Forces in Granular Hopper Flow

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Hopper Flow

Recent Interest in Hopper Flow

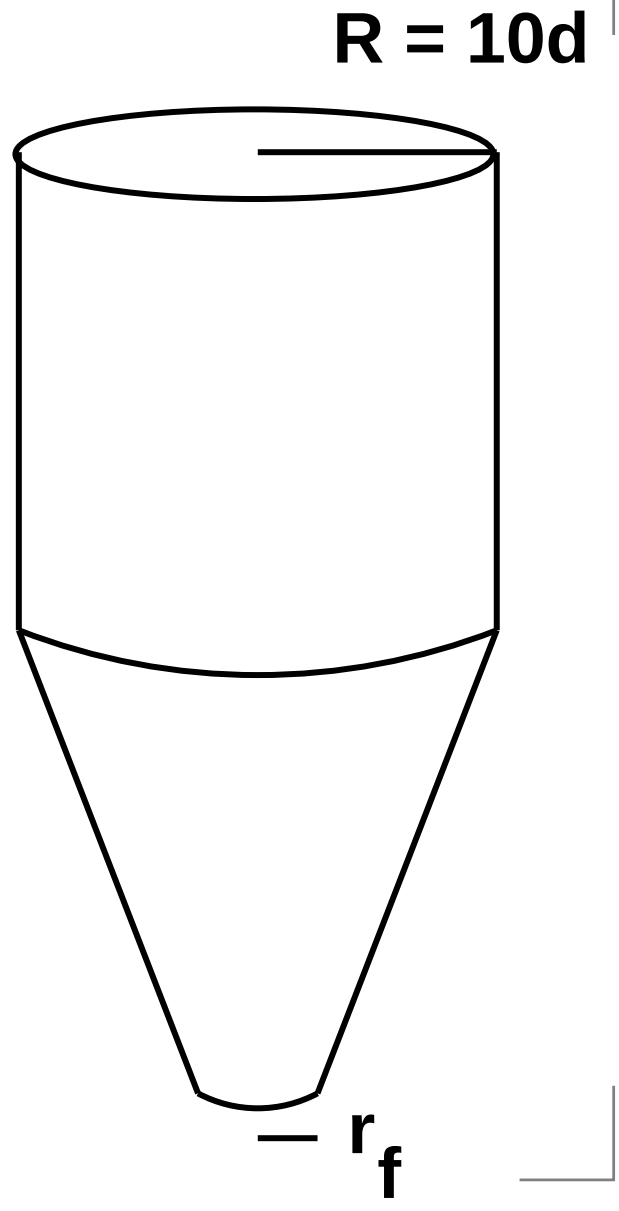
- 2D experiments measuring impulses and onset of jamming (Longhi, Easwar, and Menon; PRL **89**, 045501 (2002))
- 2D simulations on hopper flow (Ferguson, Fisher, and Chakraborty; cond-mat/0301201). See also B13.010 in this session.
- 3D experiments in progress (Easwar and Menon)

Objectives

- Understand the force distribution in a flowing medium.
- Explore how the system changes as it approaches jamming.
- What is the effect of clustering?

Model

- Molecular Dynamics simulation with translational and rotational forces and inelastic collisions
- Particles interact as soft spheres of diameter d with static friction μ
- Smooth walls with static friction μ_w
- Vertical hopper, where particle fall under gravity.
- Hopper opening radius (r_f) is adjustable (range $1d \leq r_f \leq 9d$)



