Electrostatic charging of flowing granular materials

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On my way here…

Arrested in Dubai for riding in “Women and Children Only” train car

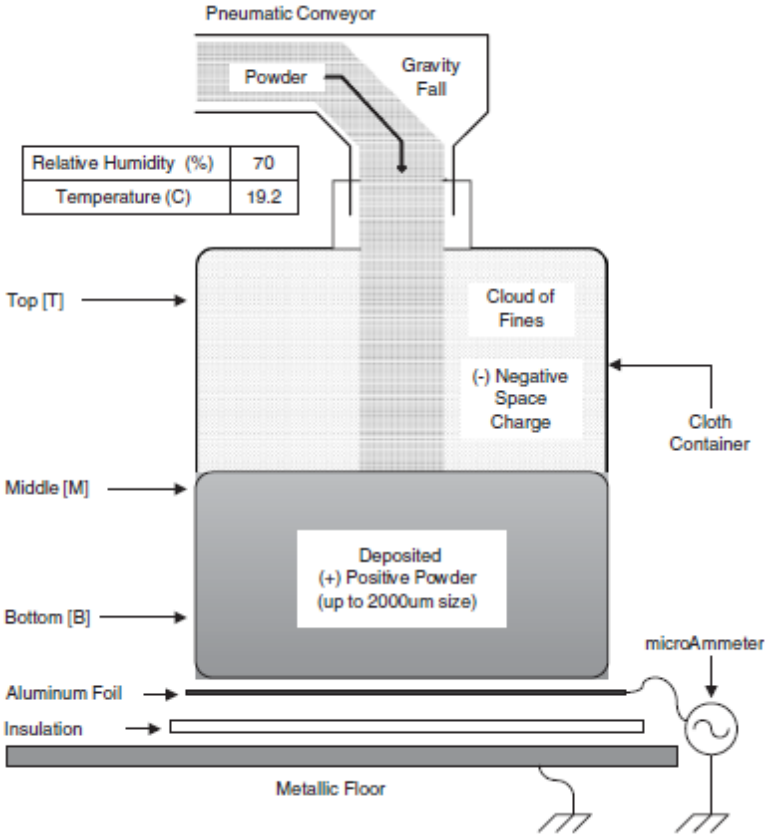
On my way here…

Arrested in Dubai for riding in “Women and Children Only” train car

Attacked in Finland by crazed woman with sword

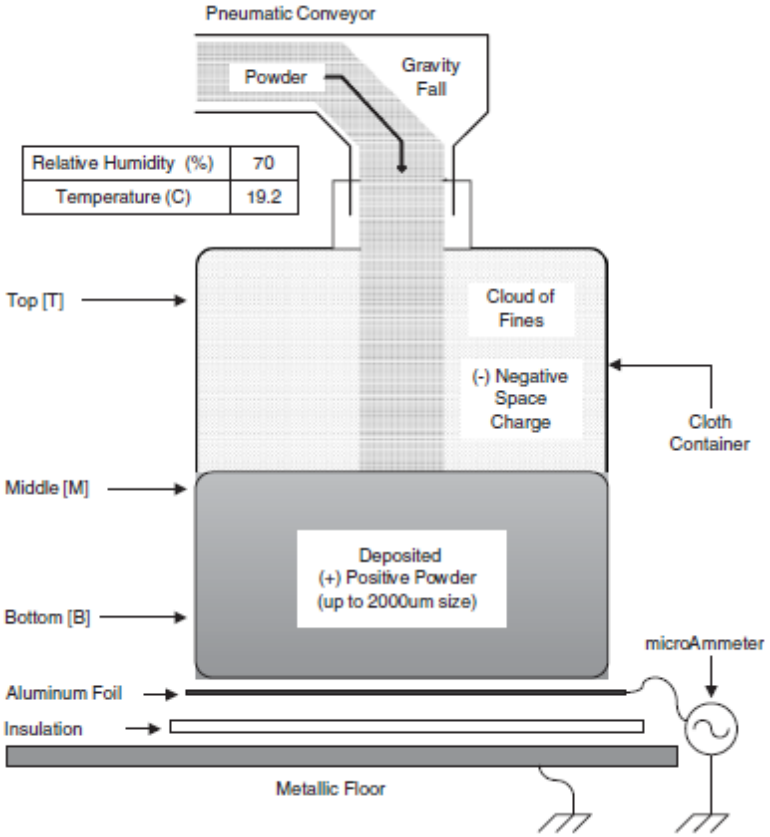
Industrial powders

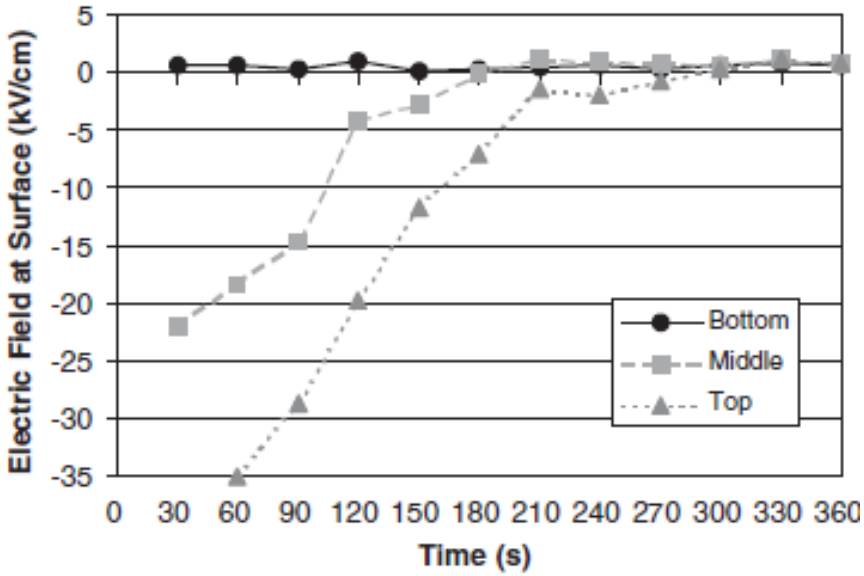
Inculet, Castle, Aartsen, *Chem. Eng. Sci.* (2006)



