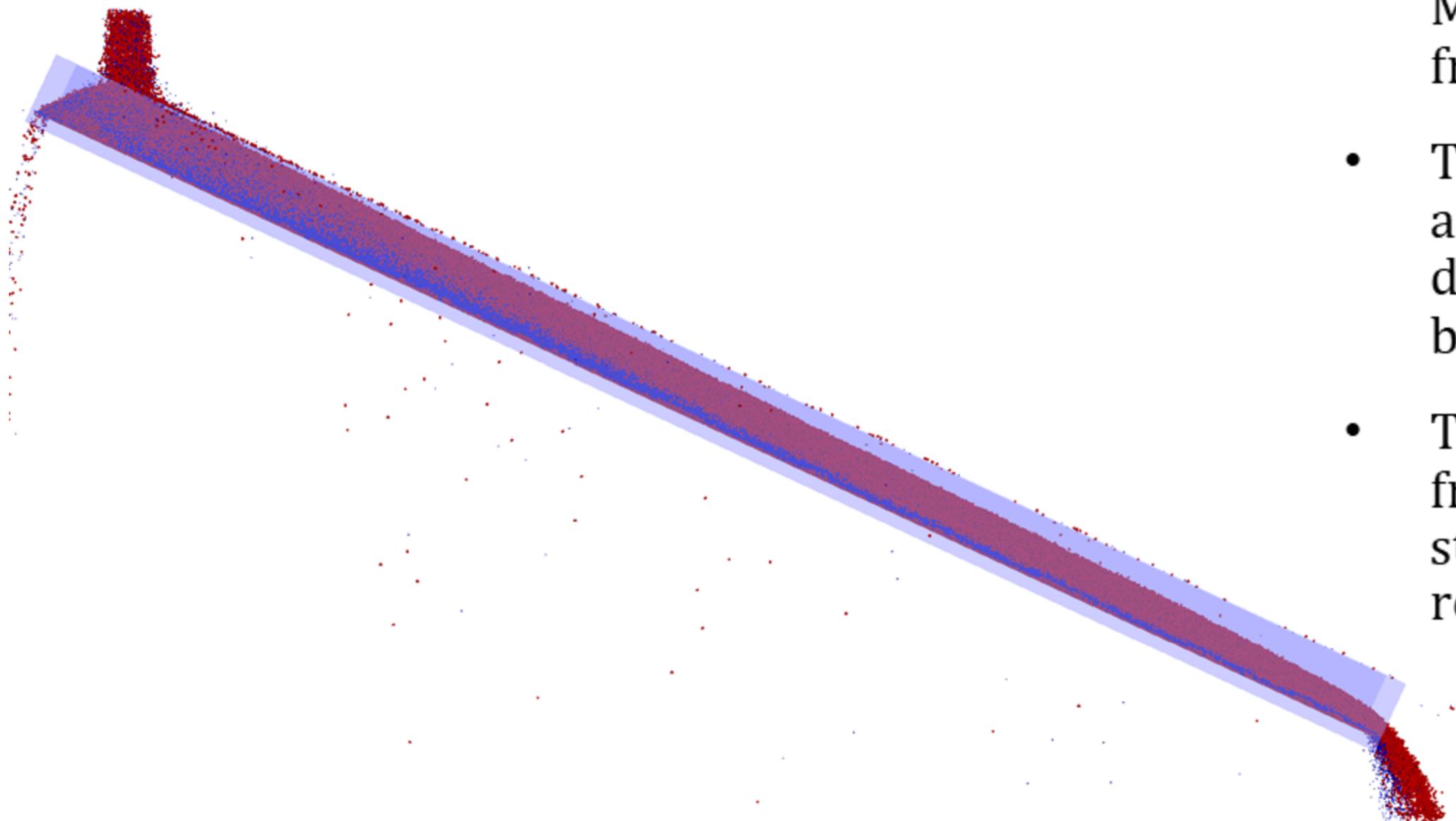


Segregation of Particles in Steady Fully Developed Flow Down an Inclined Surface

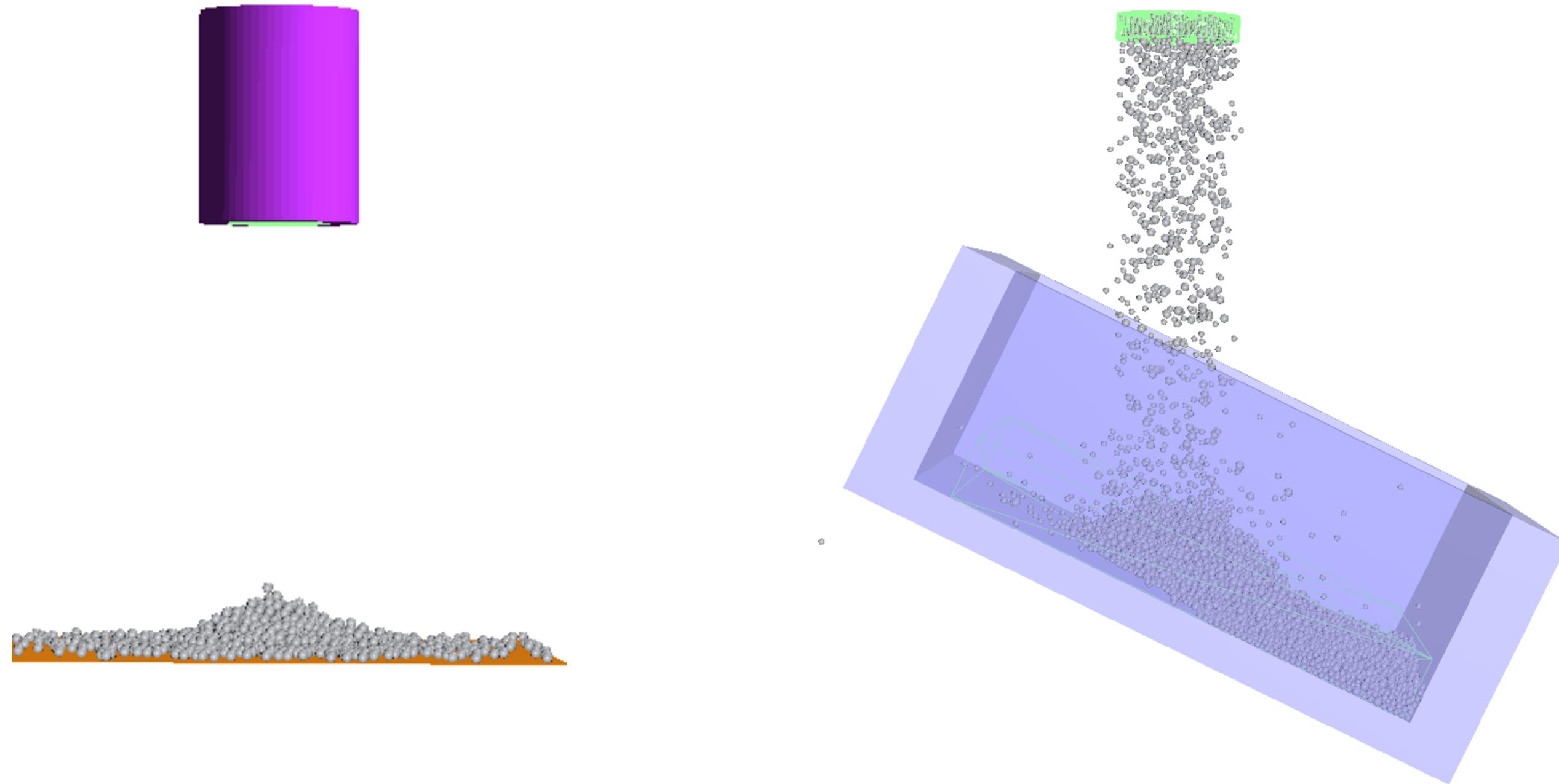
CHE616 Course Project
Sayeedul Islam Sheikh(210953)
Rohan Virmani(210871)

ABSTRACT

- This project employs a Discrete Element Method (DEM) simulation in the MUSEN framework.
- The simulation models the flow of approximately 400,000 coke particles of two distinct sizes over an inclined chute with a bumpy base.
- The study aims to analyse the packing fraction and velocity profile variations during steady-state flow and compare the simulation results with analytical predictions.



