Statistical properties of disc assemblies on an air blowing table

R. Sadah A. Valance R. Delannay
Institut de Physique de Rennes, UMR CNRS 6251, Université de Rennes ,35042 Rennes cedex France

Introduction

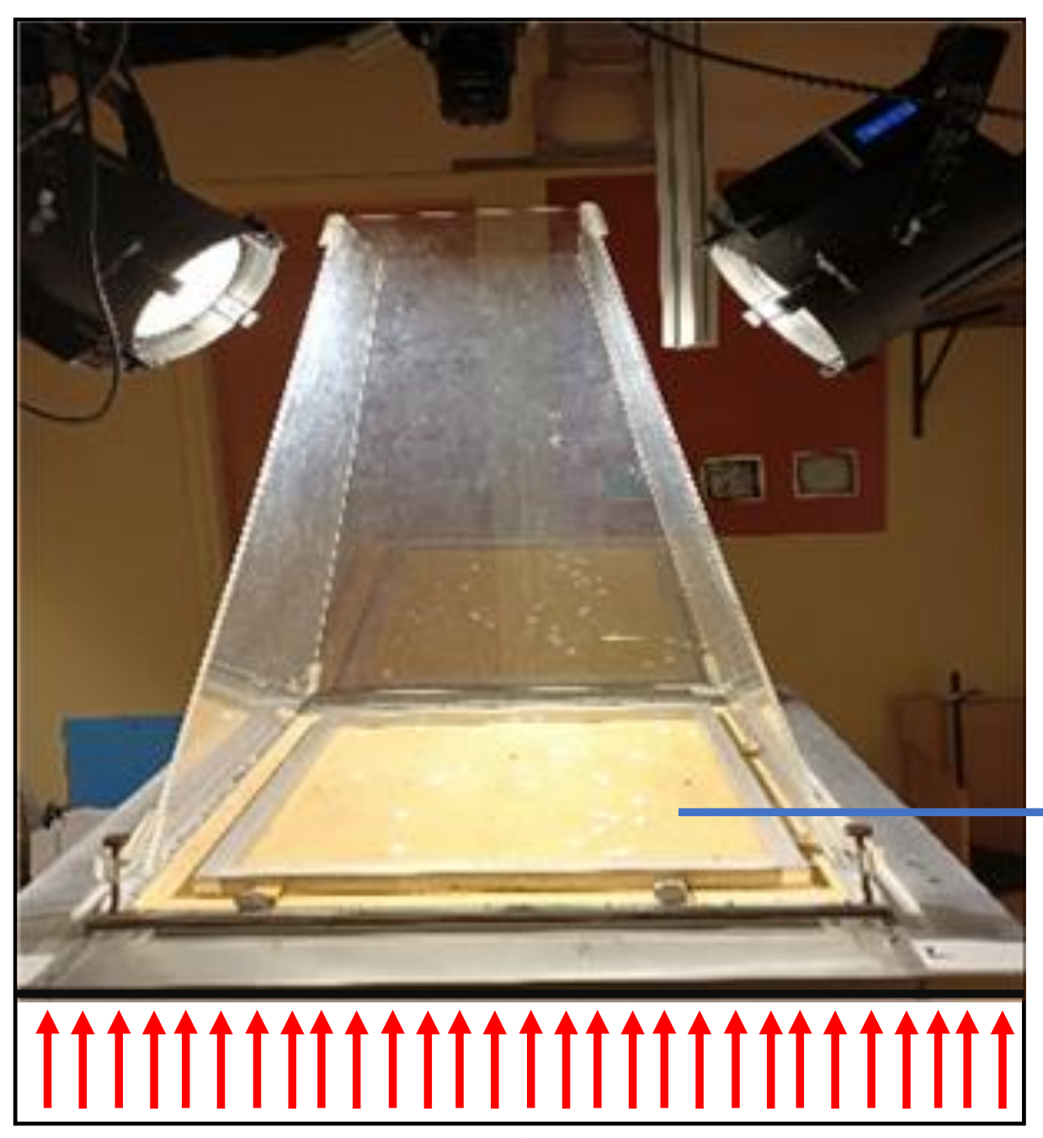
Granular gases are assemblies of colliding macroscopic particles.
They differ from molecular gases as collisions are dissipative: energy input is required to maintain a gaseous state.
Granular gases are well-described by a thermal-like kinetic theory in which the velocity fluctuations play the role of temperature.
Granular gases exist in a **nonequilibrium steady state**.
Whether **state variables (such as temperature)** can be defined generically for non-equilibrium steady states remains an open question.