Industrial powders

Inculet, Castle, Aartsen, *Chem. Eng. Sci.* (2006)



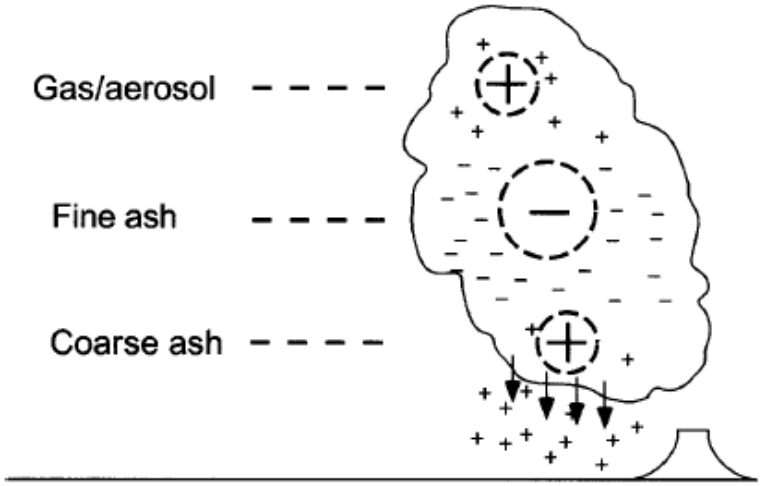


Negative electric field implies smaller particles charge negatively

Iceland, 2010

Volcanic plumes

Miura et al, *Bull Volcanol.* (2002)

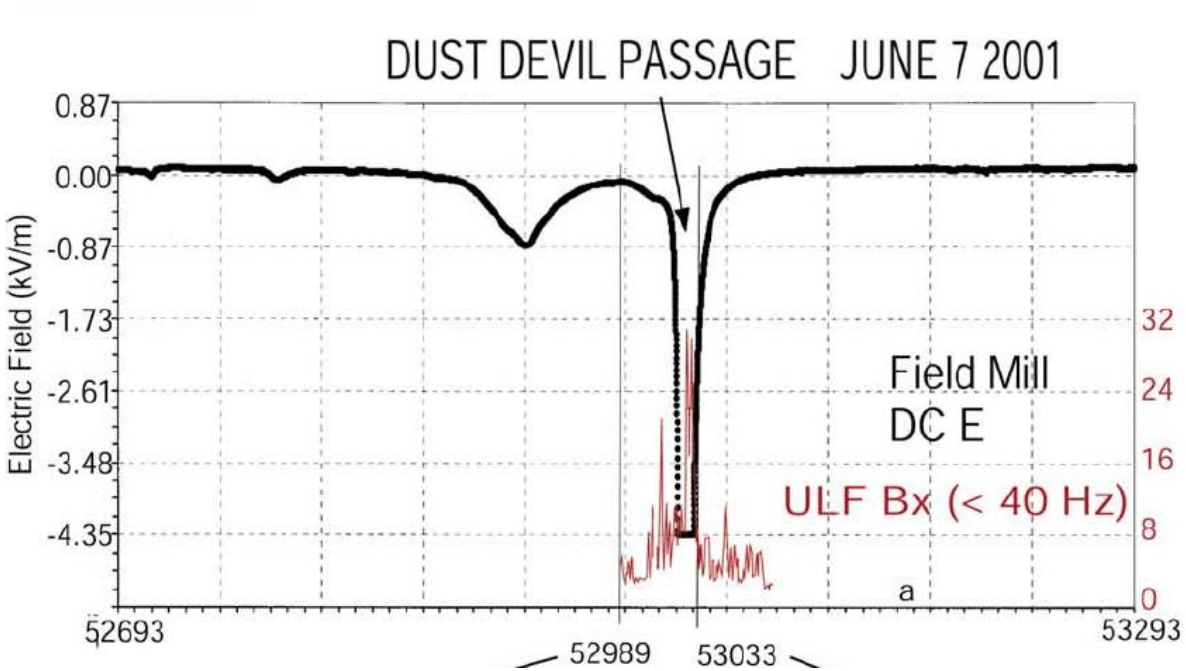


"Volcanic plumes are generally composed of three parts: an upper part with positively charged gas and aerosol, a middle part with **negatively charged fine ash particles**, and a lower part with **positively charged coarse ash particles**."

Niger, 2010

Dust devils

Farrell et al, *J. Geophys. Res.* (2004)



Smaller particles lofted higher above surface

Negative electric field implies smaller particles charge negatively

Electrostatic charging of particles

Electrostataic charging occurs whenever surfaces contact – thus difficult to study granular systems!

In granular systems can occur in 2 ways:
- particle - wall interactions
- particle - particle interactions

We developed a methodology to disentangle the particle - wall and particle - particle effects

To get reproducible results…

All experiments done in formal attire!

