Imaging your particle beam in 3D: New approaches to beam alignment and beam profiling

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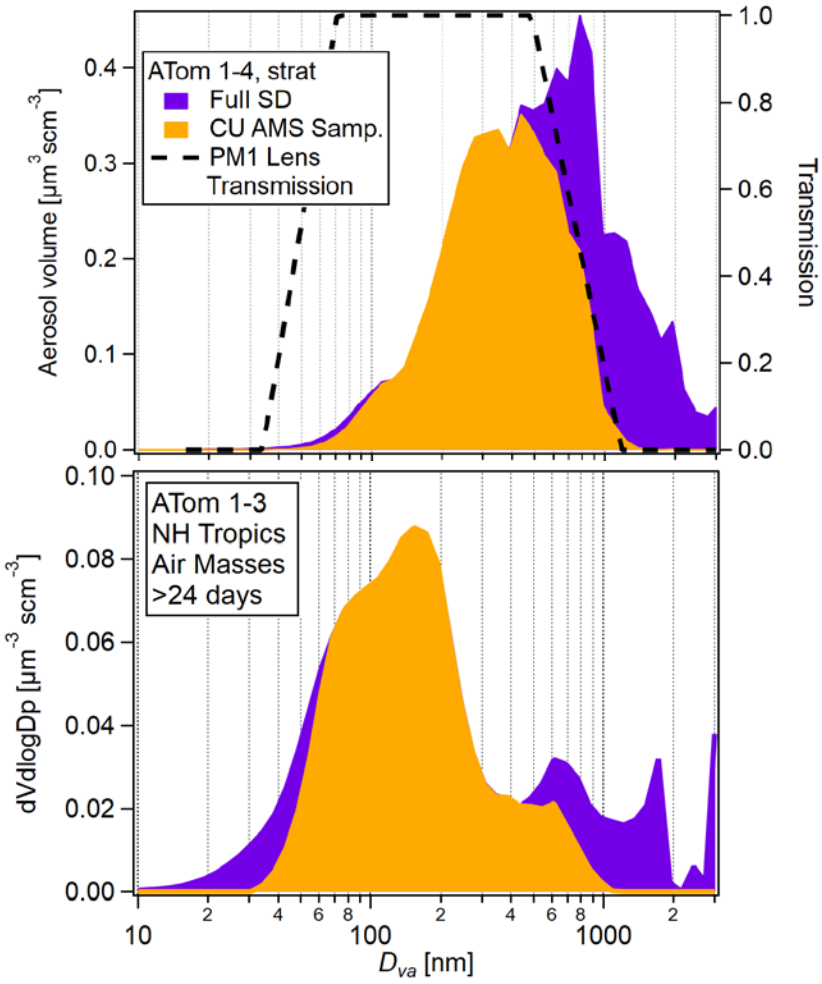
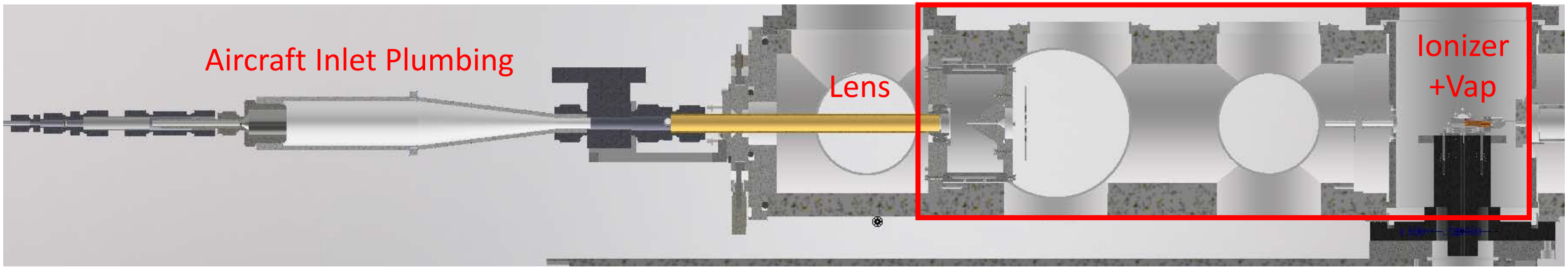
XXI AMS Users Meeting, First Virtual Meeting
Jan 20th, 2021

Motivation

- Funded aircraft deployment into the tropical upper troposphere/lower stratosphere in 2022
- Need new inlet that (Talk by Dongwook Kim, Jan 21st, 2020 13:00 EST):
  - Works at 75 mbar ambient pressure (currently 250 mbar)
  - Does ideally ~PM2 (currently PM0.75) for adequate sampling of sulfuric acid distribution
  - Does NOT lose sub-100 nm particles that are abundant in the UT (Williamson et al, 2019)
- Size dependent transmission (ignoring particle bounce) depends:
  - On the "ideal" transmission thru the lens itself (E_L)
  - On the aircraft specific plumbing
  - On our ability to direct the lens output into the ionizer (E_s)

