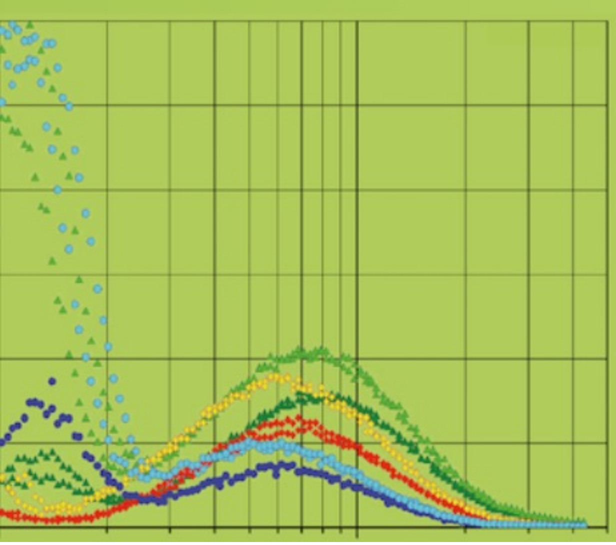

25th ETH-Conference on Combustion Generated Nanoparticles

June 21-23, 2022, Online Conference

CENTER FOR Clean Energy ENGINEERING
UNIVERSITY OF CONNECTICUT

Controlling the Sampling Parameters to quench Collision Growth of Soot Particles extracted from Laminar Premixed Flames

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Financial support for this work is being provided by the USA National Science Foundation

(Grant #CBET- 2013382, Prof. John Daily serving as Program Managers)

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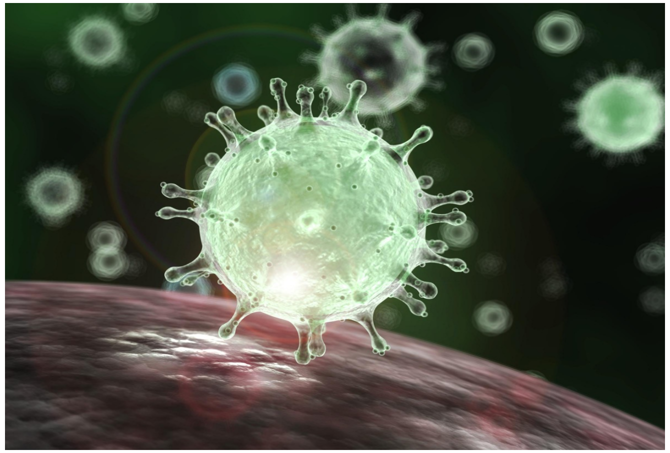
Motivations



Air Pollution

- Atmospheric visibility
- Climate change
- Cloud formation

Health

- Deposition in inhalation system
- Carcinogenic polycyclic aromatic hydrocarbons

Combustion device

- Loss of efficiency
- High maintenance
- Radiative heat transfer-heat transfer via radiation

Unravelling mechanisms of particle nucleation improves our ability to control Particulate Matter (PM) emissions

Challenges

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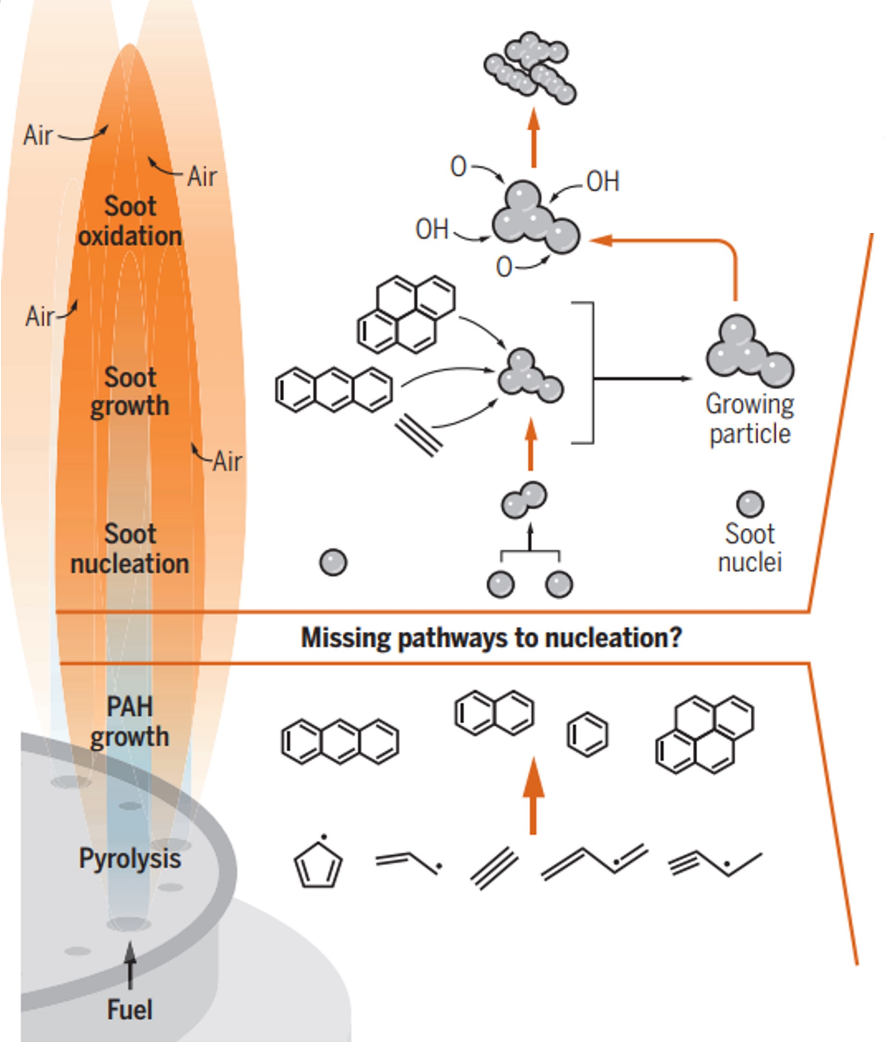

Carbone et al.(2016), Aerosol Sci Tech
Thomson and Mitra (2018), Science

Quenching the sampling modifications

⇩

Deeper understanding of gas to particle conversion

- As small as possible perturbation of the flame to be held constant in all measurements
- Controlled short residence time
- Infinite and instantaneous dilution
- Purposely charge the flame