Issues

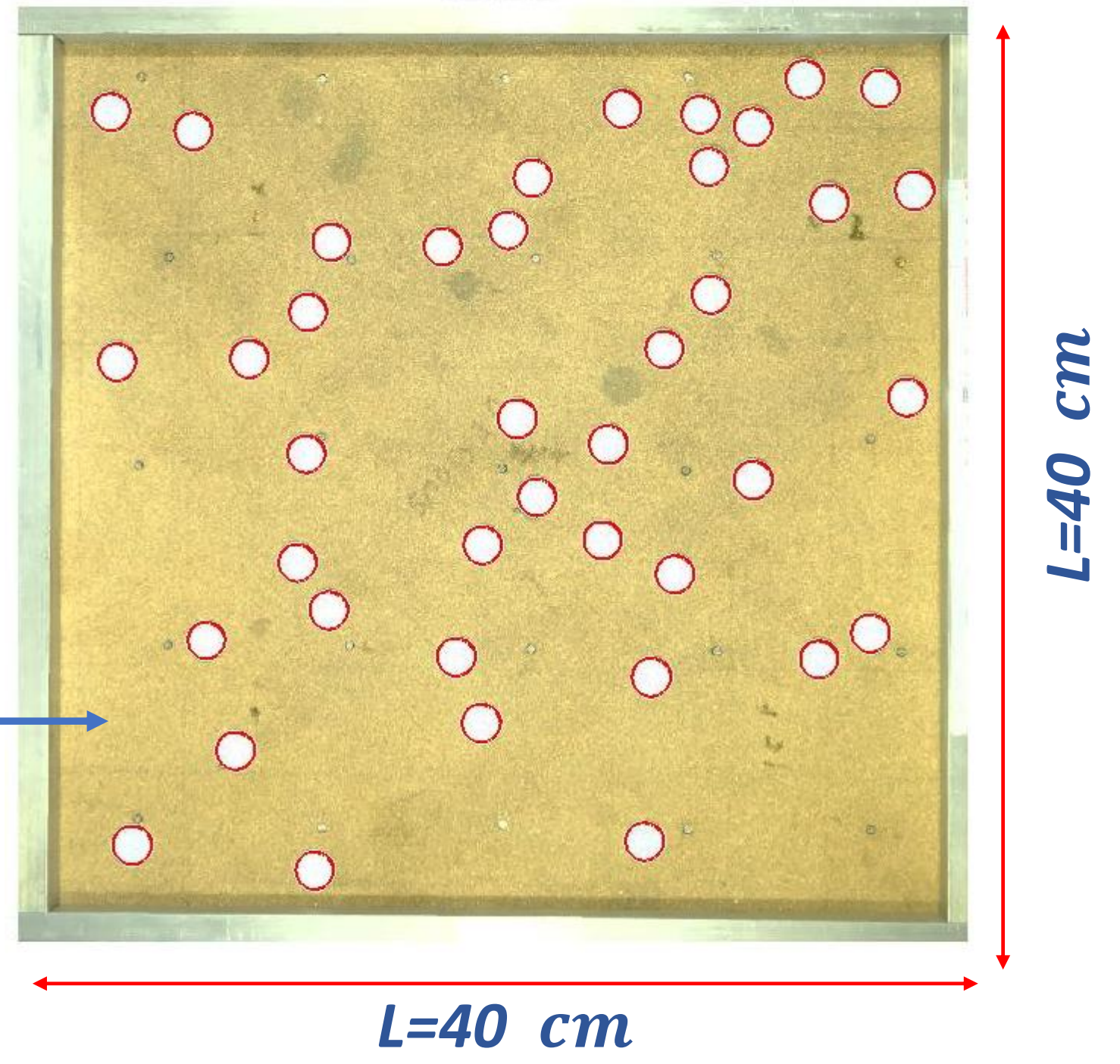
Stationary state: Does it depend on energy injection?
Velocity distribution: Gaussian or non-Gaussian velocity distributions?
Molecular chaos: particle velocities are uncorrelated or correlated?
Equipartition of energy: equally or nonequally partitioned kinetic energy in mixtures of different particles?
Temperature: Can we define a granular temperature behaving like a true temperature?

Experimental setup: Air table

Side view



Top view



Set-up: horizontal air table.
Energy injection through a relatively uniform flow of air via a porous plate (sintered bronze).

