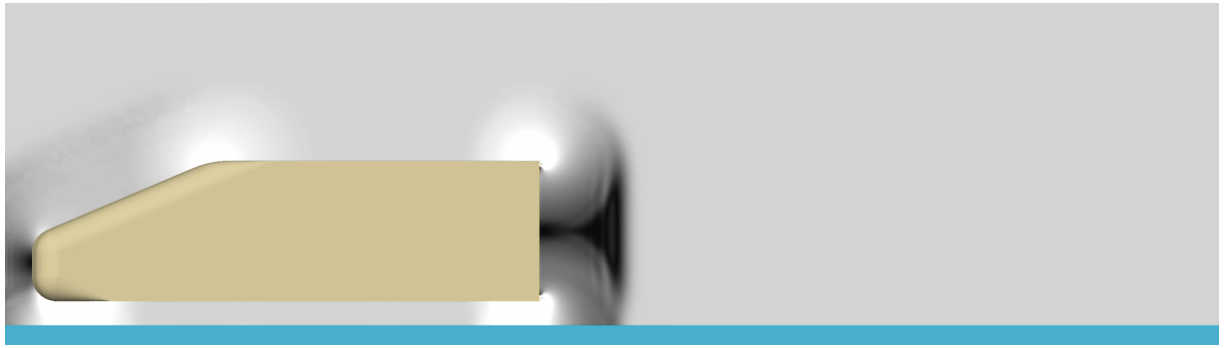


# Fifth Automotive CFD Workshop
# Case 1 Windsor Squareback

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Aeronautical & Automotive Engineering
Loughborough University

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Bologna, October 2026

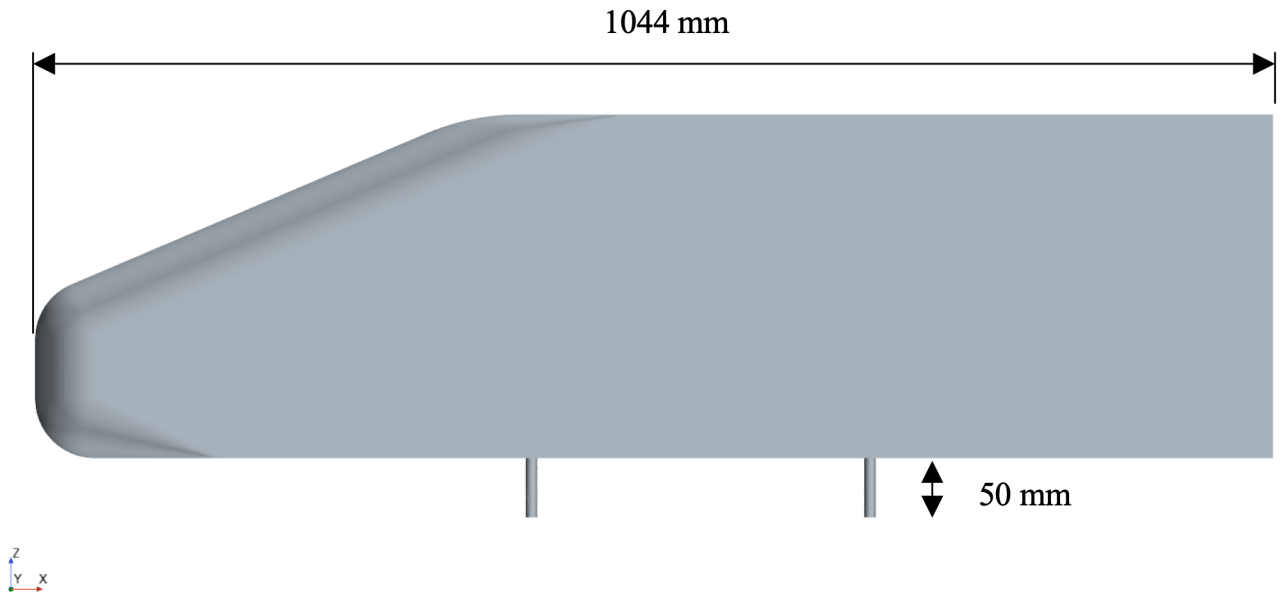
G.J.Page@lboro.ac.uk

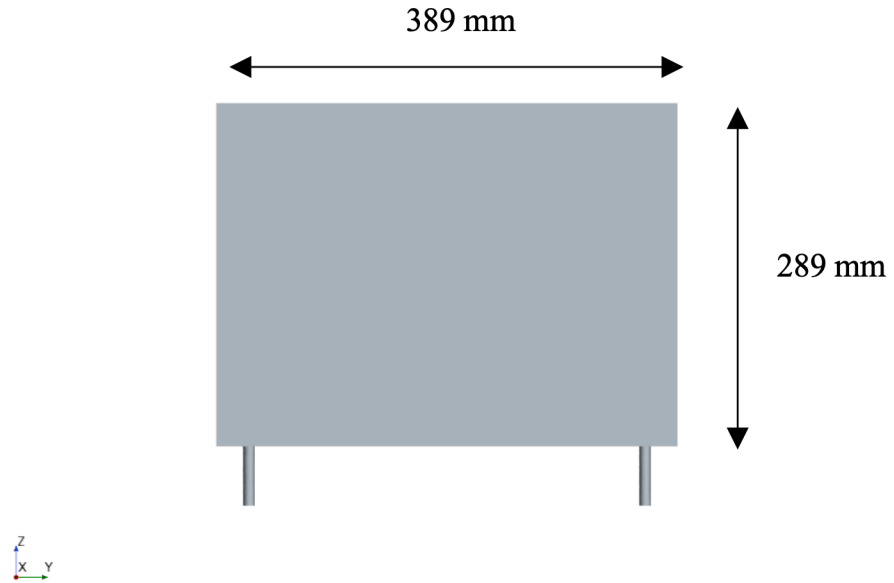
Loughborough University

# Contents

- Brief review of test case
- Overview of submissions
- Some initial thoughts on results