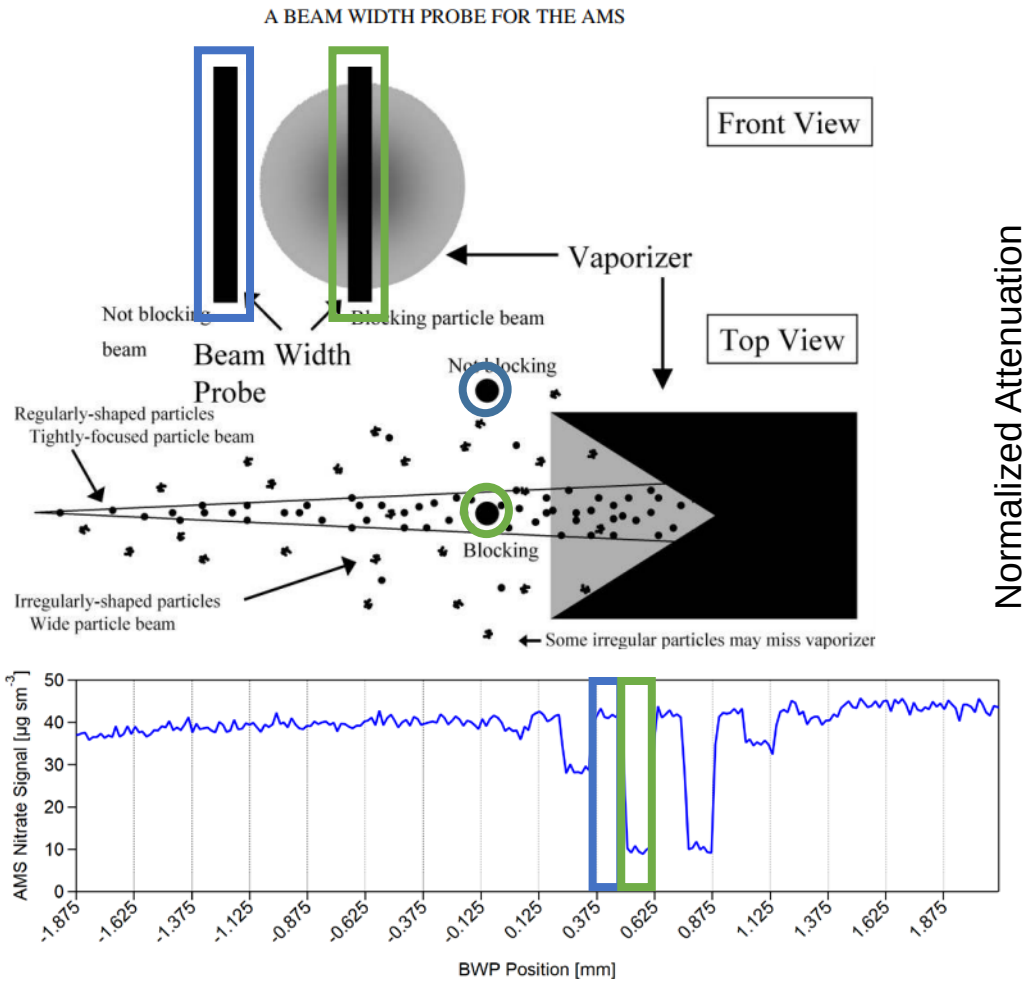
1. Fast diagnostics that inform about beam shape and position as a function of D_{va}
2. An improved alignment tool with diagnostic capability



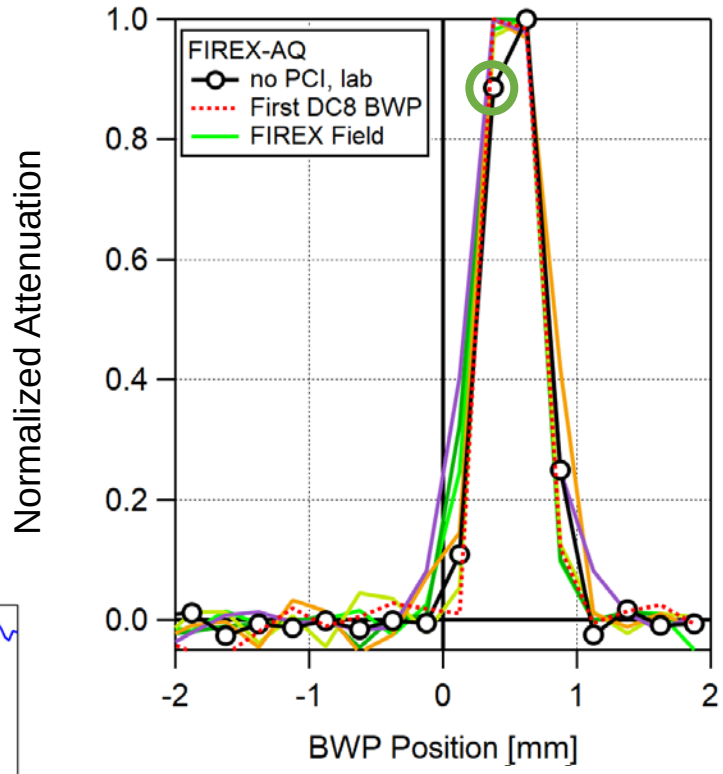


Currently available tool: Beam Width Probe (BWP)