Geometry of the System

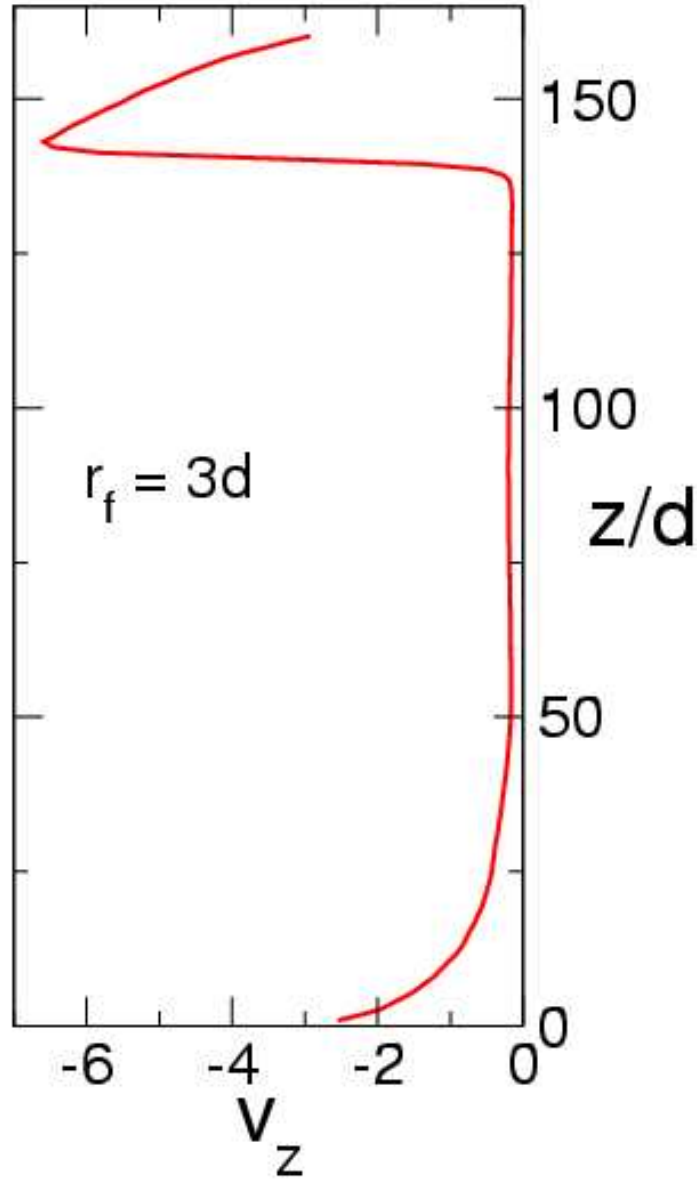
Free-fall region

Cylinder region

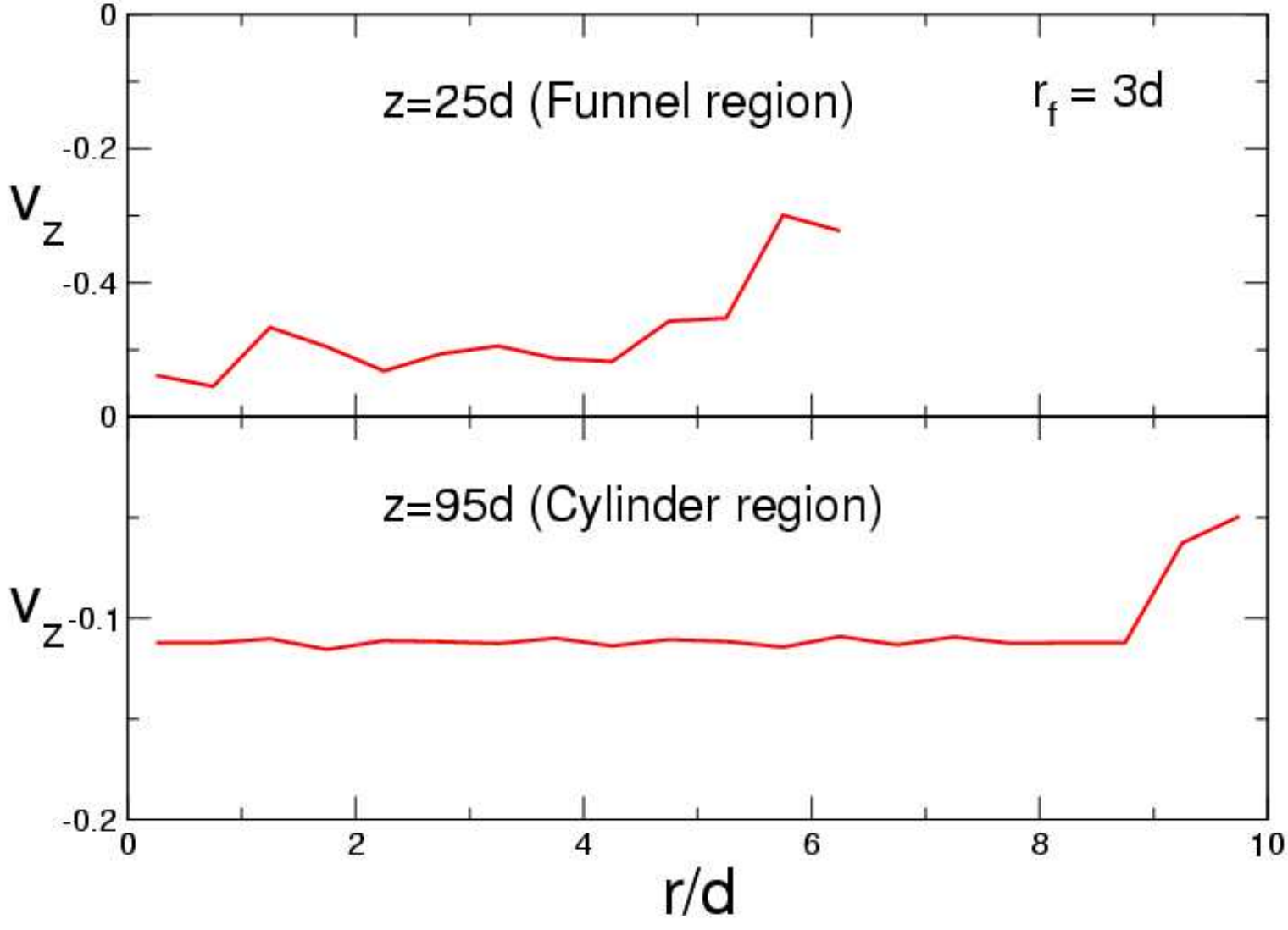
z = 50d

Funnel region

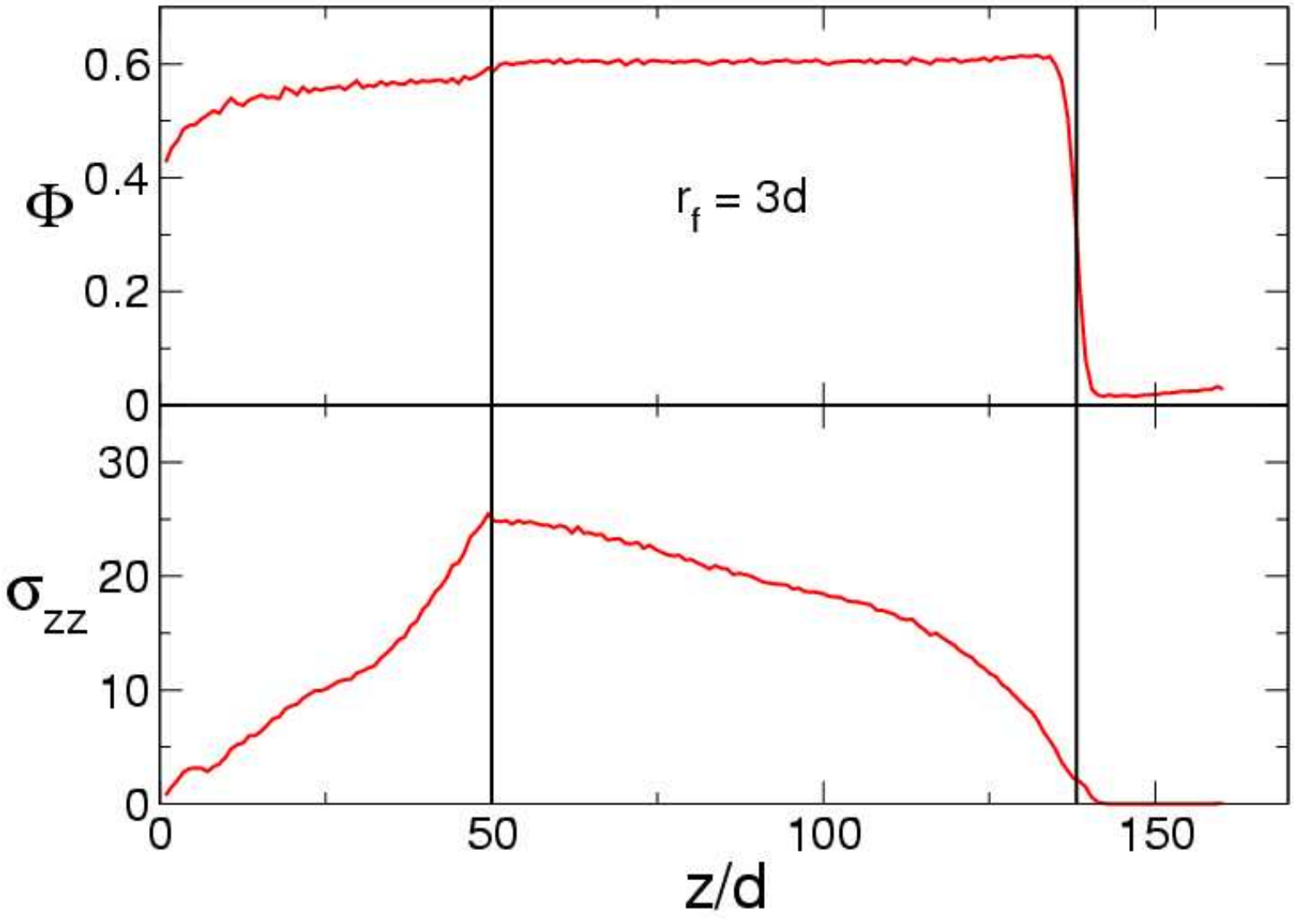
z = 0



