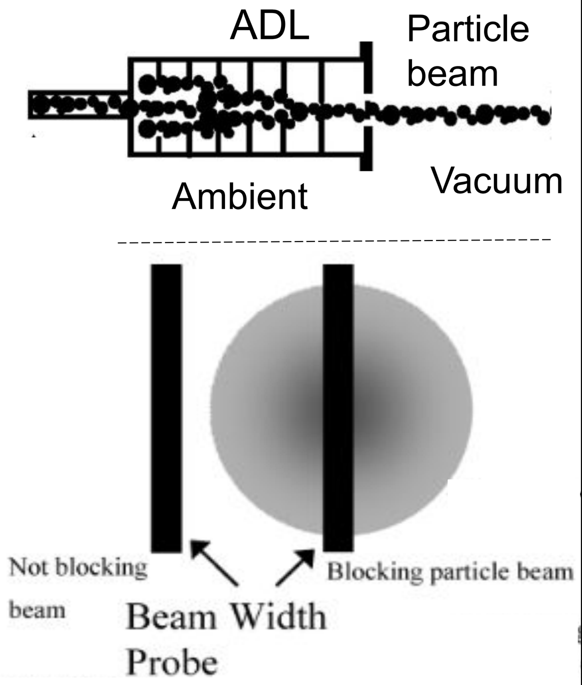
Monitoring and diagnostic tools for aerosol beams from different aerodynamic lenses

Dongwook Kim[1], Pedro Campuzano-Jost[1], Hongyu Guo[1], Da Yang[1,2], Suresh Dhaniyala[2], Leah Williams[3], Philip Croteau[3], John Jayne[3], Douglas Worsnop[3], and Jose L. Jimenez[1]

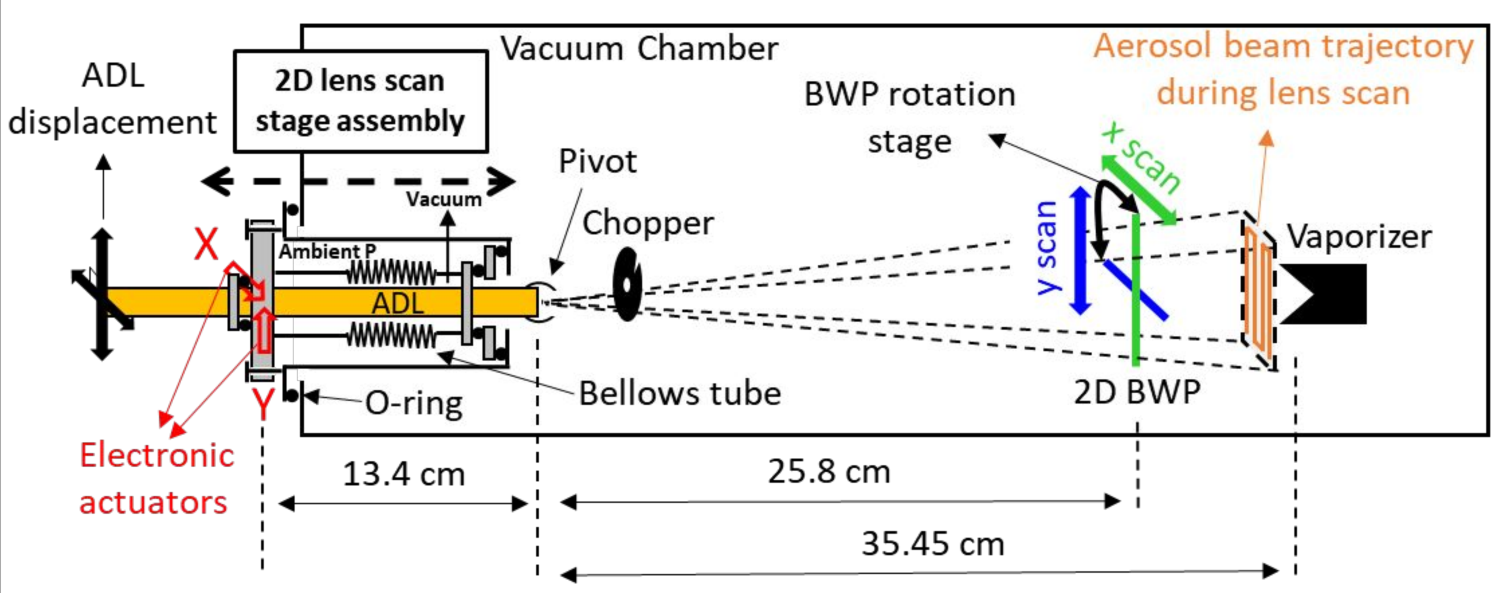
1. CIRES and Department of Chemistry, University of Colorado Boulder 2. Clarkson University 3. Aerodyne Research Inc.