Differential Mobility Analyzer Concept and Advantages

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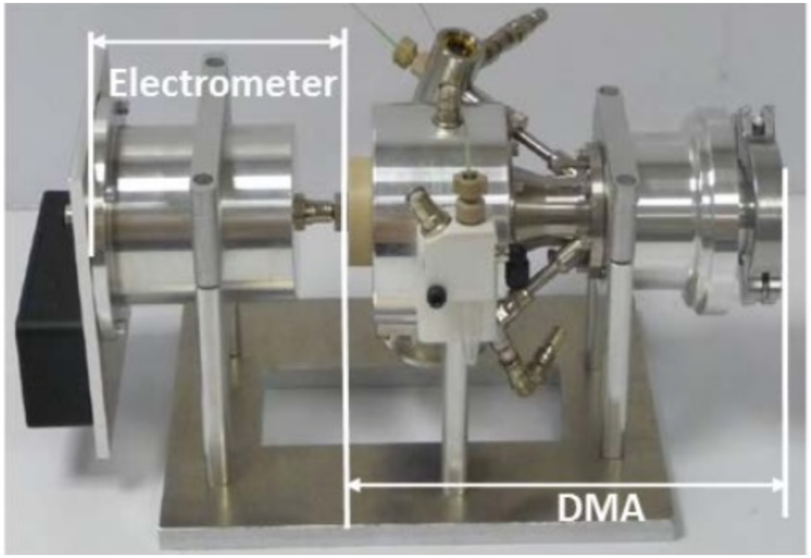
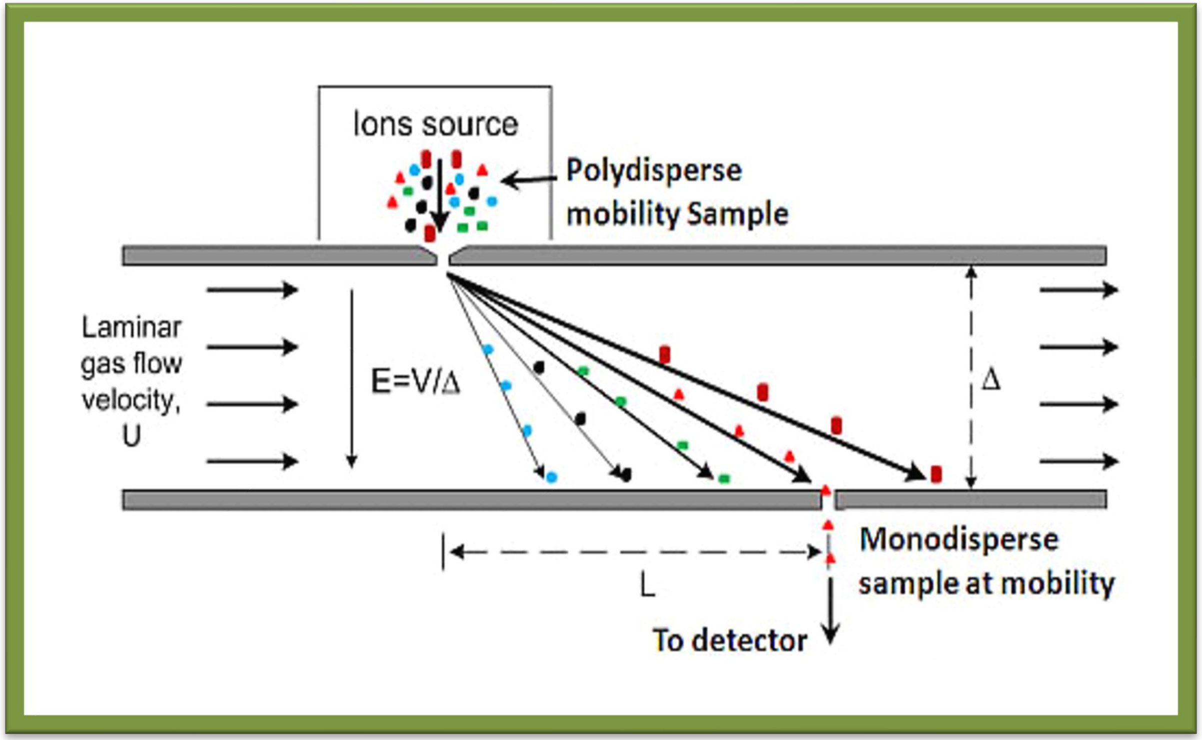
- Filters particles of chosen electrical mobility (size)
- Measures the Size Distribution Function (SDF)
- Ideal for nanoparticles (routinely as small as 2 nm but down to 0.65 nm with High-Resolution)
- No manipulation to the sample
- Need controlled charging of particles and molecules





Electrical mobility

$$Z = \frac{U}{E} \quad m^2/Vs$$

de la Mora et al (2013), J. Aerosol Sci.

Artifacts due to finite time to dilute and transport the sample to the DMA

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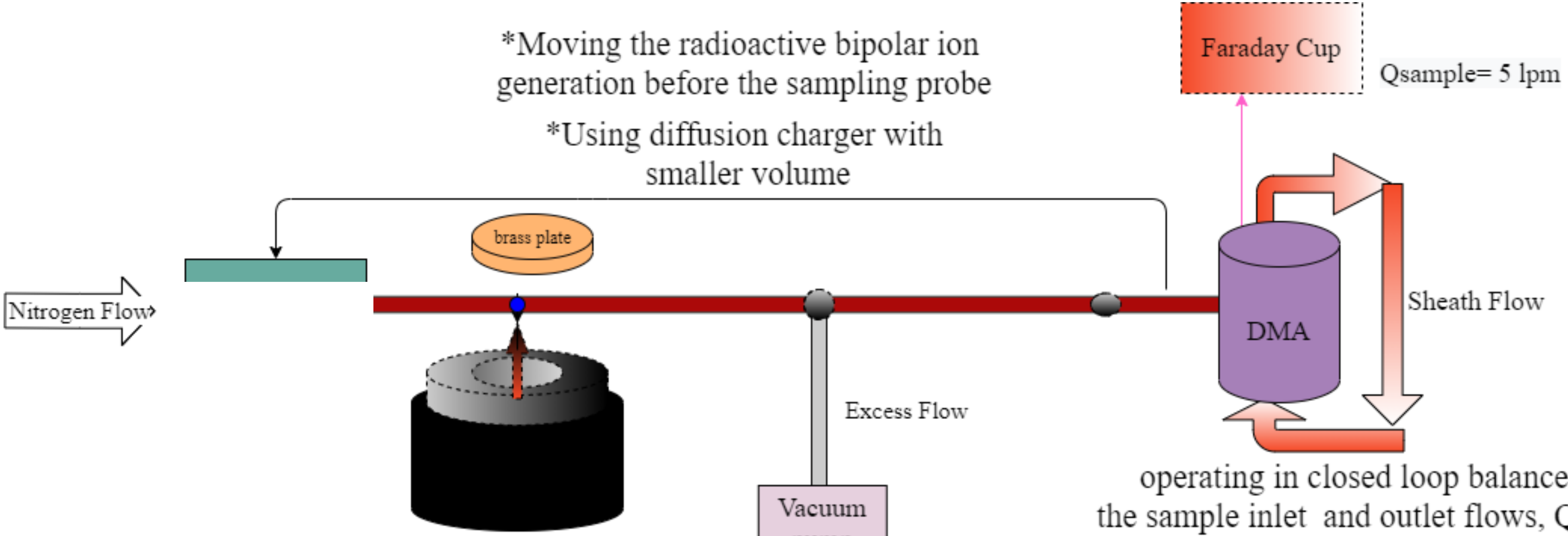
Previous Study:

*Moving the radioactive bipolar ion generation before the sampling probe

*Using diffusion charger with smaller volume



Laminar premixed Ethylene/ air flame with C/O=0.69 [Stabilized by honeycomb]

operating in closed loop balanced the sample inlet and outlet flows, Q_{DMA}, and Maximize the instrument resolution

Carbone et al.(2016), Aerosol Sci Tech
Hoppel and Frick (1990), Aerosol Science Tech.

Previous Study:

Naturally charged by the flame

Pinhole Diameter	Sample Dilution Ratio (DR)	Aerosol residence time
0.15 mm	≈ 1800	108 ms
0.25 mm	≈ 660	

Collision charged via Kr_{85} ion seeding

Pinhole Diameter	Sample Dilution Ratio (DR)	Aerosol residence time
0.08 mm	≈ 6200	108 ms
0.15 mm	≈ 1800	
0.25 mm	≈ 660	

Current Study:

For both Naturally and Collision Charged

Pinhole Diameter (mm)	Sample Dilution Ratio (DR)	Aerosol residence time
0.08	≈ 6200	**99ms (A)** **53ms (A)** **49ms (B)** **37ms (A)** **33ms (B)** **28ms (B)**
0.10	≈ 4300	
0.15	≈ 1800	
0.25	≈ 660	

Experimental Method

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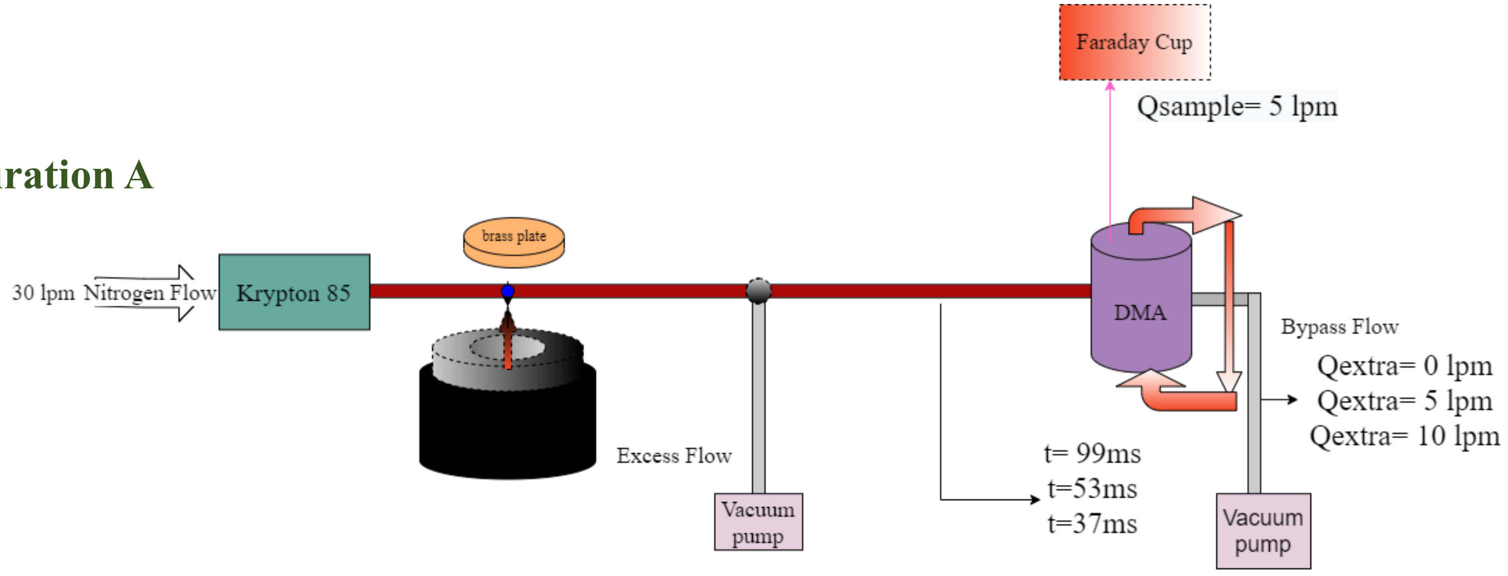
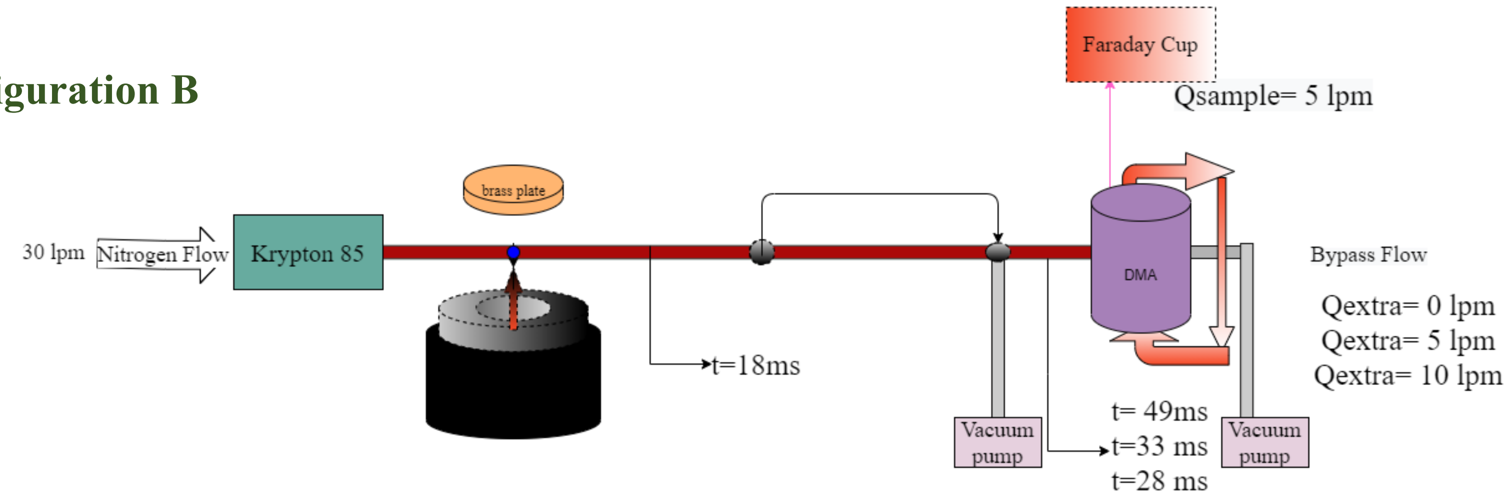
Configuration A