Collaborators

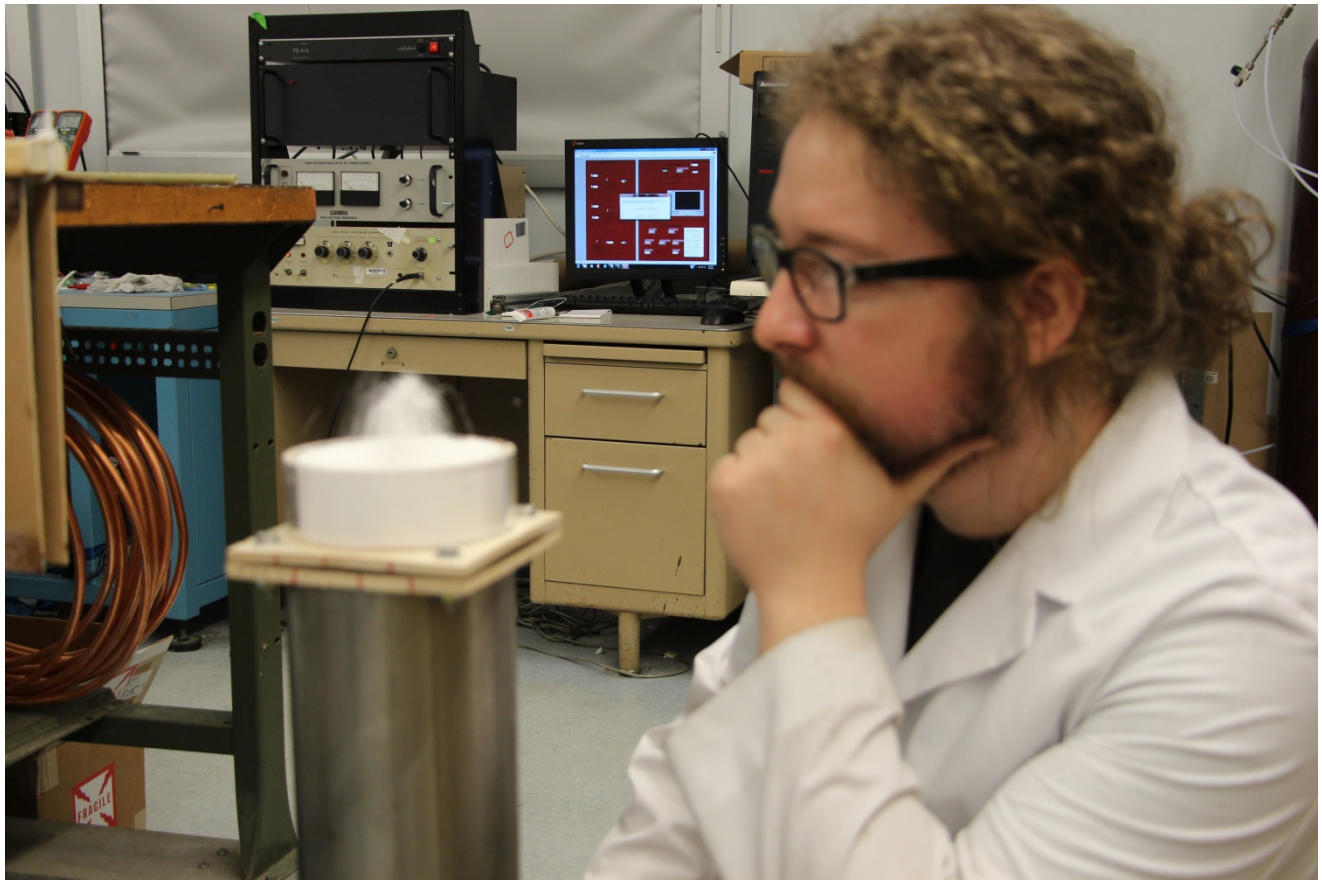
Prof. Mohan Sankaran
Dr. Keith Forward

Collaborators

Dr. Mamadou Sow

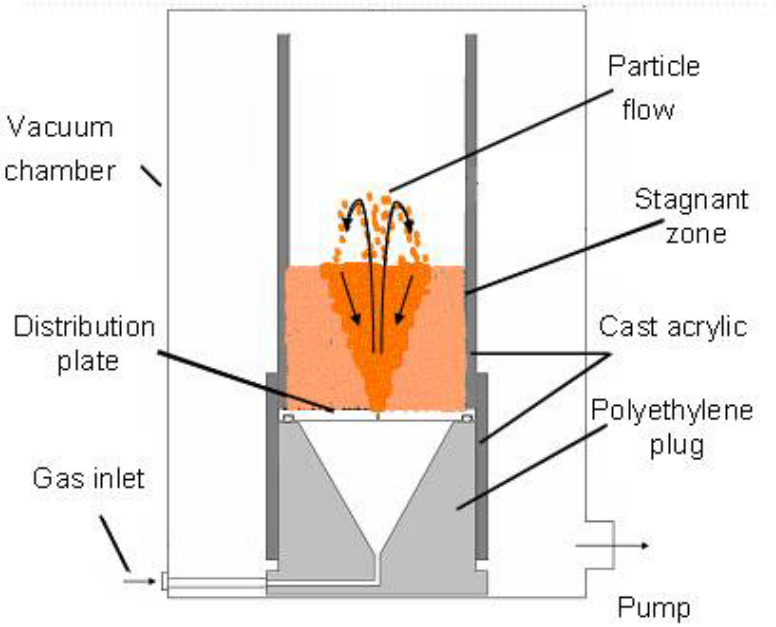
Collaborators

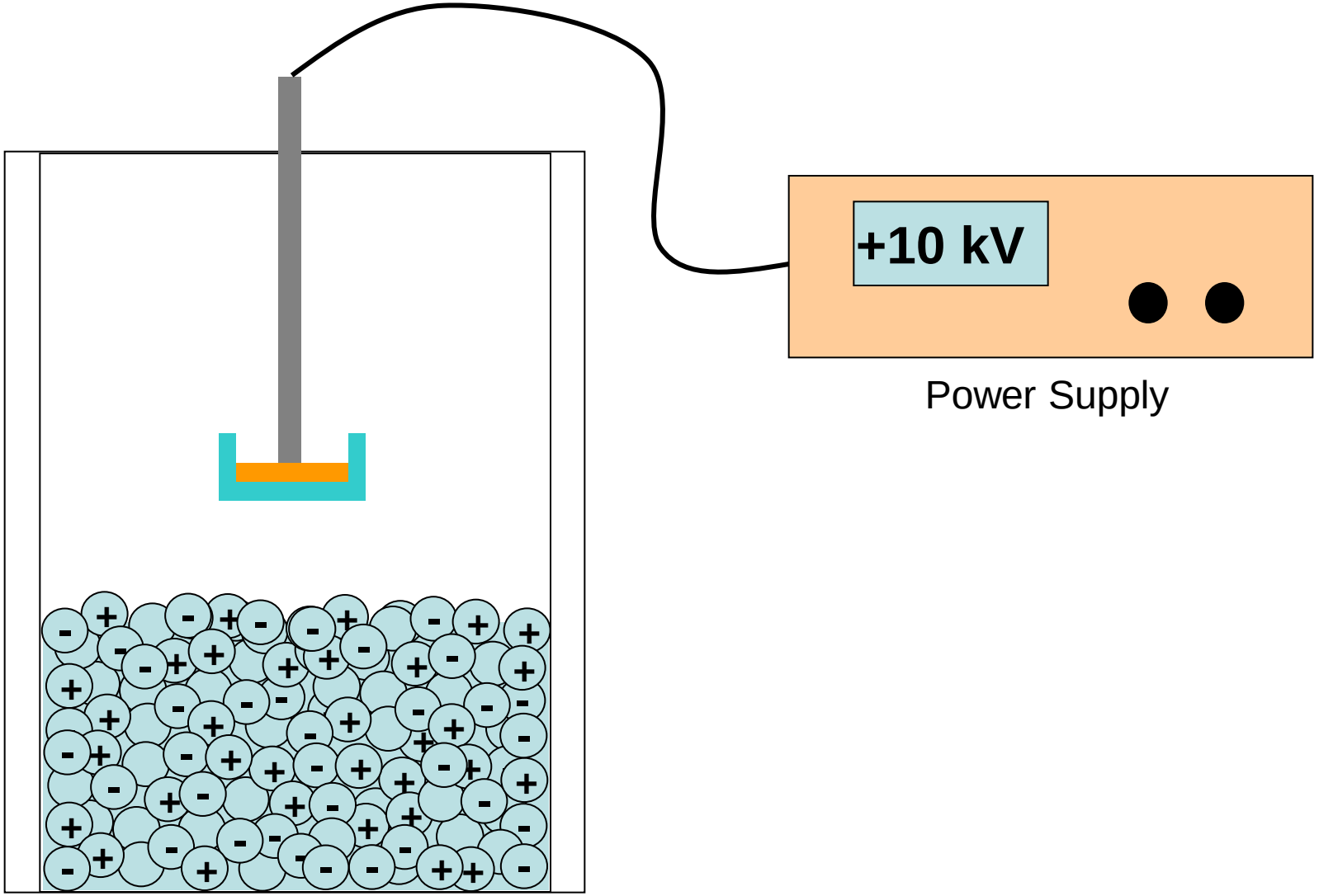