Introduction and background

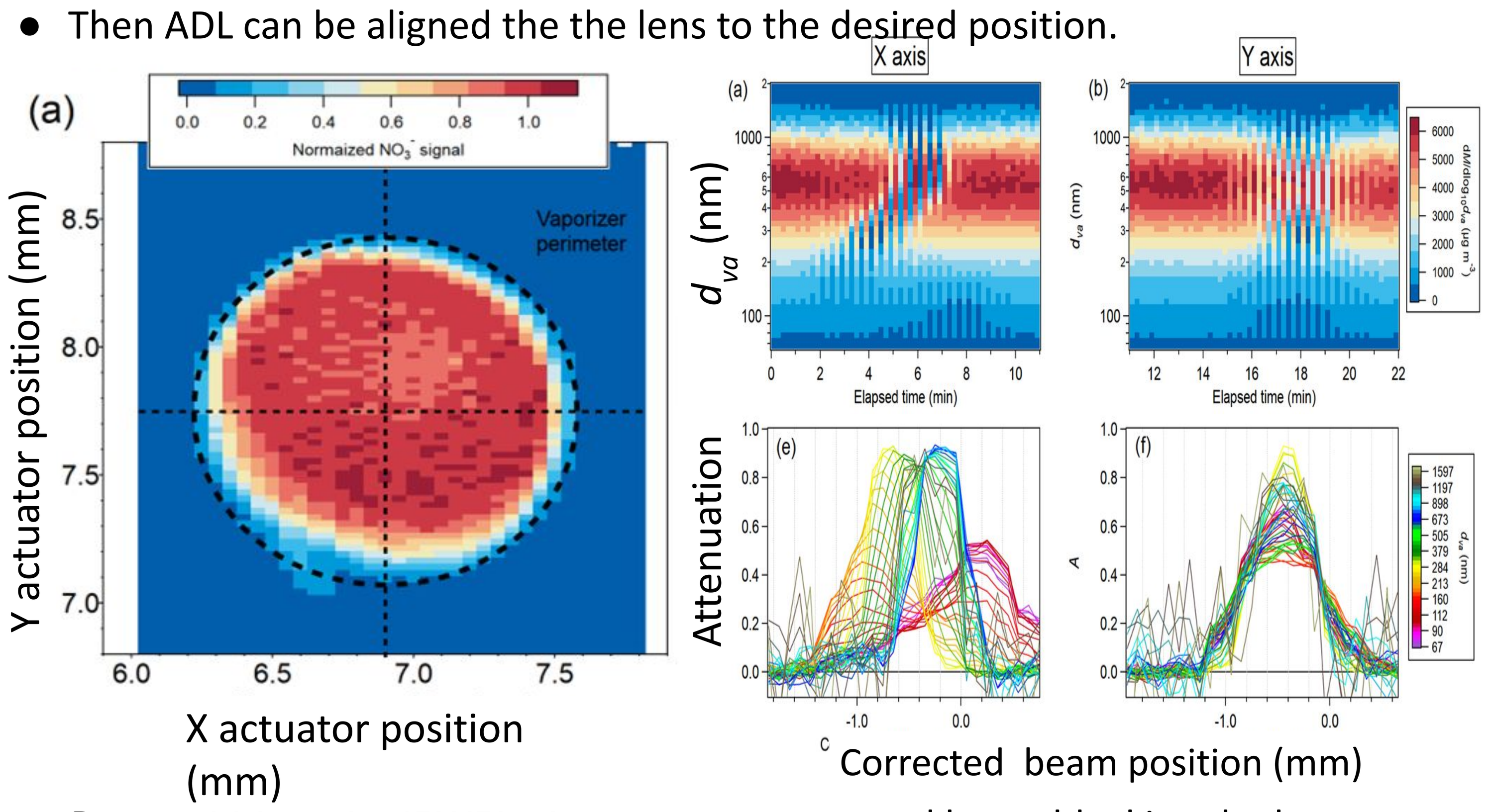


- Aerodynamic lenses (ADLs) collimate aerosols into a beam separating particles from gasses, allowing real time mass spectrometry.
- **PM_1 lens** (a modified Liu Lens (1997) commercialized by Aerodyne) is most widely used for mass spectrometers such as **AMS**. More recently developed lenses such as **$PM_{2.5}$ lens** and **HPL** shows significantly higher transmission efficiency for supermicron aerosols.
- However, the focusing and pointing properties of the collimated beams from ADLs has not been thoroughly measured to date.
- In this study, we present **1)** the development of tools for 2D aerosol beam diagnostics and modeling. **2)** we show how the beam focusing/pointing varies as a function of particle size. **3)** and estimate how such shift in beam width and position affect the quantitation of aerosol measurement.