# Windsor Squareback Model

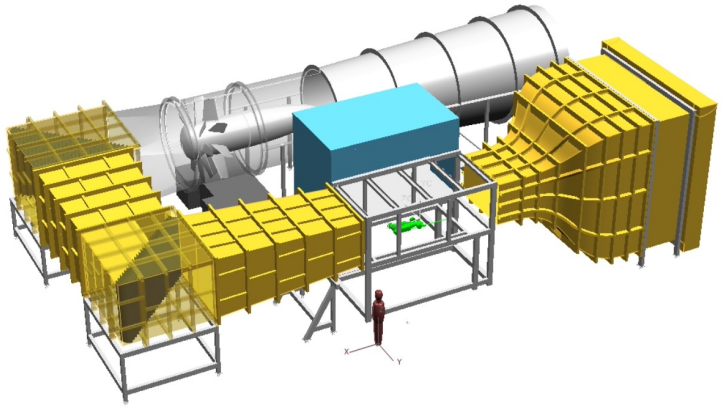


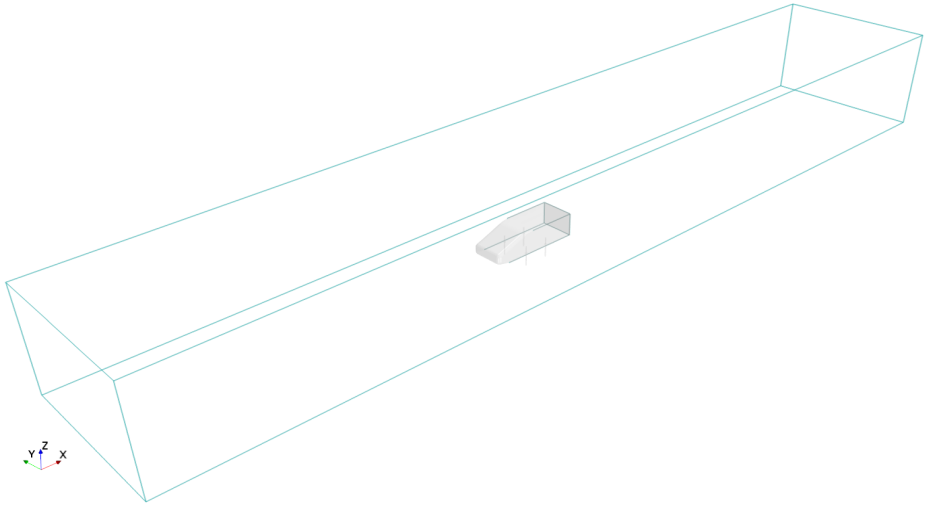




Reference area 0.112m$^2$, reference length 0.6375m

Origin on centreline, on floor, midway between pins

# Wind Tunnel and CFD domain



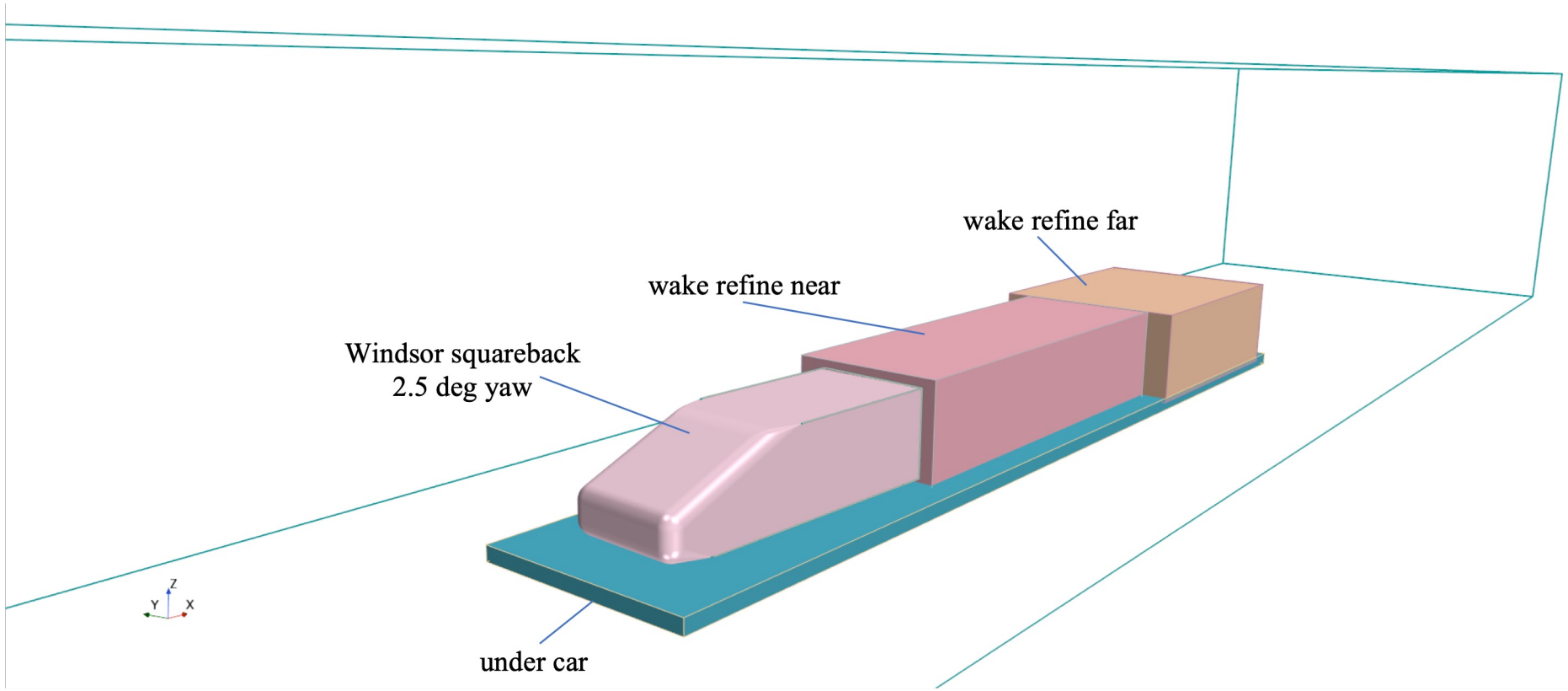


- Experiment: a 3.2m long working section, 1.92m wide x 1.32m high cross section expanding to 1.94m wide
- CFD: extend upstream and downstream to 11m long, parallel sidewalls
  - Slip wall (or symmetry) for side walls and roof (no boundary layer growth)