Dr. Mihai Bilici



Only particle-particle interactions

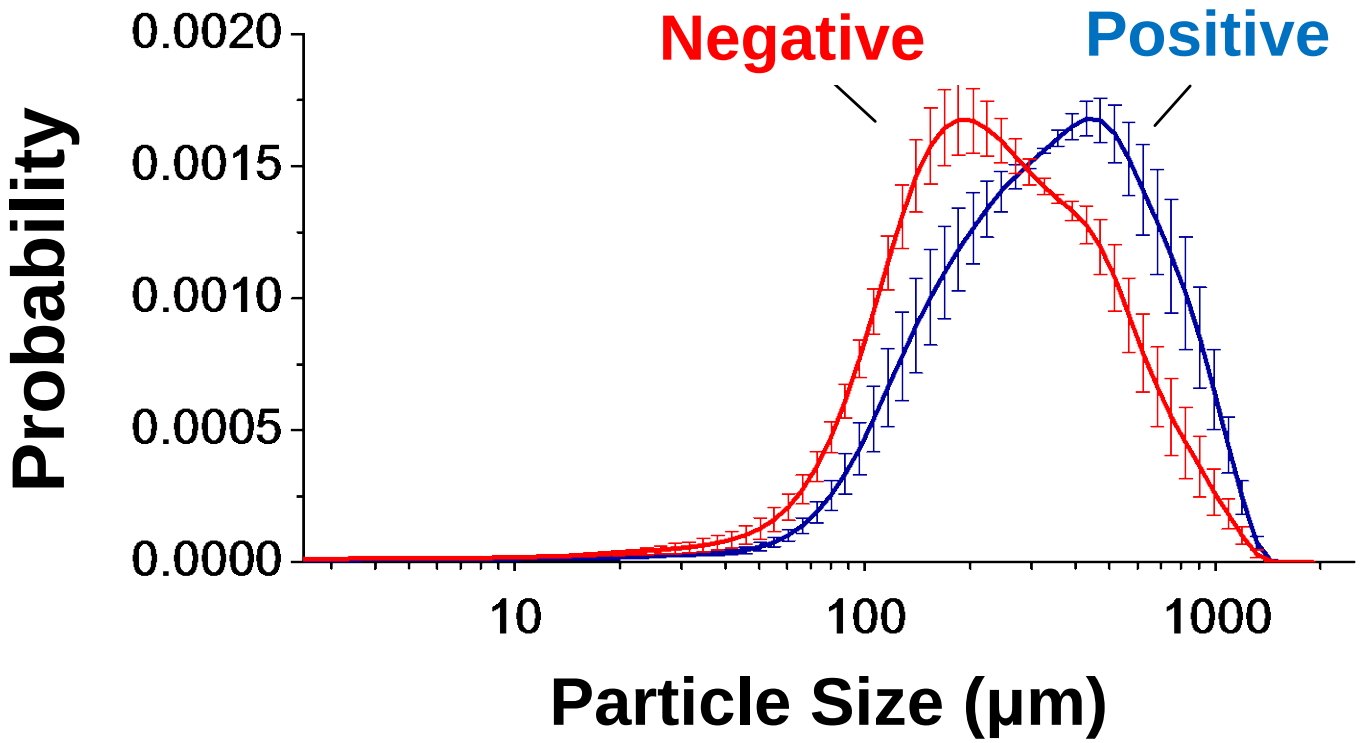
Use a single hole distribution plate that results in fountain-like flow




+10 kV
Power Supply

Results

Forward, Lacks, Sankaran, *PRL* (2009)