Lens scan & 2D-BWP stage

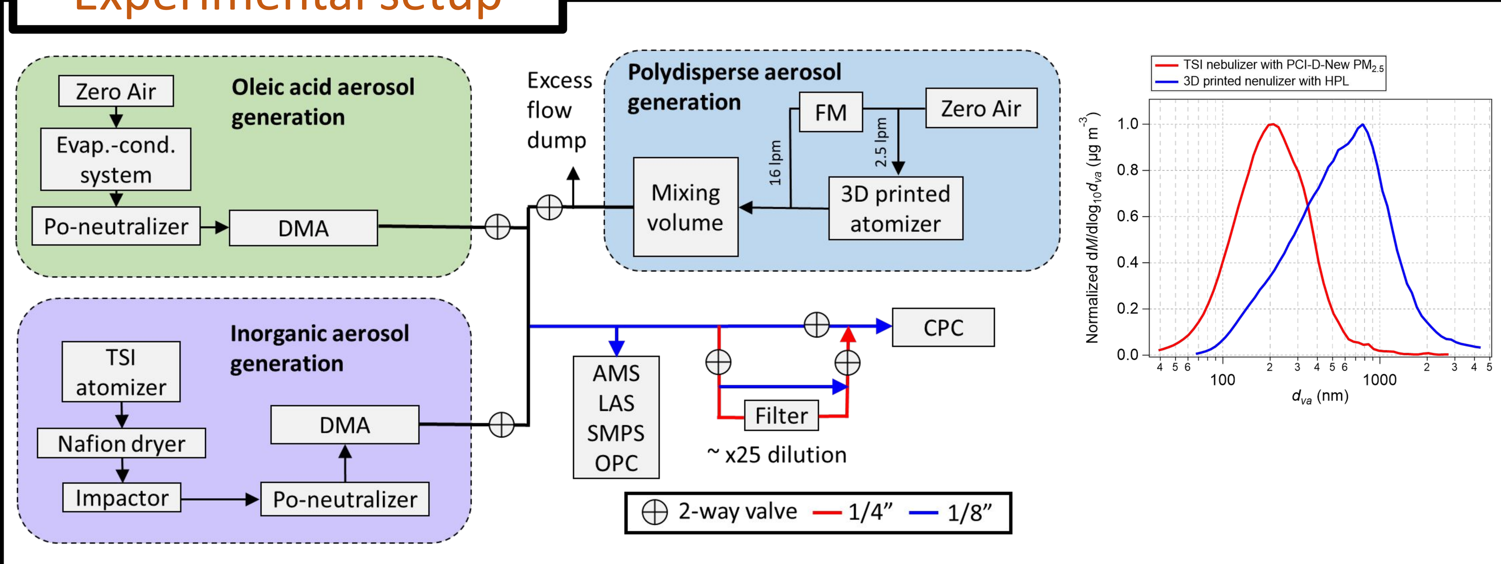


- The lens scan stage tilt the ADL using two actuators in perpendicular direction.
- The automated sequence can scan the lens over the vaporizer and find the center of the vaporizer accurately.
- Then ADL can be aligned the the lens to the desired position.



- Beam width probe (BWP) wire scan across aerosol beam blocking the beam partially or completely, providing beam width and position.
- A rotation stage was developed for BWP scan in two dimension.
- Running in AMS PToF mode (with polydisperse NH_4NO_3 input), provide size-resolved information of beam width and position (2D-SR-BWP).

Experimental setup



- Laboratory setup for generation of monodisperse and polydisperse aerosols.
- The modified the 3D-printed nebulizer (Rösch and Cziczo, 2020) and achieved broader size range than TSI atomizer. Medical nebulizer works as well.