# 'Committee' Grids (unchanged from Auto CFD3+4)

- STAR-CCM+ trimmer + prism layer
- Baseline ('compulsory') **g2** has smallest cubical cells $2.4 \times 10^{-3}$ m
  - g1 x2 $4.8 \times 10^{-3}$ m, g3 $1.32 \times 10^{-3}$ m
  - 6.7M, **37M** and 197M cells
- All three grids have same prism layer near well cell height, number of layers, and thickness
- Same grid for RANS/DES/LES
  - *Should* be suitable for WMLES
  - DES/RANS would normally have higher aspect ratios
- Aiming for near wall cell centre y+ of 40 on model and 50-75 on ground plane

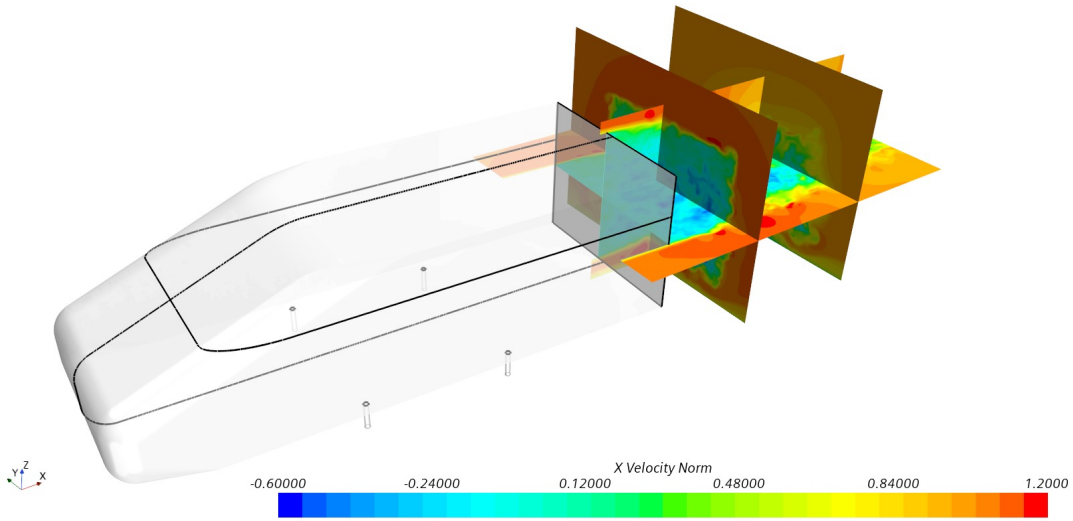
# Grid Refinement Zones



# Test Case

- 2.5 degree yaw (rotated –ve around z axis)
- 40 m/s, gives Re $3 \times 10^6$ (based on vehicle length) Use a virtual probe ahead of model on roof [-2.0,0.0,1.3]m to determine
  - Reference pressure
  - Reference velocity
  - Use for all force and pressure coefficients
- No wind tunnel corrections
- All force coefficients are in the yawed vehicle coordinate system (VCS)
- Symmetry, glasshouse base pressure in VCS
- PIV slices in Wind Tunnel Coordinate System (WTCS)

# Experimental Data



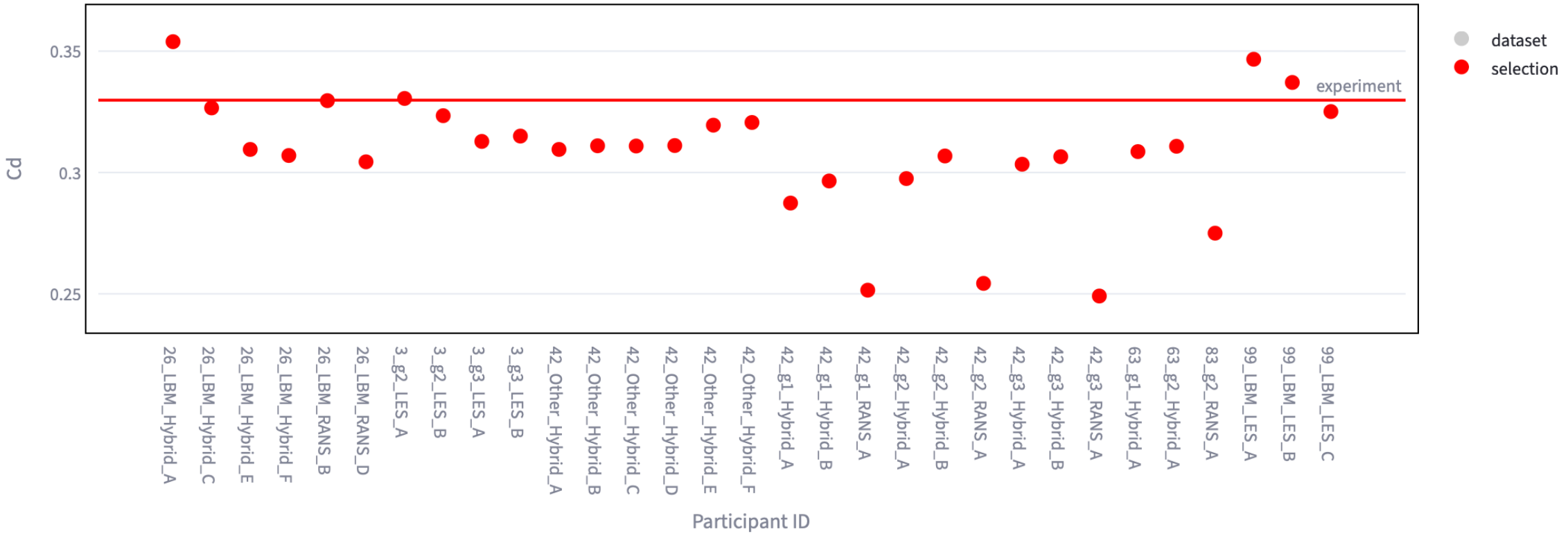

- Pressure tappings along symmetry plane and glasshouse plane
- Pressure tappings on base
- PIV slices (red, green, blue) - fixed in wind tunnel position

https://www.nwtf.ac.uk/dataset/1709/
https://repository.lboro.ac.uk/articles/dataset/Windsor_Body_Experimental_Aerodynamic_Dataset/13161284