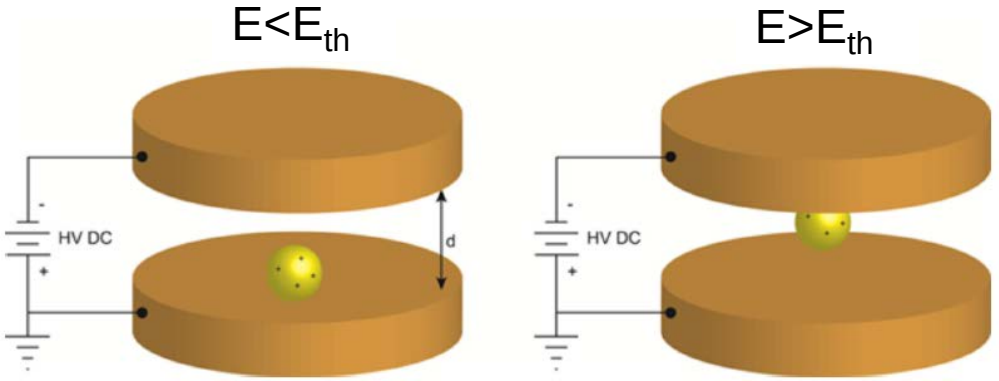


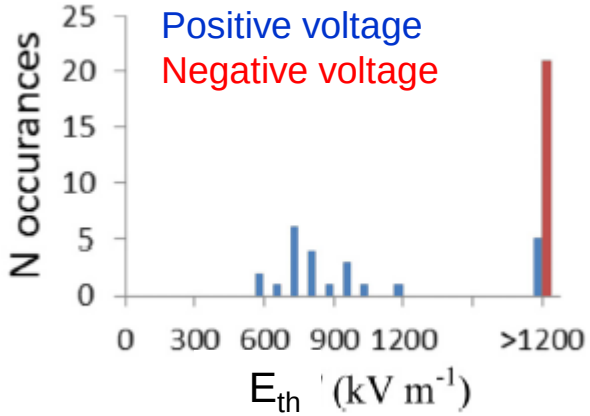
Charged particle will be lifted in electric field

Sow *et al.*, *J. Brazil Chem. Soc.* (2012)

PTFE particle:

- 2 mm particle
- Charged negative by triboelectric charging
- Placed on lower plate
- E-field increased. Above E_{th} particle jumps



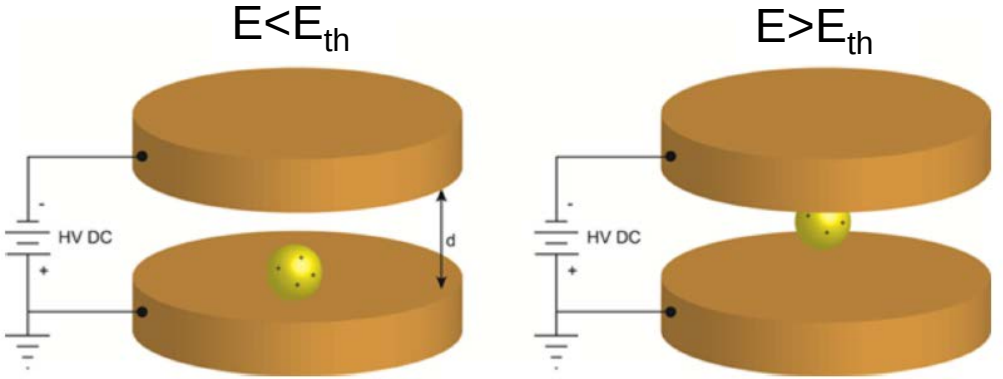


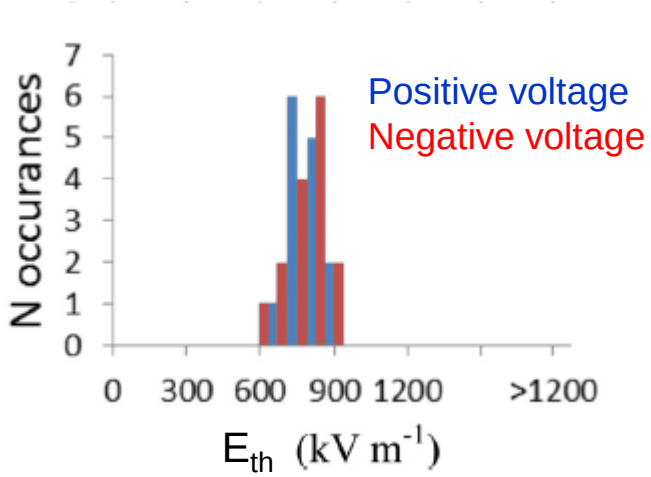
… but so can neutral *conducting* particle

Sow *et al.*, *J. Brazil Chem. Soc.* (2012)

Aluminum particle:

- 2 mm particle
- Charge state doesn't matter as conducing particle neutralizes when on grounded plate
- Placed on lower (grounded) plate
- E-field increased. Above E_{th} particle jumps





Insulating particles can act as conducting

Sow *et al.*, *J. Brazil Chem. Soc.* (2012)

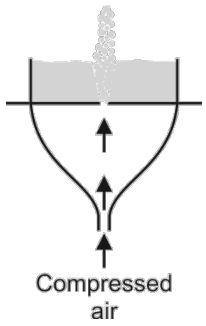
Soda-lime glass particle:

- 2 mm particle
- Charged negative by triboelectric charging
- Placed on lower plate
- E-field increased. Above E_{th} particle jumps

Low humidity (<10%): particle jumps only with negative voltage on upper plate
→ acts like insulator

High humidity (>35%): particle jumps equally well with either polarity voltage
→ acts like conductor

