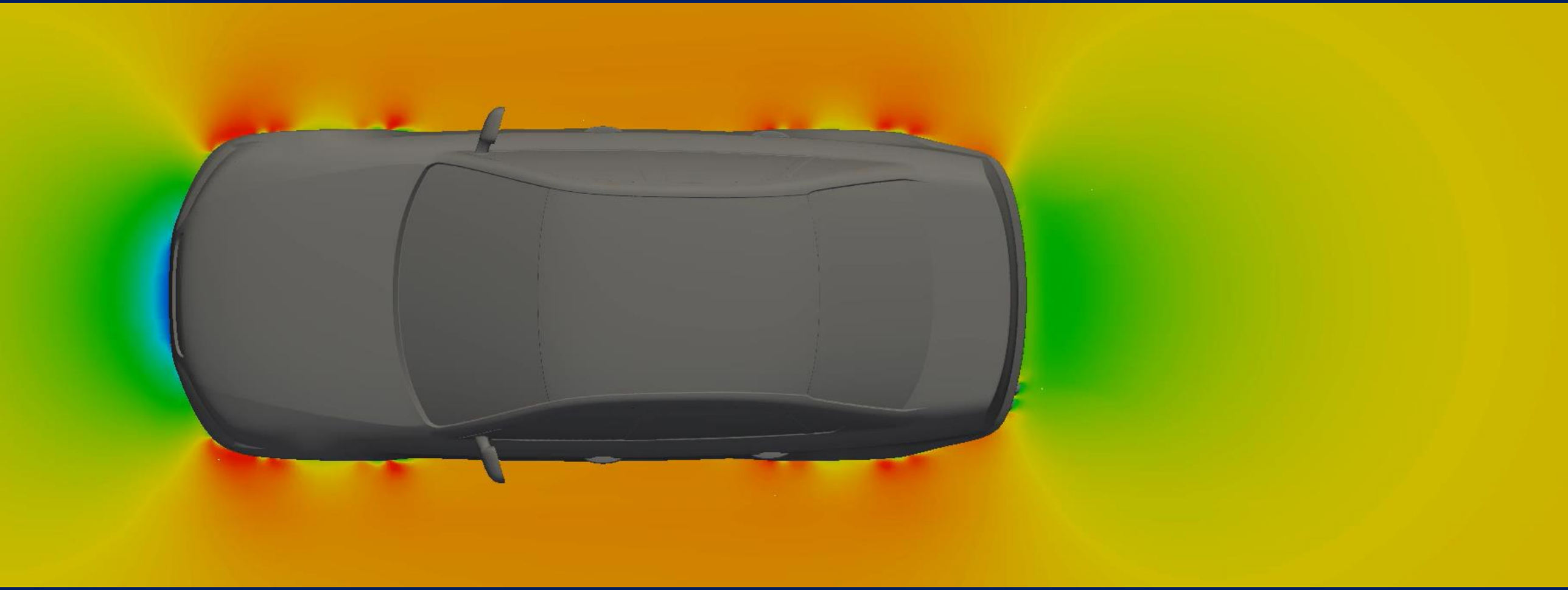
1. Repeat medium/ref set-ups at identical settings to isolate run-to-run noise
2. Split input geometry and mesh-setting parameters; add pairs for interactions
3. Run the same DoE on **ICON's new GPU solver** and compare with the same solver on CPU
4. Repeat the same DoE on less stable geometries (SUV, estate)

Scope: DrivAer, medium/ref set-ups only: the spread is conditional, not pure solver noise, and not necessarily representative of less stable geometries (SUV, estate); the method carries over.

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