Learning Musen



Setup

Simulation
Properties

Material
Properties

Interaction
Properties

Setup

Simulation
Properties

Material
Properties

Interaction
Properties

Scene

Inclination Angle(Θ)	Base	Height	No of Particles
25 deg	1000d	50d	4.1 Lakh

Parameters

- Generation Rate (1/s)- 50000
- Updating Time Step(s)- 0.01
- Simulation Step- 8e-6
- Saving Step-0.1
- Particle-Particle Contact Model = Hertz Mindlin
- Particle- Wall Contact Model= Hertz Mindlin

Setup

Simulation
Properties

Material
Properties

Interaction
Properties

	Unit	COKE	HEAVY COKE	GLASS
DENSITY	Kg/m3	1100	100000	2500
DYNAMIC VISCOSITY	Pa. s	0.1	0.1	0.1
YOUNGS MODUKUS	Pa	5e+7	1e+9	1e+9
POISSON RATIO	--	0.2	0.2	0.2
YIELD STRENGTH	Pa	2e+7	2e+10	2e+10

Setup

Simulation
Properties

Material
Properties

Interaction
Properties

Binary Size Granular Mixture

Sno	Material	Diameter(mm)	Fraction
1	Coke	1	0.4
2	Coke	2	0.6

Setup

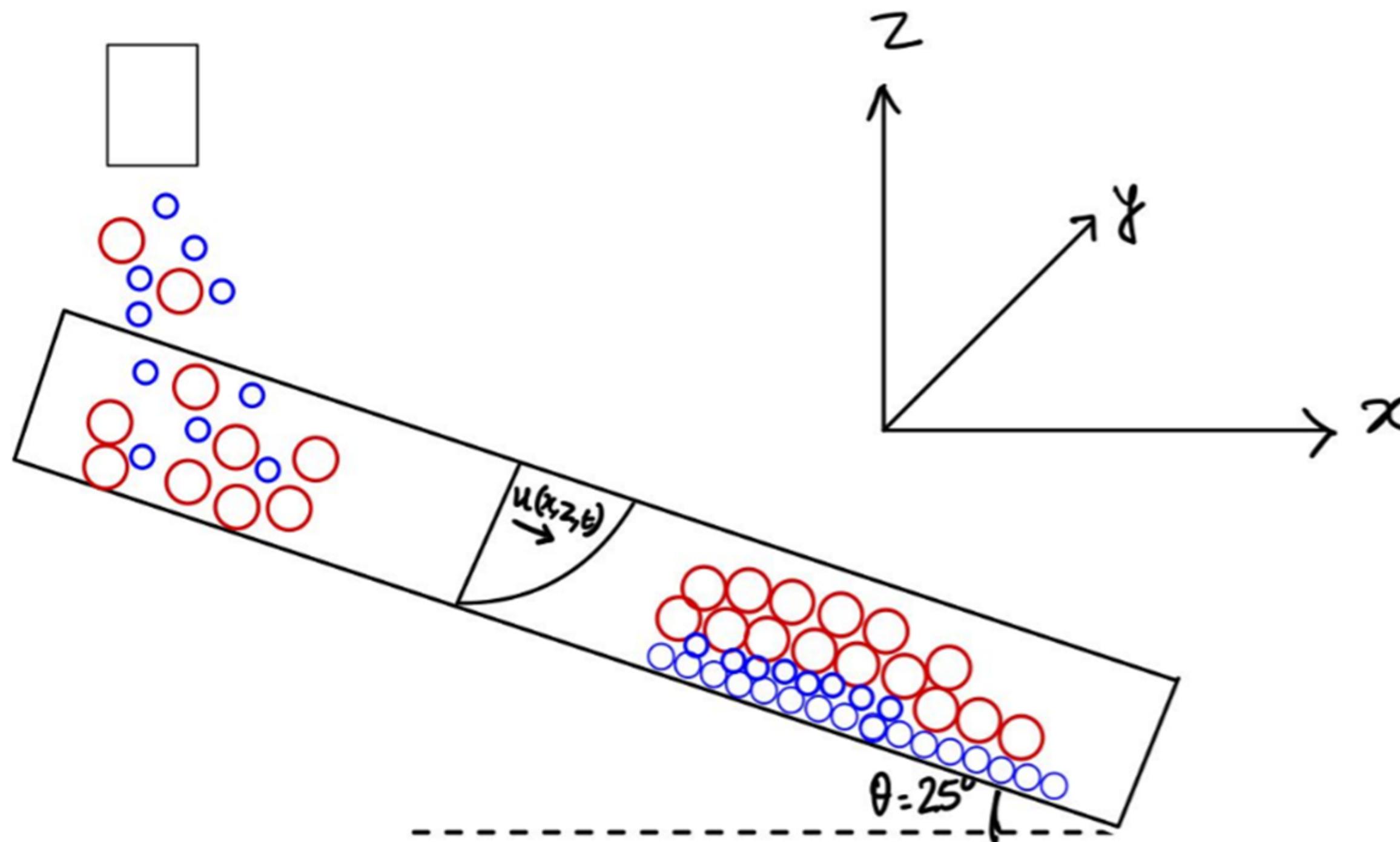
Simulation
Properties

Material
Properties

Interaction
Properties

	Coke-Coke	Coke-Glass	H Coke-H Coke	H Coke-Glass	H Coke-Coke
Restitution Coefficient	0.5	0.6	0.001	0.001	0.6
Sliding Friction	0.3	0.3	0.2	0.2	0.3
Rolling Friction	0.01	0.01	0.1	0.1	0.01

Schematic



Methodology

Bumpy
Chute
Making

Data
Retrieval

Results

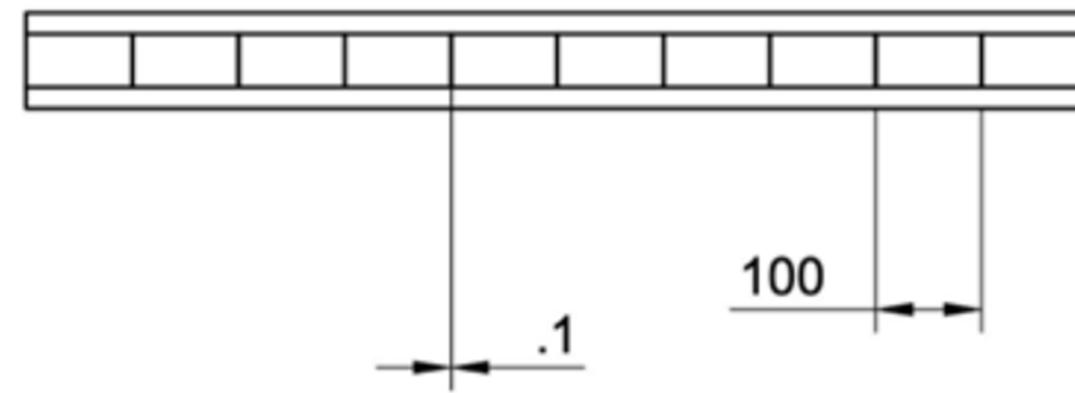
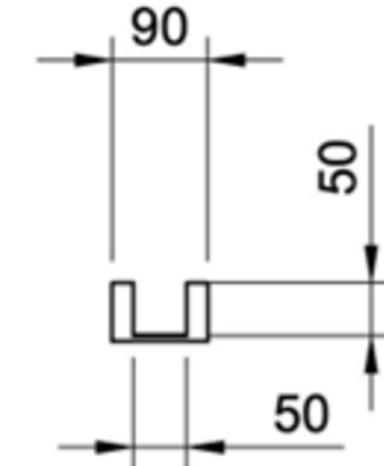
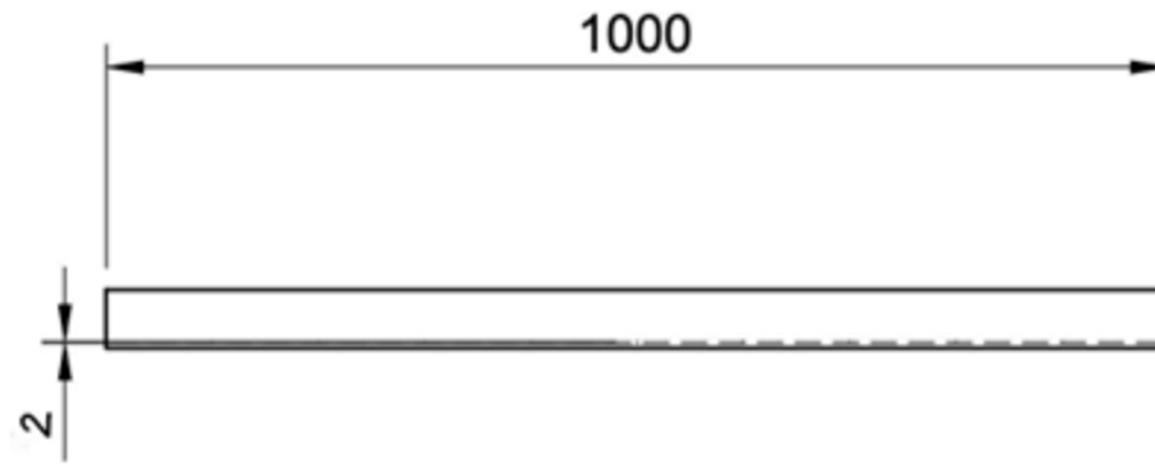
Methodology

Bumpy Chute Making

Data Retrieval

Results

- We use Autodesk Fusion to develop a long chute with equally spaced baffles with the below shown dimensions.
- The STL file is exported to MUSEN