Particle-particle charging – new method



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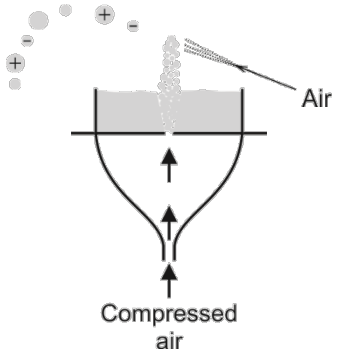

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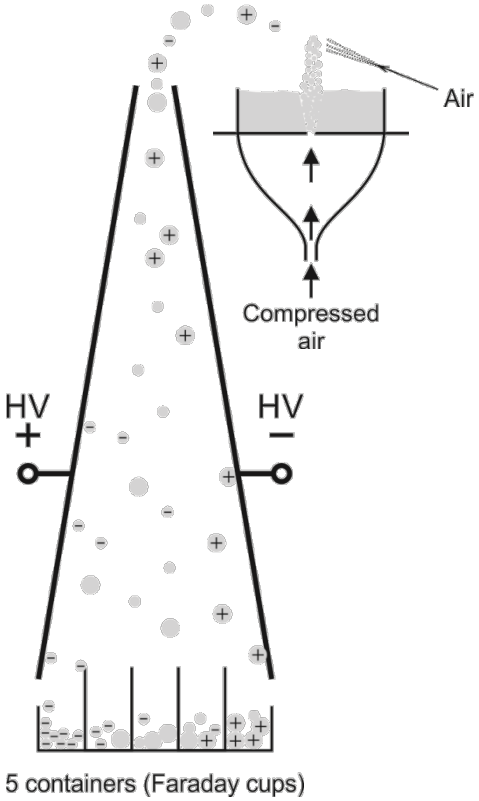
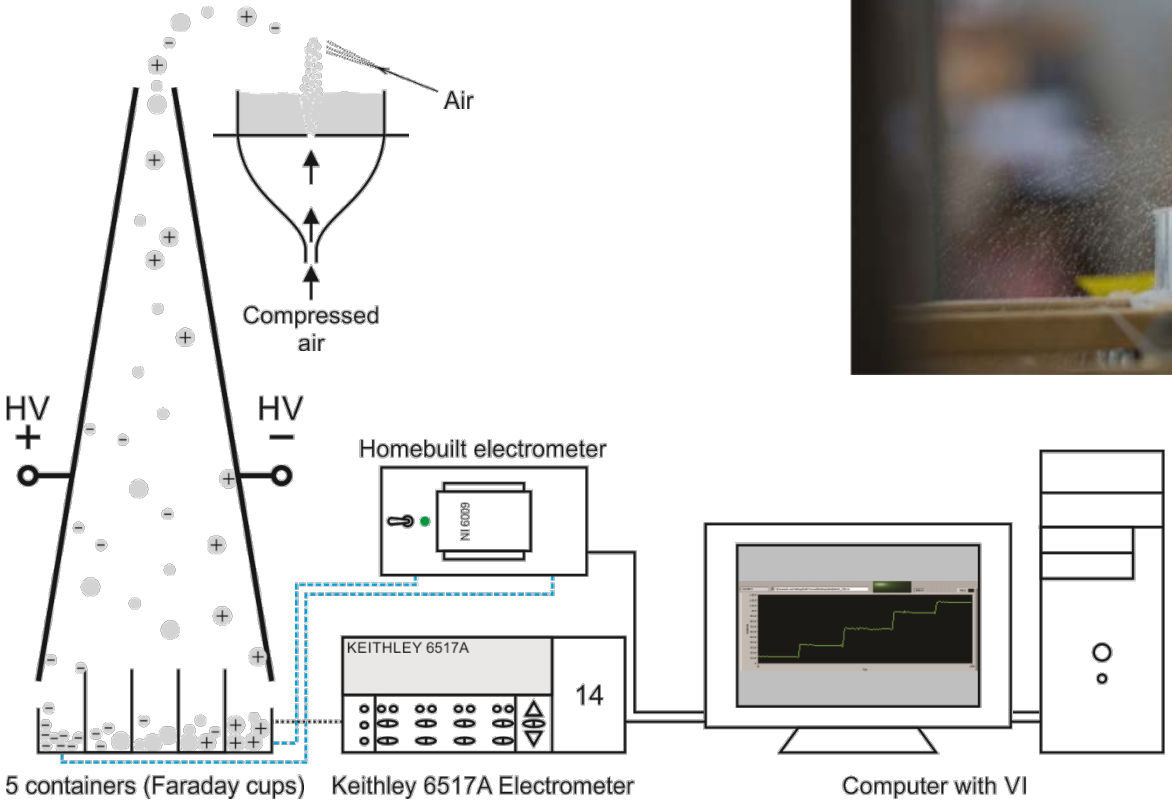
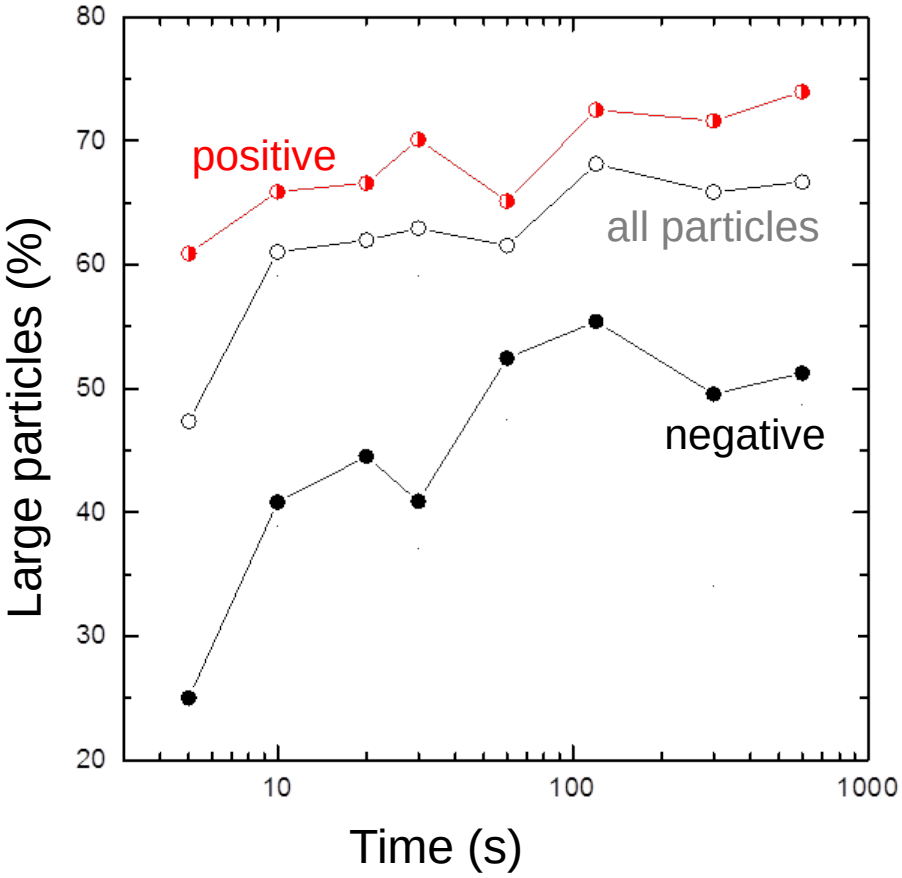