Boundary: square metallic frame with side lengths of 40 cm

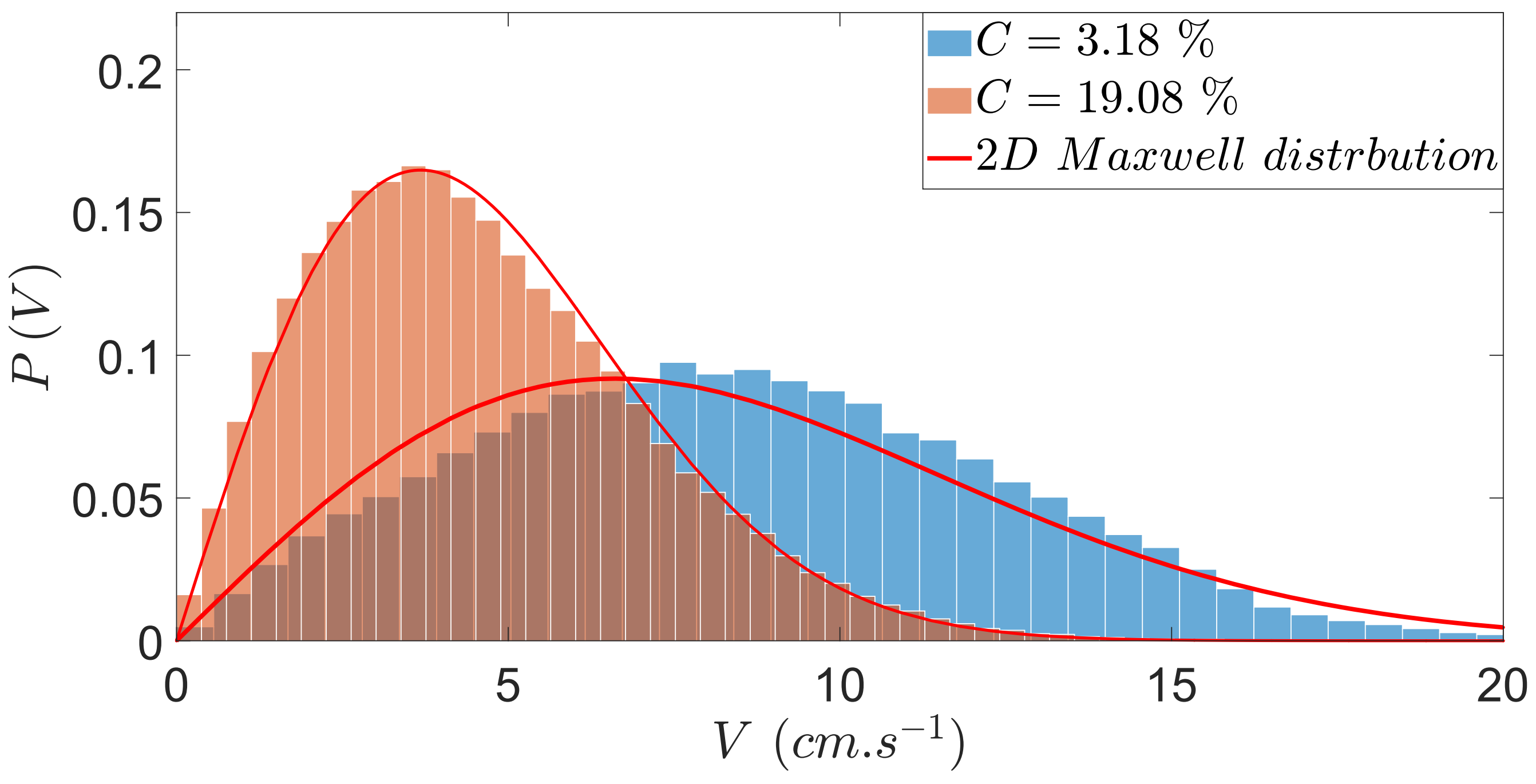
Particles: collection of polystyrene discs floating on the porous plate and interacting mainly through binary collisions