Configuration B



For both Naturally and Collision Charged

Aerosol residence time

99ms

28ms

Sample Dilution Ratio (DR)

≈ 1800

≈ 6200

Naturally Charged - Effect of residence time

Configuration A with 100 µm probe

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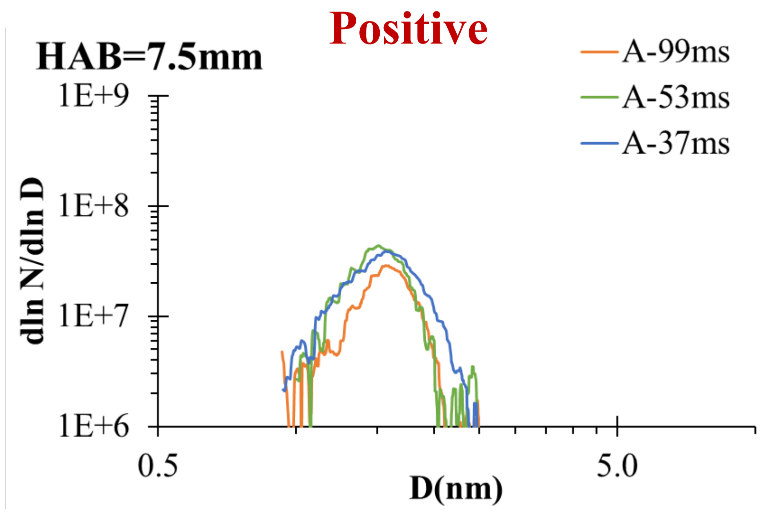
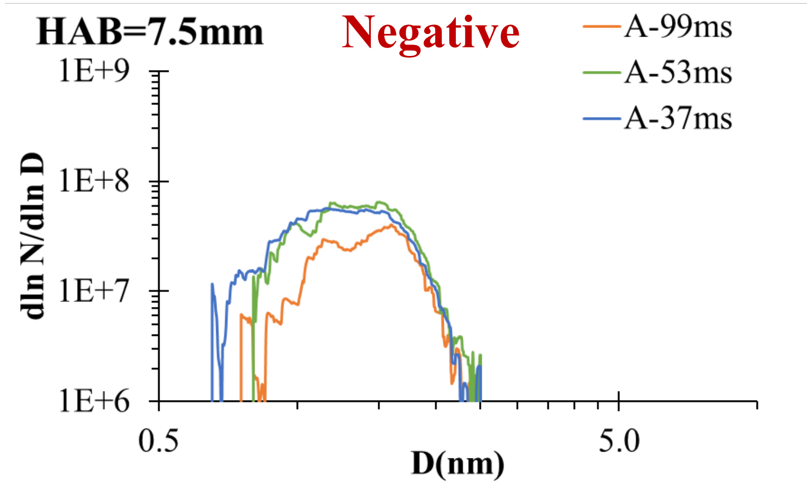
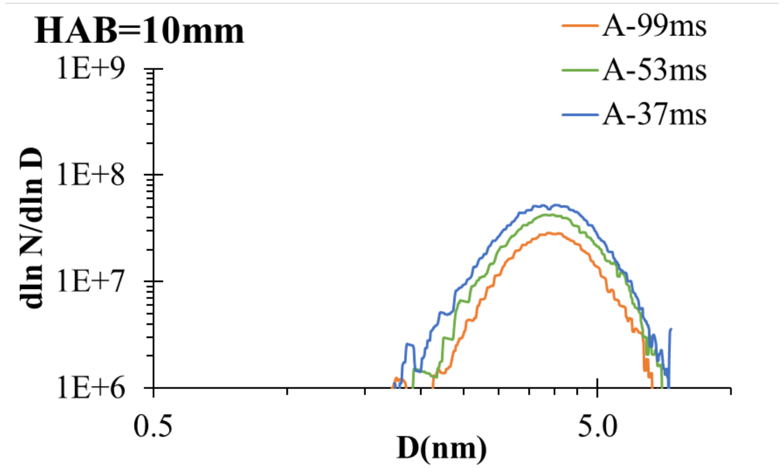
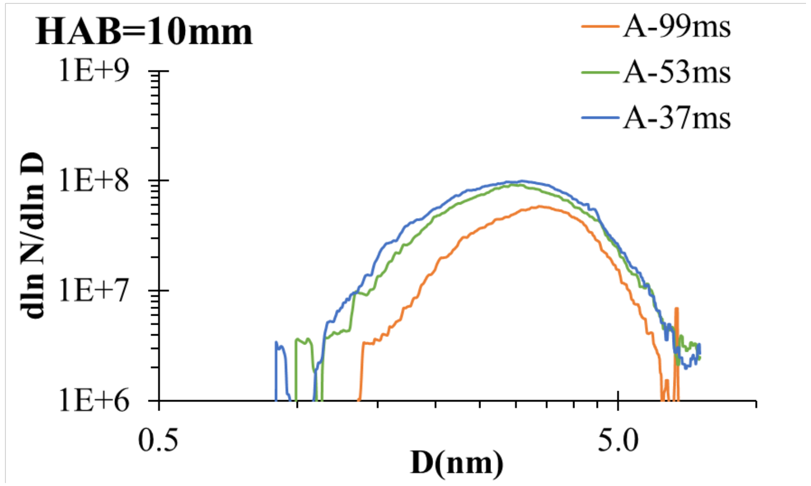