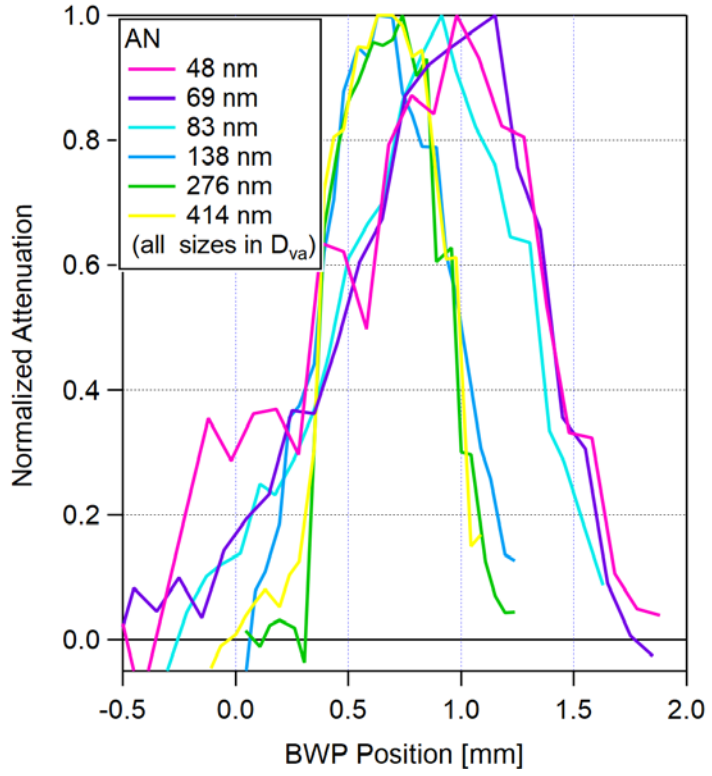
Huffman et al, 2005



500 nm AN, FIREX-AQ



Small Sizes, CU lab



- At large sizes (for PM1 lens) some resolution limitations (wire size is 0.5 mm)
- Very useful to confirm beam alignment and size dependent variability in focusing

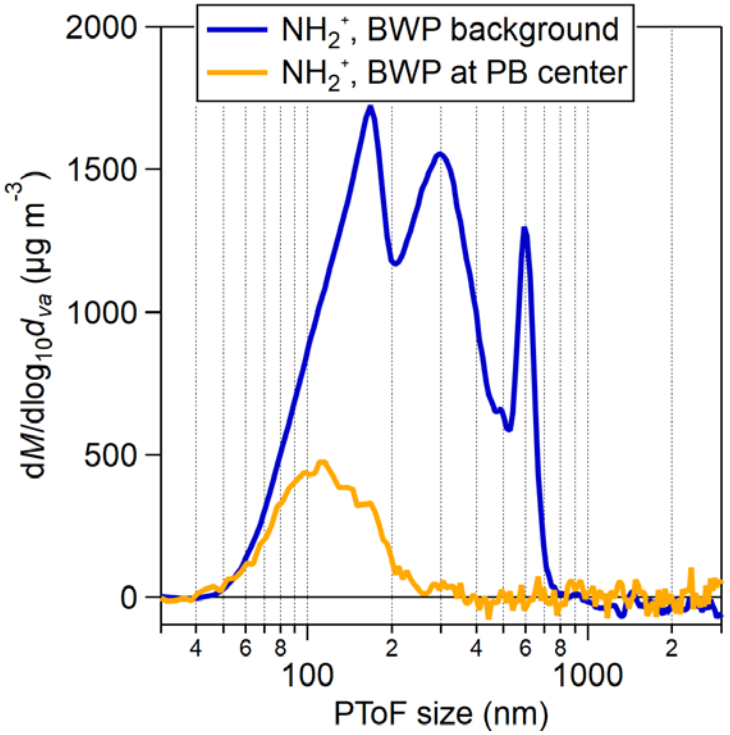
Let's try to get that size info a lot faster: 2D (SD*X) BWP

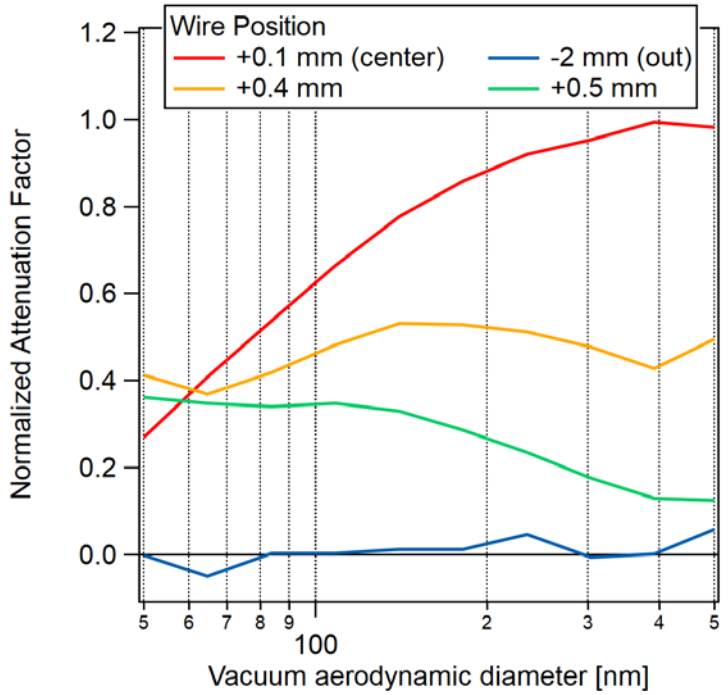
- Sample polydisperse calibration aerosol at high concentrations (>1 mg sm^{-3})
- Take one ePToF SD per BWP step (10 s), and set up the timing so wire movement is avoided