Parameters

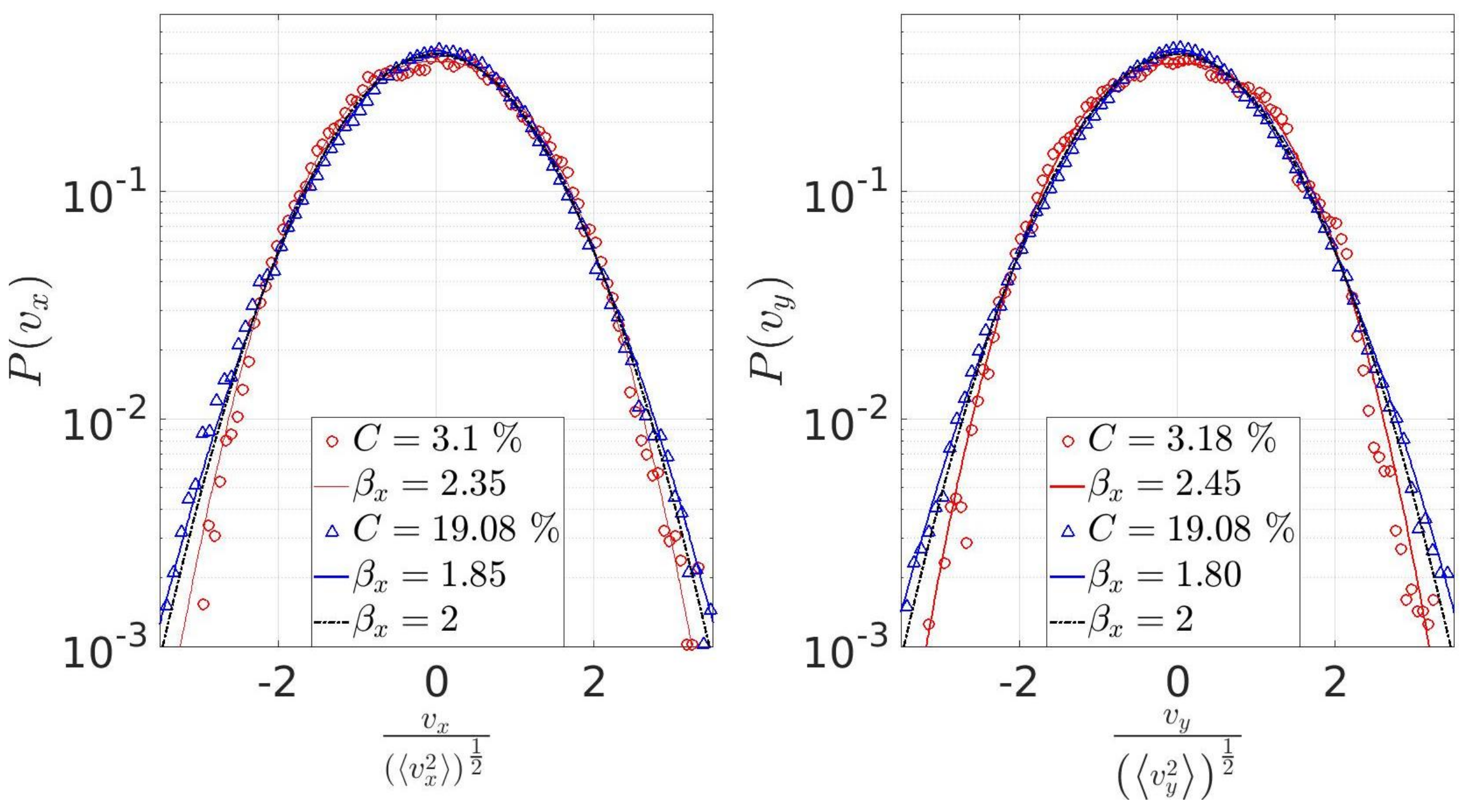
-System size: **L=40** cm
-Disc diameter $d = 1.8, 2.4$ & $3.0\ cm$
- Disc thickness: $W = 0.1\ cm$
-Number of particles: **N** (1-500)
-Surface concentration: $n = \frac{N}{L^2}$
-Area fraction: $C = n\pi\left(\frac{d}{2}\right)^2$
-Air speed (at center of the table)
$v_{air} = 0.8 - 2.0\ m.s^{-1}$

Velocity distribution

Distribution of the modulus of the particle velocity V for low (3%) and higher (19%) area fraction
$(d = 1.8\ cm, v_{air} = 0.8\, m.s^{-1})$