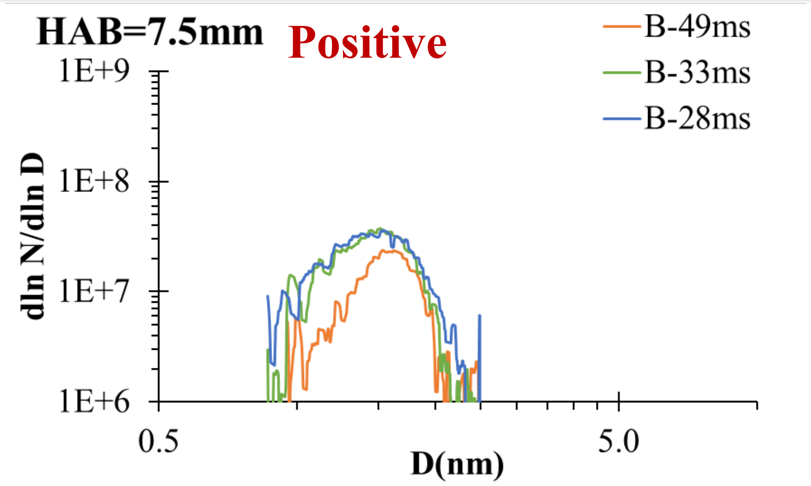


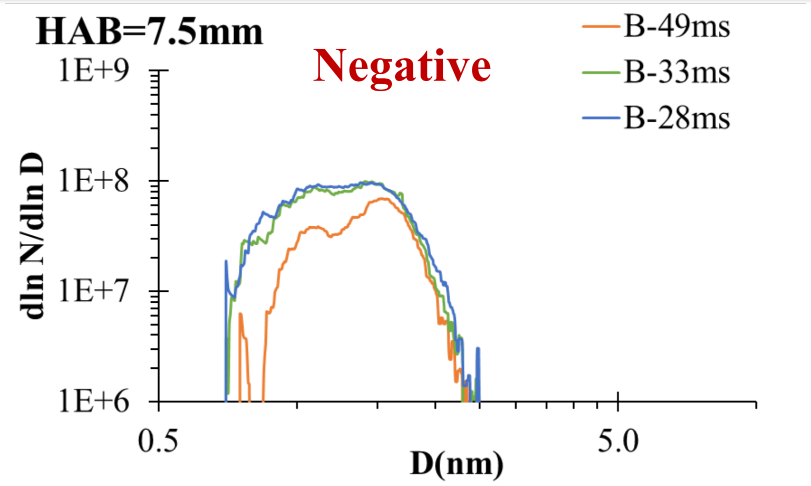


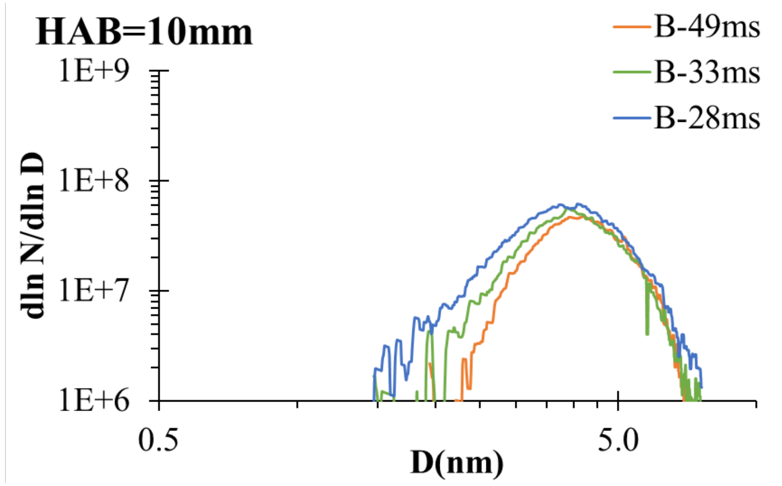
- **Key message**: Independent residence time achieved by 50% reduction of residence time For configuration A

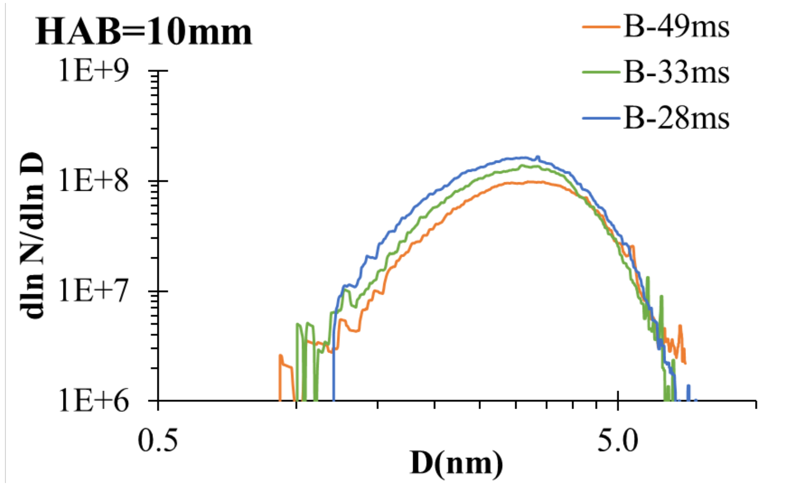
Naturally Charged - Effect of residence time

