# The Avalanching Effect: A Crucial Factor in DEM Calibration and Granular Material Behavior

18.10.23 **Adam Kolusz**, Alberto Gallina

ASTRA 2023
17th Symposium on Advanced Space Technologies in Robotics and Automation

# What is DEM (Discrete Element Method) and Why is it Important?

- A numerical technique for simulating granular materials;
- Applications:
  - terramechanics,
  - aerospace engineering,
  - soil mechanics,
  - civil engineering.
- Faster, cost-effective prototyping;
- Simulation of harsh environments, i.e. lower gravity conditions;

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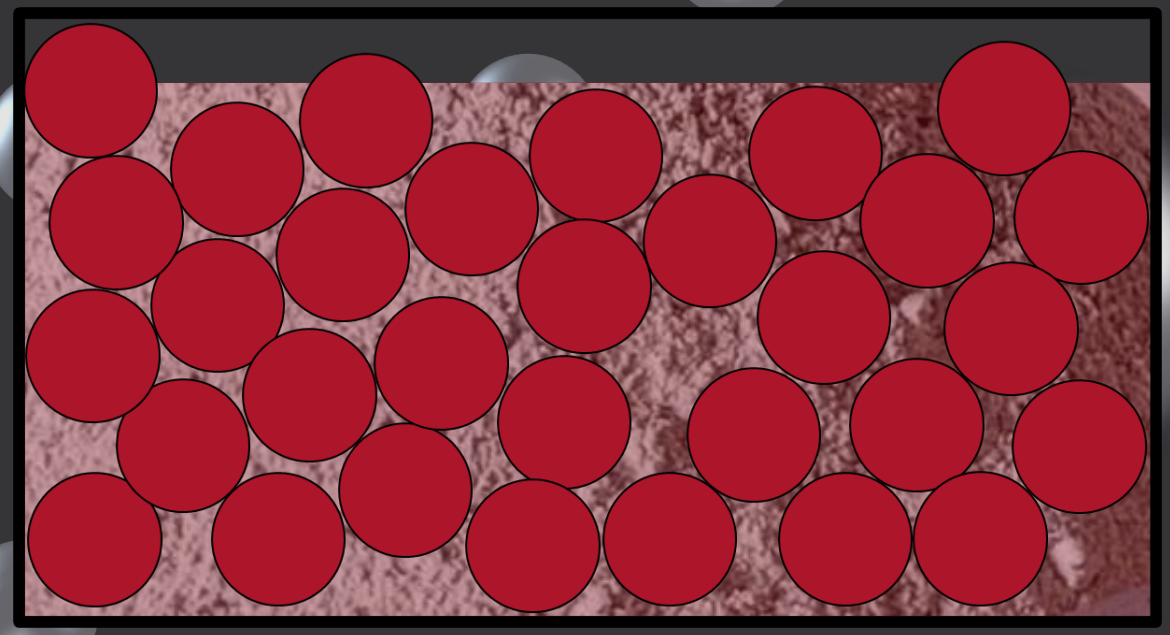

# Parameter Calibration with Experiments

- Difficult, tinkering with parameters of different contact models, no standard procedure.
- Necessary to ensure model accuracy and reliability;
- Common methods:
  - AoR (static, dynamic)
  - shear test,
  - 3-axis test,
- Vital for replicating real-world scenarios.

| Contact model numerical parameters (examples) | |
|---|---|
| Friction coefficients | Adhesive distance |
| Force fraction | Restitution coefficient |
| Rolling Resistance | Tangential stiffness ratio |