5 containers (Faraday cups)

Particle-particle charging – new method



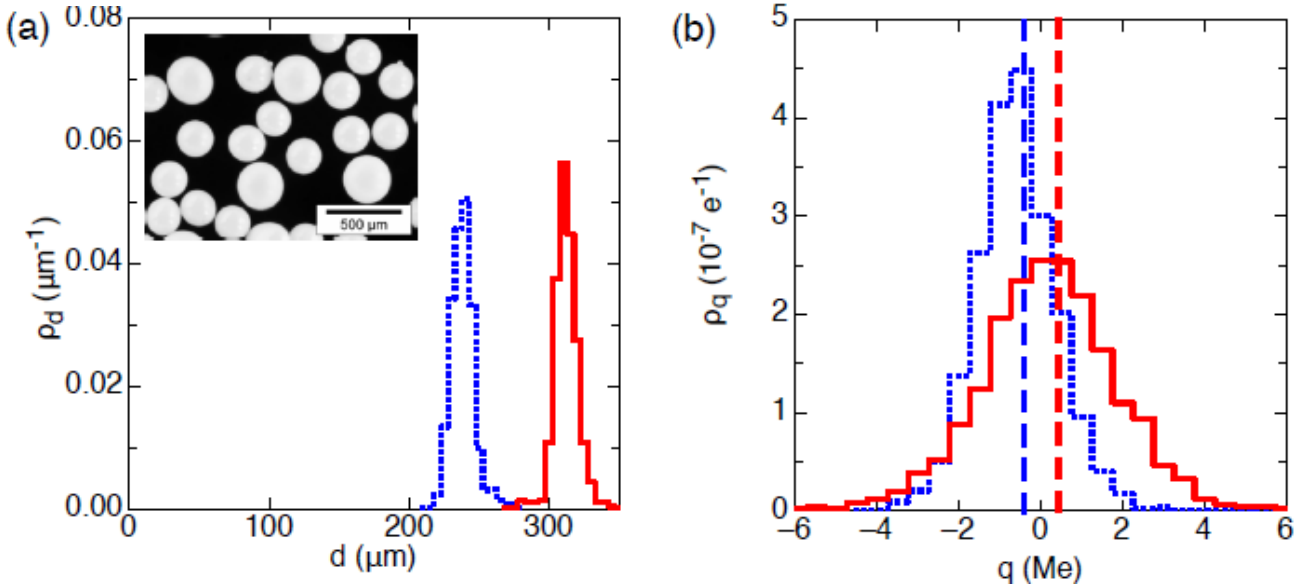
Results – new method



Smaller particles charge negative

Experiments at University of Chicago

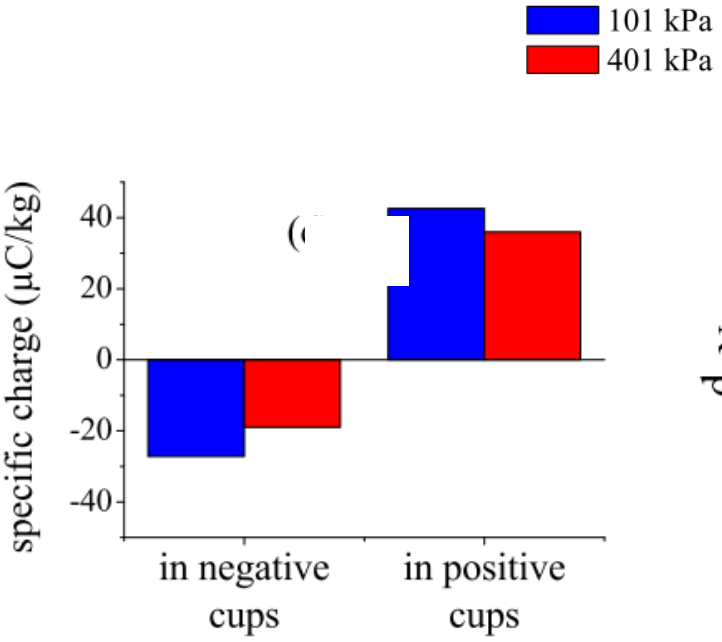
Waitukaitis and Jaeger, PRL, 2014

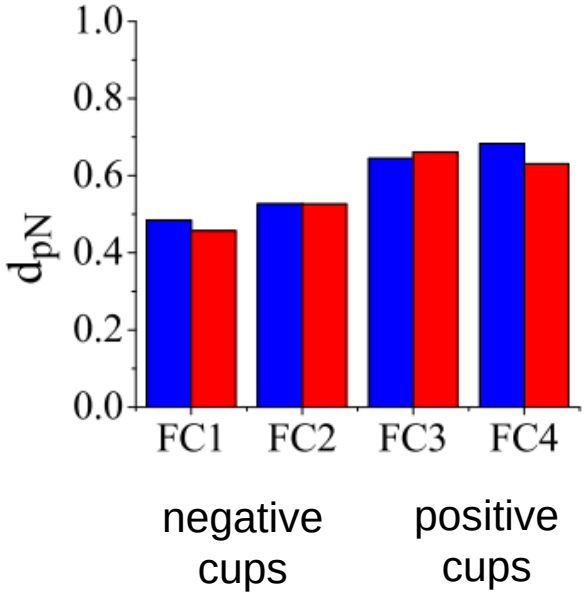


Smaller particles charge negative

Experiments at University of Ottawa

Salama and Mehrani, MS thesis, 2013

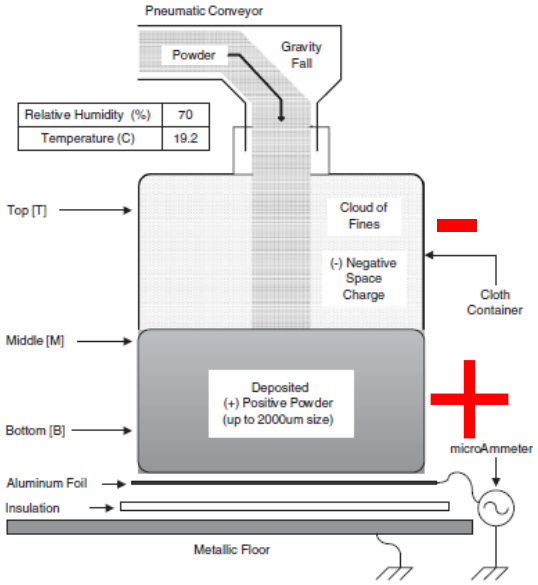




Smaller particles charge negative

Electric-field direction with gravity implies small particles tend to be negative

Industrial powders

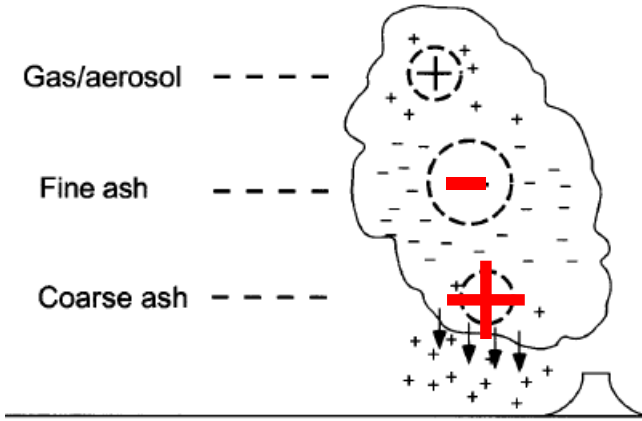


Inculet, Castle, Aartsen, *Chem. Eng. Sci.* (2006)

Dust storms

Farrell et al, *J. Geophys. Res.* (2004)

Volcanic plumes



Miura et al, *Bull Volcanol.* (2002)