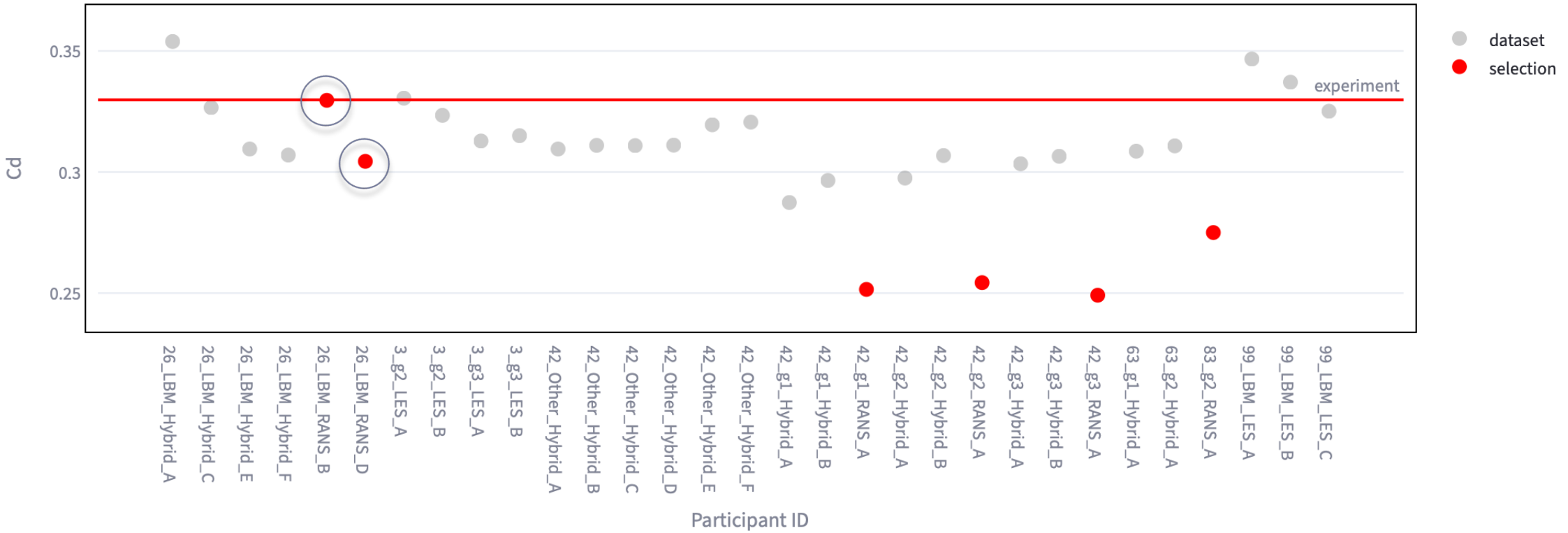
# Contributions (AutoCFD 4 comparison)

- 31 (43) calculations submitted
- 7 (9) organisations
  - 4 (4) Universities / Research Institutes
  - 0 (1) OEM
  - 0 (1) large CFD vendor
  - 3 (3) small/medium CFD vendors/consultancies
- 16 (16) on standard grids, 15 (27) on 'own' grids
- 7 (11) LES, 18 hybrid (21), 6 RANS (11)