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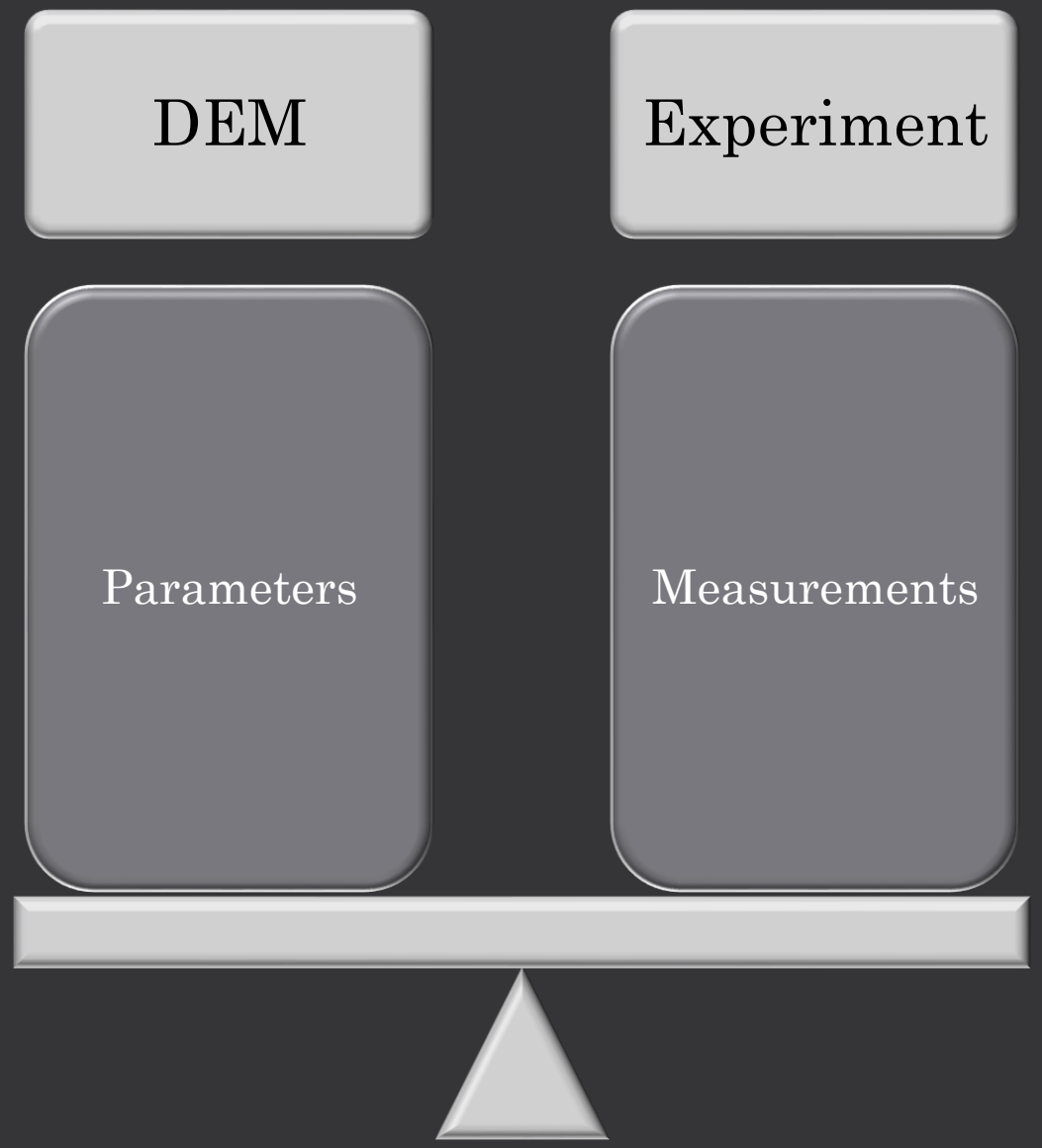