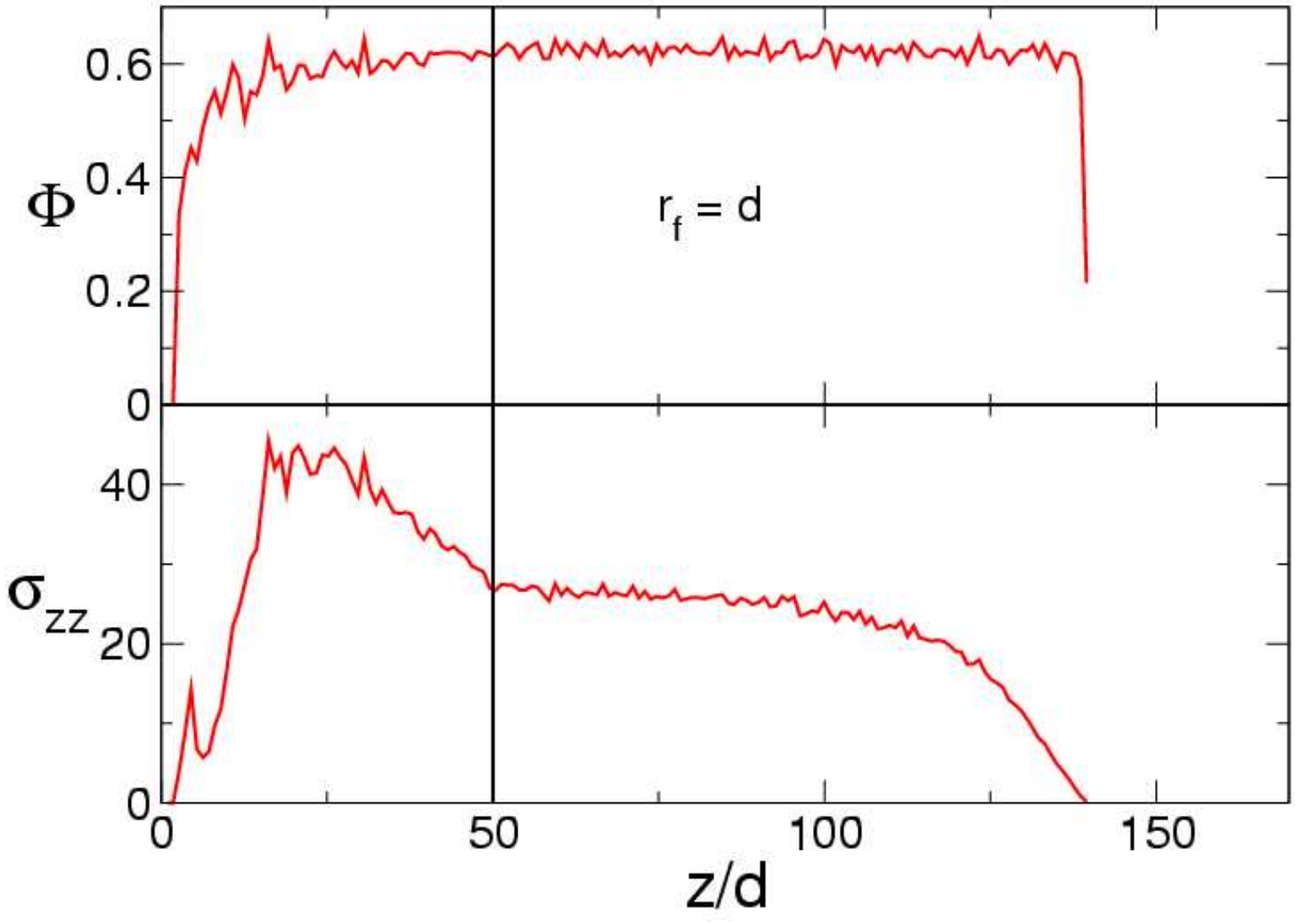
Radial Velocity



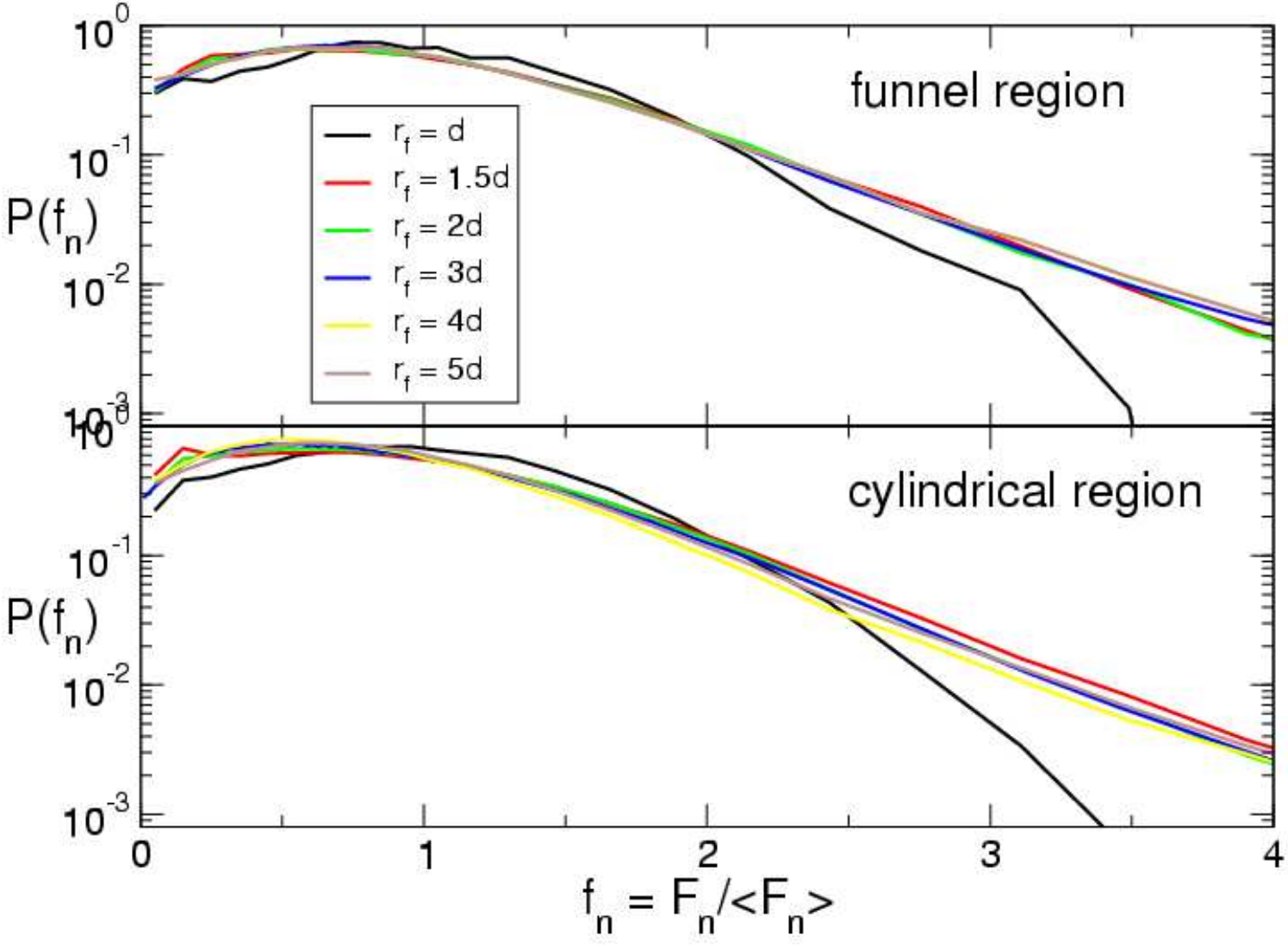
Physical Quantities in Flowing State



Physical Quantities in Jammed State



Distribution of Forces



Conclusions

- Two distinct regions in the system (cylindrical and funnel)
- Cylindrical region has plug flow and very low velocity
- Funnel region also has plug flow and high velocity
- Clear difference in forces from flowing to jammed state
- Funnel opening has no effect on $P(f)$ in funnel region and only a slight effect on $P(f)$ in the cylindrical region

Future Work

- Investigate impulse distributions (connection with experiment)
- Closer look at jamming in the system
- Role of clusters?