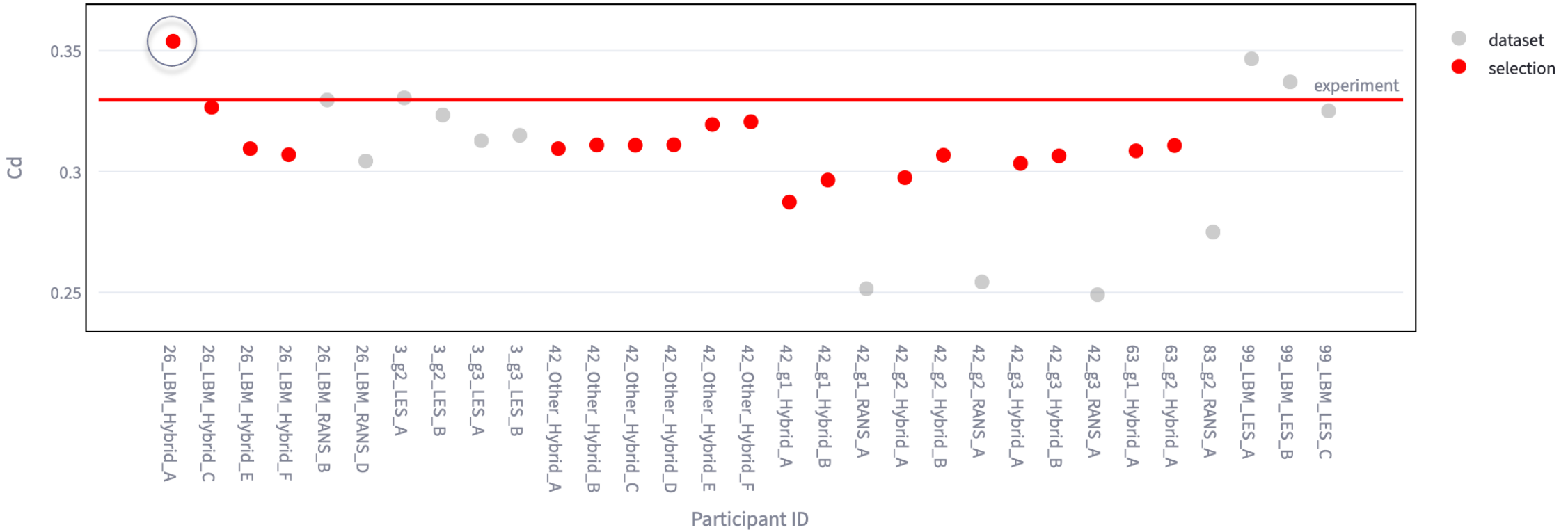
# Drag Summary **All**



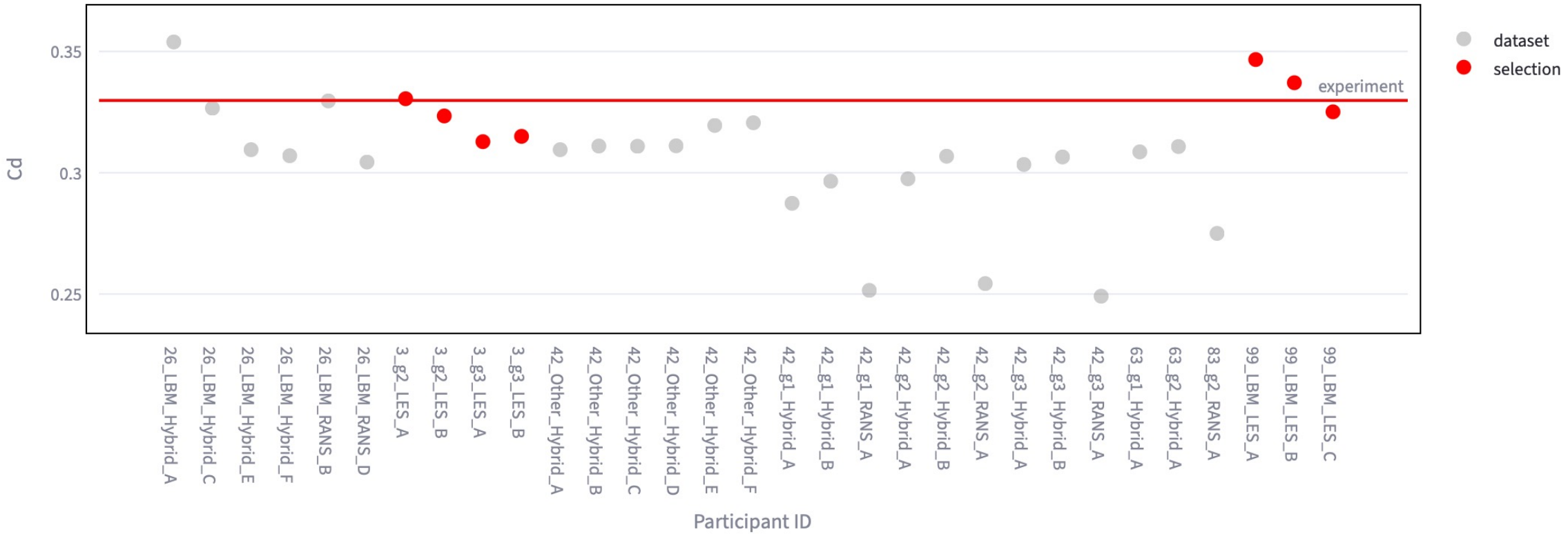
# Drag Summary **RANS**



# Drag Summary **Hybrid**

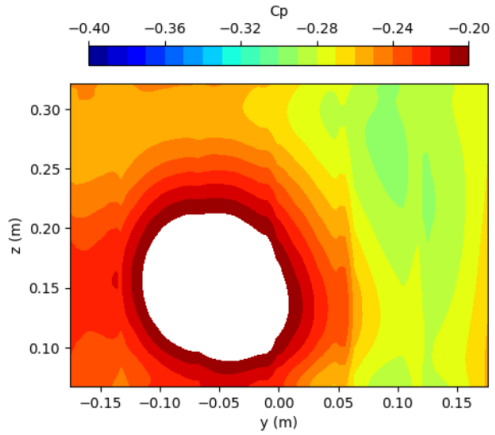


# Drag Summary **LES**

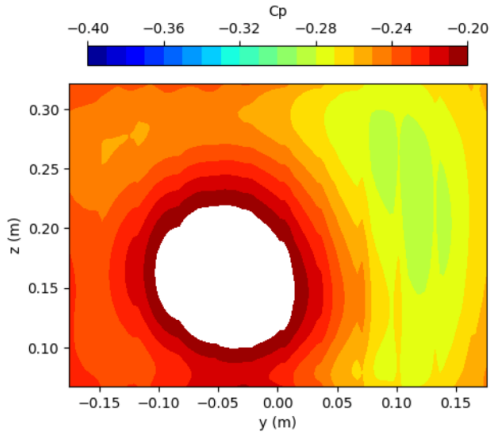


# Base Pressure **RANS**

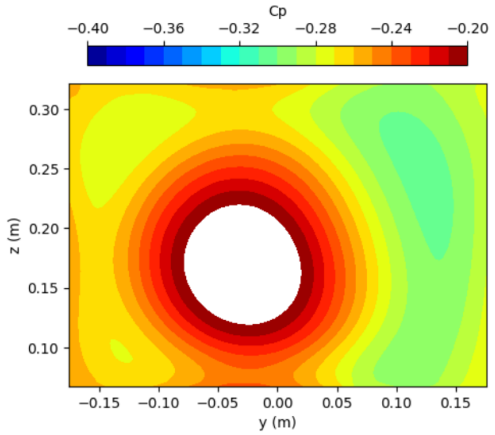
26_LBM_RANS_B



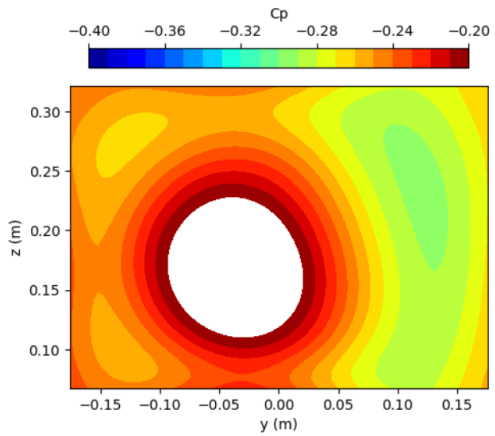

26_LBM_RANS_D



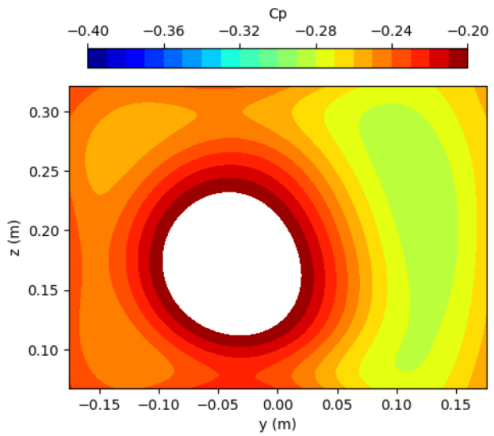

42_g1_RANS_A



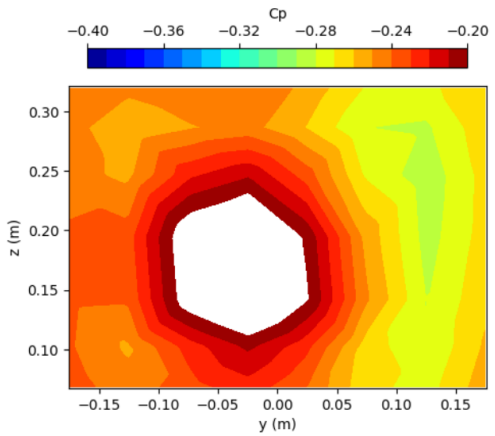

42_g2_RANS_A