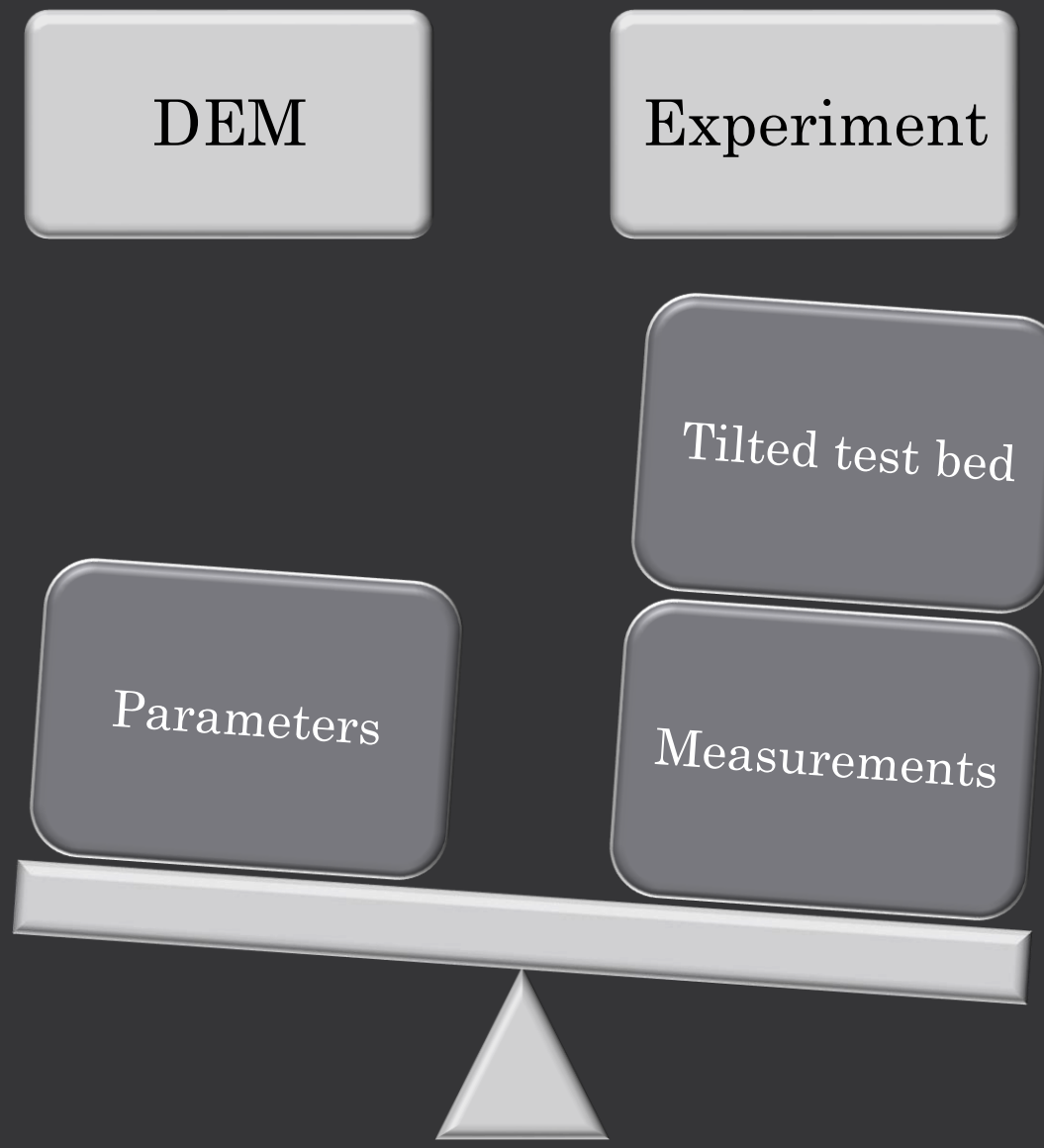
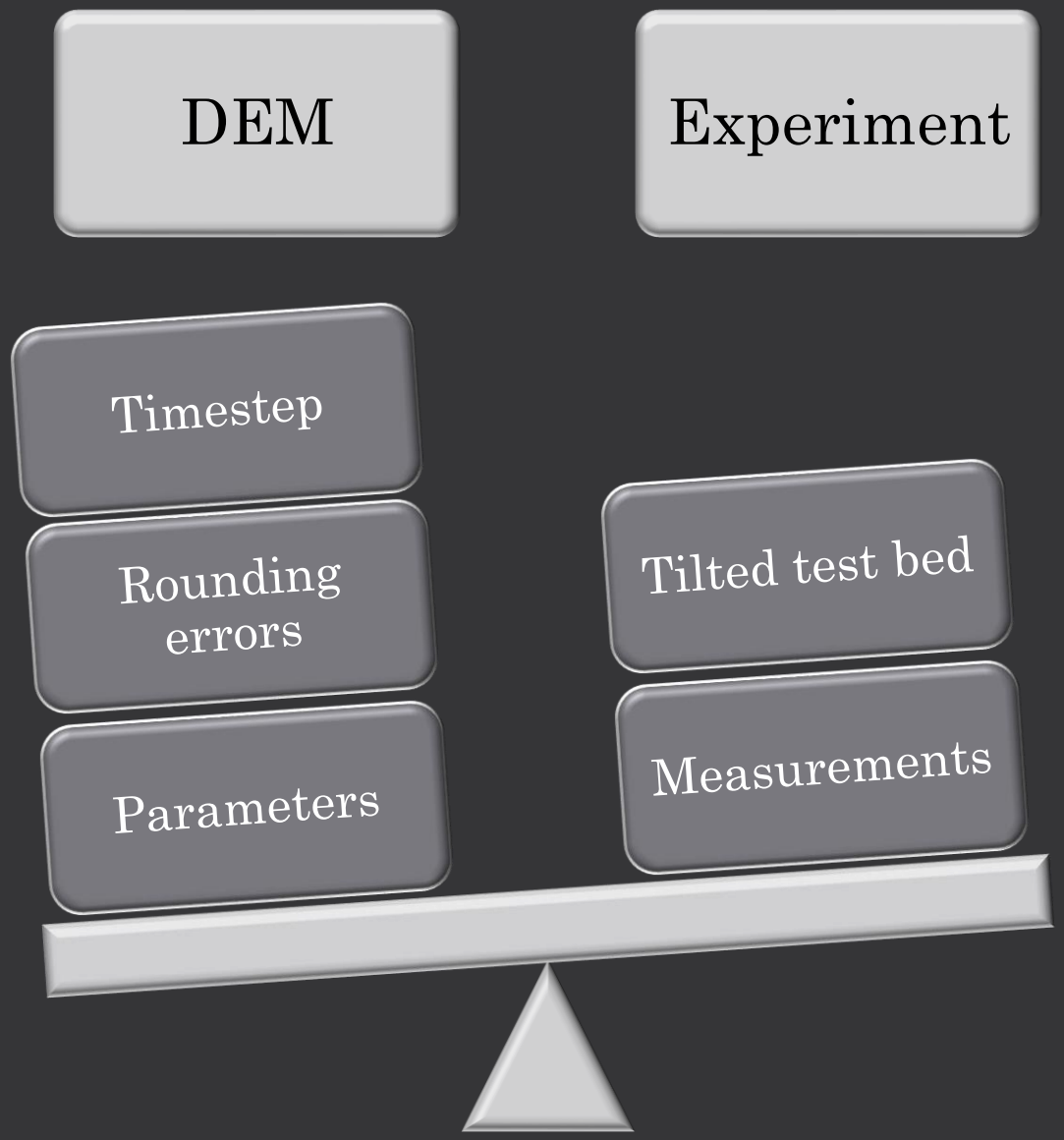
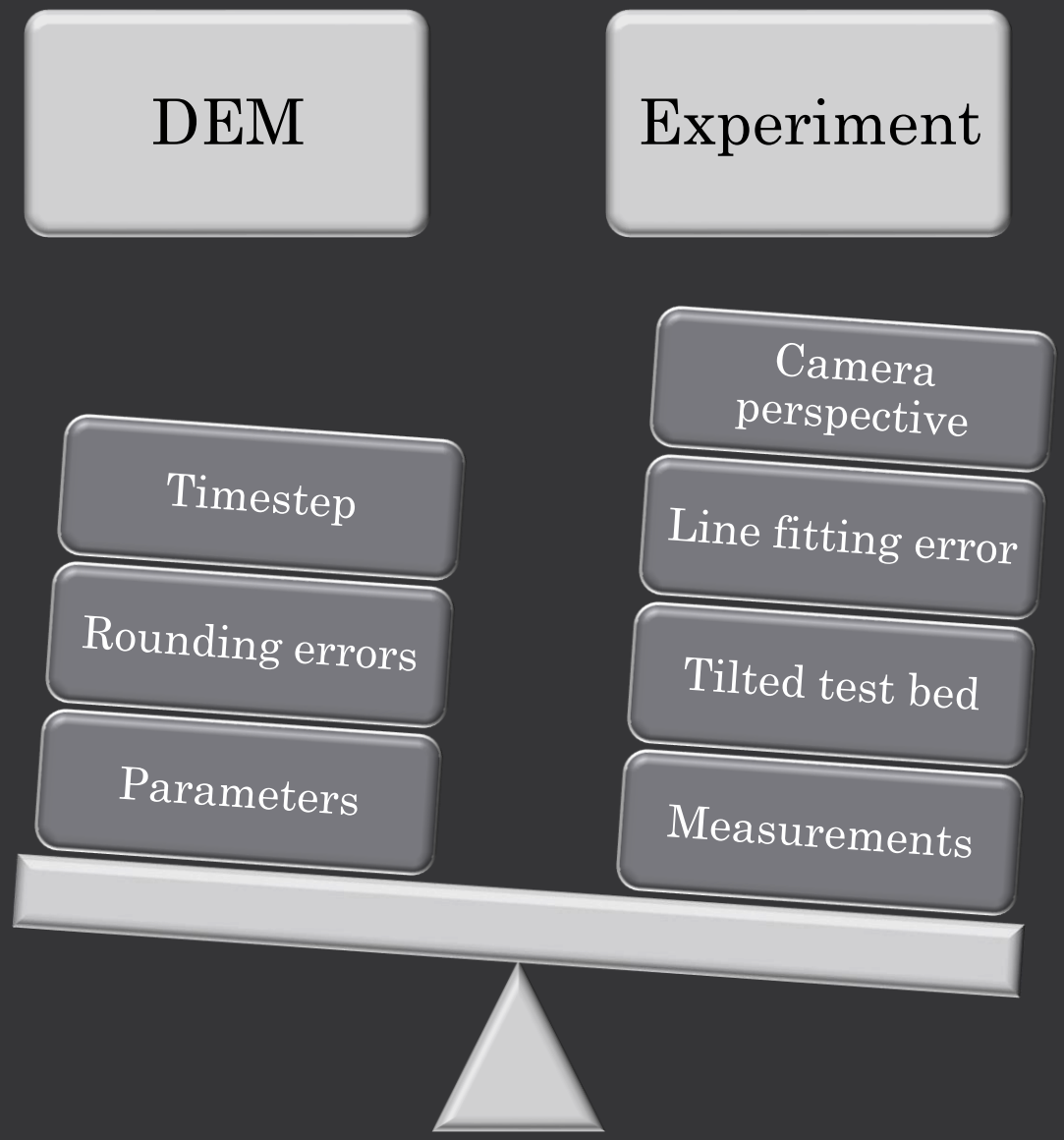