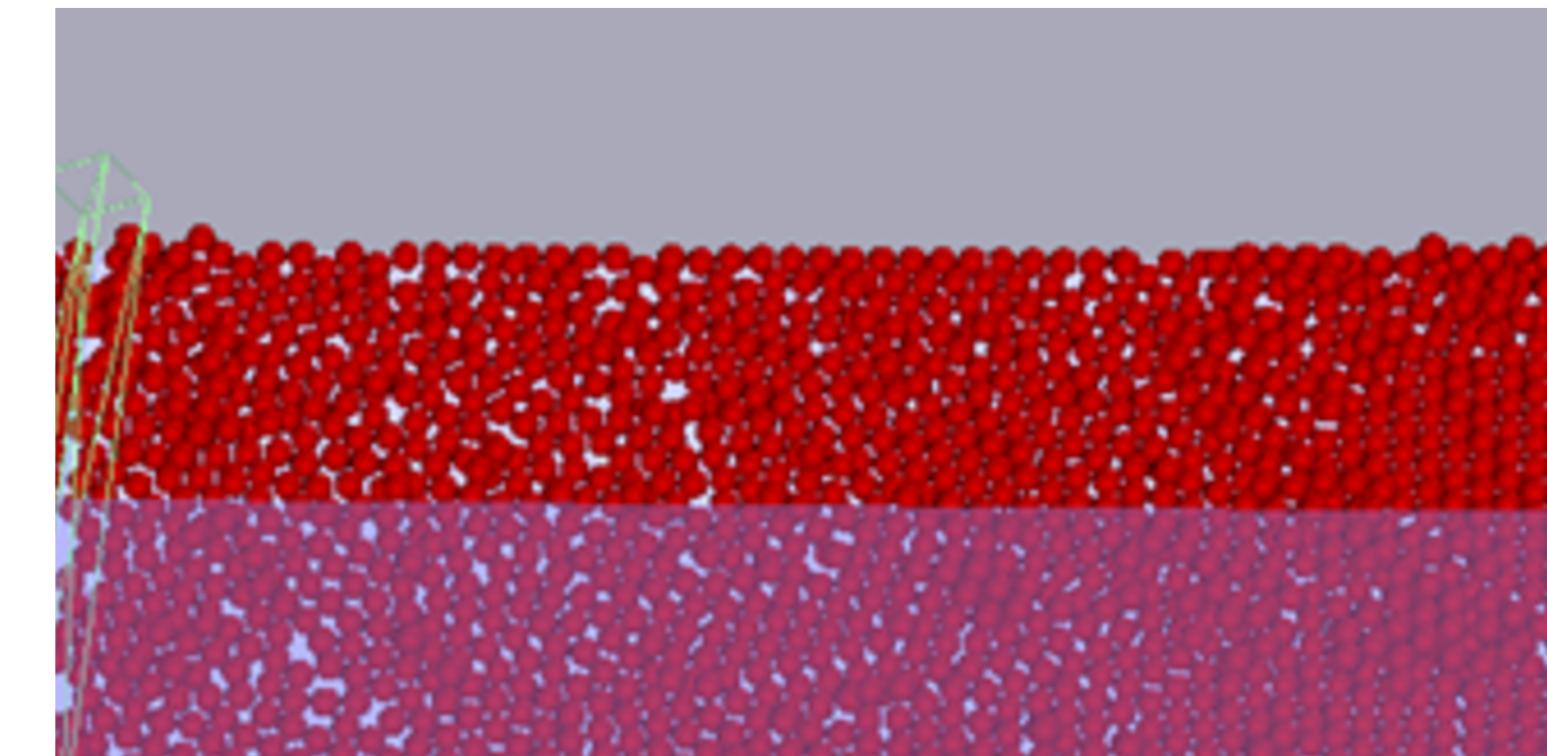
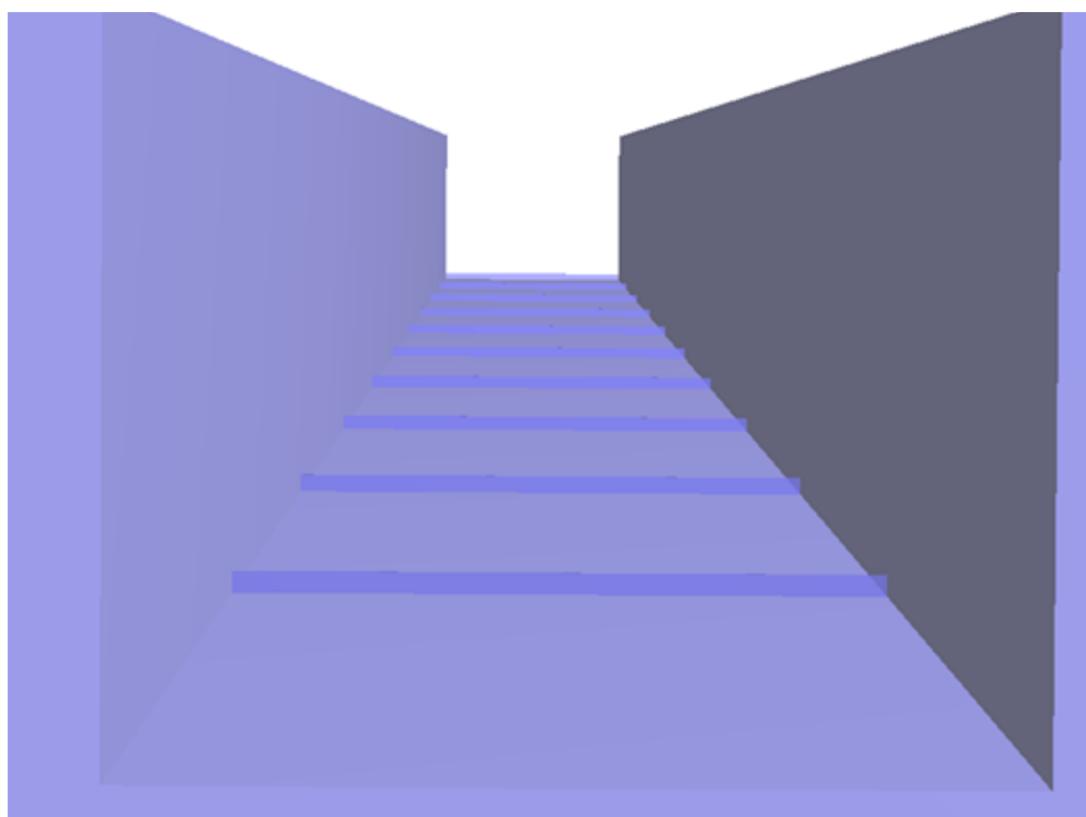
Methodology

Bumpy Chute Making

Data Retrieval

Results

- We use 10 generation volumes to generate which generate 2mm diameter particles to cover the base of the chute
- This forms the bumpy base on which we perform our analysis on.



Methodology

Bumpy Chute
Making

Data Retrieval

Results

Simulation Video

•[Link](#)

Link to Code

[Link](#)

Methodology

Bumpy Chute Making

- We generate an analysis box over the chute, making sure to keep the box over the bumpy base particles.
- The details of all the particles within the chute are exported as a text file.
- From this text file we extract the position coordinates and velocities along X, Y and Z axes into a data frame in python

Data Retrieval

Results

Object id	Dia (m)	x	y	z	Vx	Vy	Vz
192	2.0	61.4529	10.288400	-32.5134	0.057745	0.006391	-0.026560
195	2.0	335.1410	2.770710	-153.9060	0.173451	0.006024	-0.067080
243	2.0	-415.8060	-0.821557	187.8180	0.000082	-0.000046	-0.000003
245	2.0	-407.0930	12.307500	182.2080	-0.000314	0.000073	-0.000171
292	2.0	-408.6980	15.631600	184.4040	-0.000054	-0.000105	0.000062
...
956376	1.0	-411.9450	1.926480	225.4310	0.000000	0.000000	-0.117249
956424	2.0	-409.5200	-16.842000	222.9930	-0.006353	-0.142296	-0.370995
956448	1.0	-402.2590	-4.662650	221.0030	-0.199074	-0.083866	-0.719992
956471	1.0	-405.3730	-12.422100	220.8350	0.115690	0.057176	-0.166836
956656	1.0	-411.7920	6.572520	225.6590	-0.206153	0.053614	-0.150035

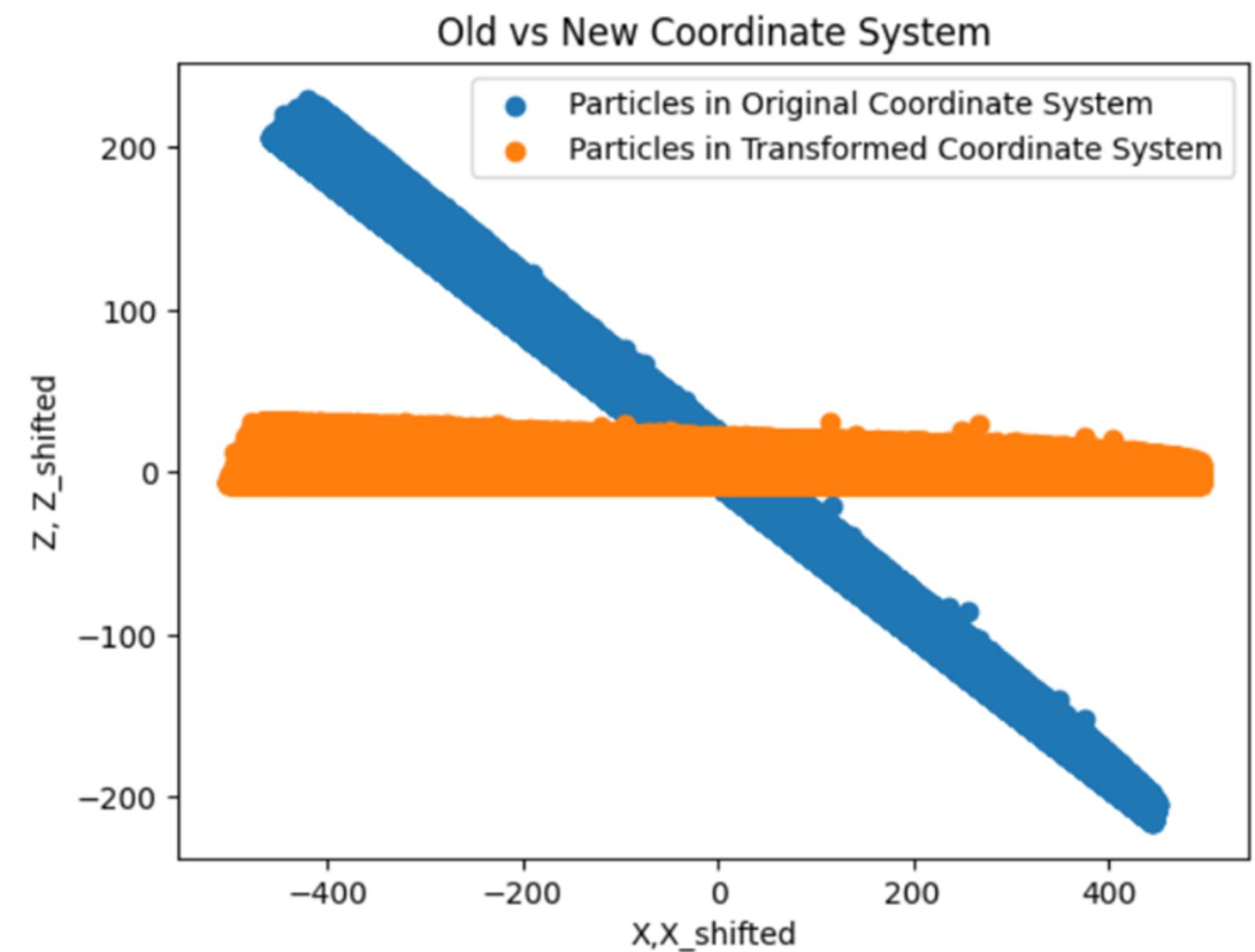
Methodology

Bumpy Chute Making

Data Retrieval

Results

- For further analysis, we divide the space into 3D grids.
- In order to simplify the analysis process, we perform all calculations on an axis that is turned 25° clockwise from the original axis.