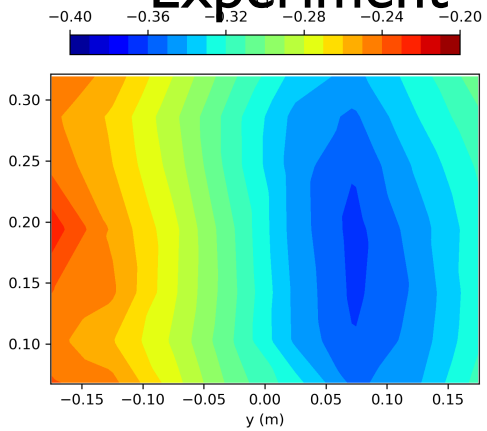

42_g3_RANS_A




83_g2_RANS_A

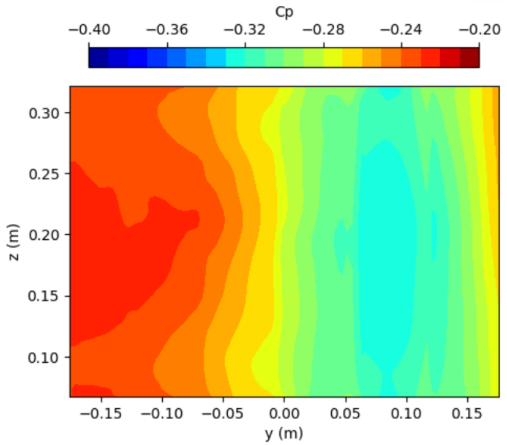



Experiment

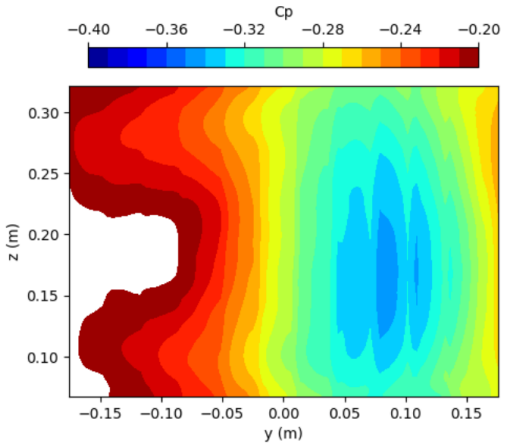


# Base Pressure **Hybrid**

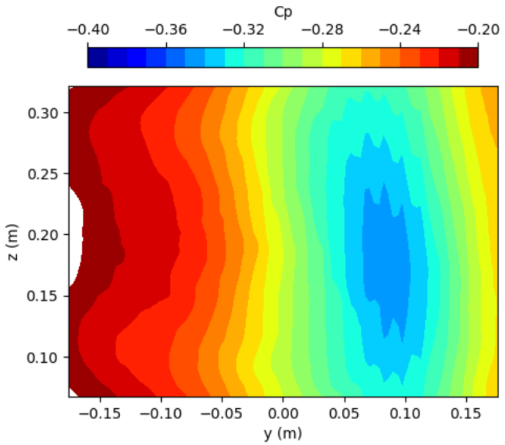
26_LBM_Hybrid_A



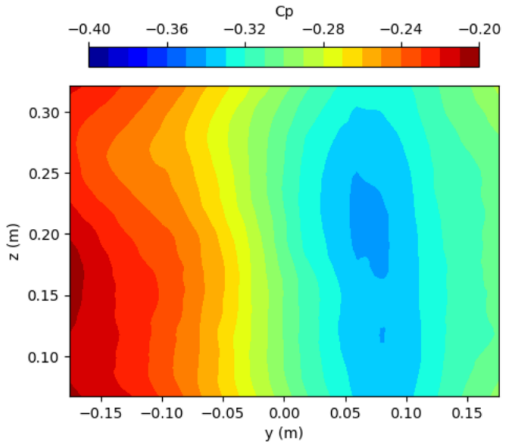

26_LBM_Hybrid_C



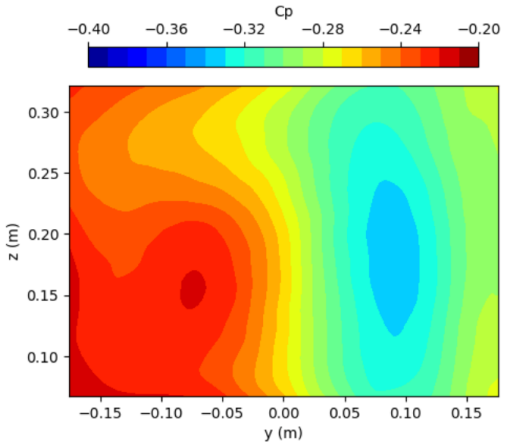

26_LBM_Hybrid_E



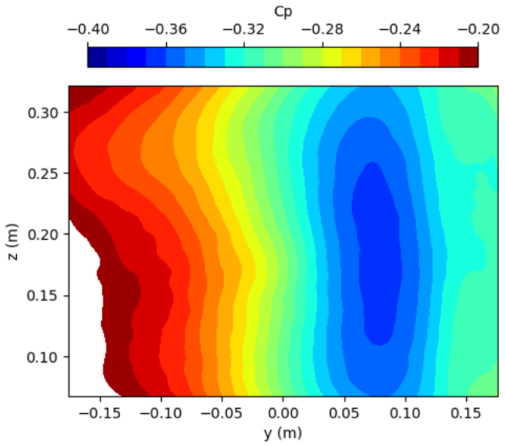

26_LBM_Hybrid_F



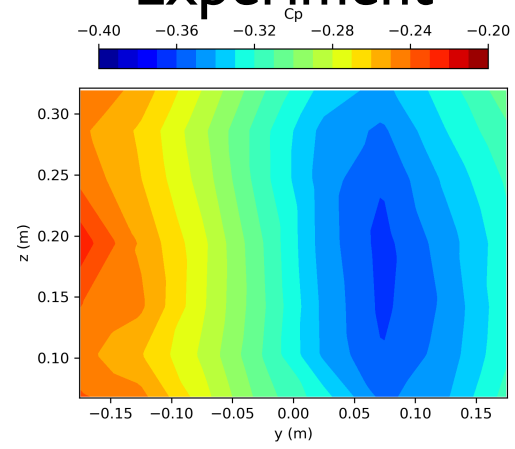

63_g1_Hybrid_A




63_g2_Hybrid_A

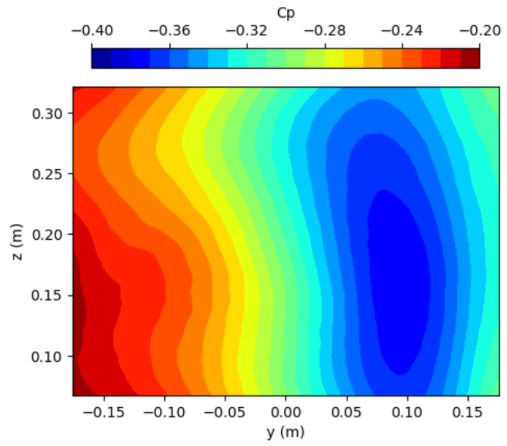