DEM
Experiment
Parameters
Measurements

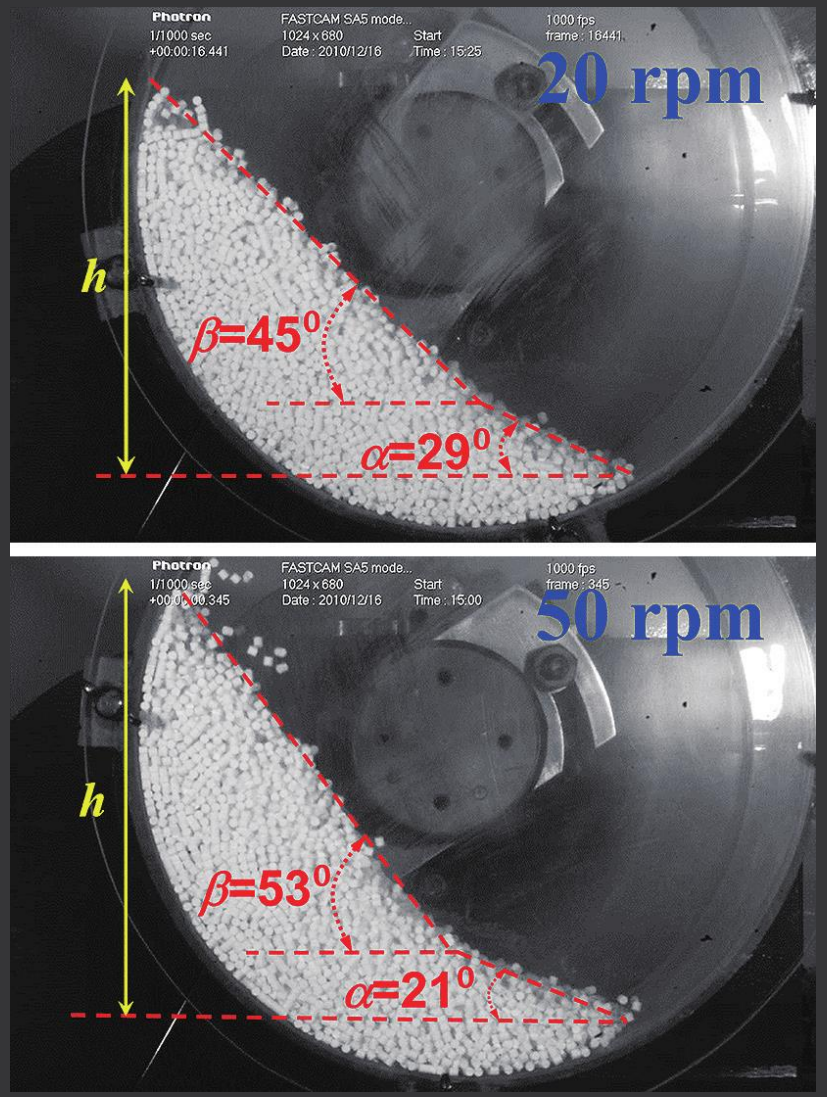

DEM
Experiment
Tilted test bed
Parameters
Measurements


DEM
Experiment
Timestep
Rounding errors
Parameters
Tilted test bed
Measurements


DEM
Experiment
Timestep
Rounding errors
Parameters
Camera perspective
Line fitting error
Tilted test bed
Measurements

