SAND2011-7039C

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Electrostatic Aerosol Filtration at Moderate Fiber Reynolds Numbers

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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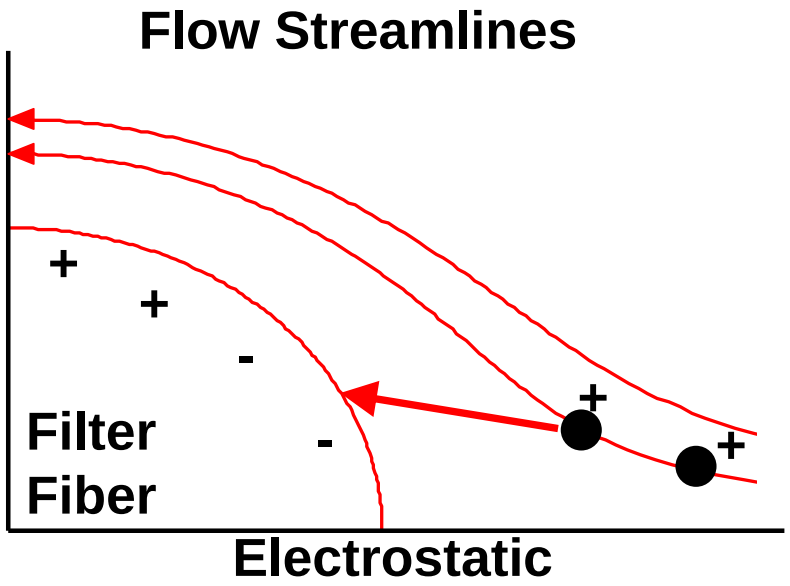
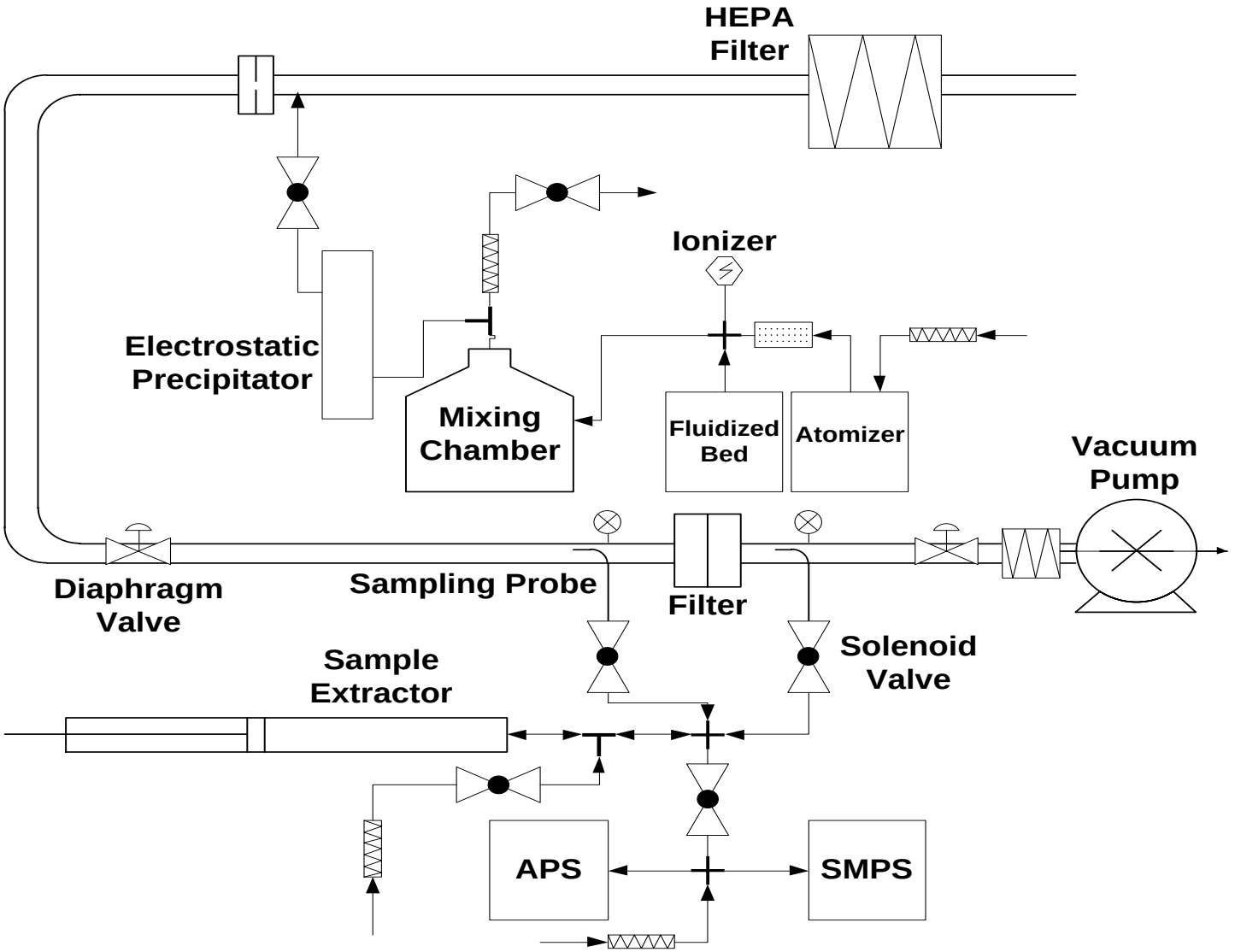
Background



- 3M Filtrete
  - Dipolar charge distribution
  - Coulomb Forces
- Nontraditional face velocities
  - 0.5 to 2.5 m/s
- Moderate Reynolds number regime
  - 0.4 to 2.0
  - Non-Viscous Flow
- Purpose: Measure effects of particle charge and fiber charge on filtration efficiency in moderate fiber Reynolds number regime

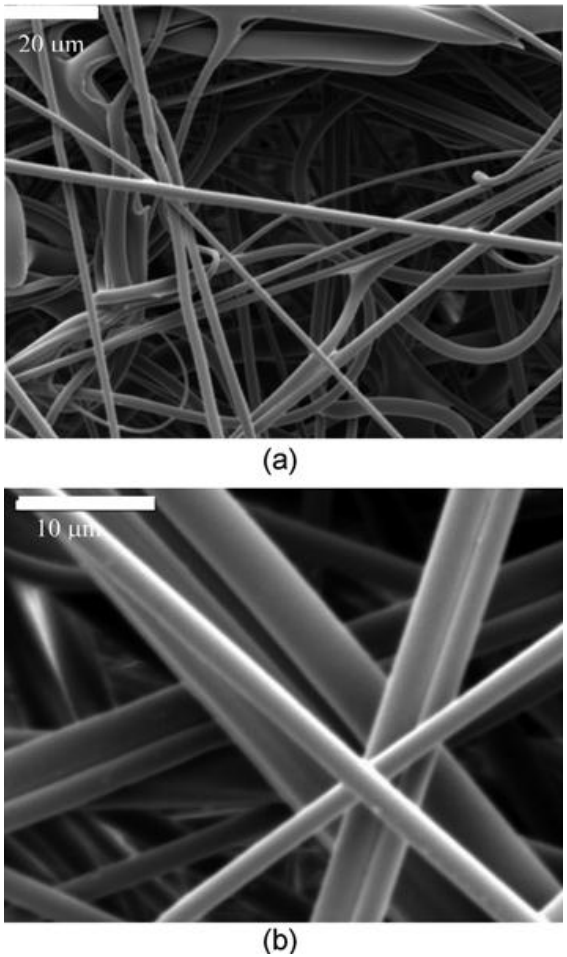
Filter Test Bed Setup



(Hubbard et al. 2011)

Effect of Fiber Charge

- Electrets neutralized by organic solvents (Kim 2010)
- Significantly reduces collection efficiency
- Theories for charge deterioration[1]:
  - chemical reaction
  - charge detrapping by solvent molecules
  - Increase chain and charge mobility in polypropylene fibers (plasticization)



(Taken from Kim 2010)