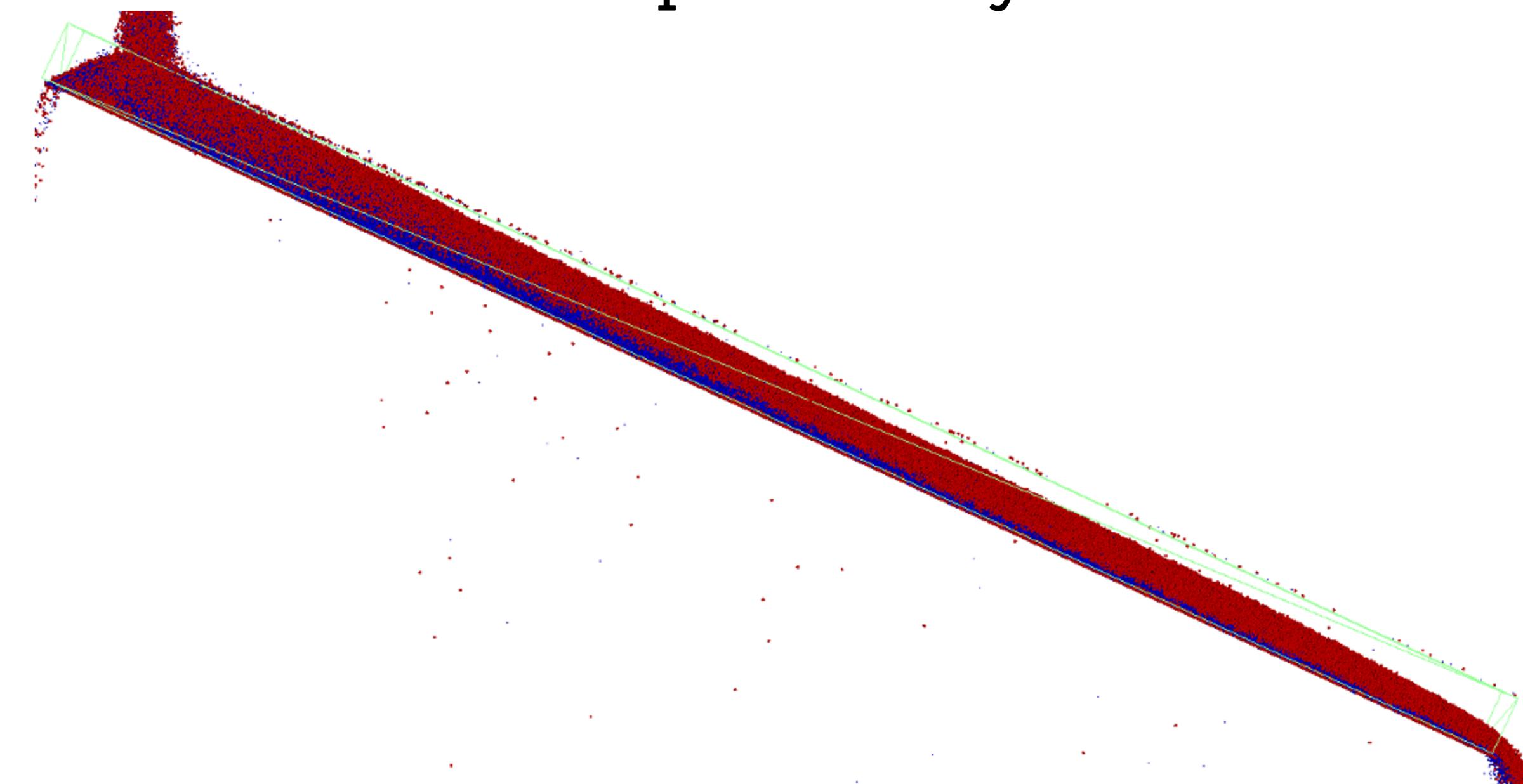
Methodology

Bumpy Chute
Making

Data Retrieval

Results

Grid Setup & Analysis



Methodology

Bumpy Chute
Making

Data Retrieval

Results

Grid Setup & Analysis

- We divide the space into 3D grids.
- The grid size is kept at 5mm
- The total grids along an axis is given by below equation:

$$x_bins = \text{int}((x_{\max} - x_{\min}) / \text{grid_size}) + 1$$

- A particle is assumed to belong fully to a grid, if its center is in that grid.
- We find number density, packing fraction, concentration and variations in center of mass and velocity.
- In order to ignore the effect of particles that are not part of the heap, we also use gaussian smoothening, in order to prevent sudden spikes due to particles that might be bouncing but be inside the grid.