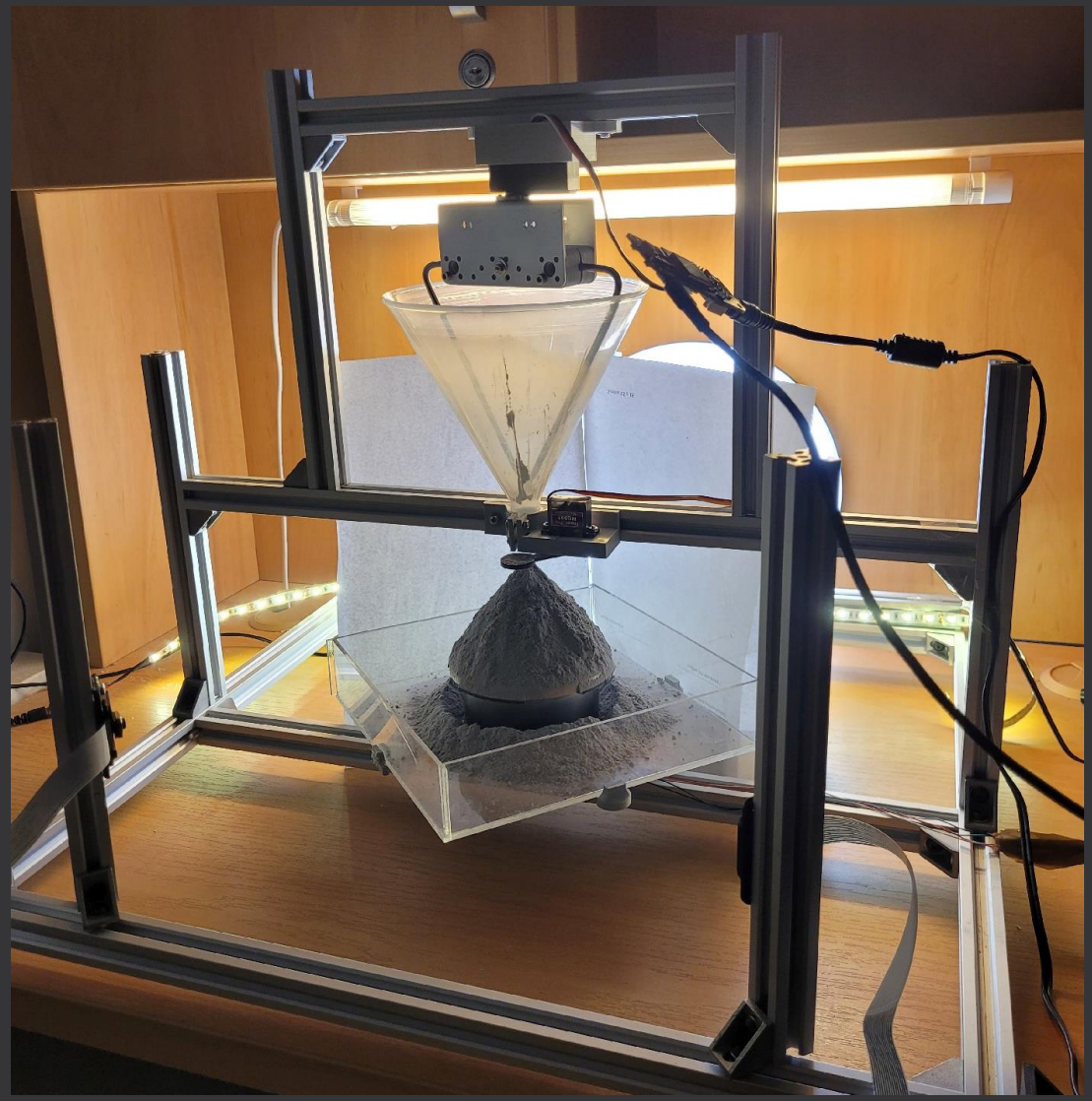
# Angle of Repose (AoR) - Traditional Measurements

KARG Industrietechnik repose angle tester
https://www.karg-industrietechnik.de/en/products/raw-material-testing/angle_of_repose_tester.php




Marigo, M. & Stitt, E.. (2015). Discrete Element Method (DEM) for Industrial Applications: Comments on Calibration and Validation for the Modelling of Cylindrical Pellets. KONA Powder and Particle Journal. 32. 236-252.

# The Missing Piece - Avalanching Effect



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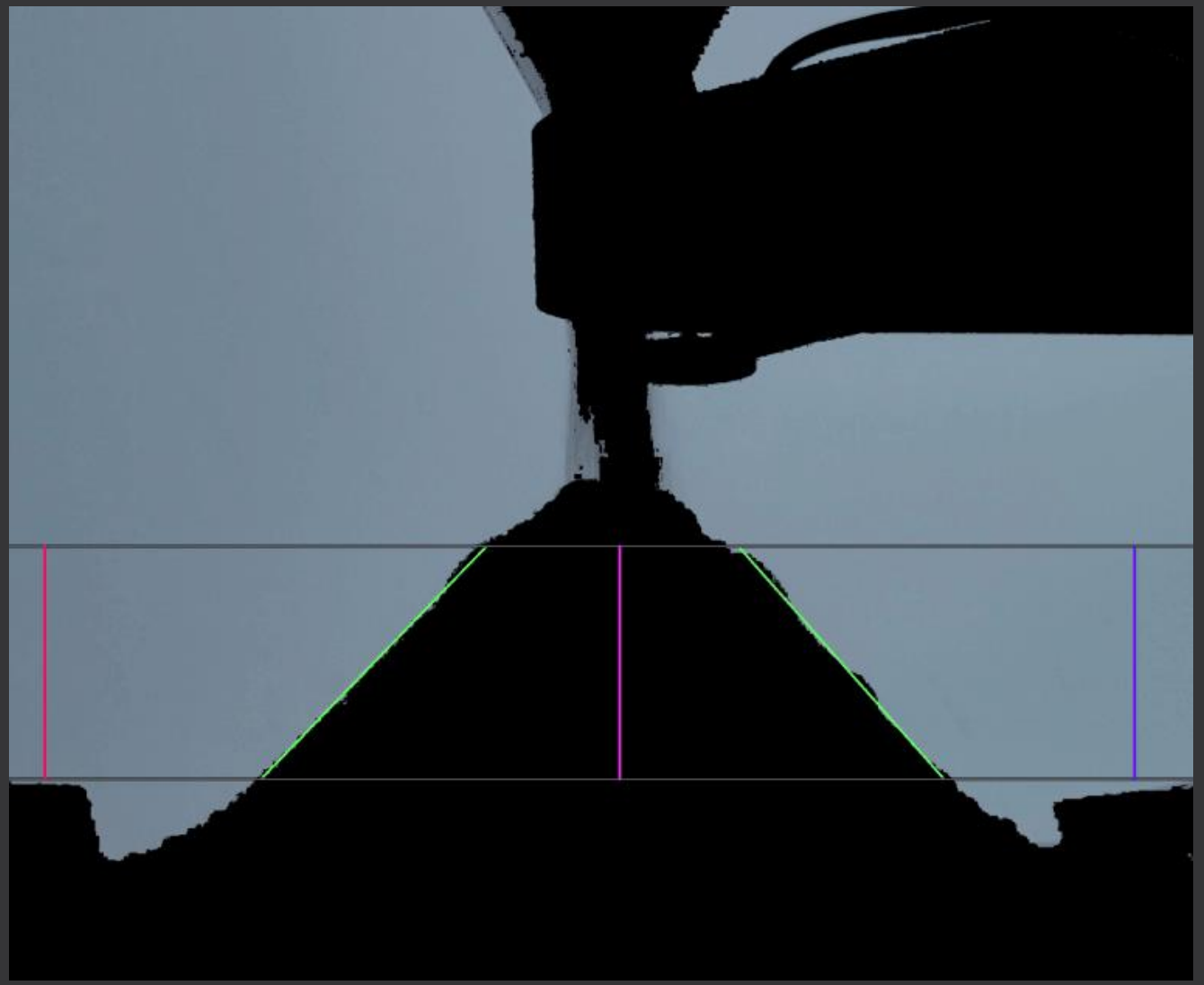
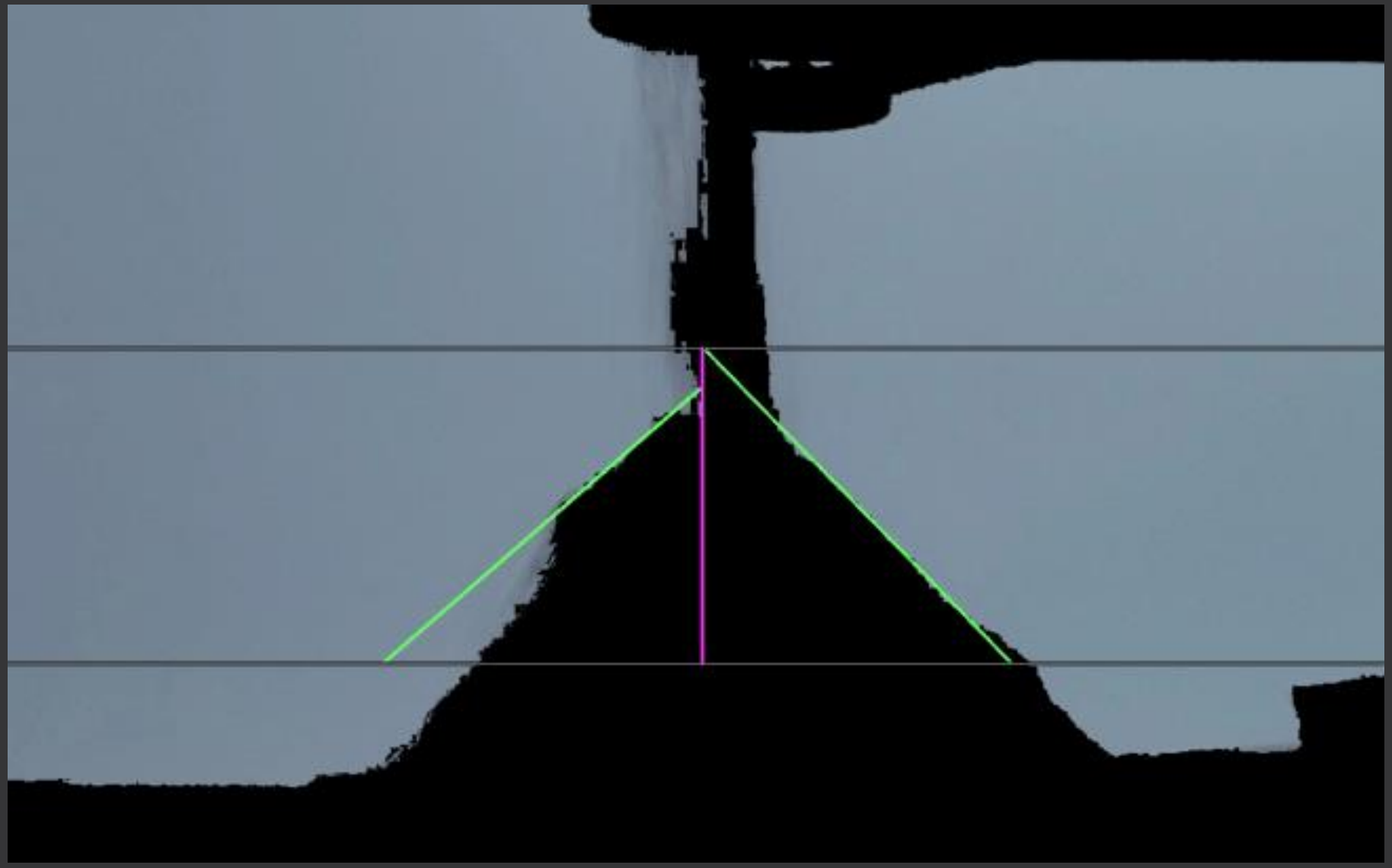