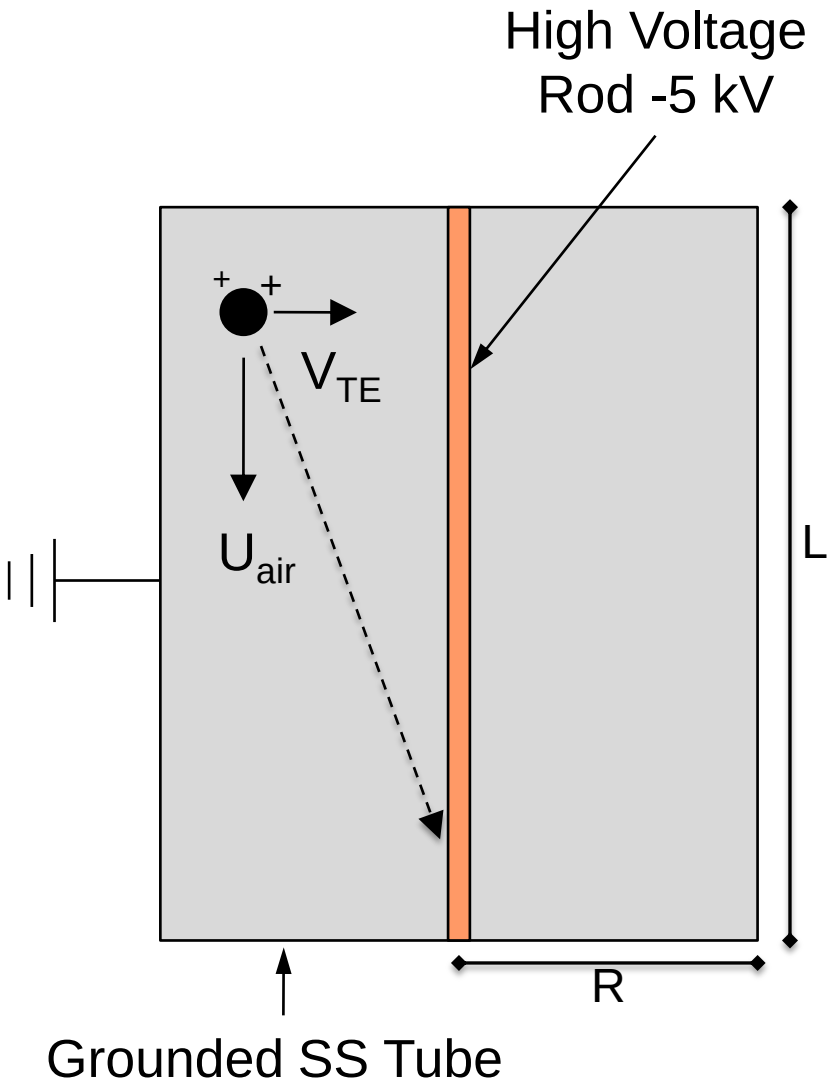
Effect of Particle Charge

- Simple electrostatic precipitator to remove charged particles
- Determining dimensions

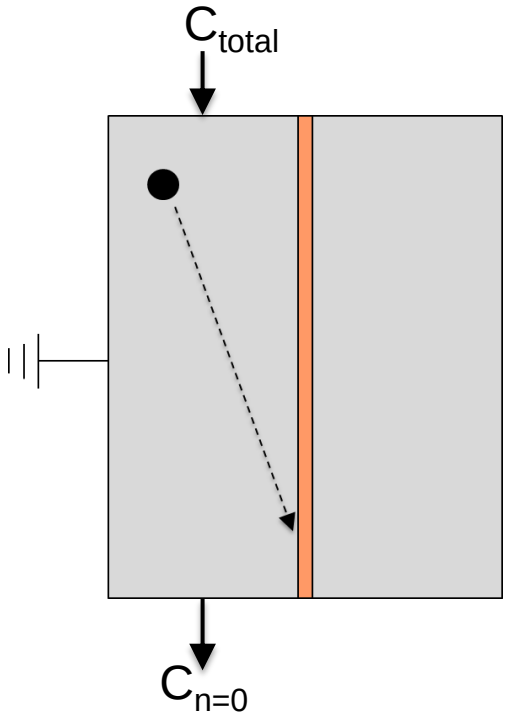
$$\frac{R}{V_{TE}} = \frac{L}{U_{air}}$$

- Terminal electrostatic velocity

$$V_{TE} = \frac{neC_c}{3\pi\eta d}\,\mathrm{E}$$

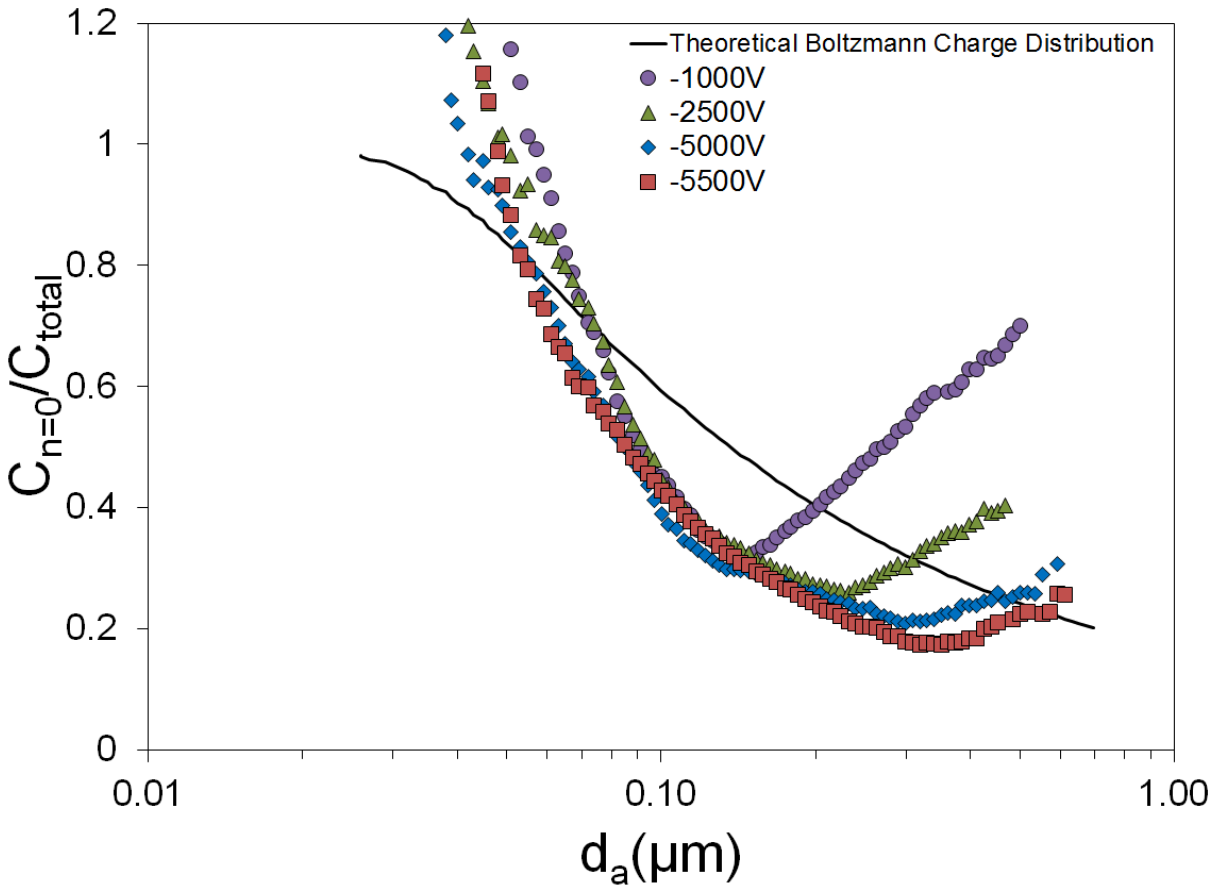


Effect of Particle Charge



From Boltzmann:

$$\frac{C_{n=0}}{C_{Total}}$$



Filter Collection Efficiency

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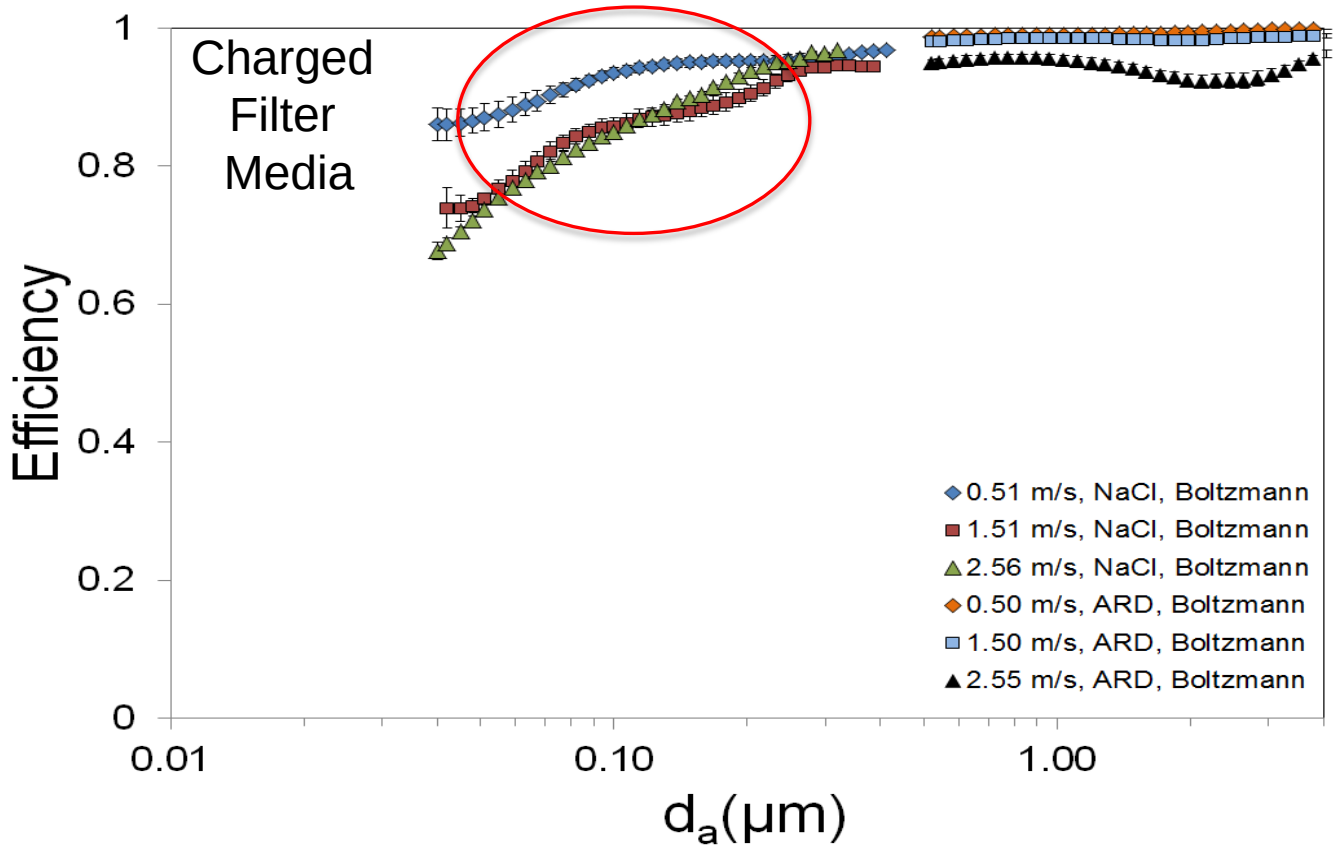
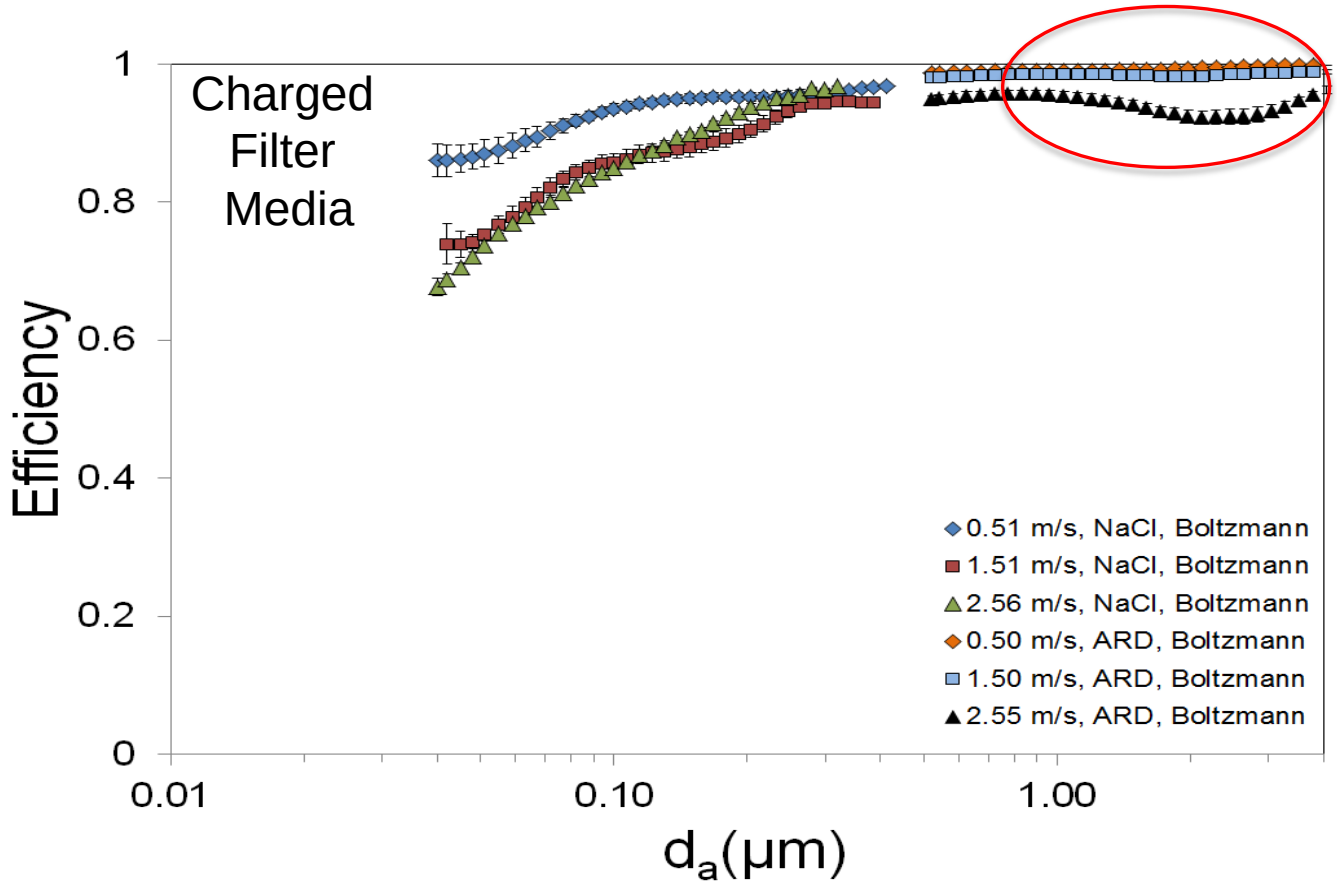