Experiment

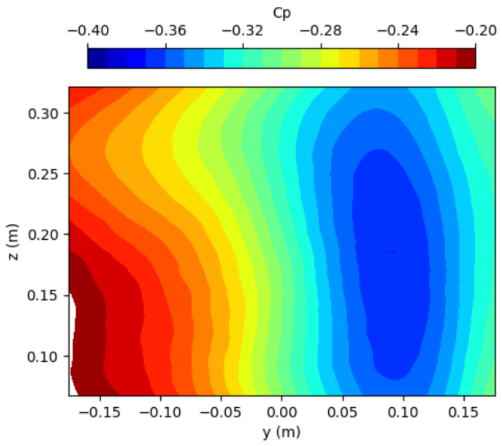


# Base Pressure **LES**

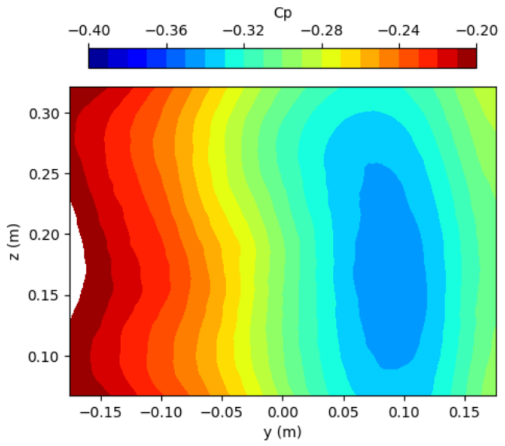
3_g2_LES_A



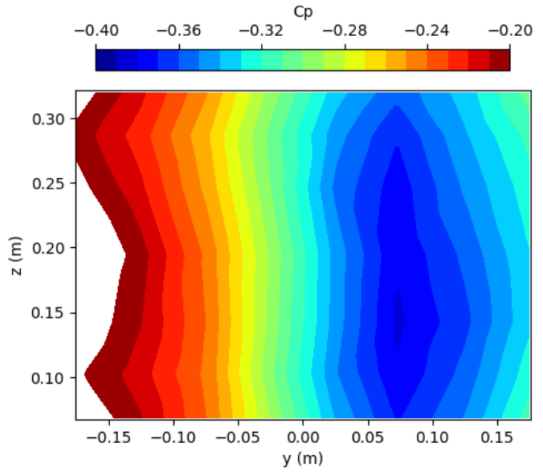

3_g2_LES_B



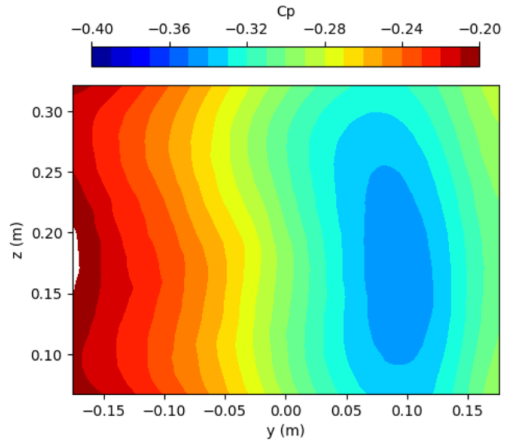

3_g3_LES_A



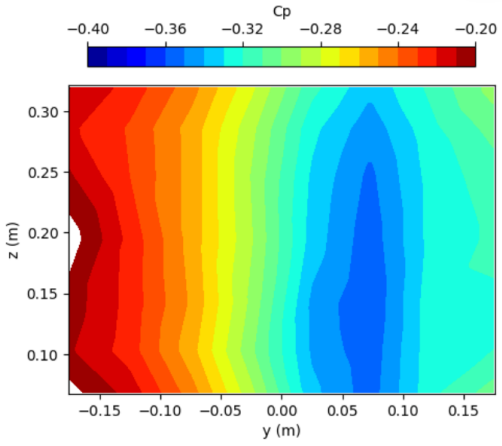

99_LBM_LES_C



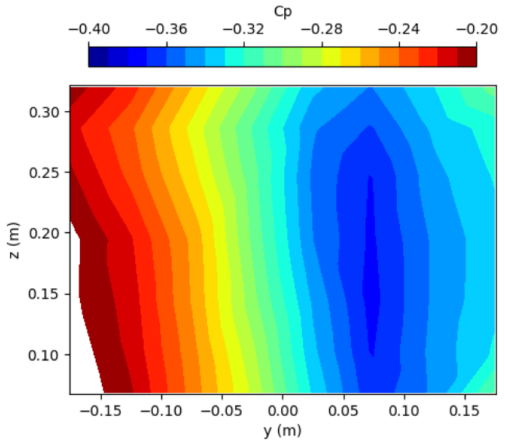

3_g3_LES_B



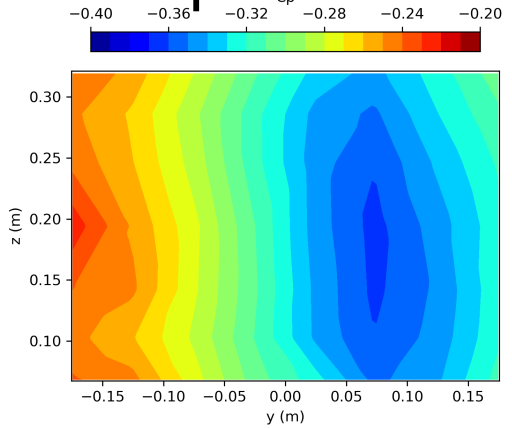

99_LBM_LES_A




99_LBM_LES_B

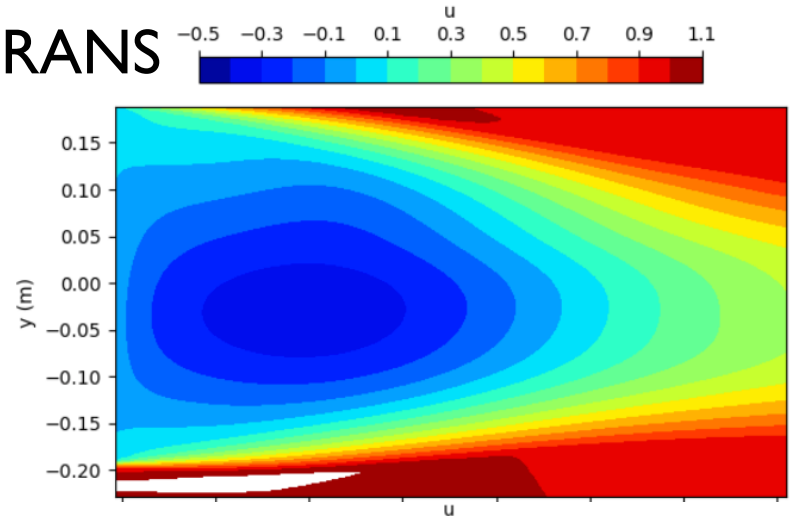



Experiment

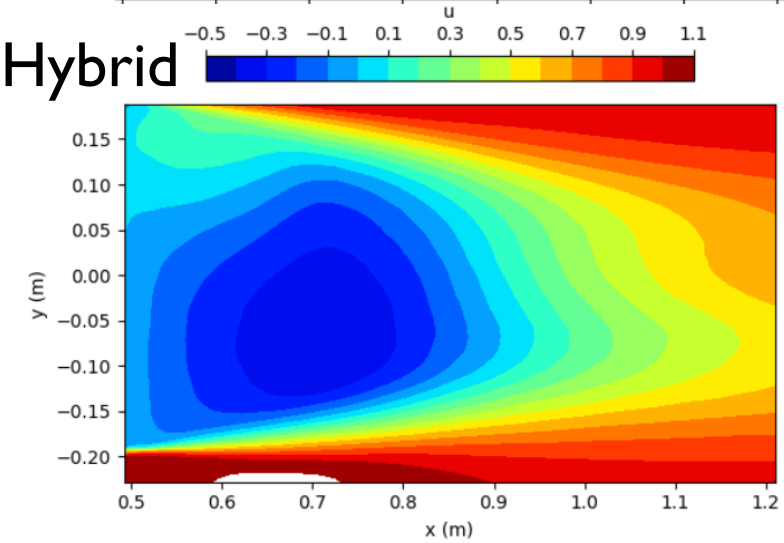