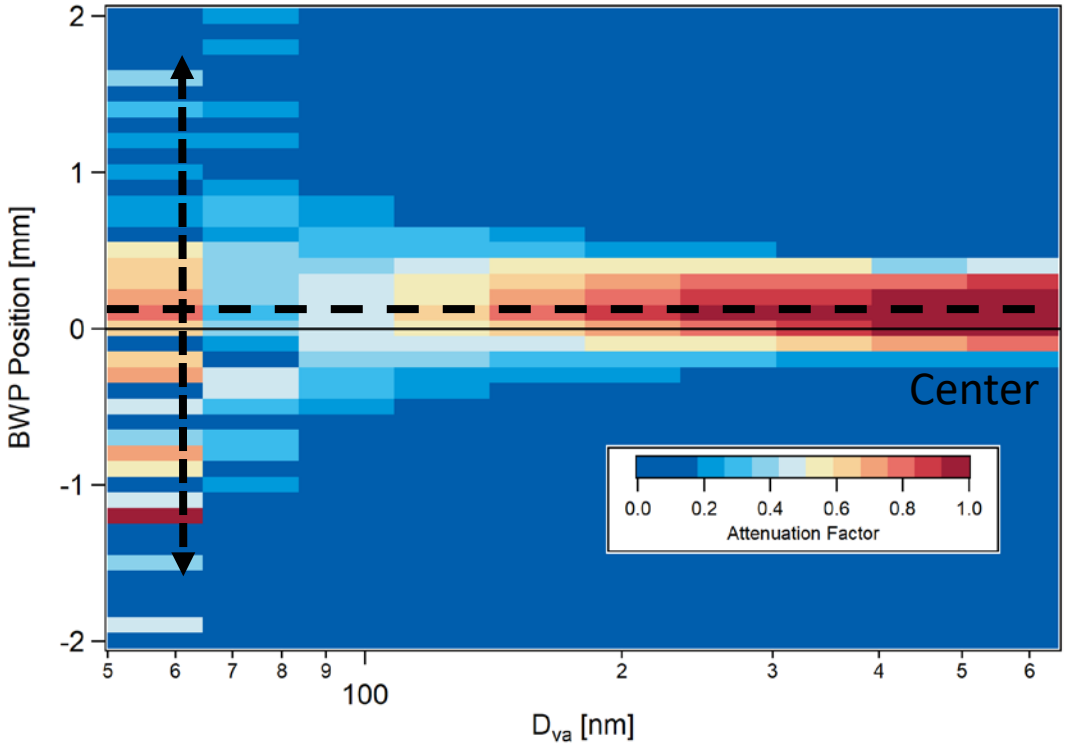
Compute:

$$Att\_ePToF(X, D_{va}) = \frac{SD(back) - SD(X)}{SD(back)}$$

Now take the whole scan of BWP positions and matrix transpose

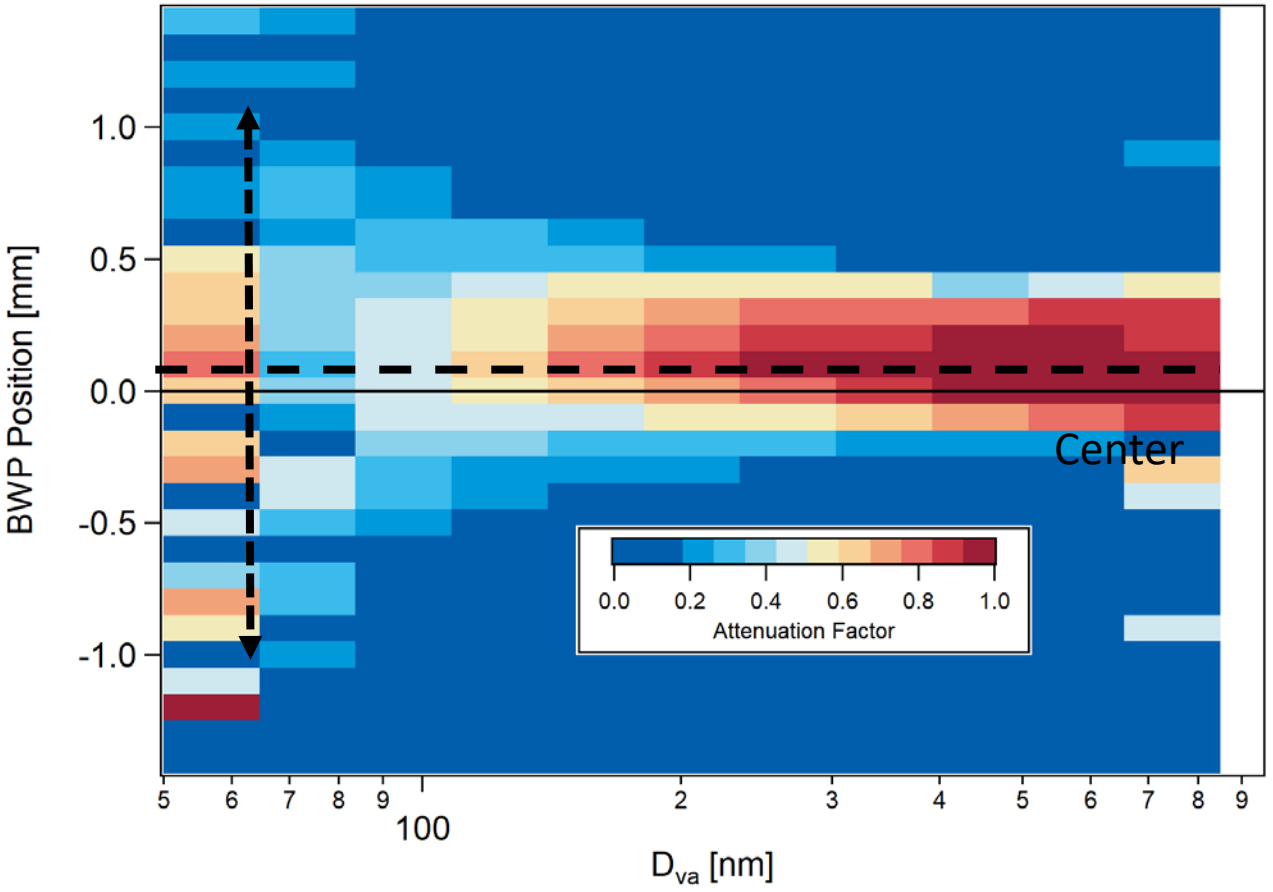




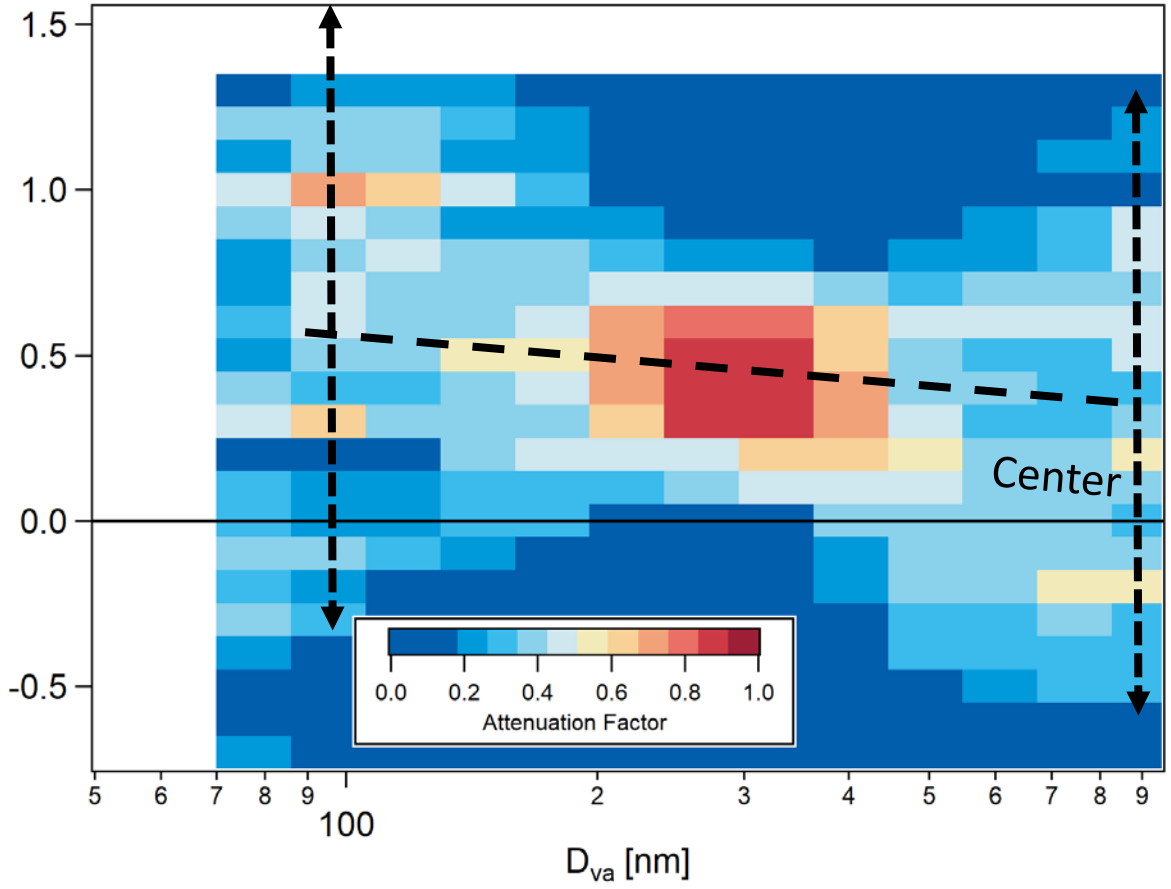


Rapid lens comparisons across sizes

PM1 Lens



PM2.5 Lens

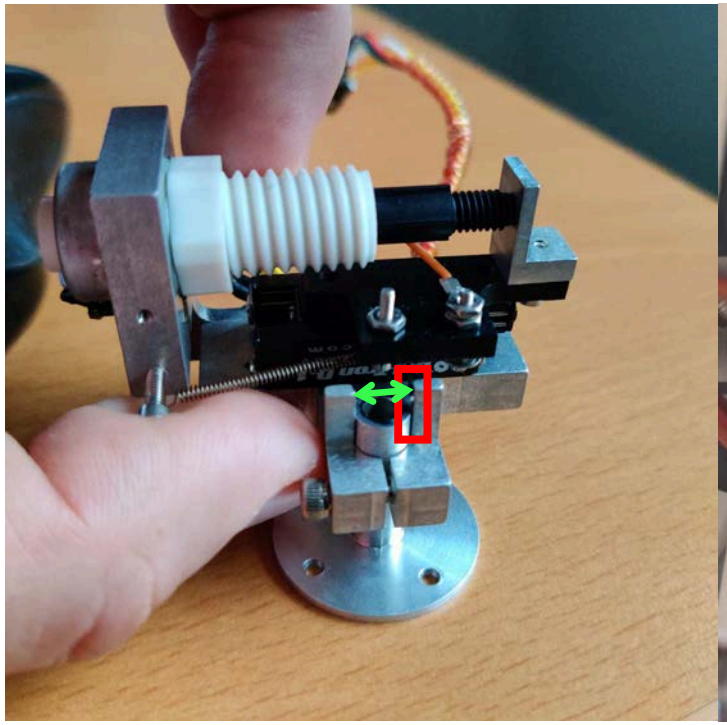


REMINDER: Minimum Beam width/focus is limited by the BWP wire size