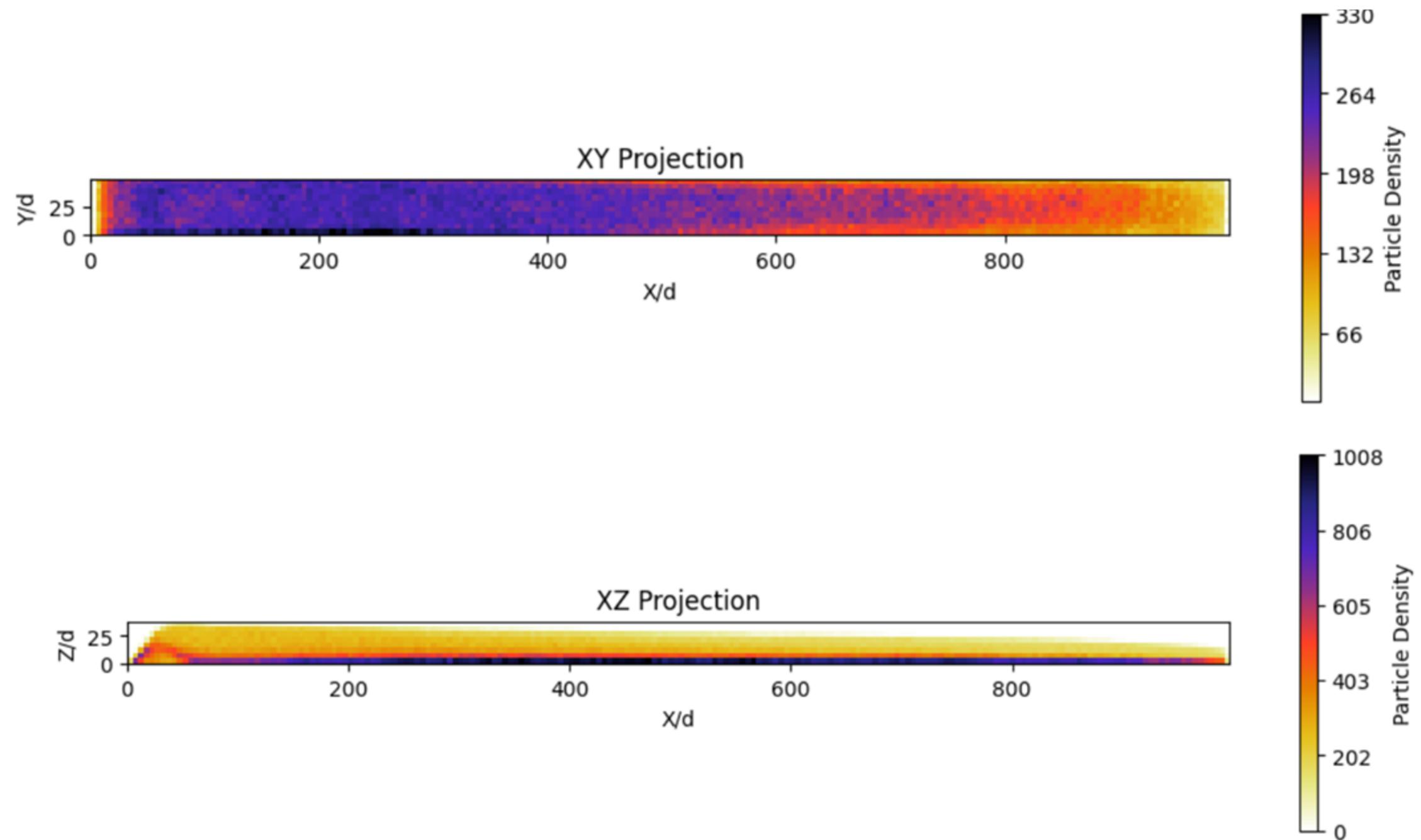
Methodology

Bumpy Chute
Making

Data Retrieval

Results

NUMBER
DENSITY



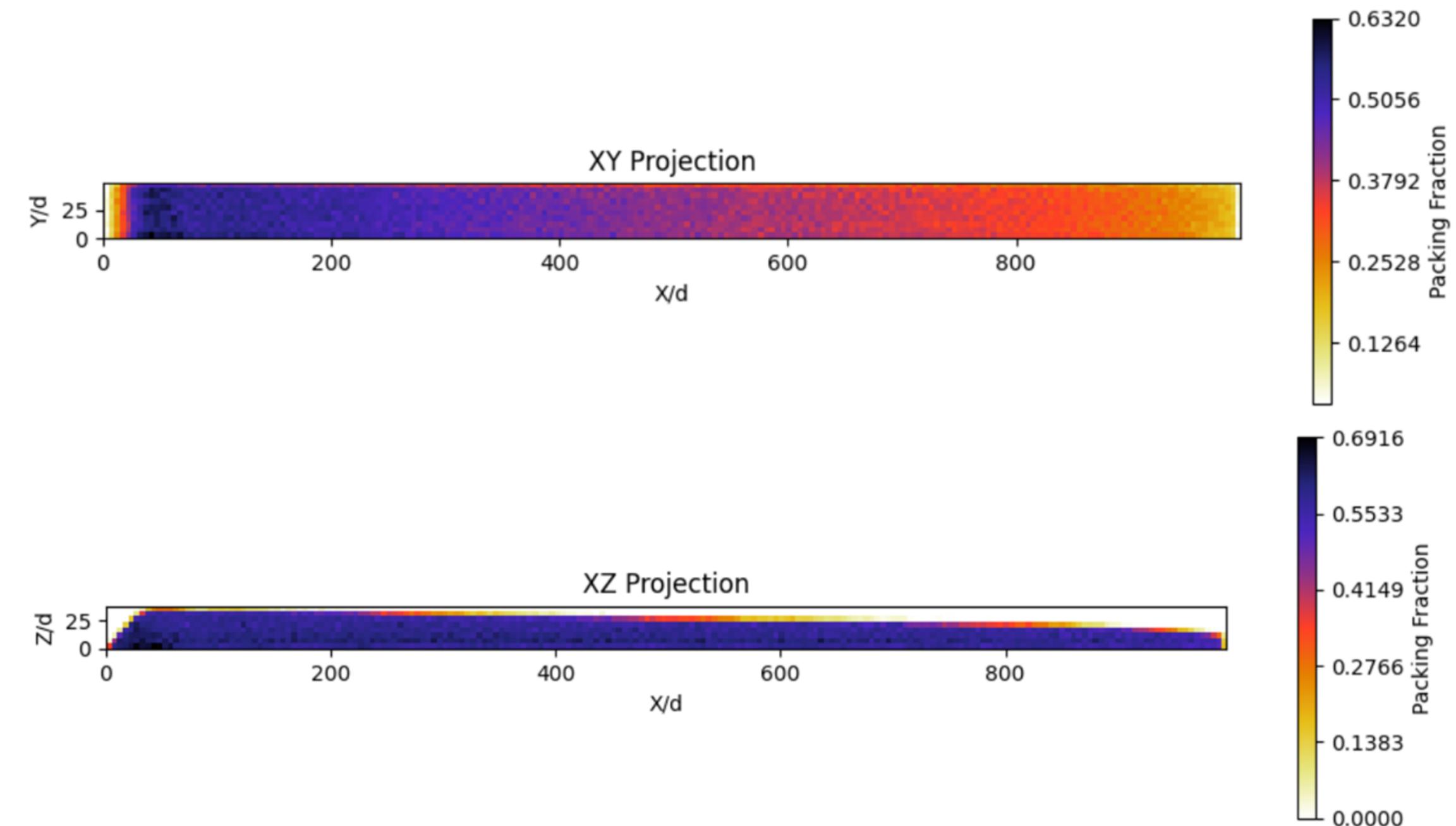
Methodology

Bumpy Chute
Making

Data Retrieval

Results

TOTAL
PACKING
FRACTION



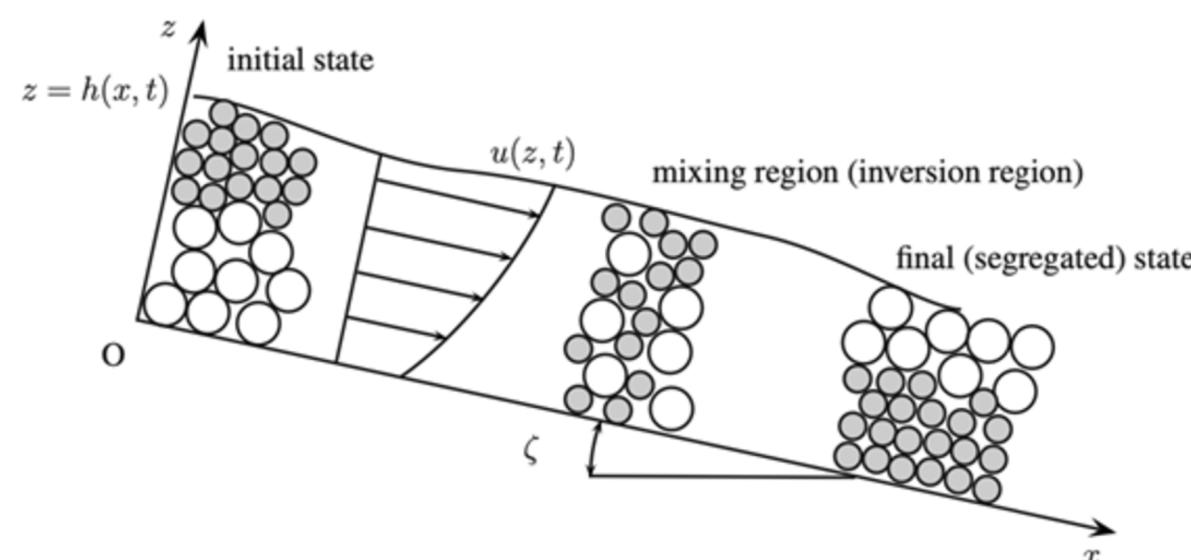
Methodology

Bumpy Chute
Making

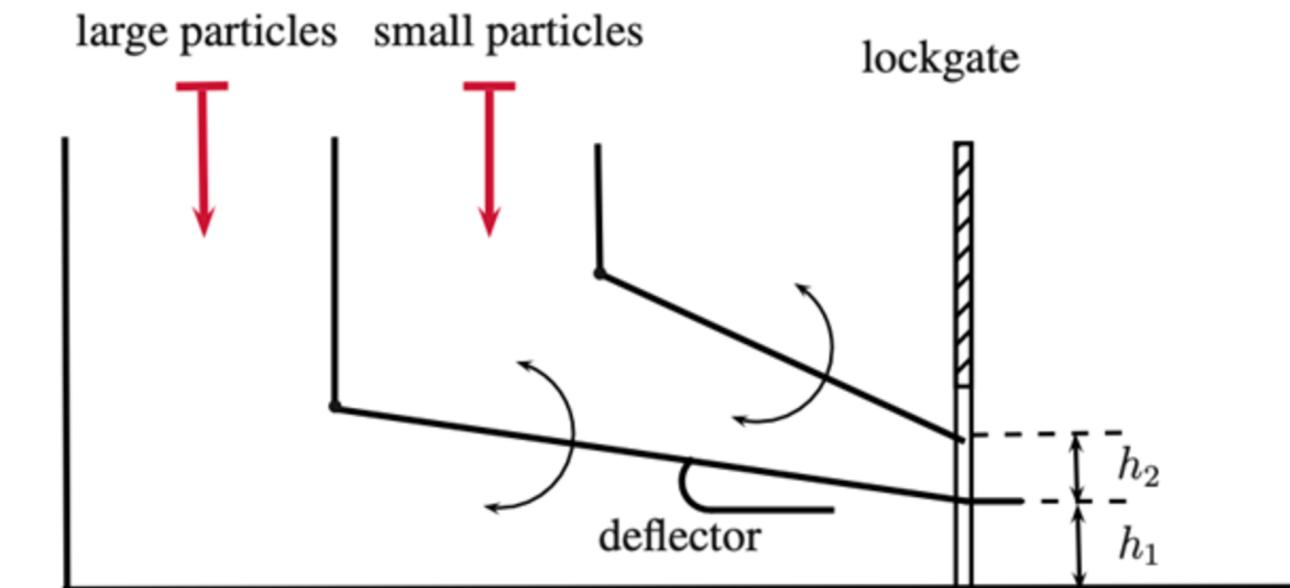
Data Retrieval

Results

- We compare our results with Wiederseiner et al.[[Link](#)], which has a similar objective but a slightly different setup.
- The feeding system used by Wiederseiner et al. is different from our simulation setup.
- The authors perform experiments on glass beads of diameter 1 and 2mm



Credits:Wiederseiner et al.