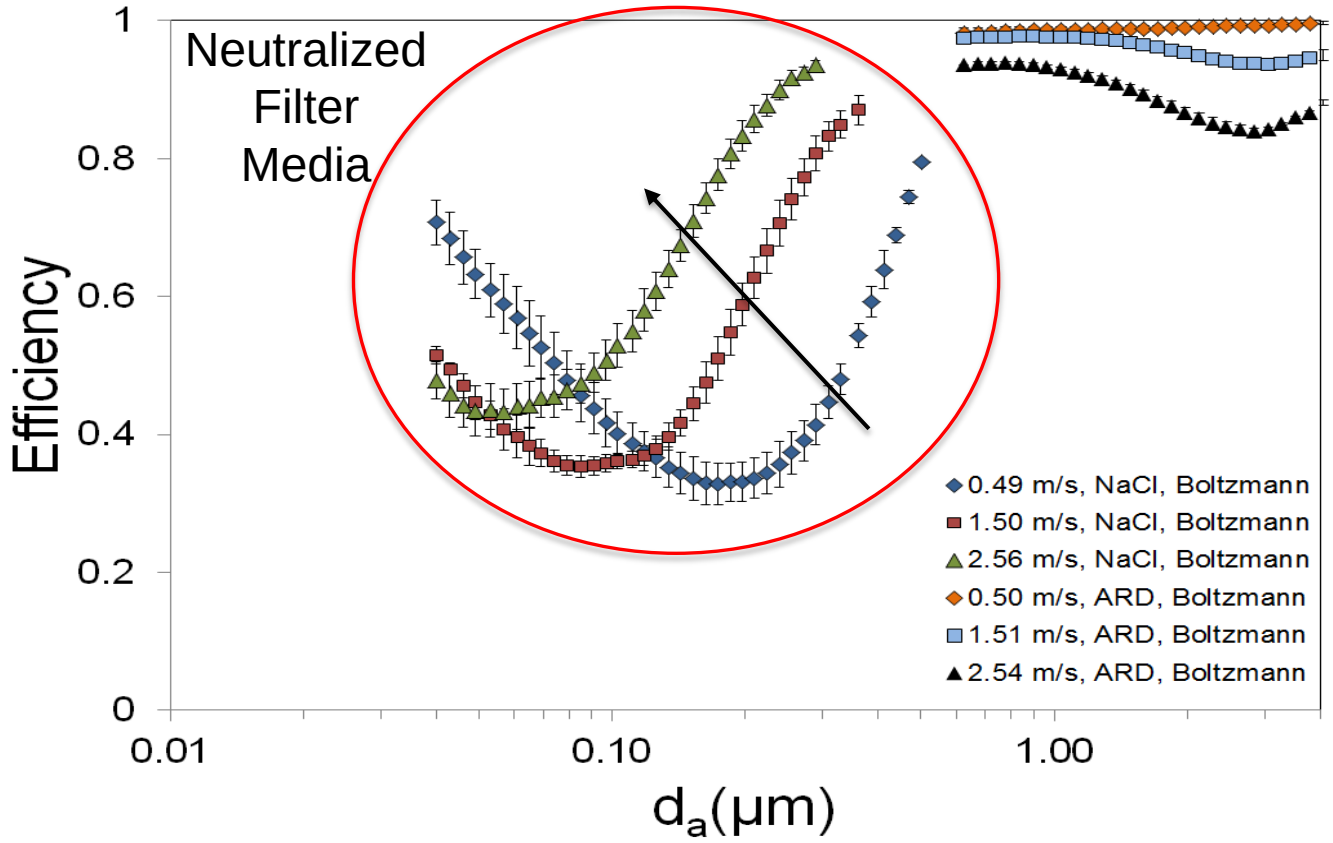
- Effect of *Coulomb forces*
- Decreased time for electrostatics to take effect