Acknowledgements

This research has been supported by NSF grant AGS-2027252, and NASA grants 80NSSC21K1342, 80NSSC21K1451, and 80NSSC23K0828. DK has also been partially supported by the CIRES Graduate Student Research Award and the AGU Jerome M. Paros Scholarship in Geophysical Instrumentation.

References

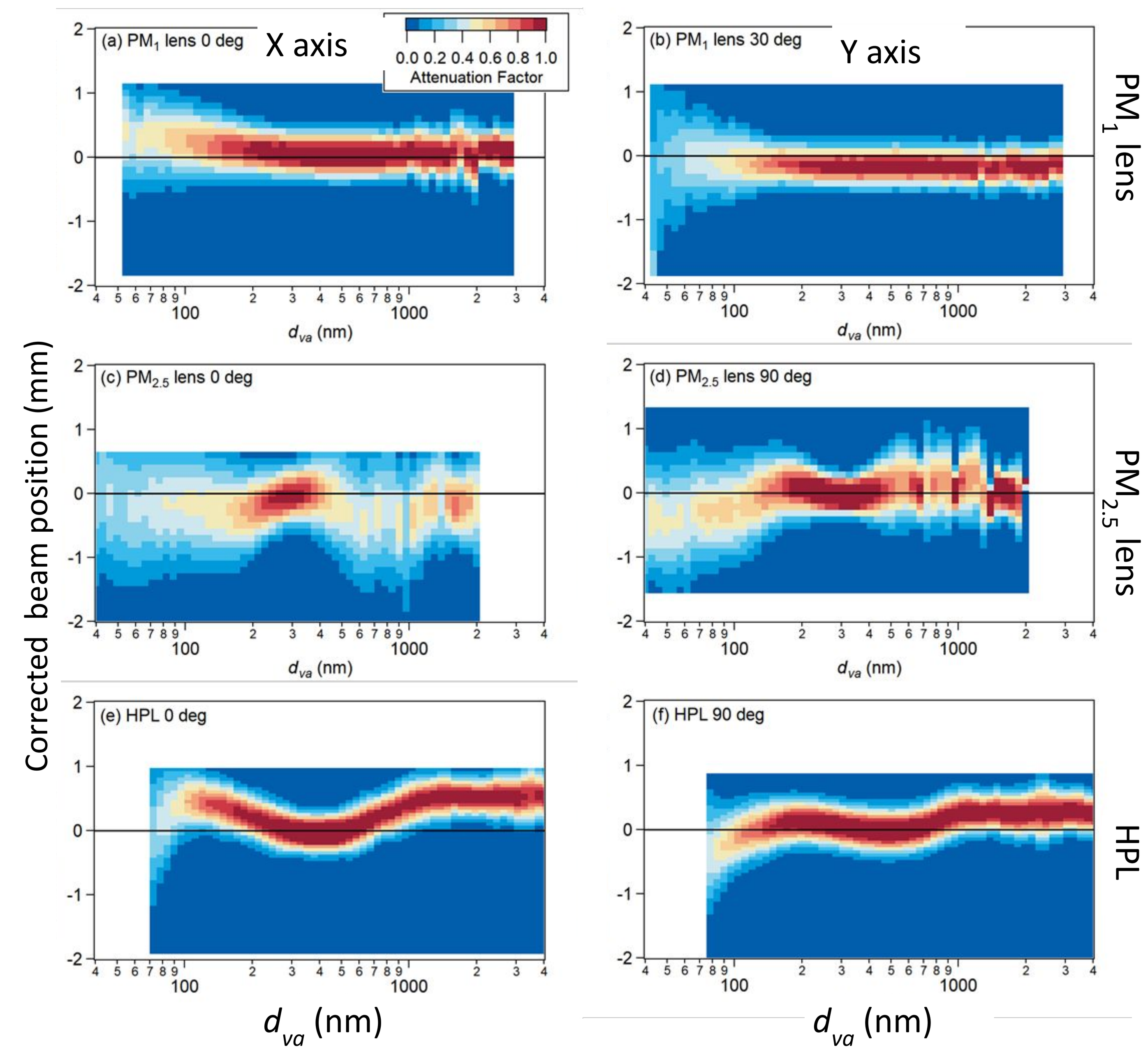
DeCarlo et al. (Anal. Chem., 2006), Liu et al. (AS&T, 1997),Liu et al. (AS&T, 2007), Williams et al. (AMT, 2013), Xu et al. (AS&T, 2017), Huffman et al. (AS&T, 2005), Rösch and Cziczo (AMT, 2020), Clemen et al. (AMT, 2020)