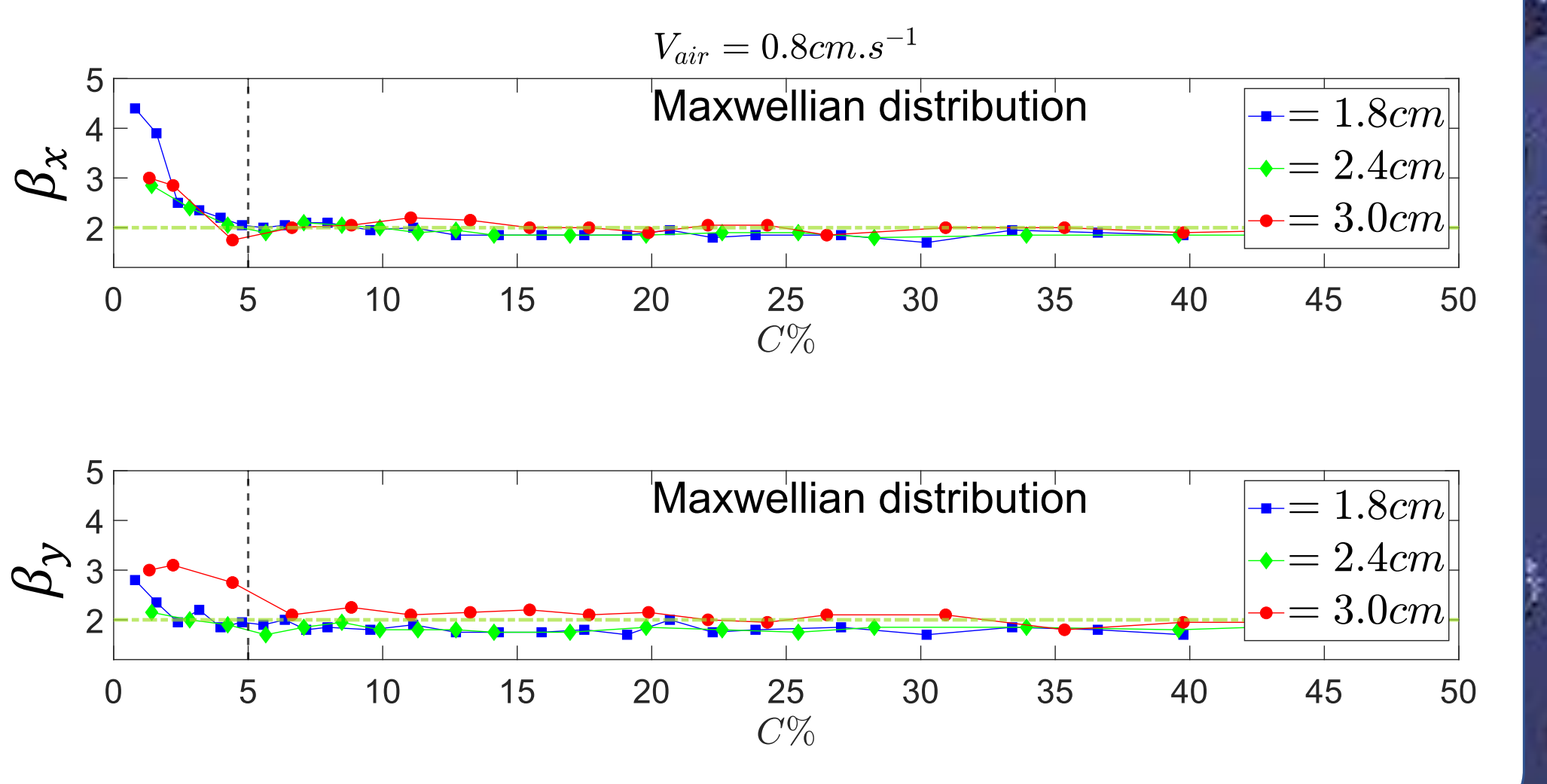
Distribution of each velocity component v_x and v_y for low (3%) and higher (19%) area fraction.
$(d = 1.8\ cm\ v_{air} = 0.8\, m.s^{-1})$



Generalized normal distribution:

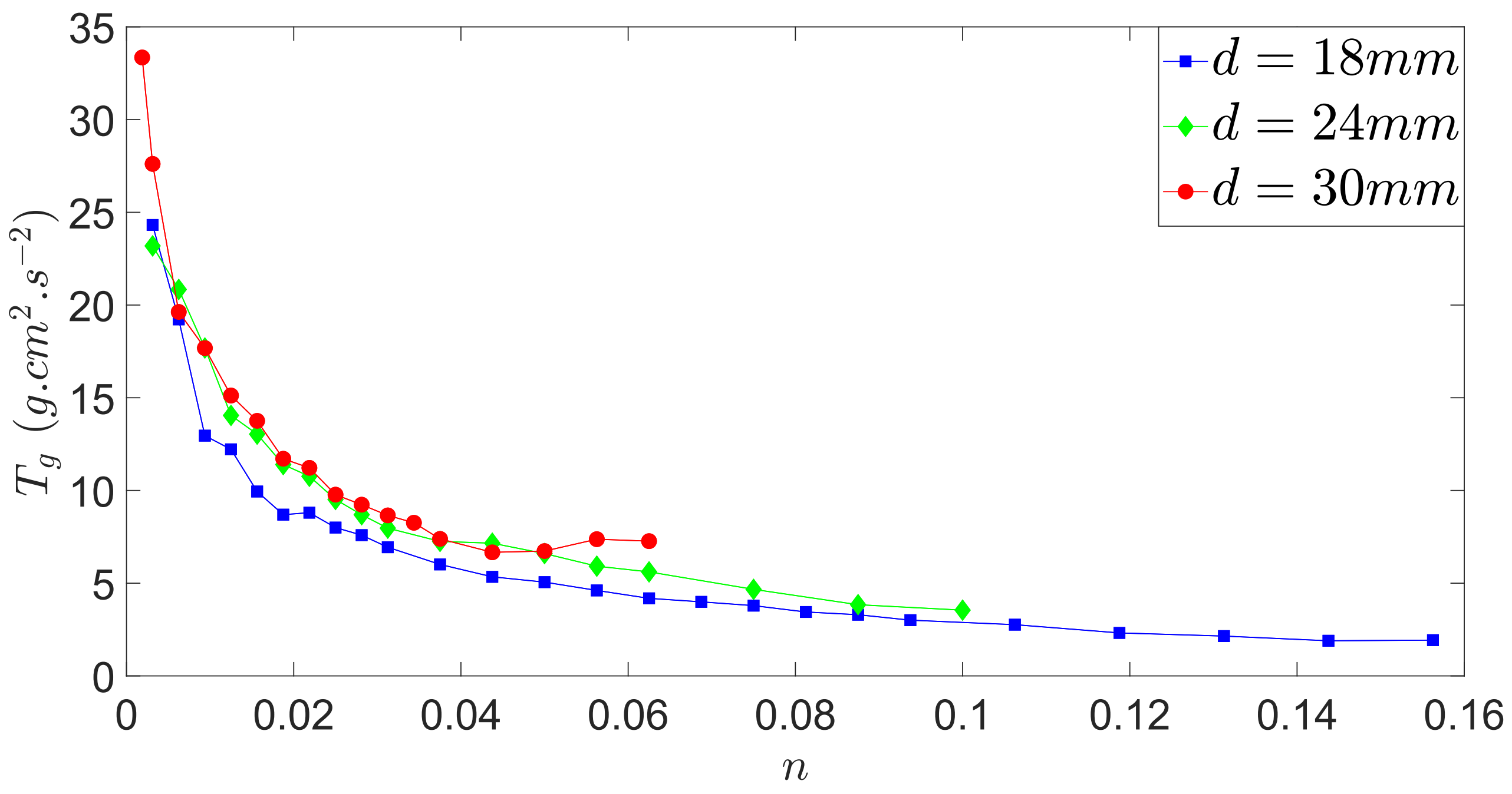
$$P(v) = \frac{\beta}{2\alpha\Gamma(\frac{1}{\beta})} e^{-(\frac{|v|}{\alpha})^{\beta}}$$