Configuration B with 100 µm probe





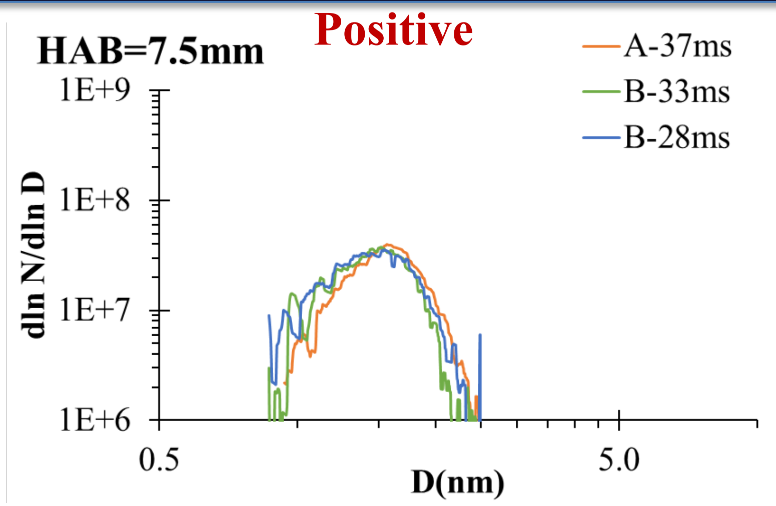


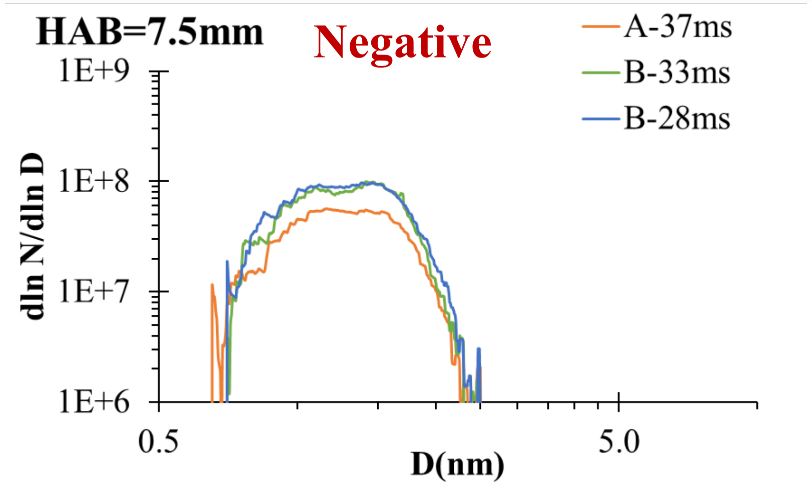


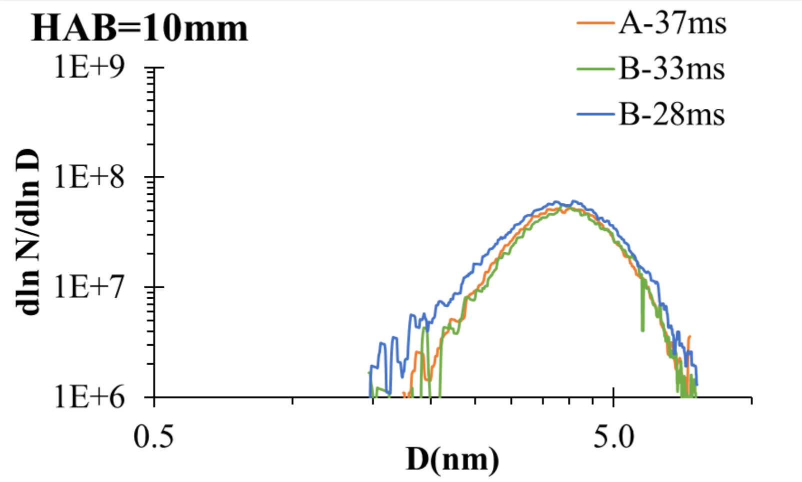
- **Key message**: Using bypass flow at the DMA inlet for configuration B results in residence time independency

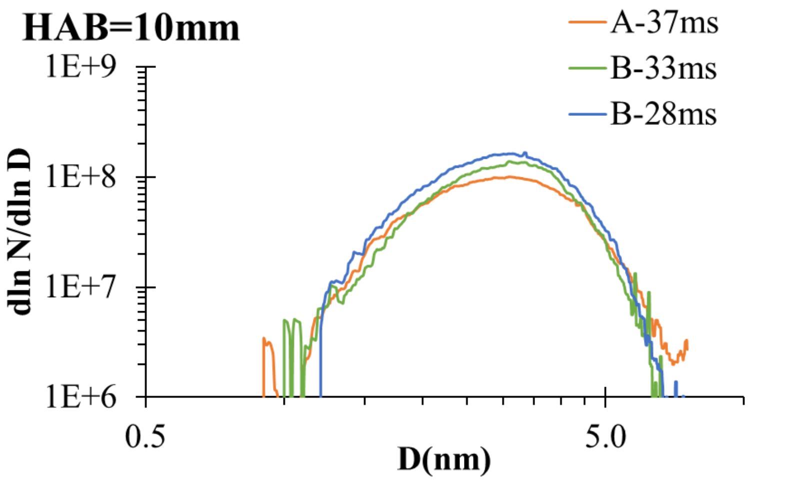
Naturally Charged - Effect of residence time

Comparison at constant residence time of Configurations A and B with 100 μm probe







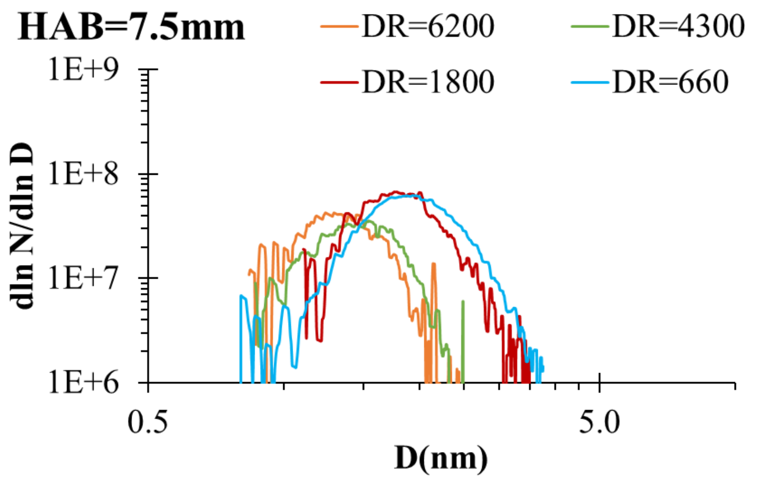


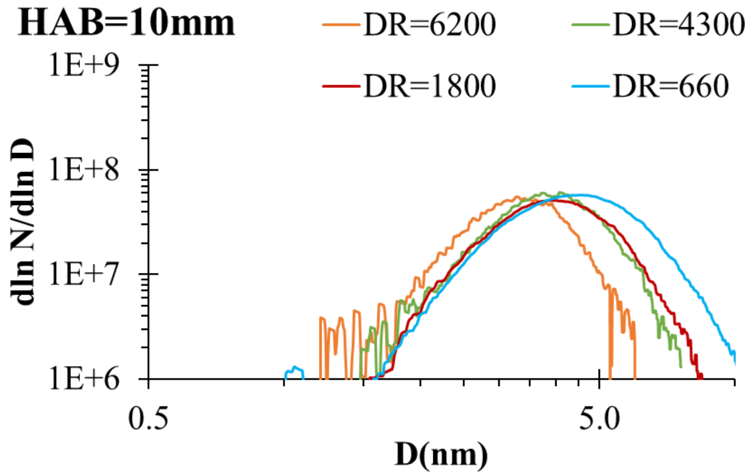
- **Key message**: Below 40ms of residence time the results are totally overlapped in both configurations