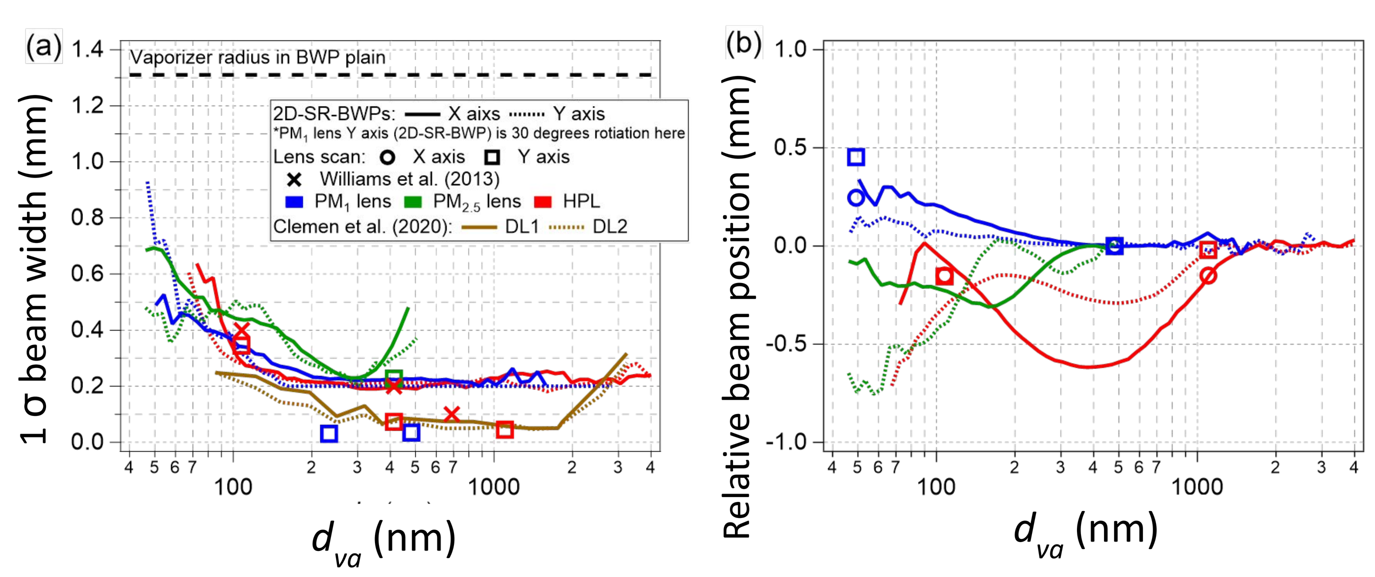
Take home messages

CONTACT: dongwook.kim@colorado.edu, jose.jimenez@colorado.edu

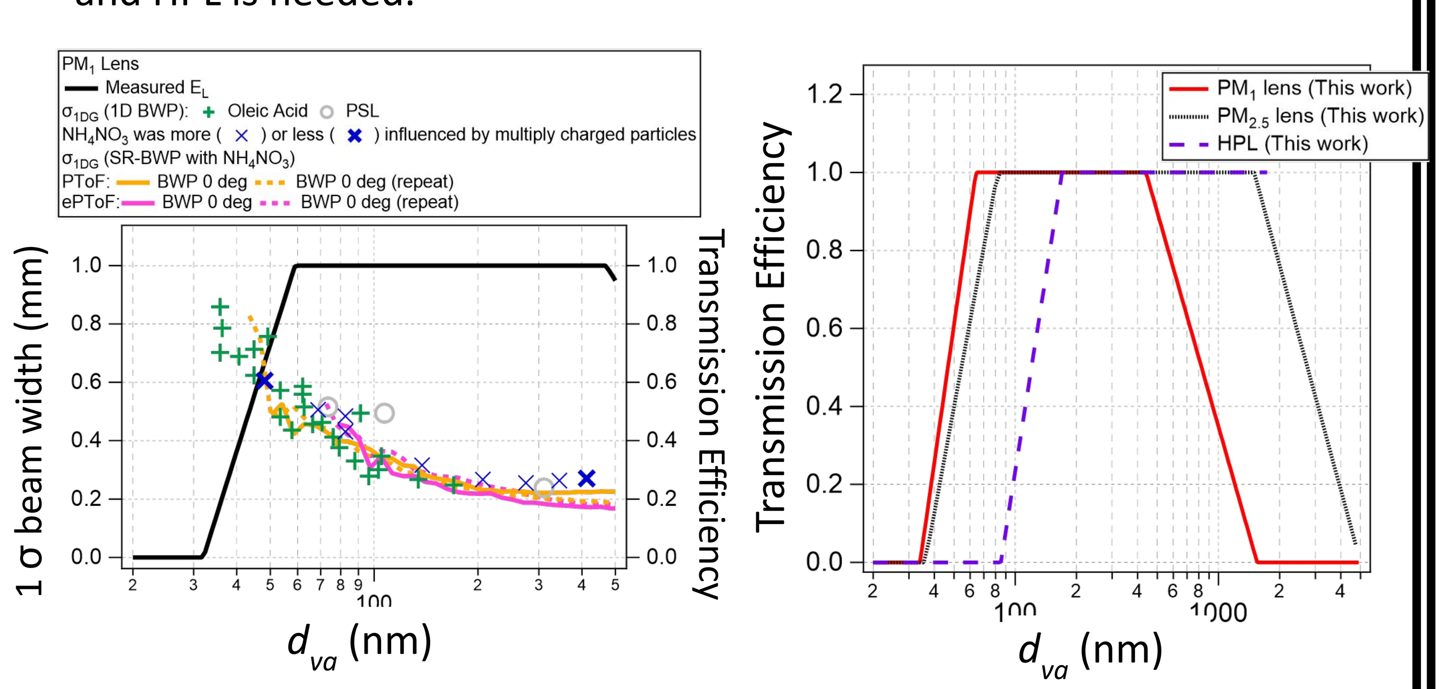
- New tools were developed to measure particle beam and to align the aerodynamic lens.
- Aerosol beam focusing (**beam width**) and pointing (**beam position**) **depends on particle size**.
- **$PM_{2.5}$ lens:** careful lens aligning, monitoring, and optimization is recommended.
- HPL and $PM_{2.5}$ lens transmit supermicron particles but show irregular beam focusing/pointing.
- Beam modeling can estimate particle transmission efficiency.
- PM_1 lens showed least irregularity in beam focusing/pointing.

2D size resolved beam width probe (2D-SR-BWP)