# Invalid region selection, large flowrate



# The Missing Piece - Avalanching Effect

- Time series data, extra information to compare materials
- Large impact on Angle of Repose;
- Can lead to large discrepancies (up to 9%);
- Often overlooked (no standard for measuring AoR)

# AGK2010 Simulant

- Cohesive
- Large quantity available
- Particle distribution
- Similar to Chenobi

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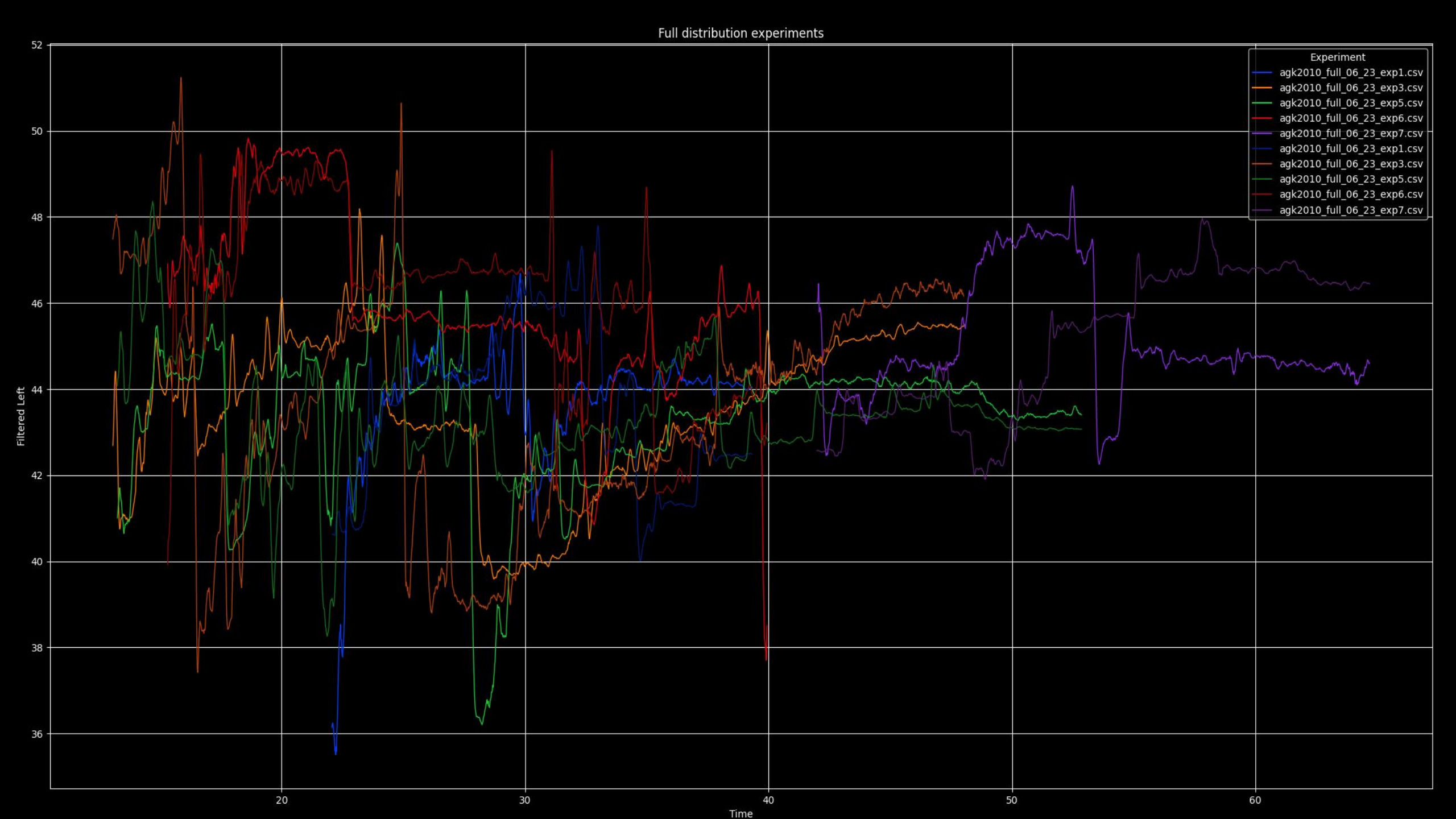
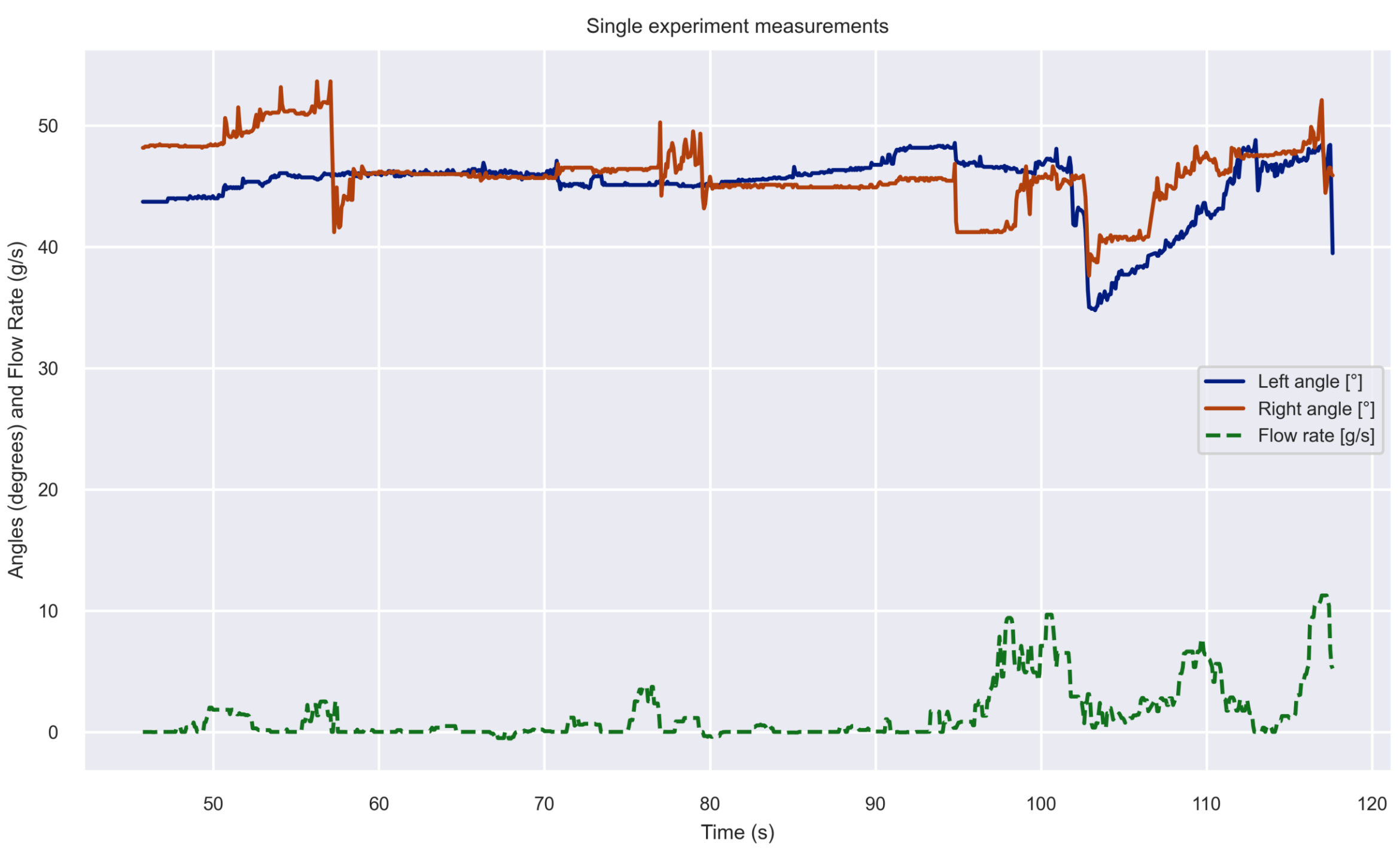
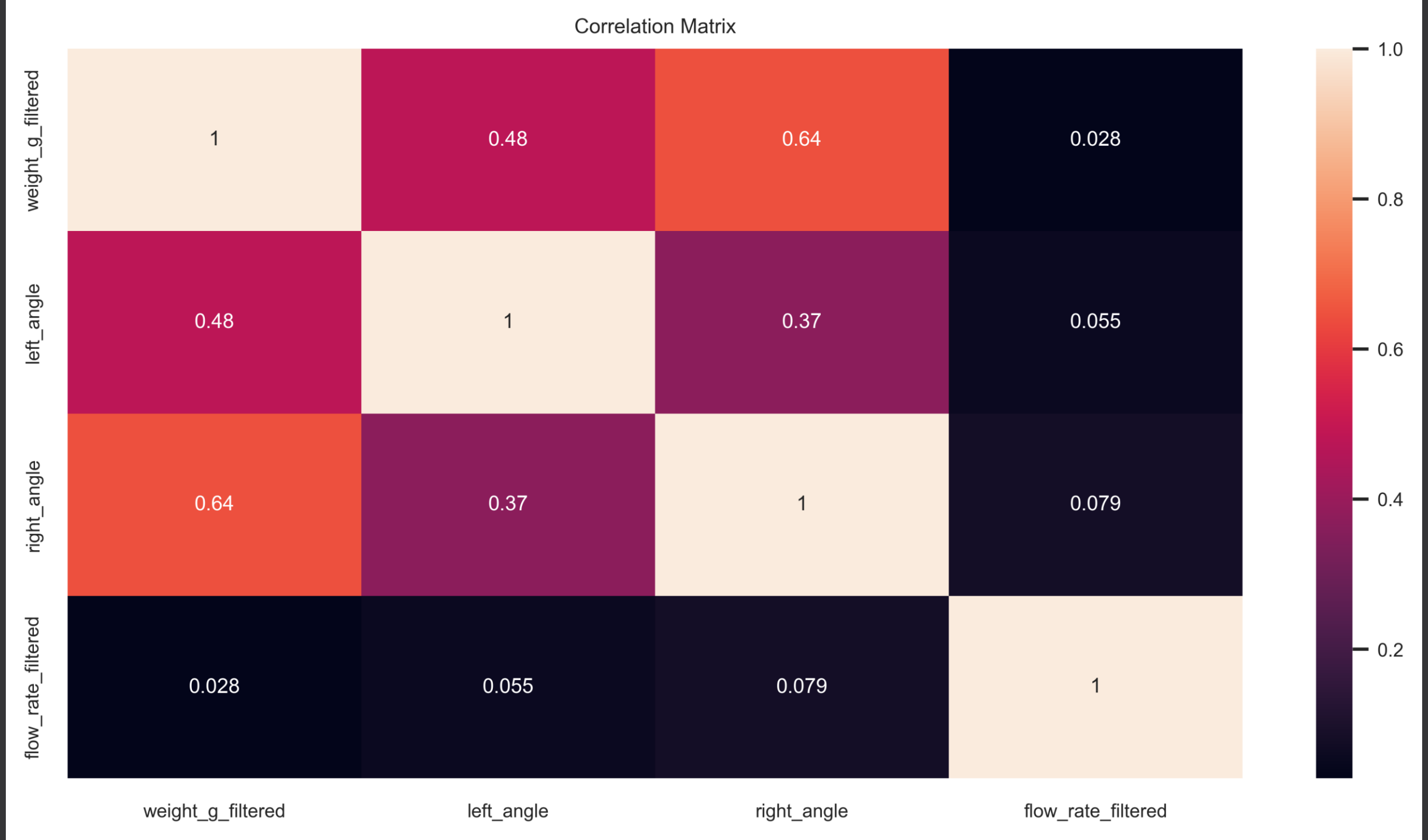
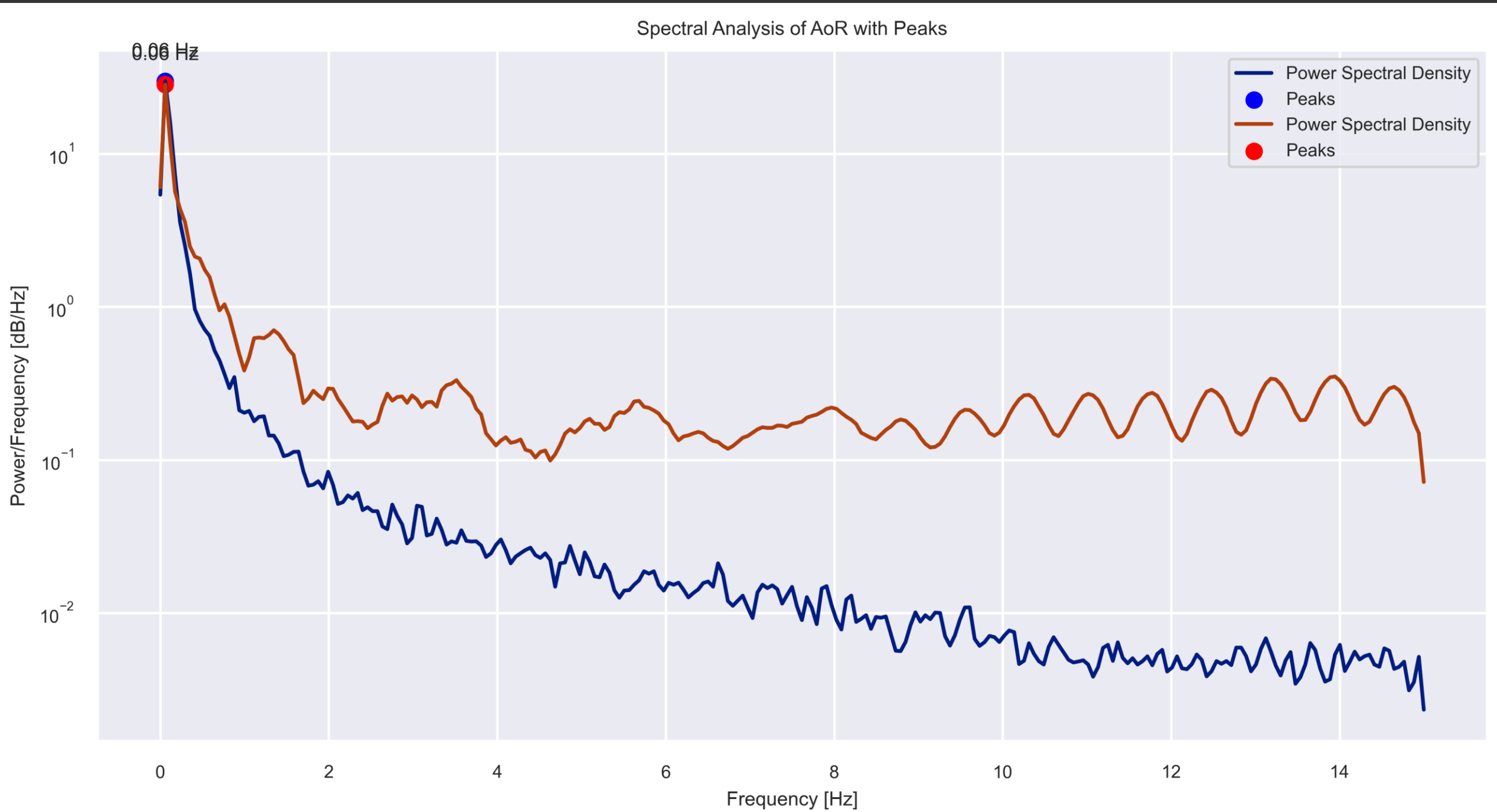
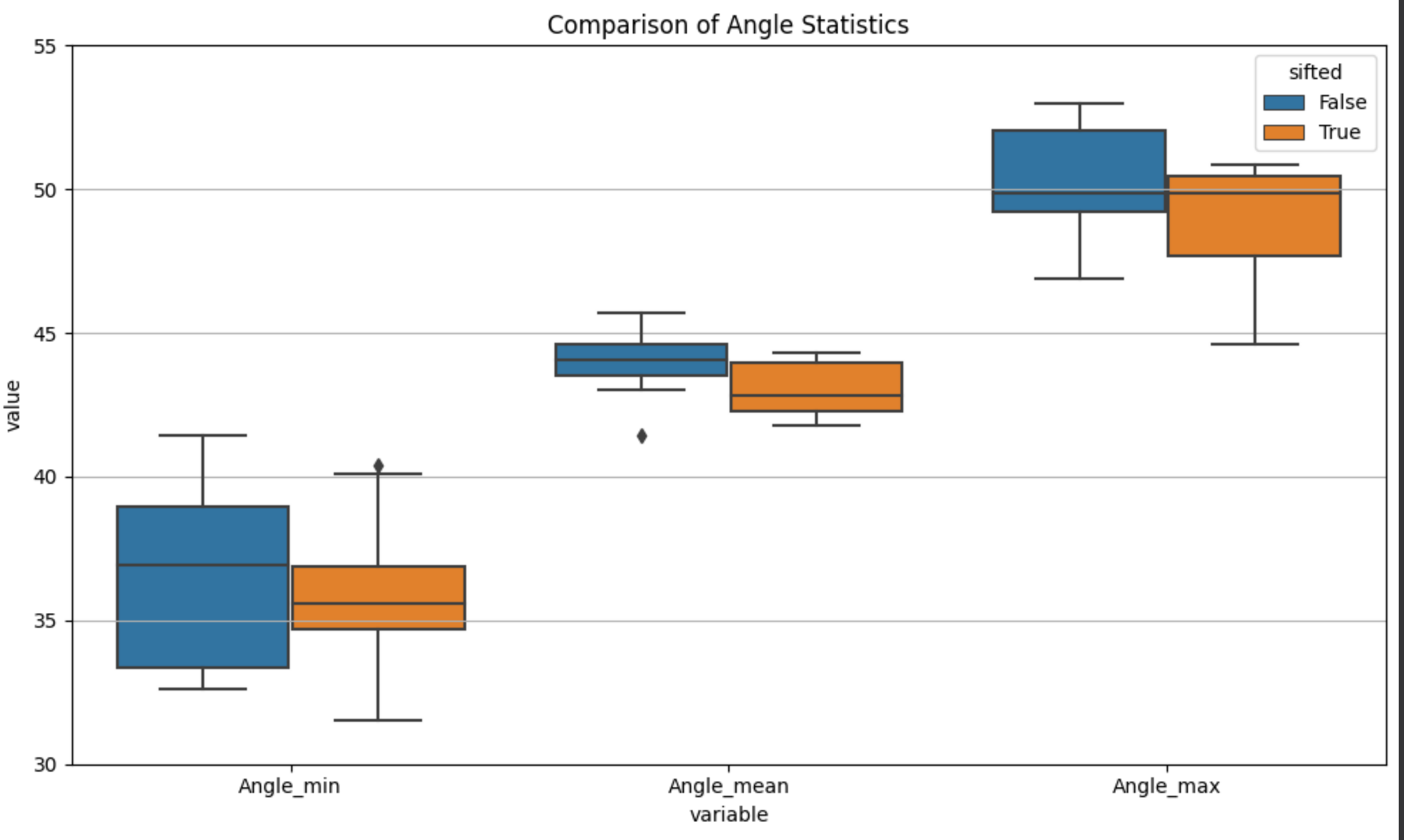
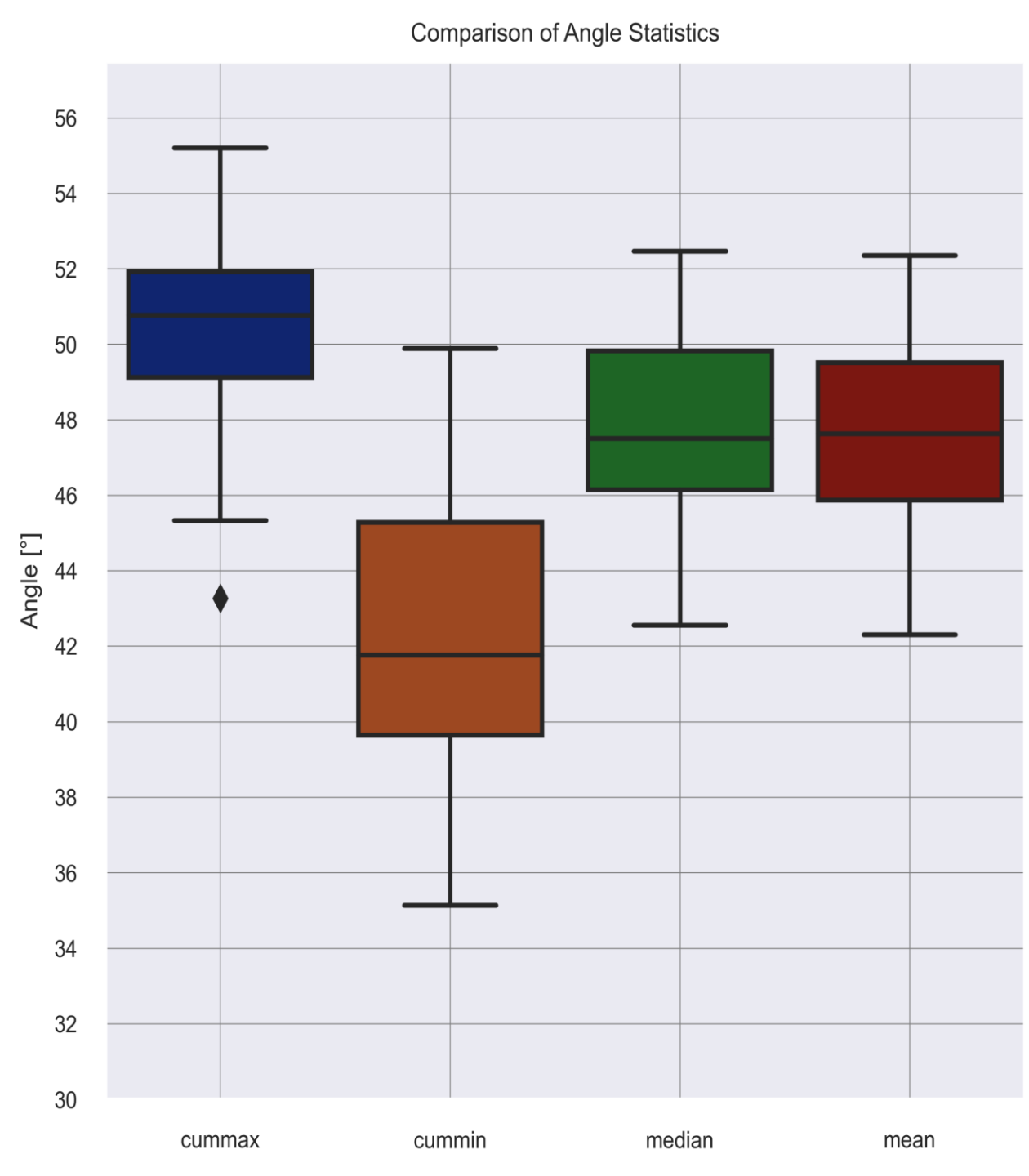