With α and β two free parameters



Granular temperature T_g

$(v_{air} = 0.8\, m.s^{-1})$

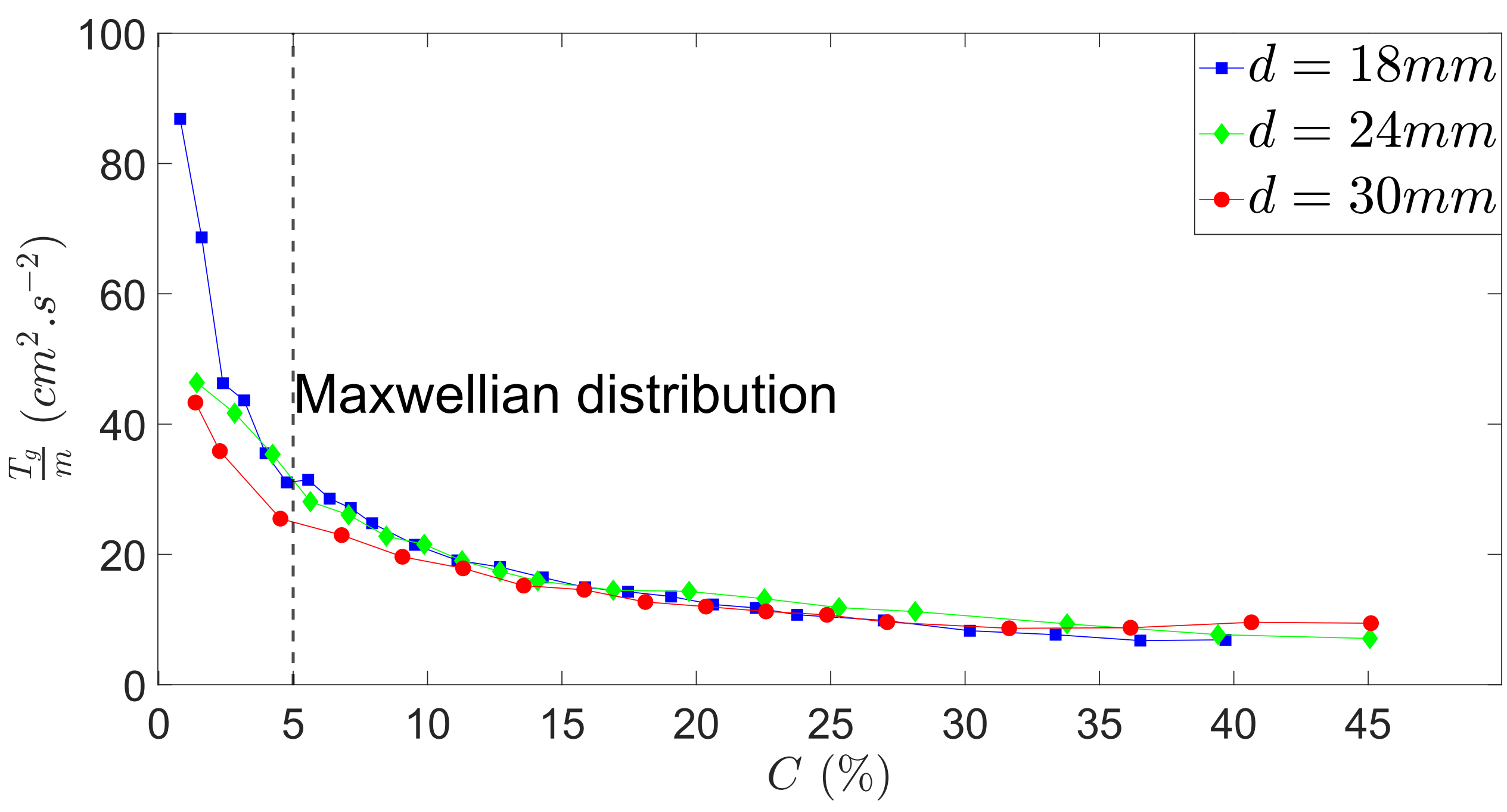


⇒ T_g Is Independent of m

Granular Temperature: $T_g = \frac{m\langle V^2\rangle}{2}$

- **T_g decreases with increasing surface concentration n**
This could be explained by the fact that when n increases the frequency of collision increases.
- When v_{air} and n are prescribed, T_g is independent of disc size (mass).

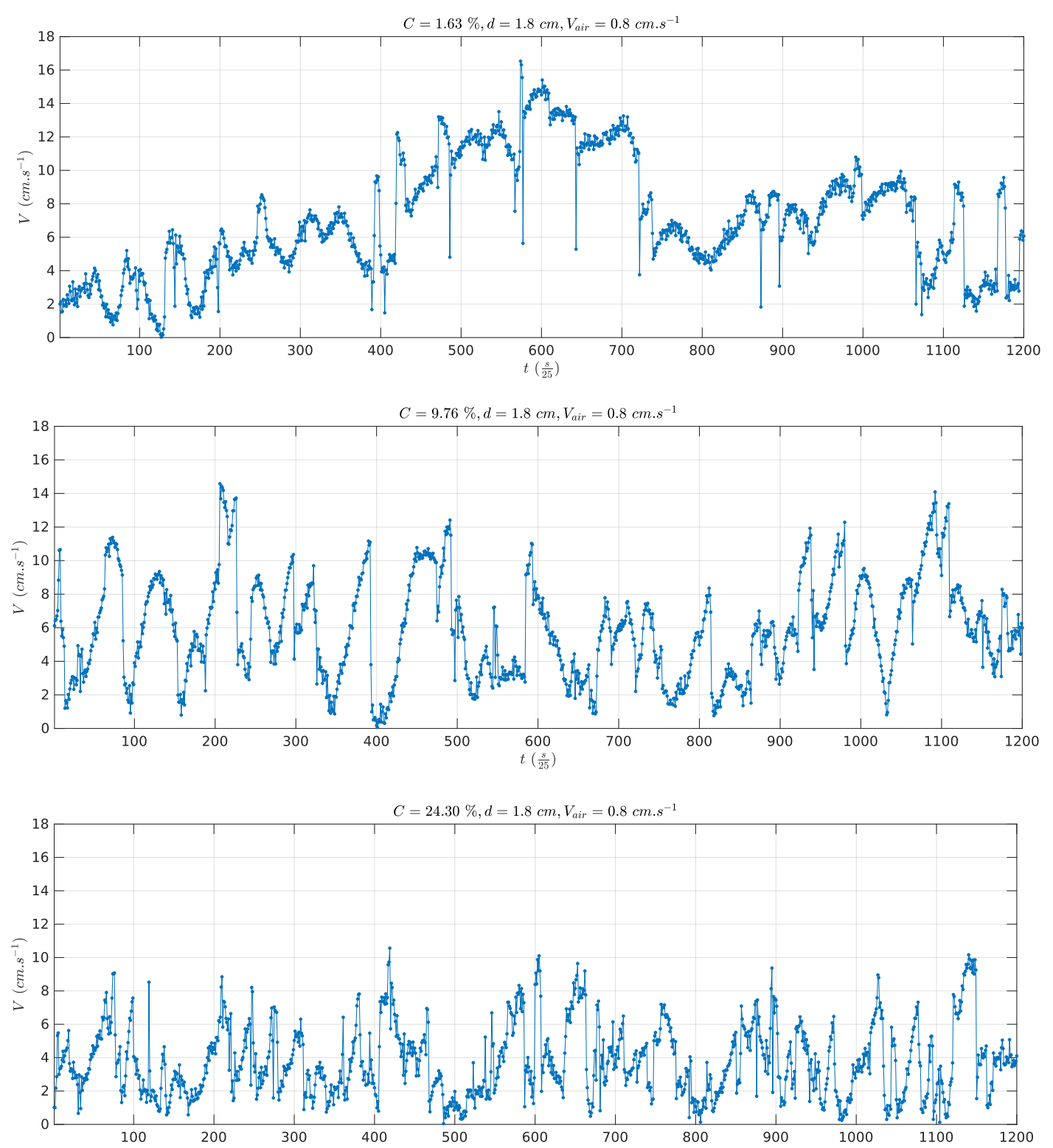
- **If we prescribe v_{air} and C, T_g/m is independent of particle size.**