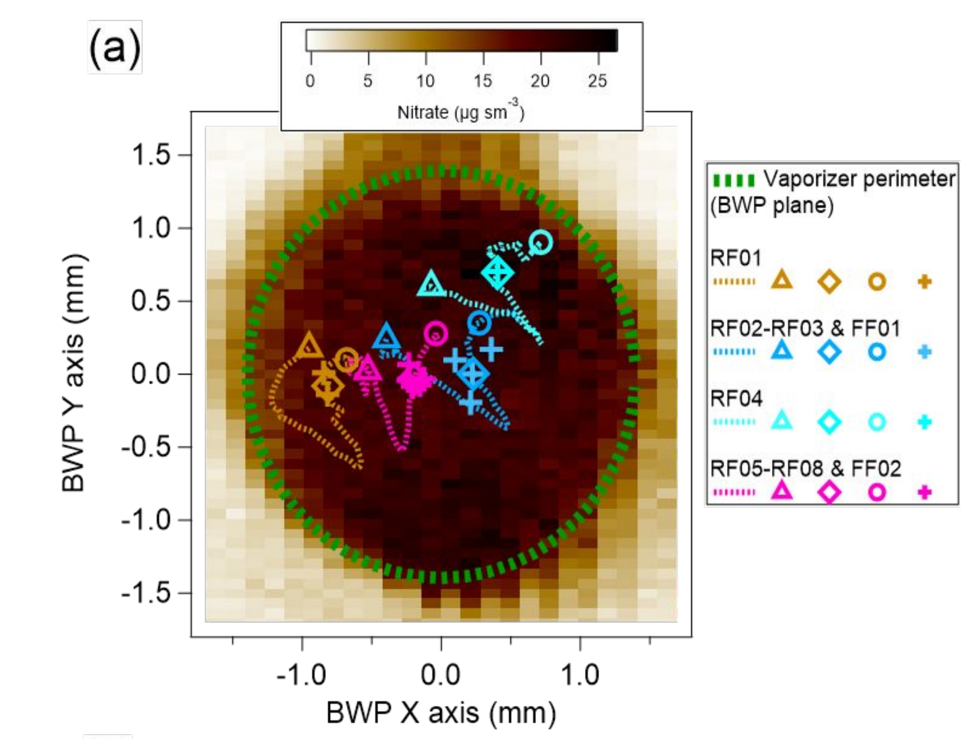


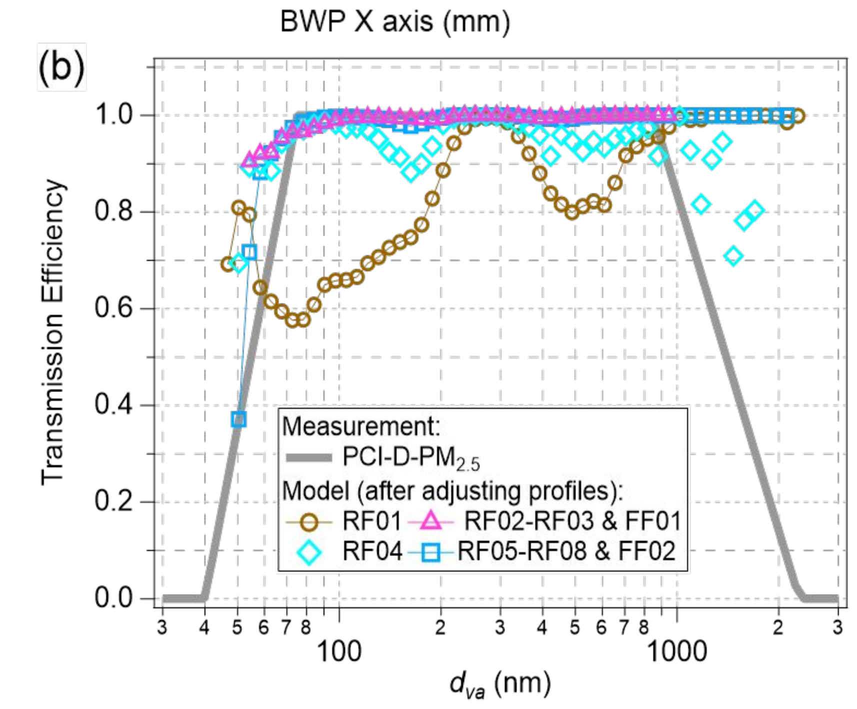
- 2D size resolved BWP (2D-SR-BWP) was performed for three lenses, PM_1 lens, $PM_{2.5}$ lens and HPL.
- PM_1 lens and HPL showed monotonic decrease of beam width for larger particles.
- HPL and $PM_{2.5}$ lens significant beam position shift for different particle sizes.
- The beam width of $PM_{2.5}$ lens decrease for larger d_{va} until 300 nm and broadened for 300-700 nm dva.
- These results suggest that more careful lens alignment for $PM_{2.5}$ lens and HPL is needed.