Full distribution experiments
Experiment
agk2010_full_06_23_exp1.csv
agk2010_full_06_23_exp3.csv
agk2010_full_06_23_exp5.csv
agk2010_full_06_23_exp6.csv
agk2010_full_06_23_exp7.csv
agk2010_full_06_23_exp1.csv
agk2010_full_06_23_exp3.csv
agk2010_full_06_23_exp5.csv
agk2010_full_06_23_exp6.csv
agk2010_full_06_23_exp7.csv
Filtered Left
Time
52
50
48
46
44
42
40
38
36
20
30
40
50
60

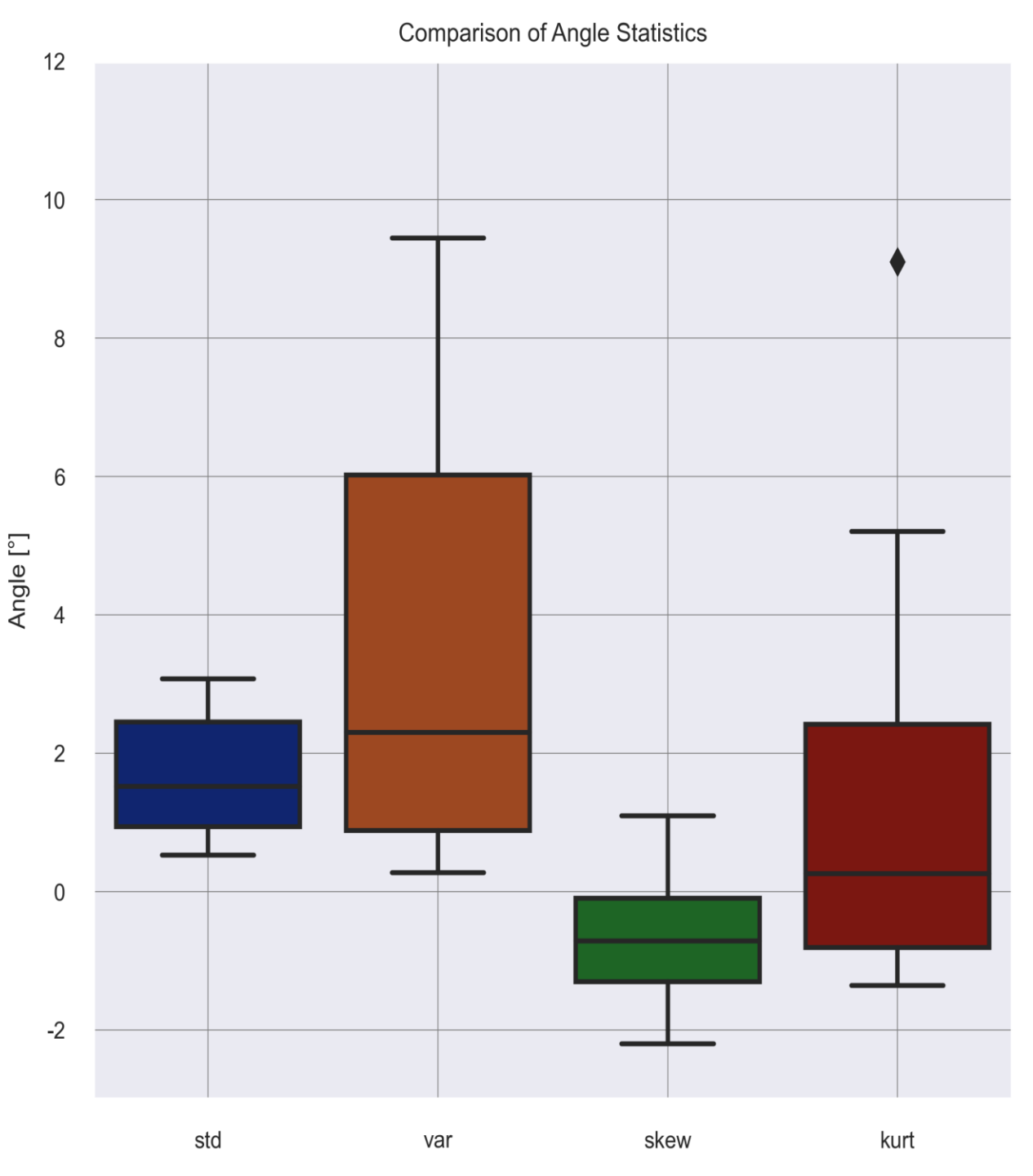

Single experiment measurements
Angles (degrees) and Flow Rate (g/s)
0
10
20
30
40
50
50
60
70
80
90
100
110
120
Time (s)
Left angle [°]
Right angle [°]
Flow rate [g/s]


Correlation Matrix
weight_g_filtered
left_angle
right_angle
flow_rate_filtered
1
0.48
0.64
0.028
0.48
1
0.37
0.055
0.64
0.37
1
0.079
0.028
0.055
0.079
1
weight_g_filtered
left_angle
right_angle
flow_rate_filtered
1.0
0.8
0.6
0.4
0.2


Spectral Analysis of AoR with Peaks
0.06 Hz
Power Spectral Density
Peaks
Power Spectral Density
Peaks
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
Power/Frequency [dB/Hz]
0
2
4
6
8
10
12
14
Frequency [Hz]


Comparison of Angle Statistics
55
50
45
40
35
30
value
sifted
False
True
Angle_min
Angle_mean
Angle_max
variable


Comparison of Angle Statistics
Angle [°]
56
54
52
50
48
46
44
42
40
38
36
34
32
30
cummax
cummin
median
mean


Comparison of Angle Statistics
Angle [°]
12
10
8
6
4
2
0
-2
std
var
skew
kurt

# Conclusions

- Not considering avalanching = invalid measurement;
- Better statistical analysis required;
- DEM calibration
  - Experiment flowrate as simulation input;
  - Multiple seconds of simulation necessary;
- Remote testing of material? (i.e. rover with a gripper sifting remotely)

# Acknowledgements and Q&A


- AGH UST
- The Space Research Centre of the Polish Academy of Sciences (CBK PAN)
- This research was funded by the National Science Centre 2020/38/E/ST8/00527.

# Thank you for your attention

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