Naturally Charged - Effect off dilution ratio

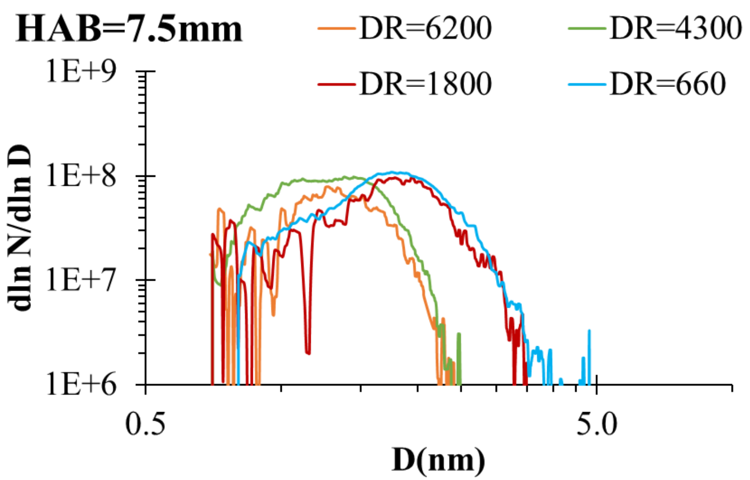
Configuration B with shortest residence time of Δt = 28 ms

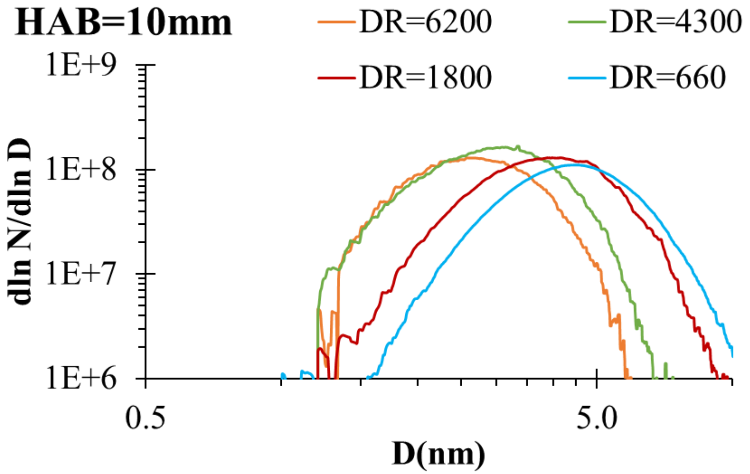
Positive





Negative





- **Key message**: SDF is independent of dilution ratio just up to 7.5mm

Collision Charged - Effect of residence time

Configuration A and B with 100 μm probe

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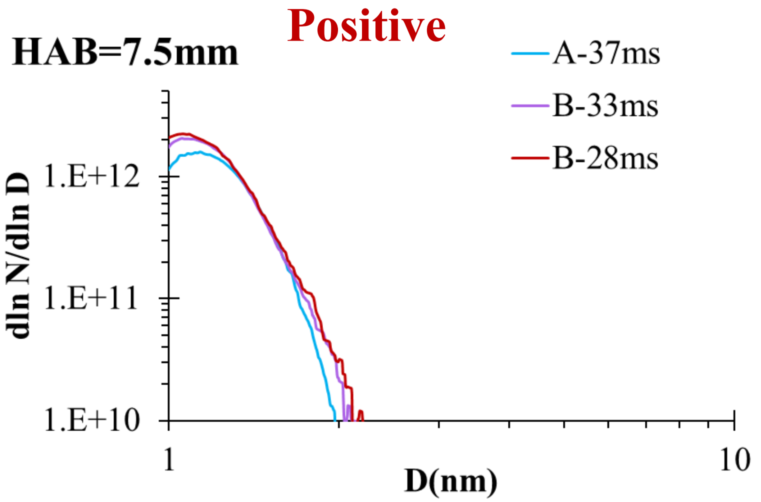
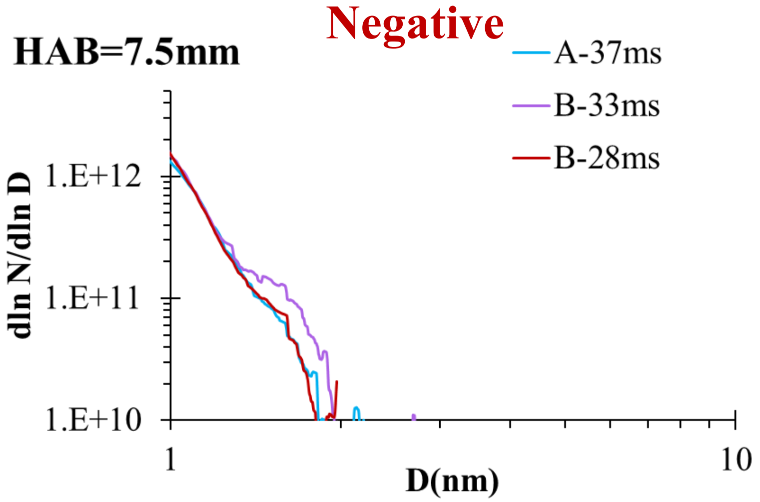
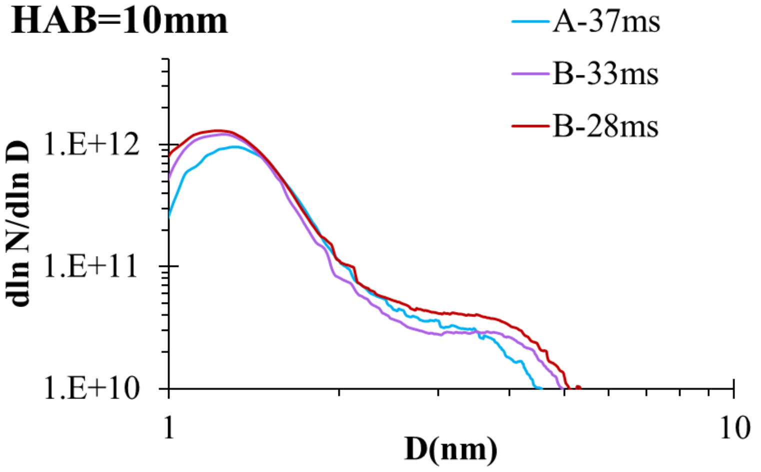
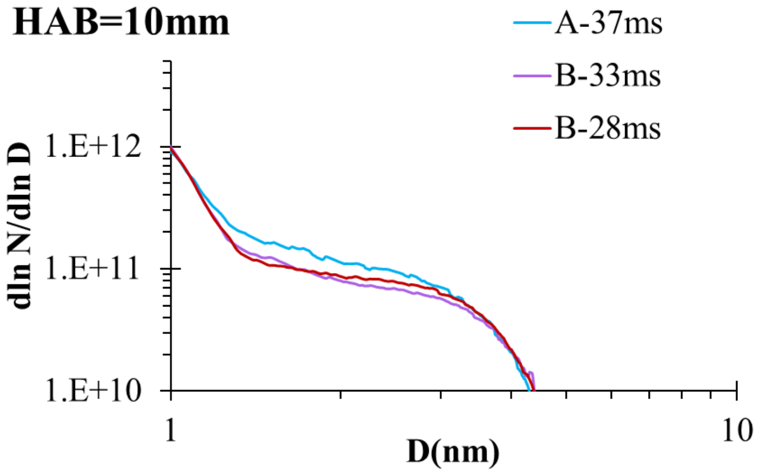