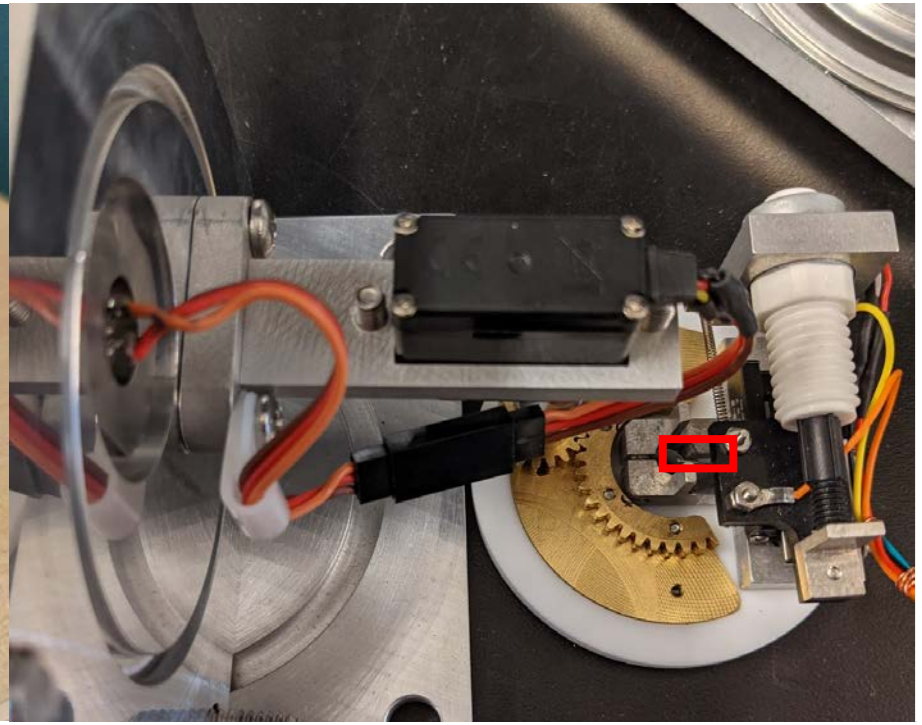
This PM2.5 lens (S/N 61) has a slightly tilted focus, in general focuses slightly worse

So can we measure such deflections in 2D? (e.g. 3D BWP SD*(X,Y) attenuation)?

Aerodyne BWP



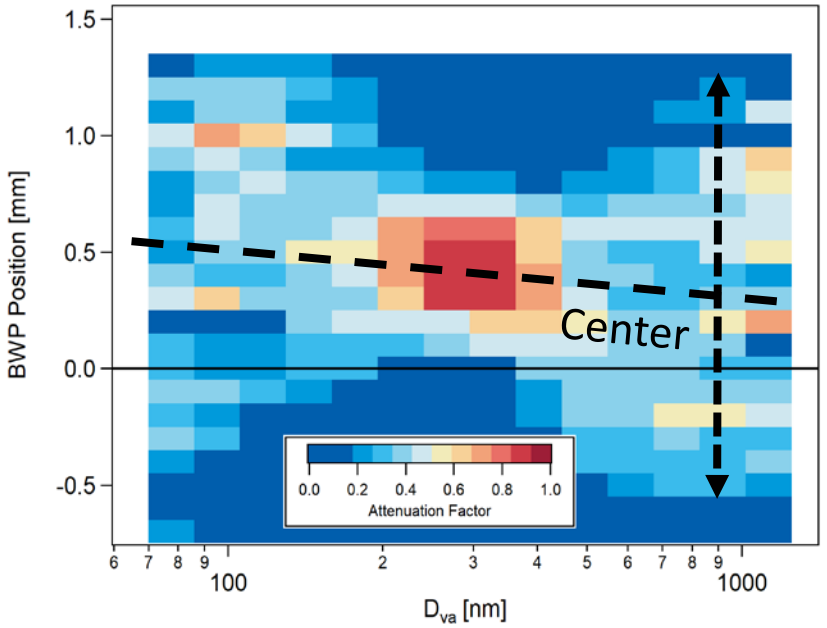
2D BWP



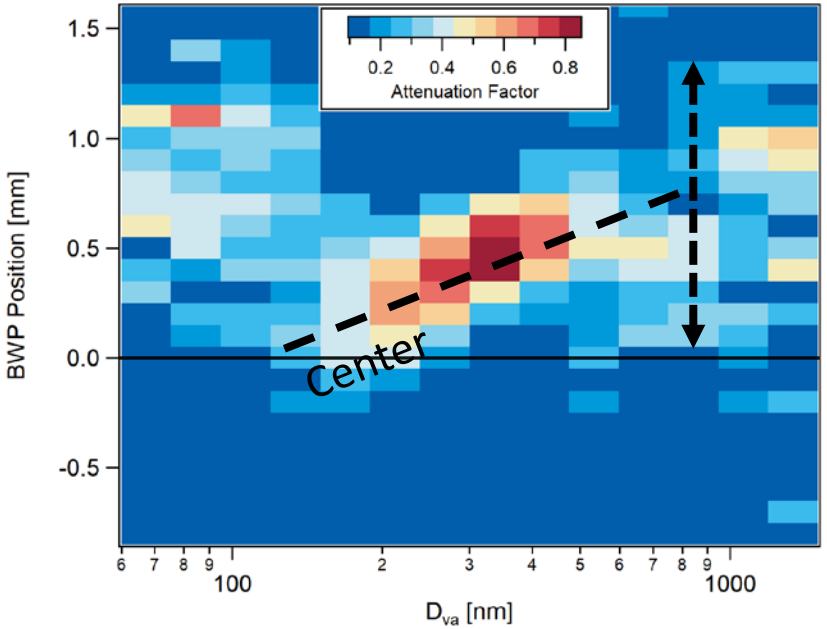
Luckily when John designed the BWP, he left 6 mm of unused space there..