Filter Collection Efficiency



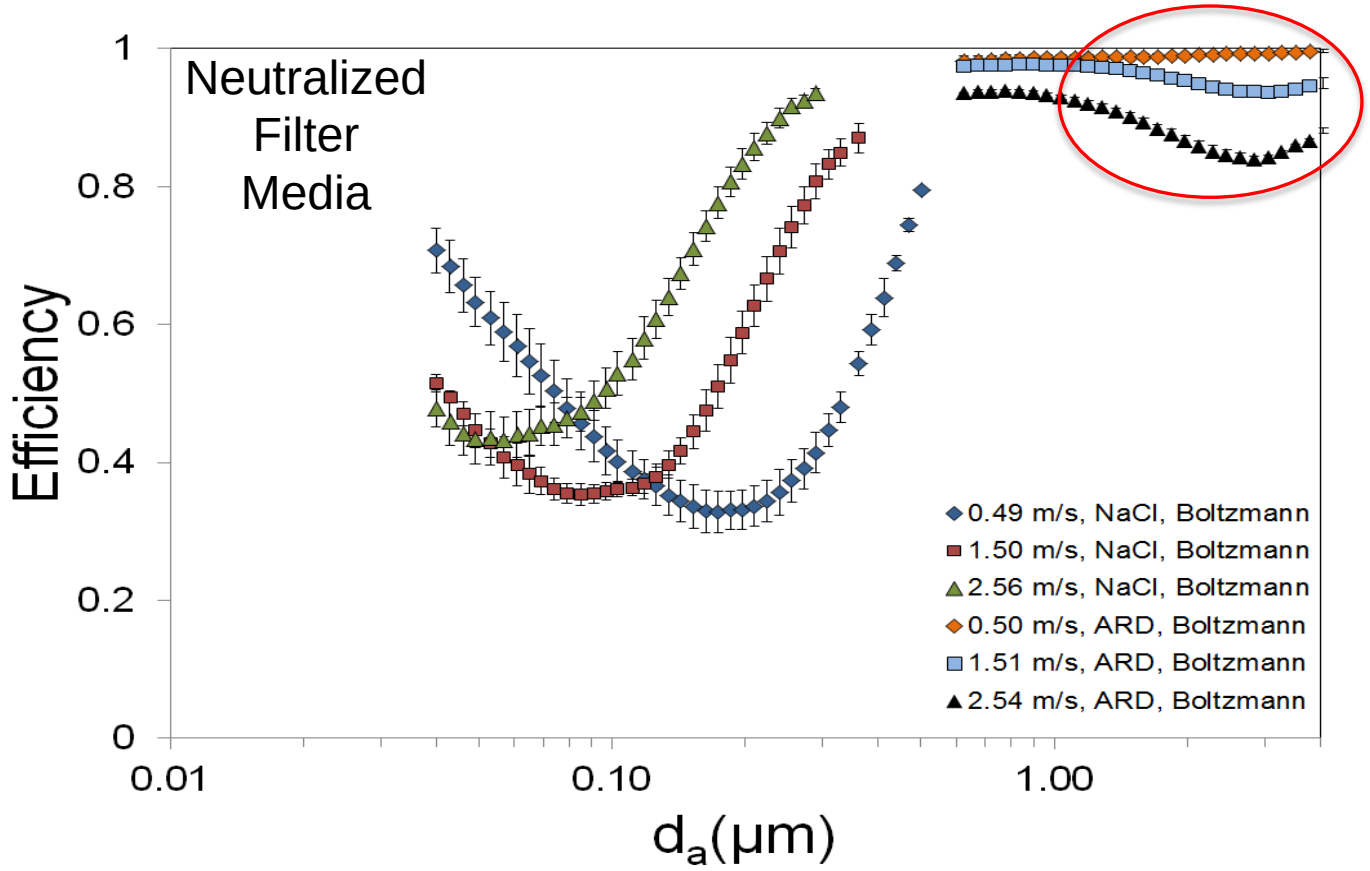
- Inertia Impaction
- Particle Bounce

Filter Collection Efficiency



- Increasing inertial separation

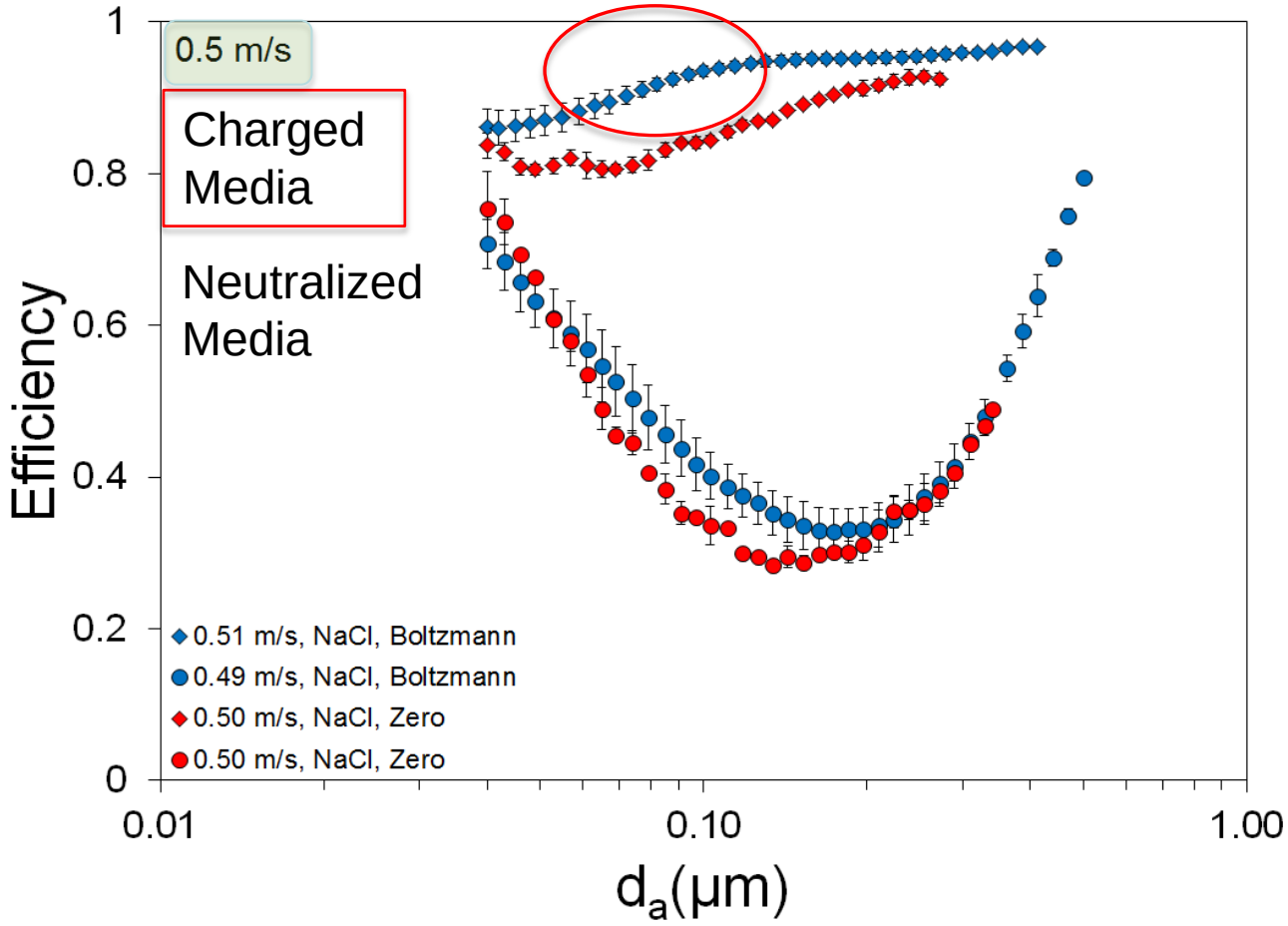
Filter Collection Efficiency



- Particle Bounce

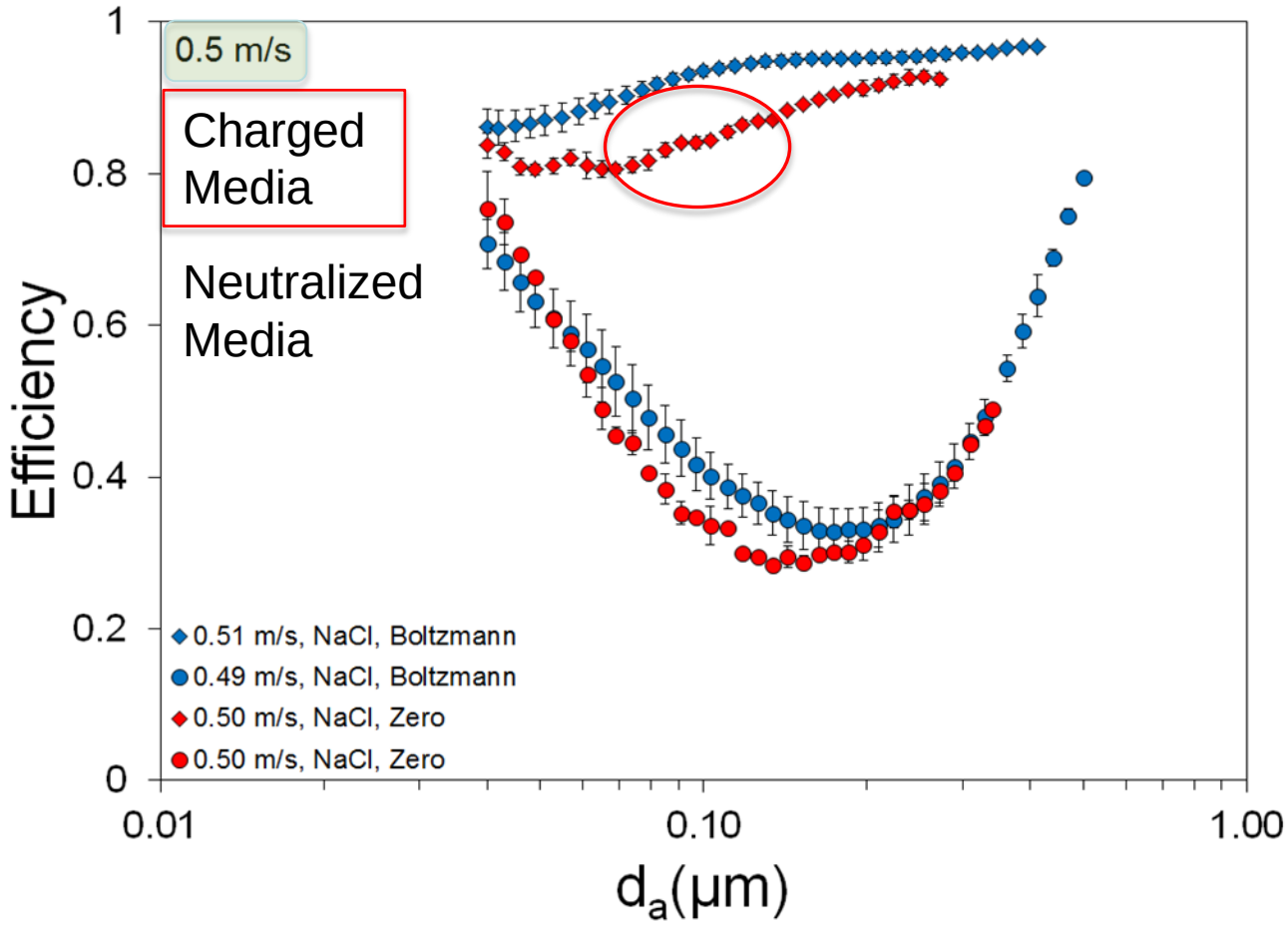
Effect of Particle Charge

- Coulomb Forces