Why particle-size dependent charging?

Lacks, Duff, Kumar, *PRL* (2008)

We adapt non-equilibrium model for asymmetric rubbing (Lowell and Truscott, J. Phys. D, 1986) to particle systems

‘Money-exchange game’

- bring 1% of savings in $1 bills, in **left** pocket
- everyone blindfolded
- when collide with someone, give them $1 from **left** pocket
- put money you get into **right** pocket

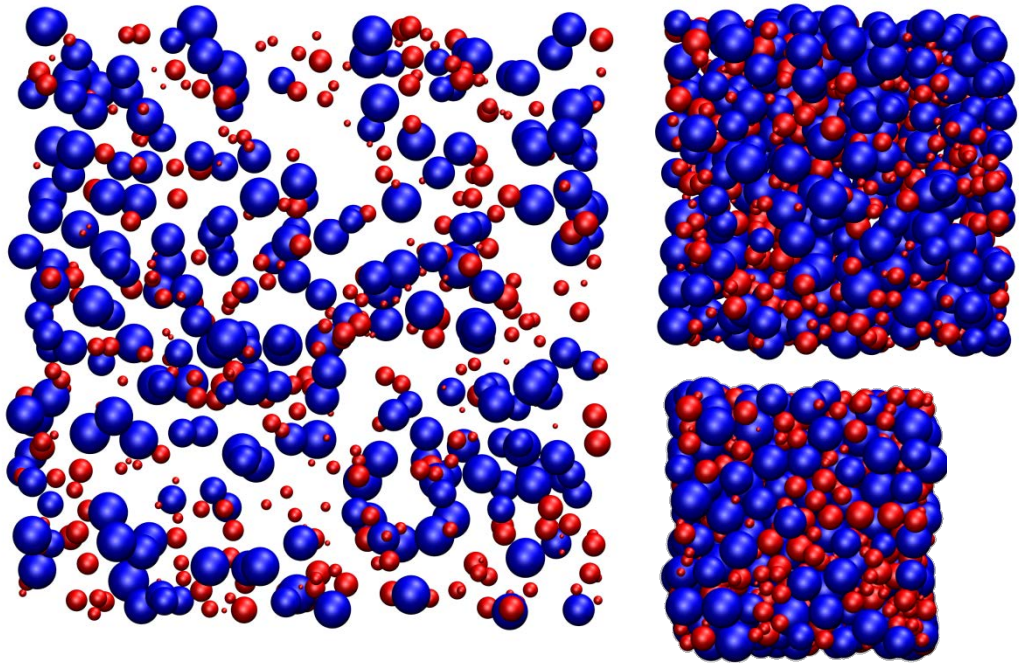
Particle dynamics simulations

Lacks, Duff, Kumar, *PRL* (2008)

Simulation methodology

- 864 particles of different sizes
- Newtonian dynamics
- Transfer electrons at each collision according to trapped electron model
- Run simulation for 10 million collisions

Results for different densities



Blue: positive **Red: negative**

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