Preliminary Results (hot off the press): Elliptical beam

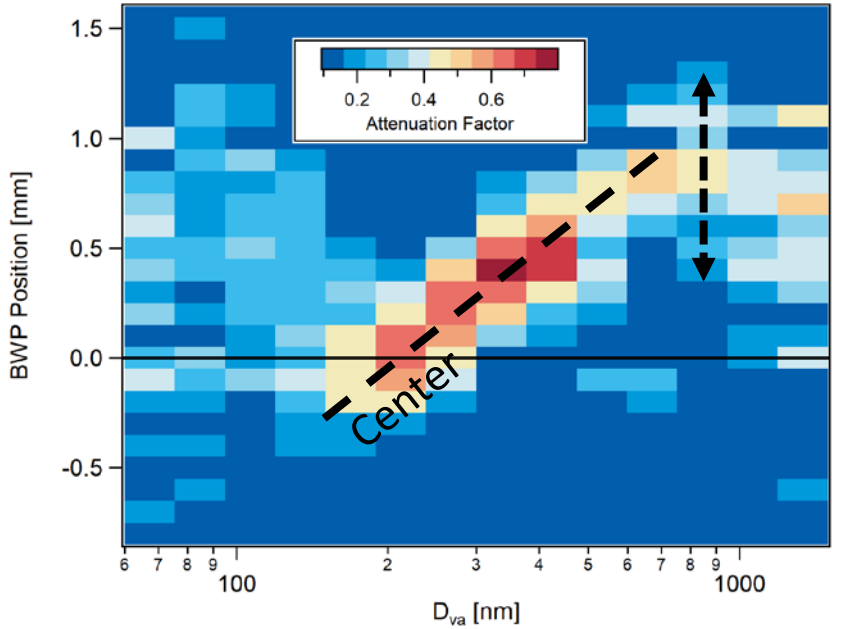
"vaporizer up/down"