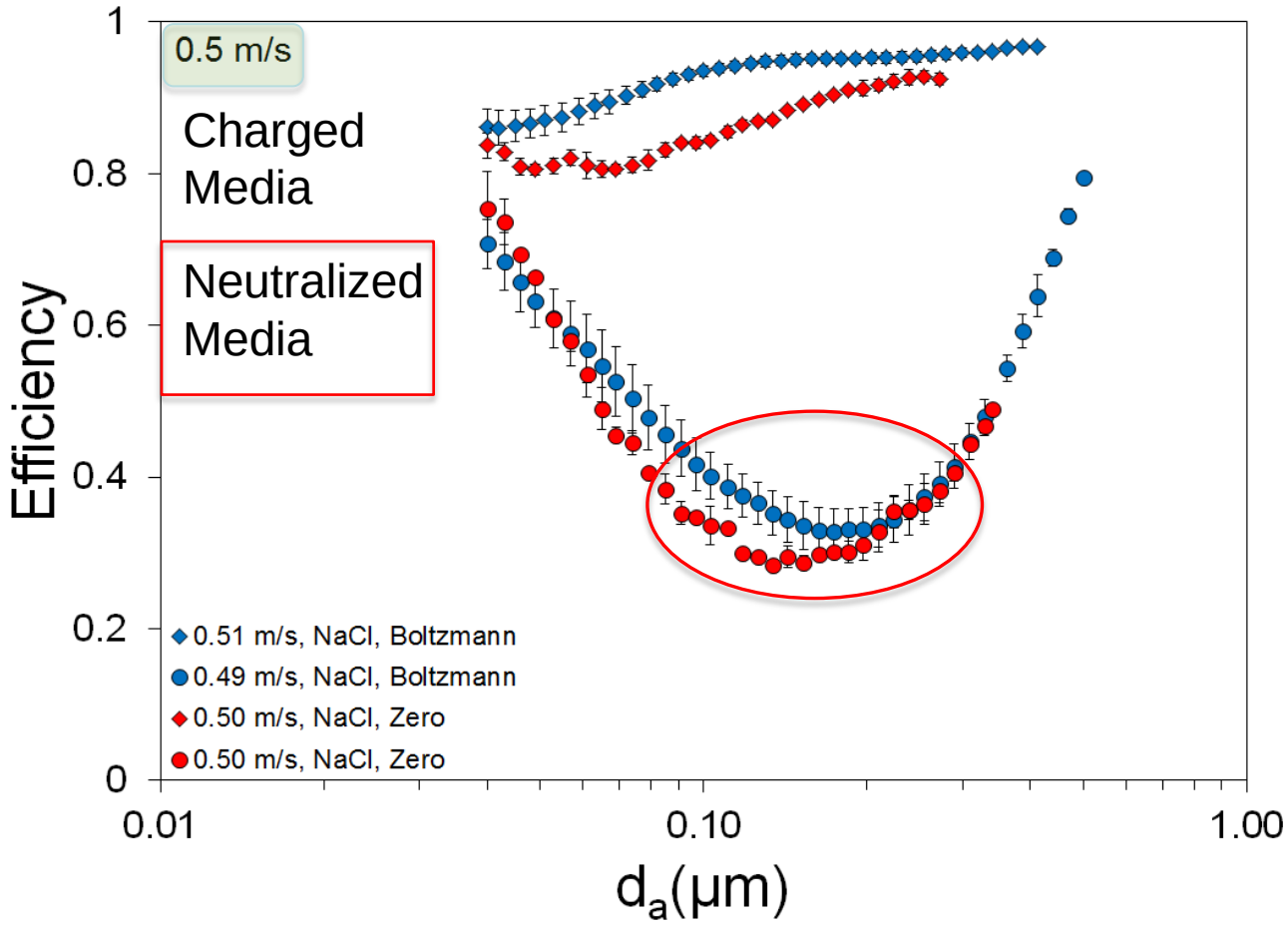
Effect of Particle Charge

- Coulomb Forces
- Image Forces
  - Electrostatic Fiber inducing a charge on uncharged particles



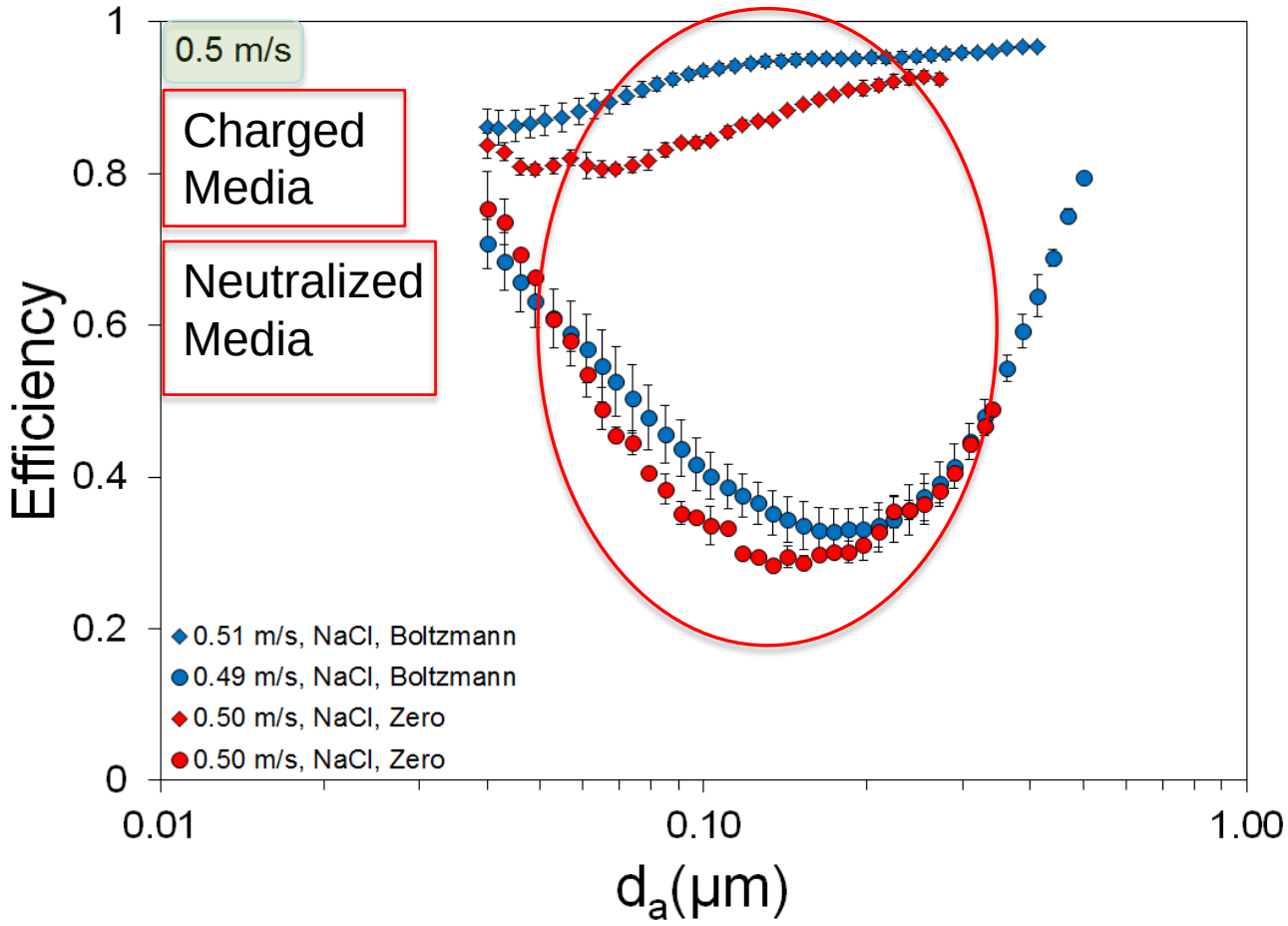
Effect of Particle Charge

- Coulomb Forces
- Image Forces
  - Electrostatic Fiber inducing a charge on uncharged particles
- Inertial Force