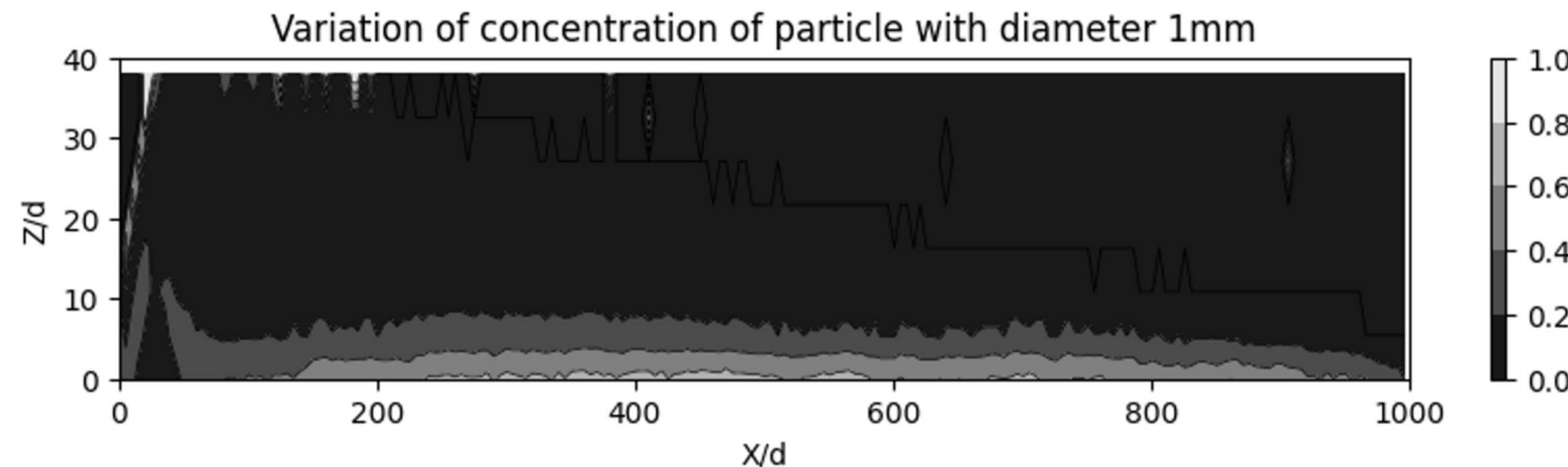
Methodology

Bumpy Chute
Making

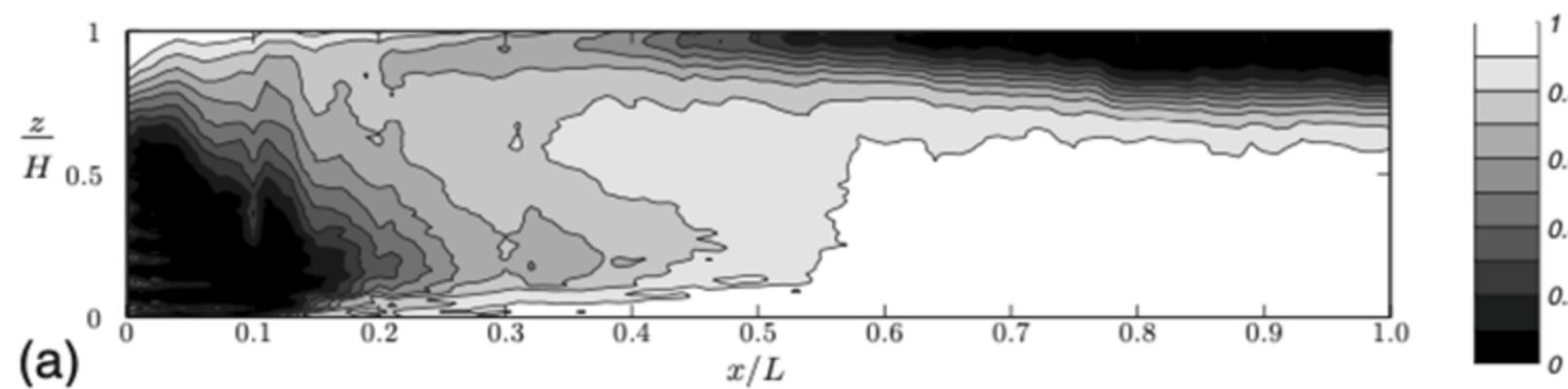
Data Retrieval

Results

Concentration
Contour
(1mm particle)



Reference from
Paper



Credits:Wiederseiner et al.

Methodology

Bumpy Chute
Making

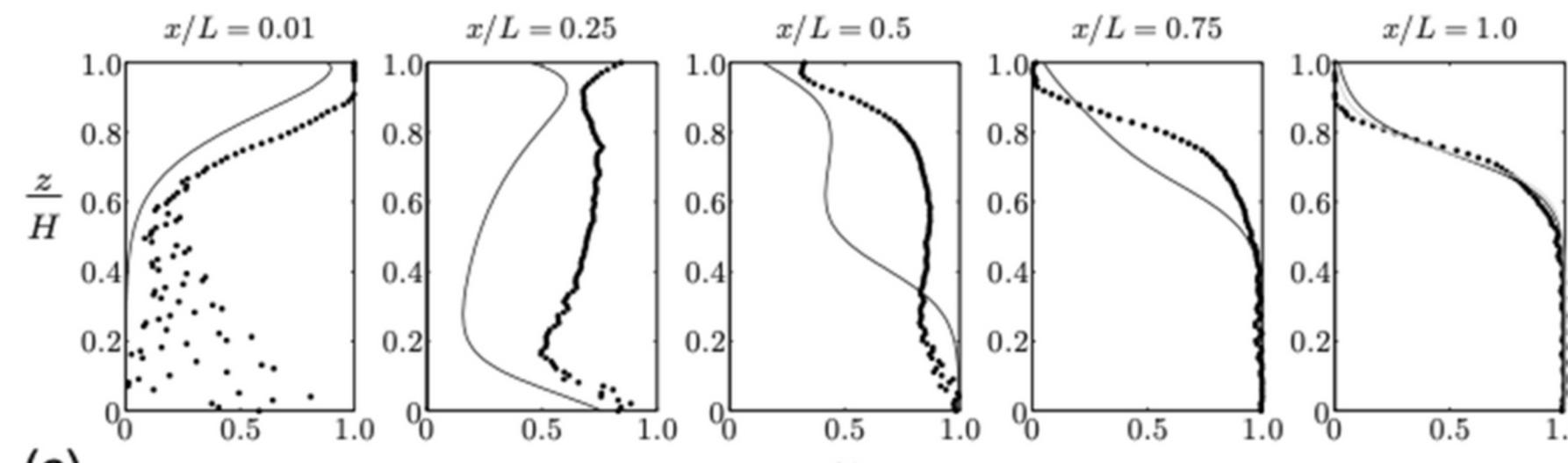
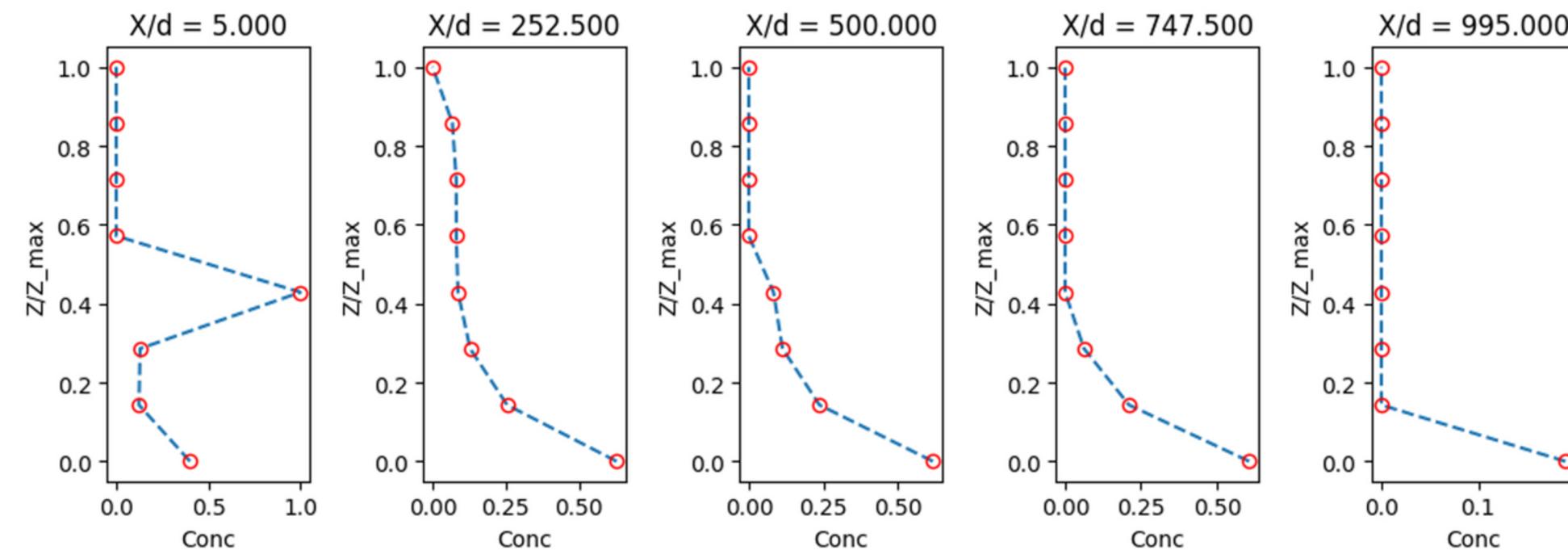
Concentration
Profile
(1mm particle)

Reference from
Paper

Data Retrieval

Results

Variation of concentration of particle with diameter 1mm with Z at different points along the Chute



Credits:Wiederseiner et al.