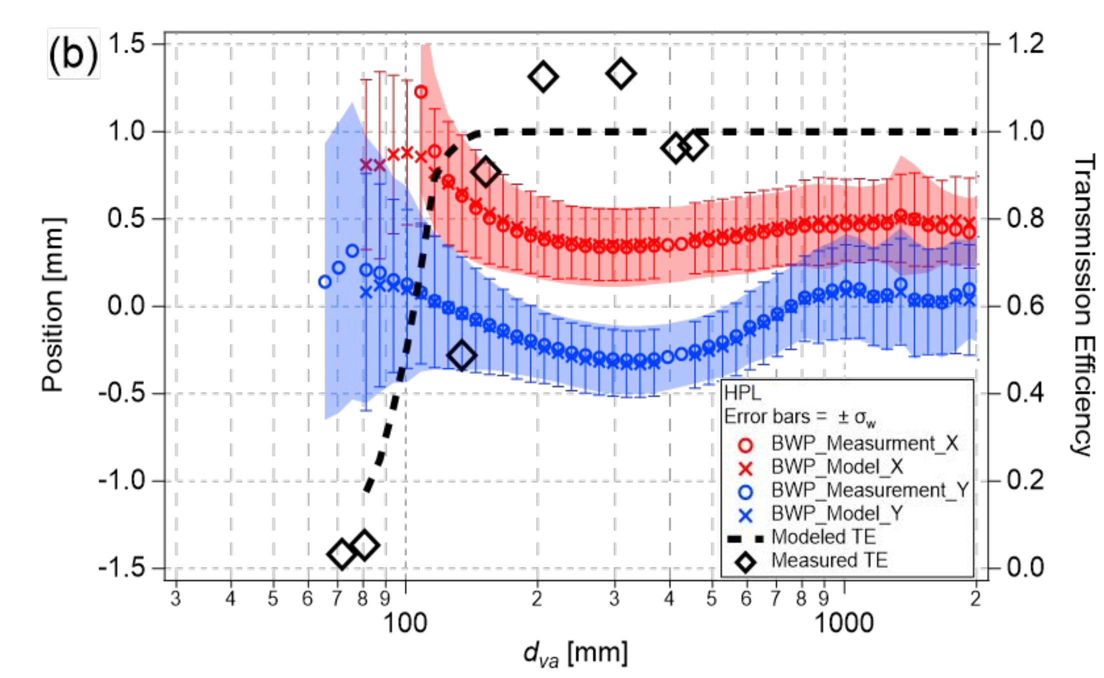
- The beam widths from 2D-SR-BWP were compared to the traditional operation (monodisperse aerosol), and they agreed well (left Fig.).
- The broadening of beam width at smaller particle sizes match with the decline of lens transmission efficiency (E_L), indicating the particle losses due to beam broadening.
- Right Fig.: While HPL shows superior transmission for supermicron particles, PM_1 lens and $PM_{2.5}$ lens are better at Aitken mode aerosol sampling.