# PIV Blue (Horizontal Cut z=0.194m) mean u

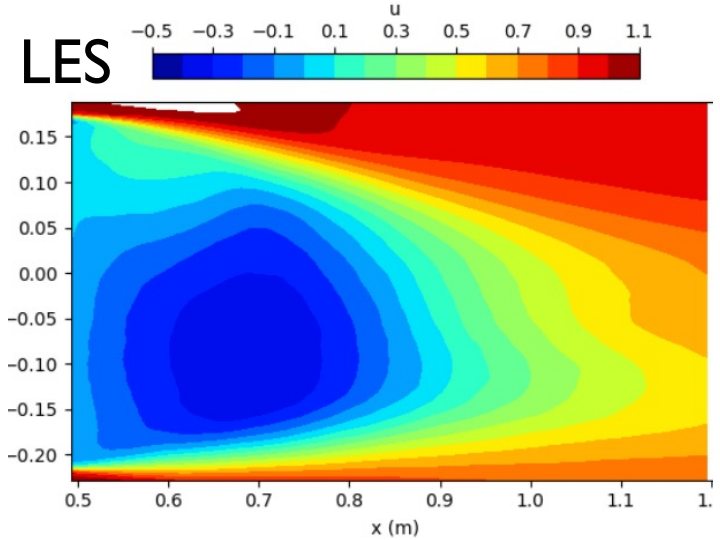
RANS



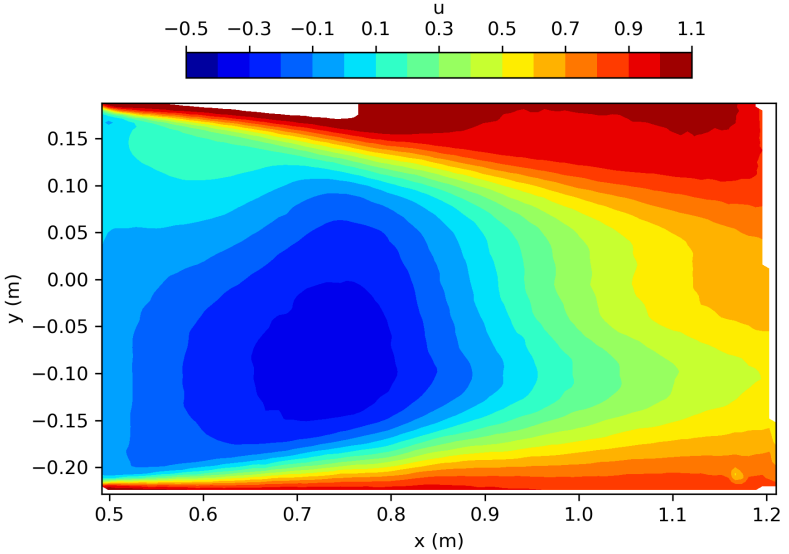

Hybrid




LES




Experiment



# Outcomes

- Be careful to judge quality on accuracy of drag prediction
- Clear distinction between RANS and Eddy Resolving
  - RANS has the wrong flow and underpredicts drag
- For Eddy Resolving
  - More variability in hybrid methods
  - LES quite consistent with good drag predictions (but fewer contributors)
- Some extremely good agreement with PIV measurements