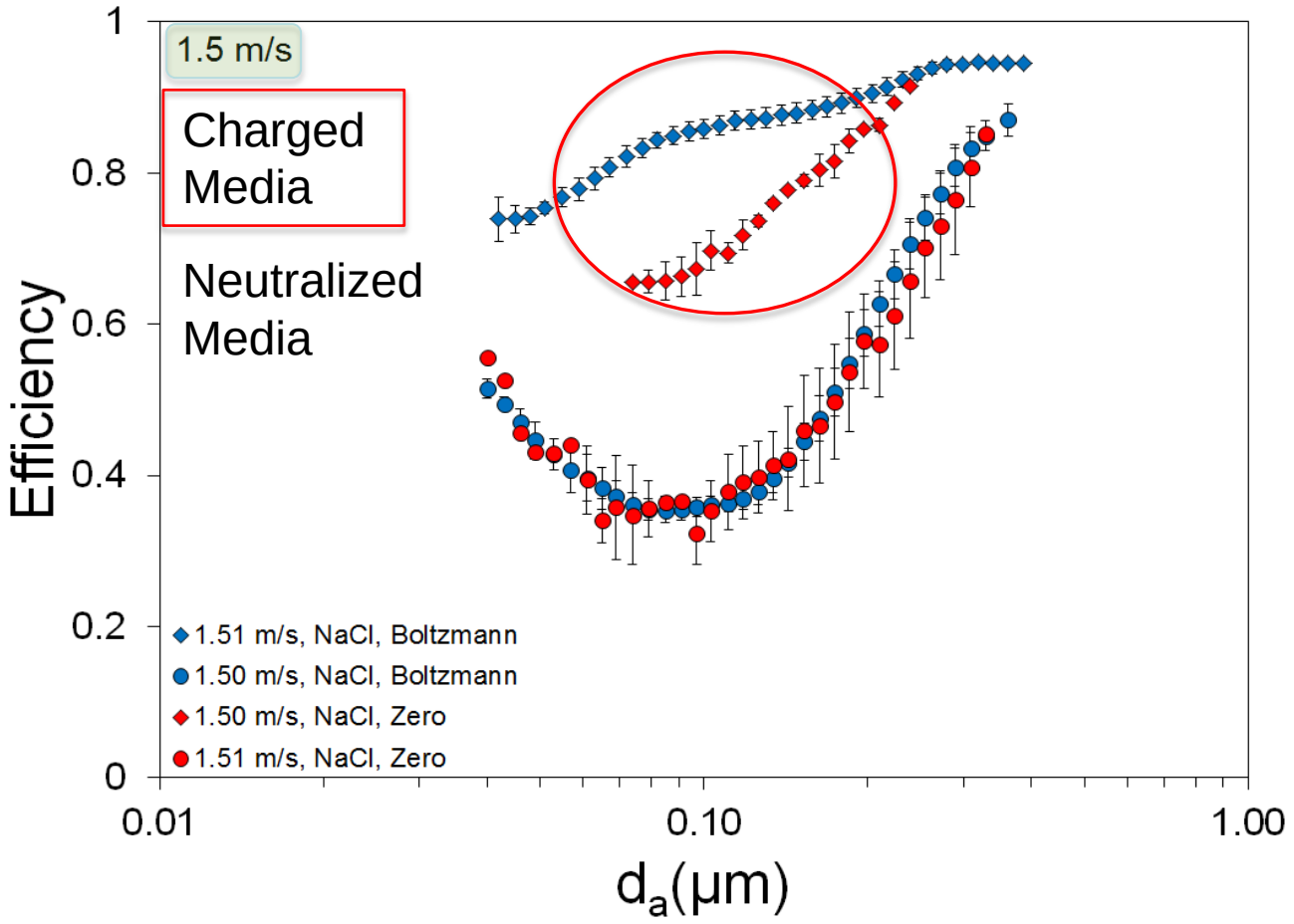
Effect of Particle Charge

- Coulomb Forces
- Image Forces
  - Electrostatic Fiber inducing a charge on uncharged particles
- Inertial Force
- Difference