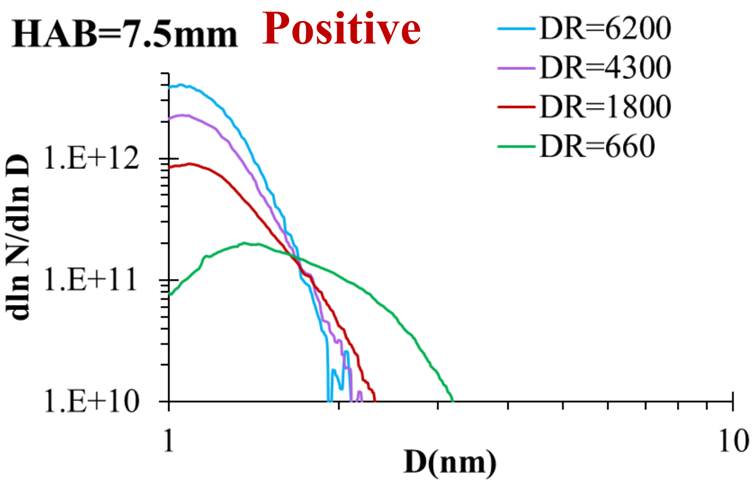


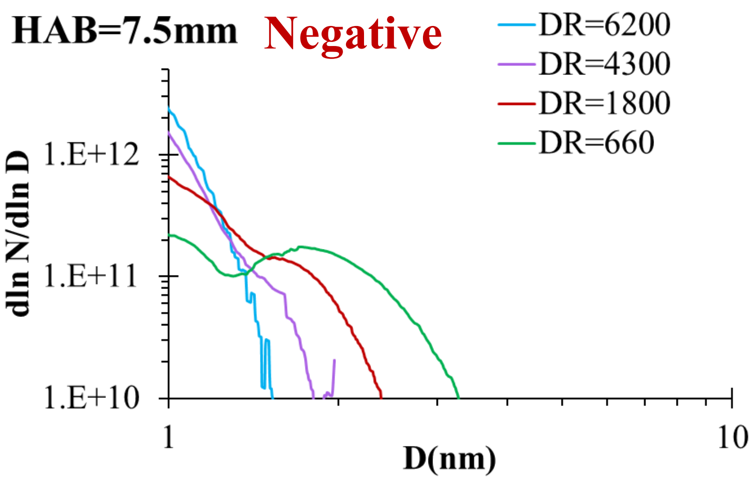


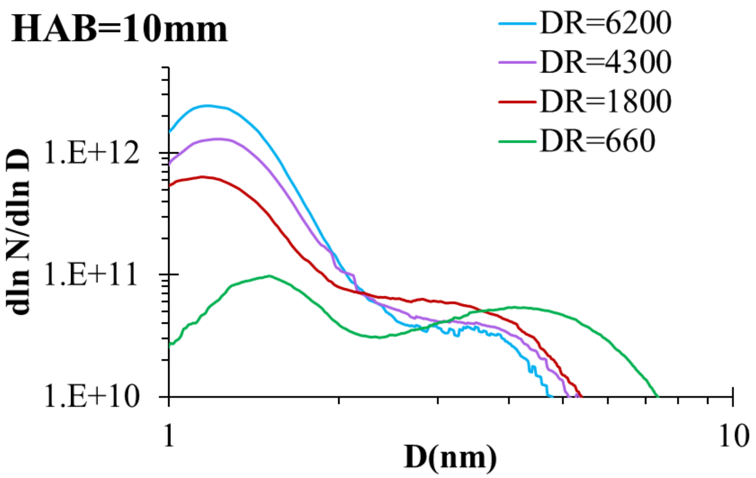
- **Key message:** In the case of collision charge, the shape of the measured SDFs is virtually independent of residence time when Δt is shorter than 40 ms

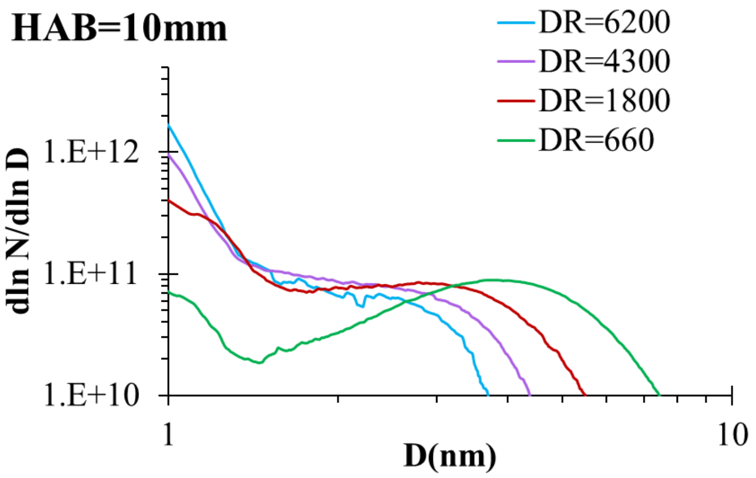
Collision Charged - Effect of dilution ratio

Configuration B with shortest residence time Δt = 28 ms









- **Key message:** SDF is approximately independent of dilution ratio for the case of minimum residence time

Conclusion

In this study, we :

- Obtained the size distribution of naturally and collision charged particles for sizes smaller than 2nm
- Controlled the transport and charging residence time (Δt) independent of all other parameters
- Minimize the residence time to 28 ms
- Quenched the sample coagulation using residence time Δt below 40 ms
- Achieved dilution independent results for collision charged particles when the Dilution Ratio (DR) is larger than 4300 (with 28ms residence time)
- Reached dilution independent results for naturally charged at HAB≤7.5mm (particles smaller than 2.5nm) but not yet at HAB=10mm where the nanoparticles have larger number concentrations and sizes.