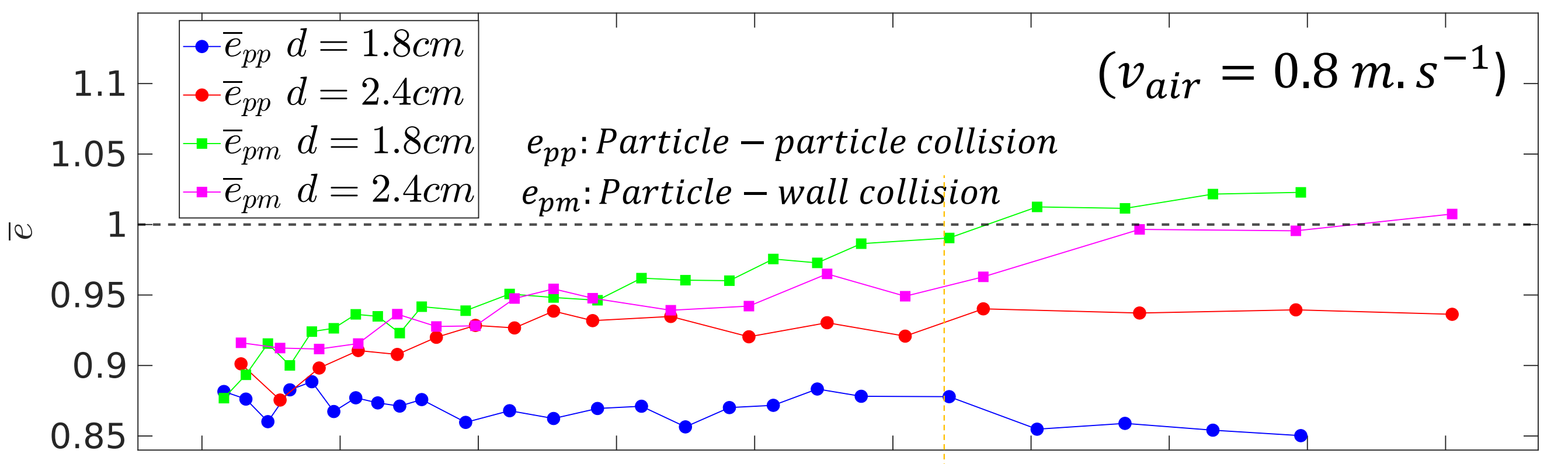
$T_g \propto m \Rightarrow \langle V^2\rangle$ Is independent of m

Collisions

Time evolution of the velocity of a particle



Variation of normal restitution coefficient $\bar{e}$ of a particle with C



- Discontinuities in the evolution of kinetic energy reveal collisions
- For $C > 25\%$, collisions are generally not independent.
- $\bar{e}_{pp}$ does not vary much with C, collisions involving smaller discs tend to be more dissipative.
- $\bar{e}_{pm}$ increases slightly with C but does not depend on the disc size.

Conclusions and open issues

Conclusions:
-Velocity distribution obey Maxwell-Boltzmann.
-At fixed n, T_g Independent of m. At fixed C, $T_g \propto m$
Open issues:
-Energy exchange: identifying when a disc gains and loses energy
-Polydisperse granular gas: Velocity distribution, equipartition?

References

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