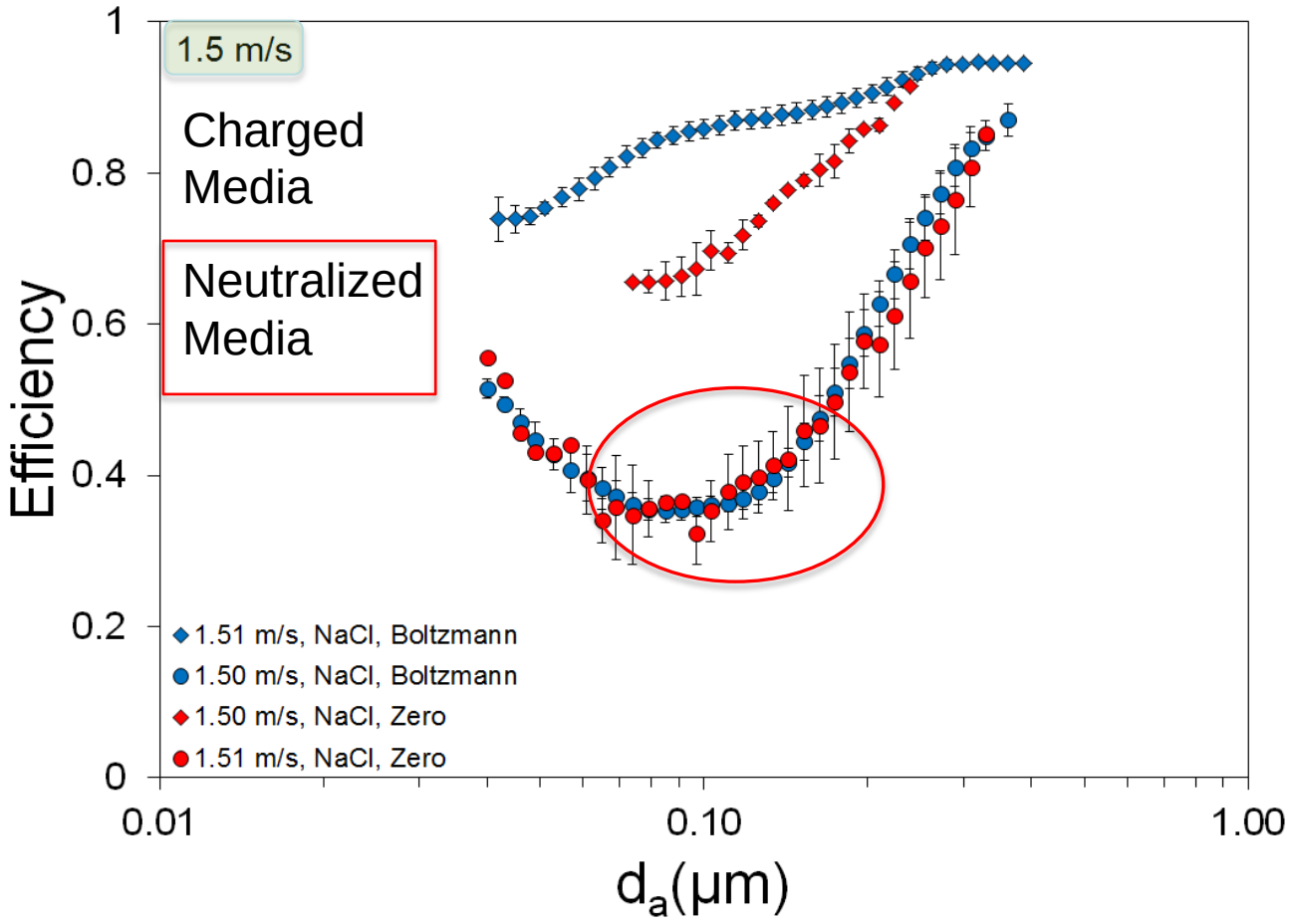
Effect of Particle Charge

- Less time for electrostatics to take effect



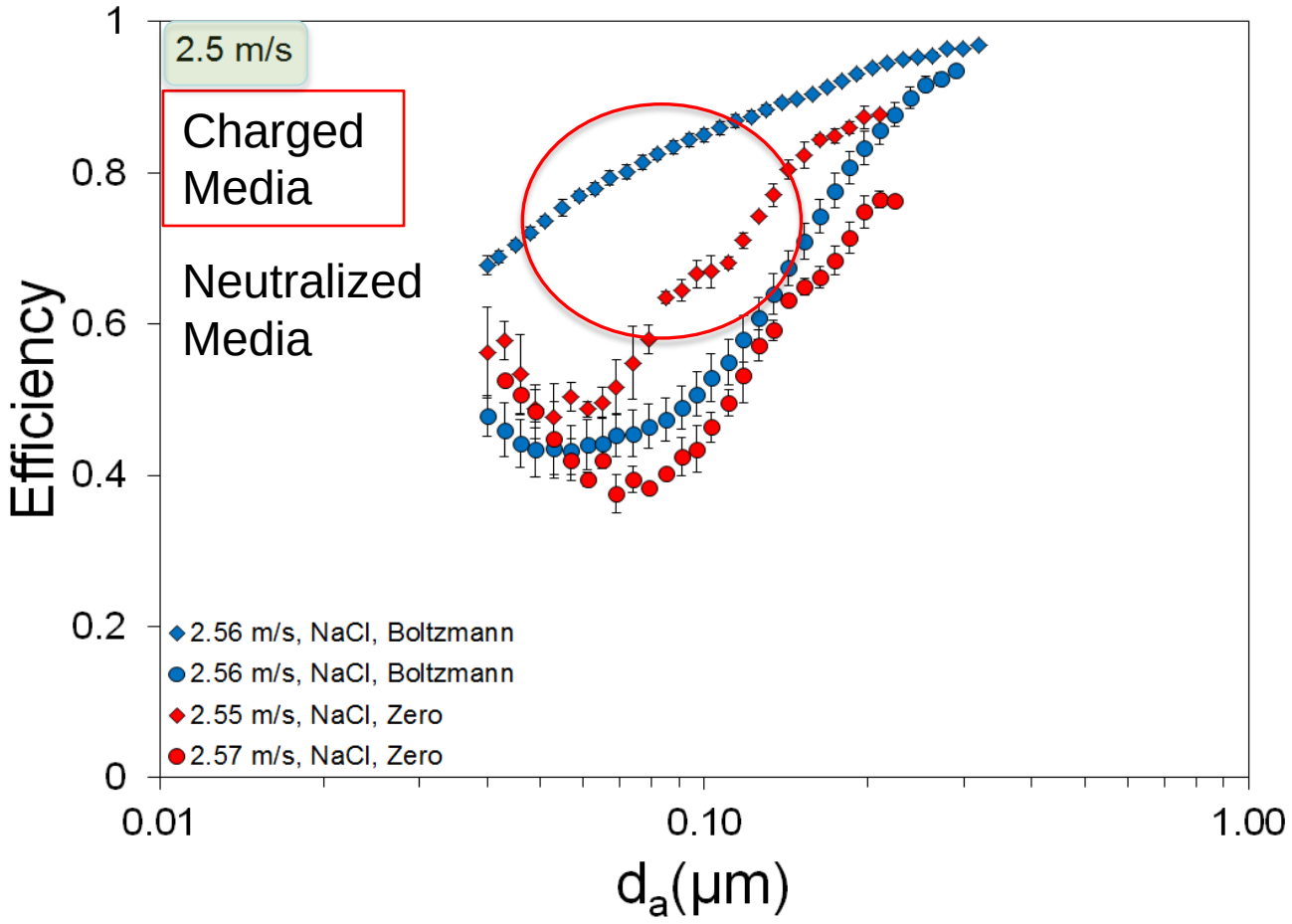
Effect of Particle Charge

- Less time for electrostatics to take effect
- Inertial Force



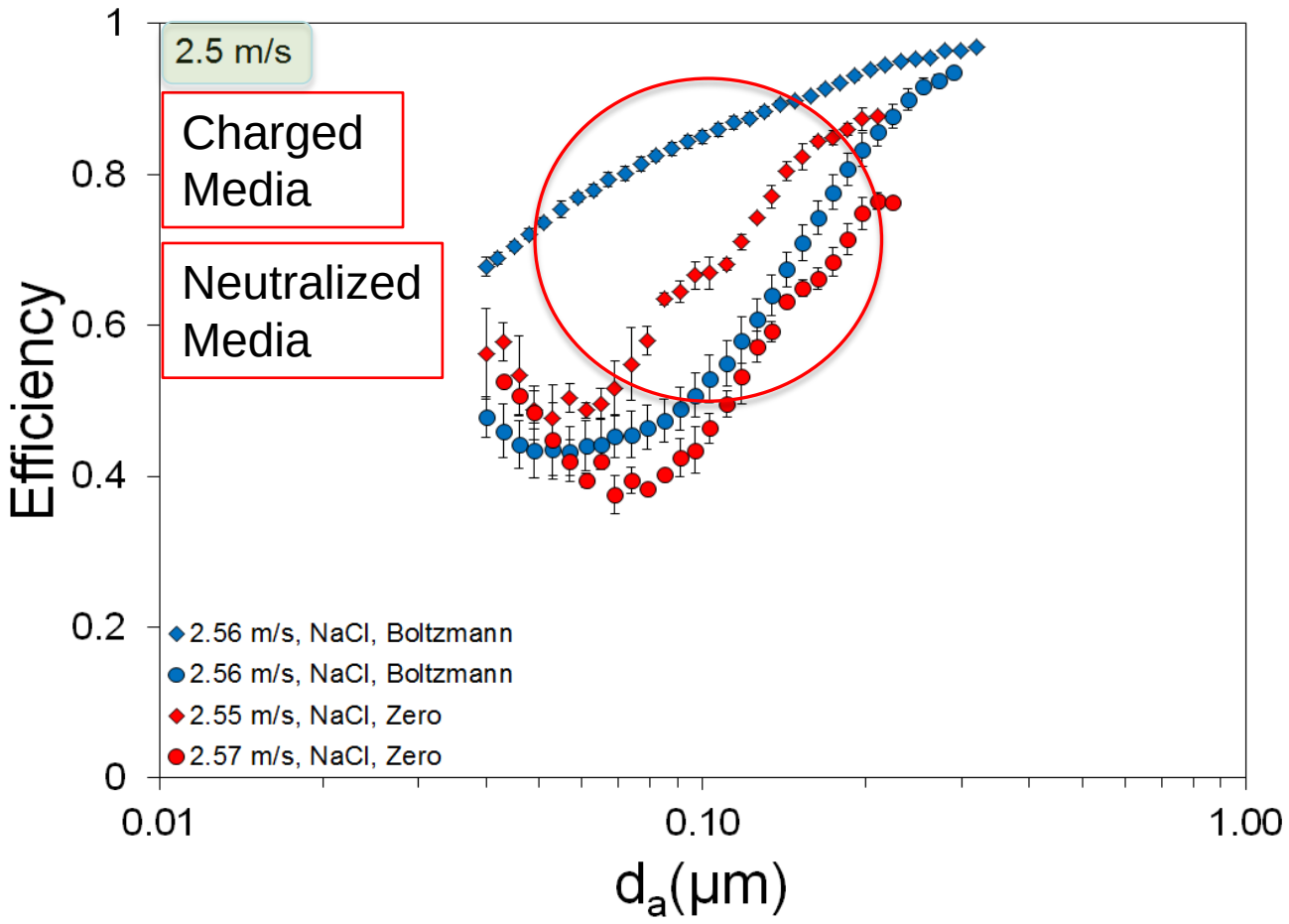
Effect of Particle Charge

- Less time for Image Forces
  - Relatively the same as 1.5 m/s



Effect of Particle Charge

- Less time for Image Forces
  - Relatively the same as 1.5 m/s
- Smaller Coulomb Force



Acknowledgments

We would like to acknowledge NNSA/NA-22, Office of Nonproliferation R&D for making this research possible. I also acknowledge Joshua A. Hubbard, Jennifer Dellinger, Brandon L. Servantes, John Brockmann, and Daniel A. Lucero for their time and effort in the preparation of this presentation

References

1. Kim, J., Jasper, W., Barker, R.L., and Hinestroza, J.P.(2010). Application of Electrostatic Force Microscopy on Characterizing an Electrically Charged Fiber *Fibers and Polymers*.11,5: 775-781.
2. Hubbard, J.A., Brockmann, J.E., Dellinger, J.G., Lucero, D.A., Sanchez, A.L., and B.M. Servantes. (2012). Fibrous Filter Efficiency and Pressure Drop in the Viscous-Inertial Transition Flow Regime. *Aerosol Science and Technology.* 46:138-147.

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