Methodology

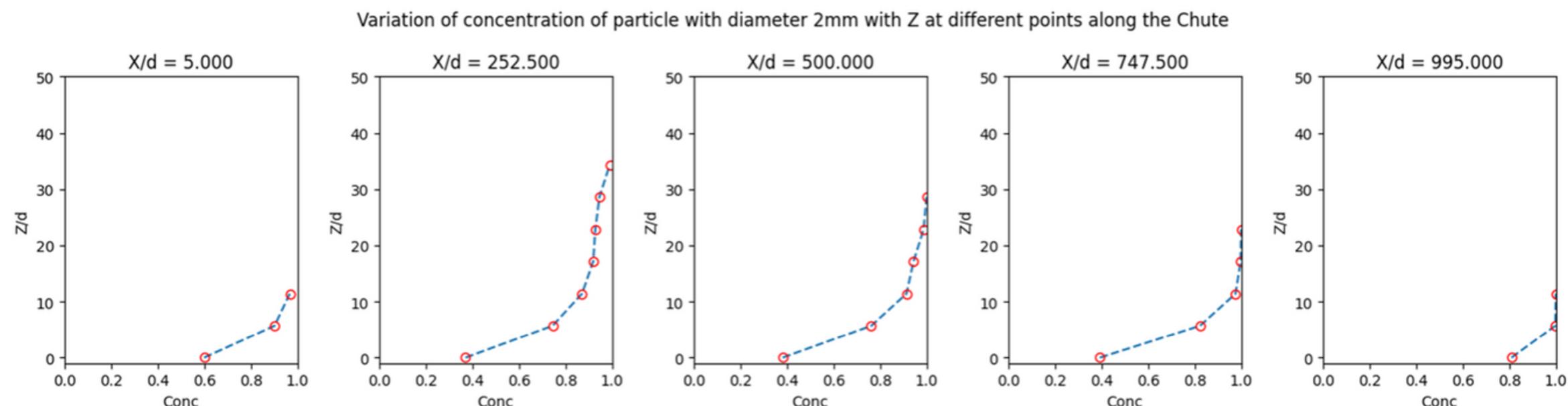
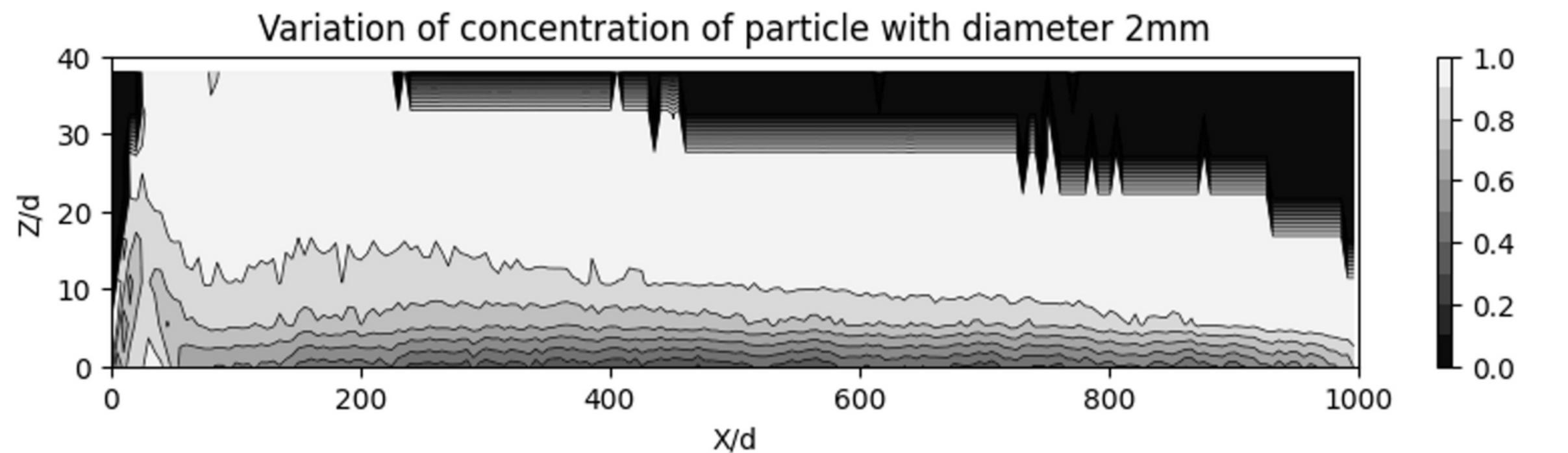
Bumpy Chute
Making

Data Retrieval

Results

Concentration
Contour
(2mm particle)

Concentration
Profile
(2mm particle)



Methodology

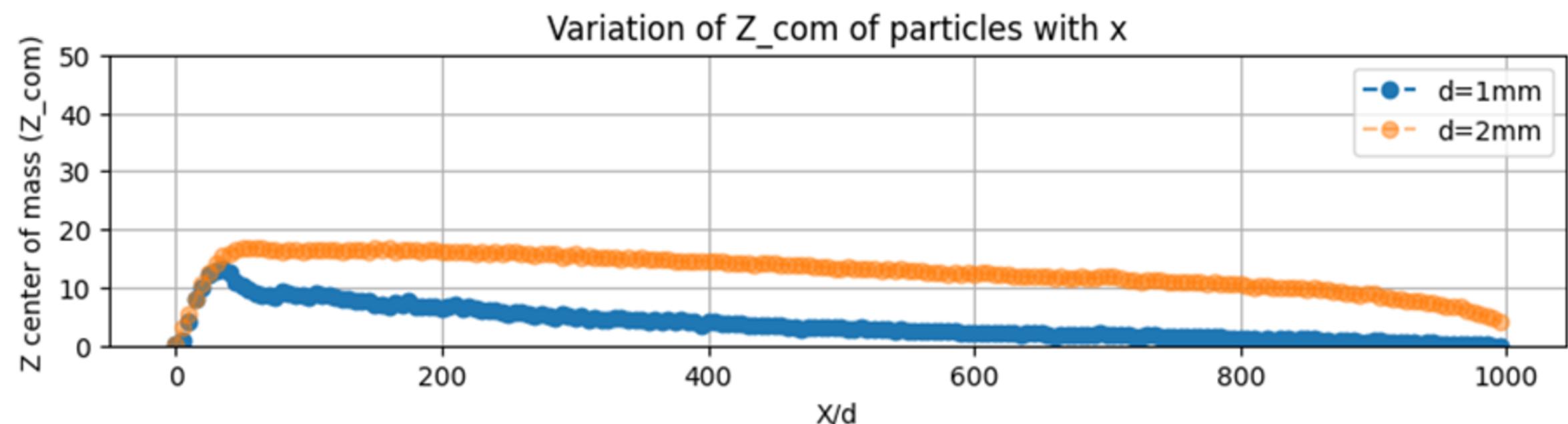
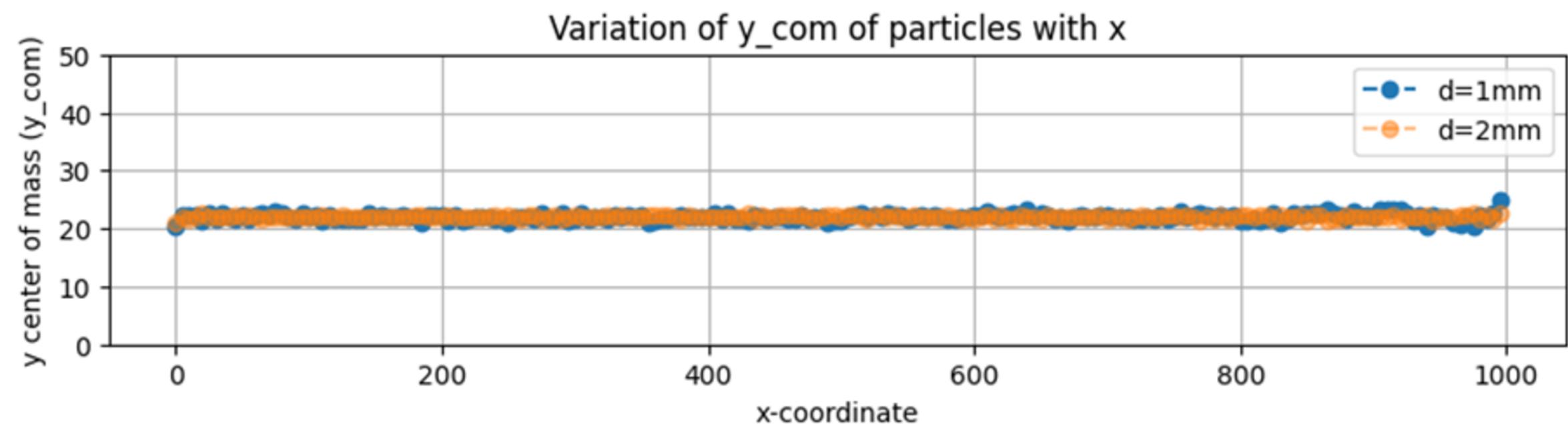
Bumpy Chute
Making

Position of Y-COM
(Center of Mass)