Beam modeling and particle transmission

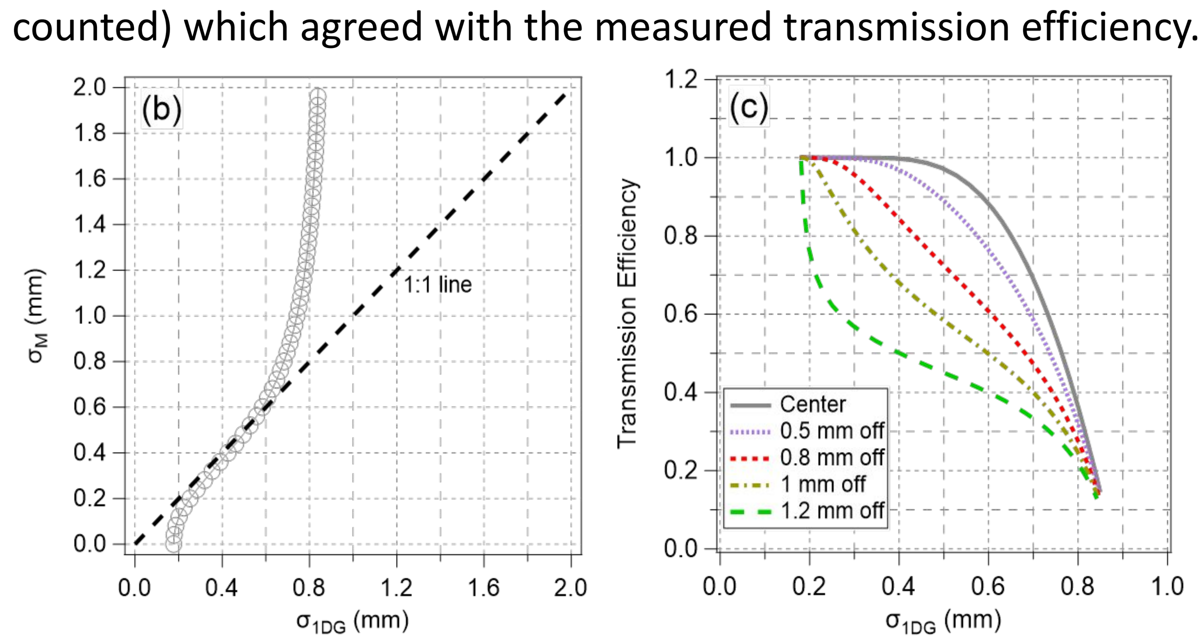




- Such 2D-SR-BWP measurements were conducted in-field condition (NSF TI³GER). During the campaign $PM_{2.5}$ lens was used with a PCI.
- The transmission efficiency (that accounts for the missed particles by the vaporizer) was estimated throughout the campaign.
- The model showed that the transmission was not impacted by the irregular beam focusing/pointing, except for the first flight.



- The beam model constrained by 2D-SR-BWP reconstructs the elliptical 2D Gaussian beam.
- Then the fraction of aerosol of the reconstructed beam that impact the vaporizer is calculated (particle losses inside ADL not counted) which agreed with the measured transmission efficiency.



- The measured beam width by BWP is different from the actual width due to the convolution of wire width in the measurement.
- We developed the model that account for the wire effect and estimate more realistic width assuming a Gaussian beam.