Position of Z-COM

Data Retrieval

Results



Methodology

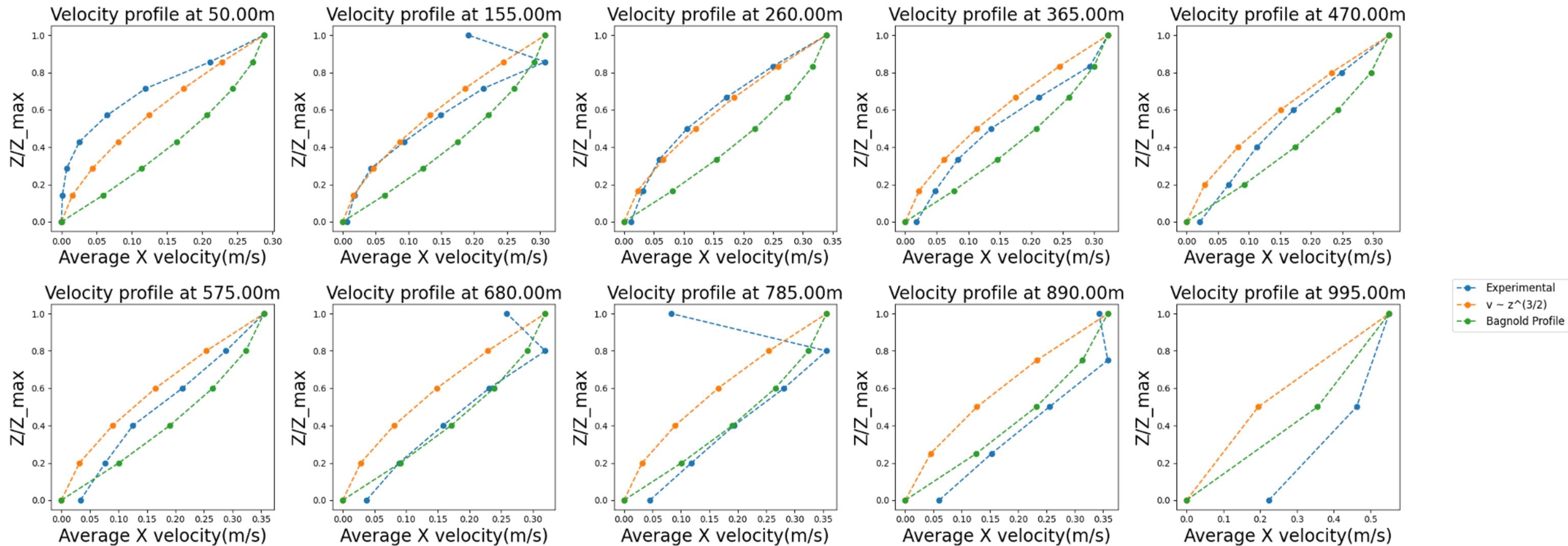
Bumpy Chute Making

Data Retrieval

Results

VELOCITY
PROFILE

Variation of Velocity with Z/d for various X/d

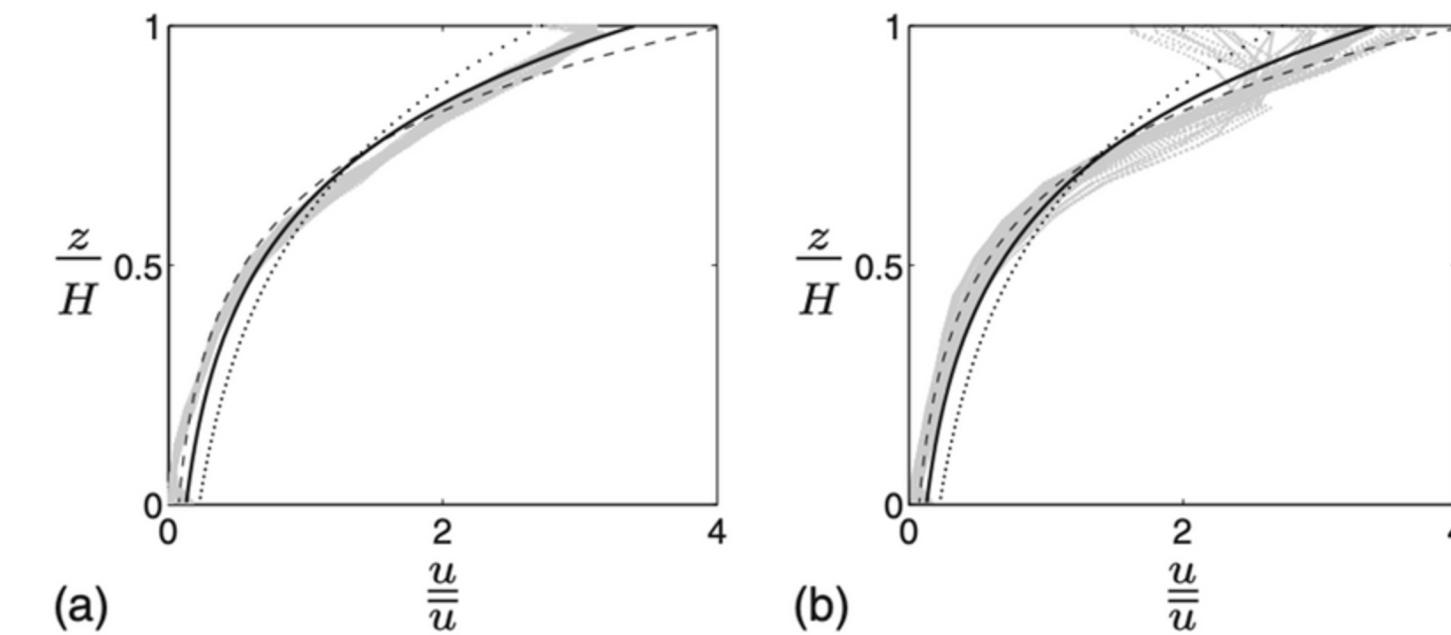
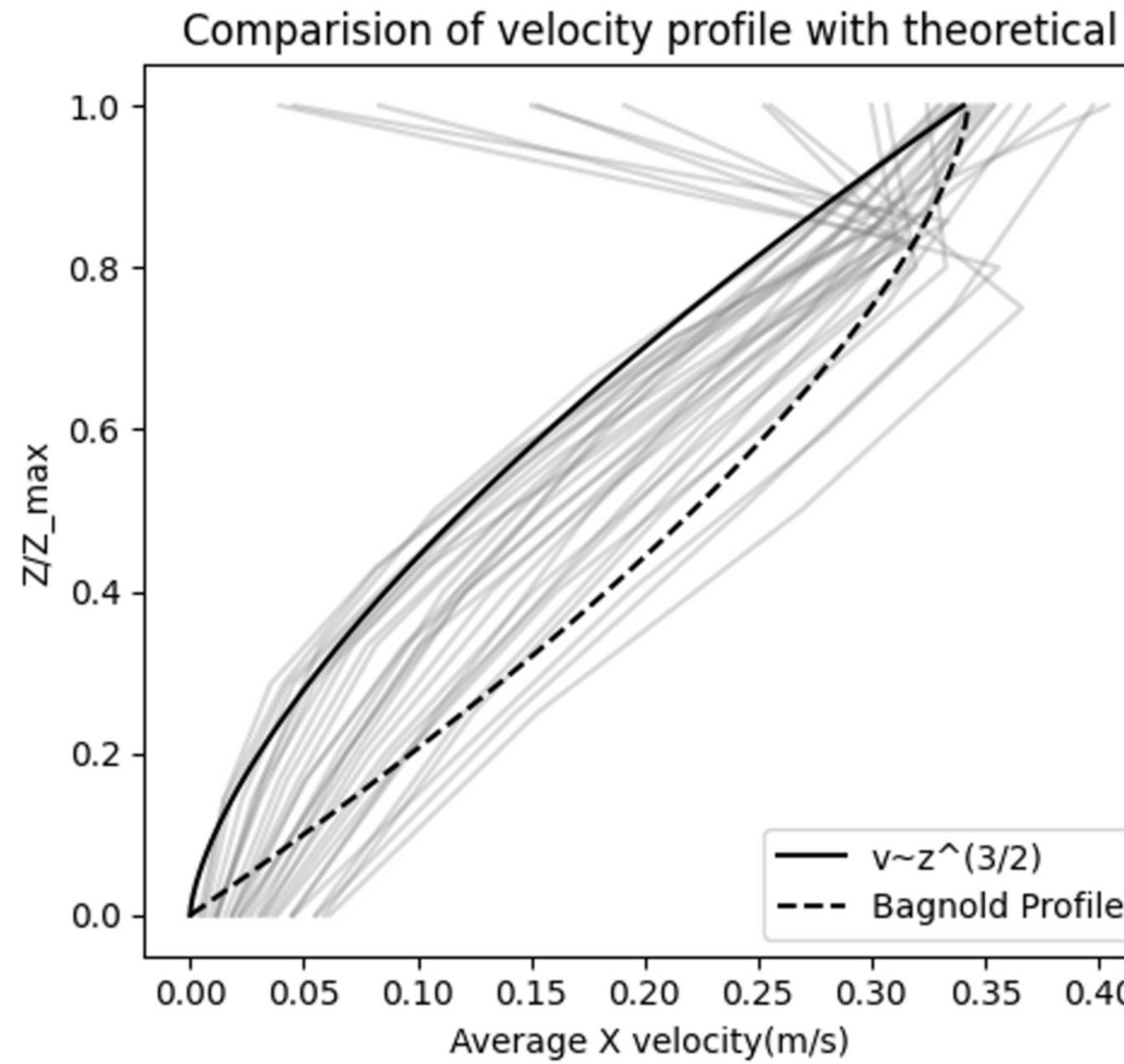


Methodology

Bumpy Chute
Making

Data Retrieval

Results



Credits: Wiederseiner et al.

THANK YOU

References

- Sébastien Wiederseiner, Nicolas Andreini, Gaël Épely-Chauvin, Gaudenz Moser, Mathieu Monnereau, JMNT Gray, and Christophe Ancey. Experimental investigation into segregating granular flows down chutes. *Physics of Fluids*, 23(1), 2011.