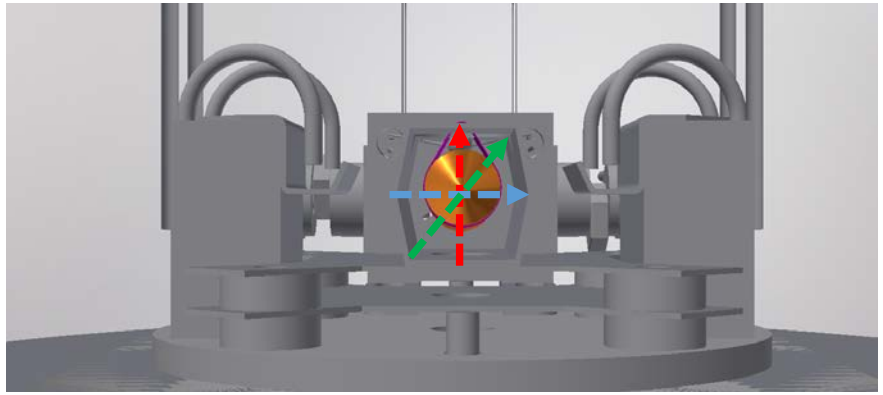


45 degree angle

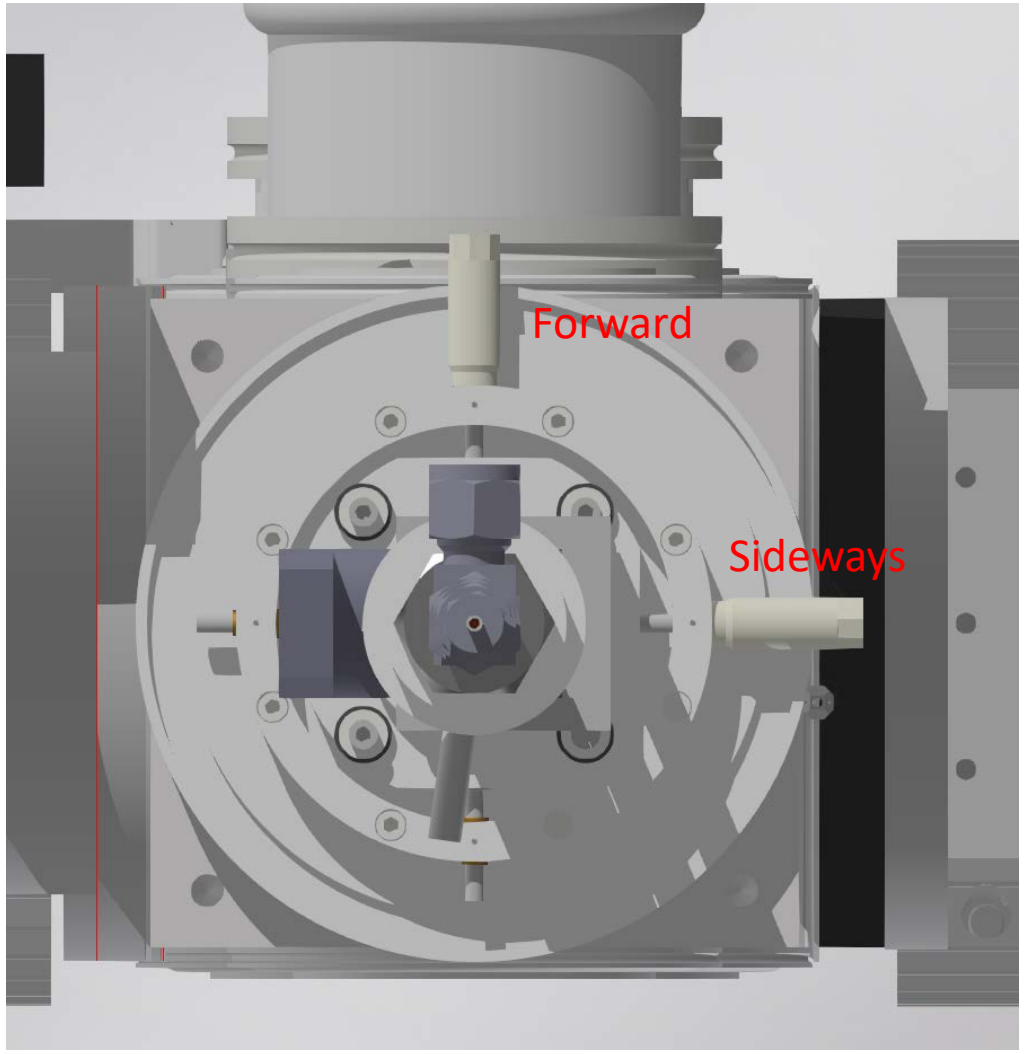


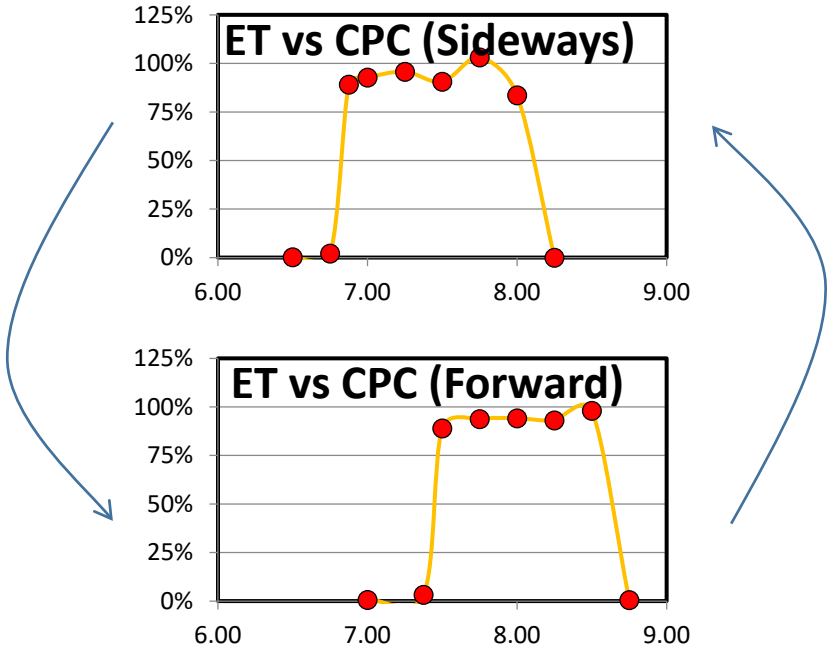
"vaporizer left/right"





Refresher: Aligning the aerosol lens in the AMS



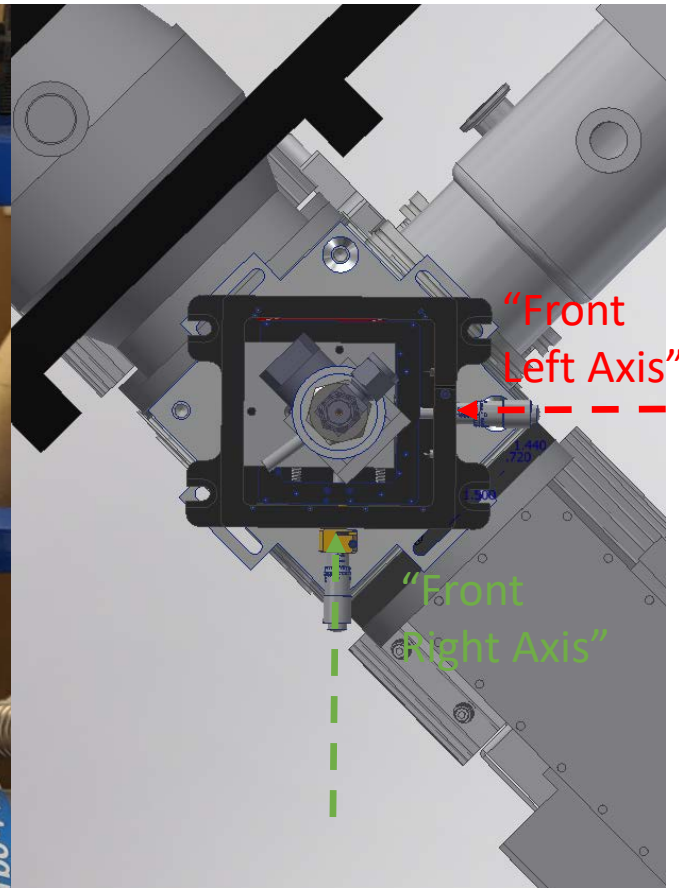


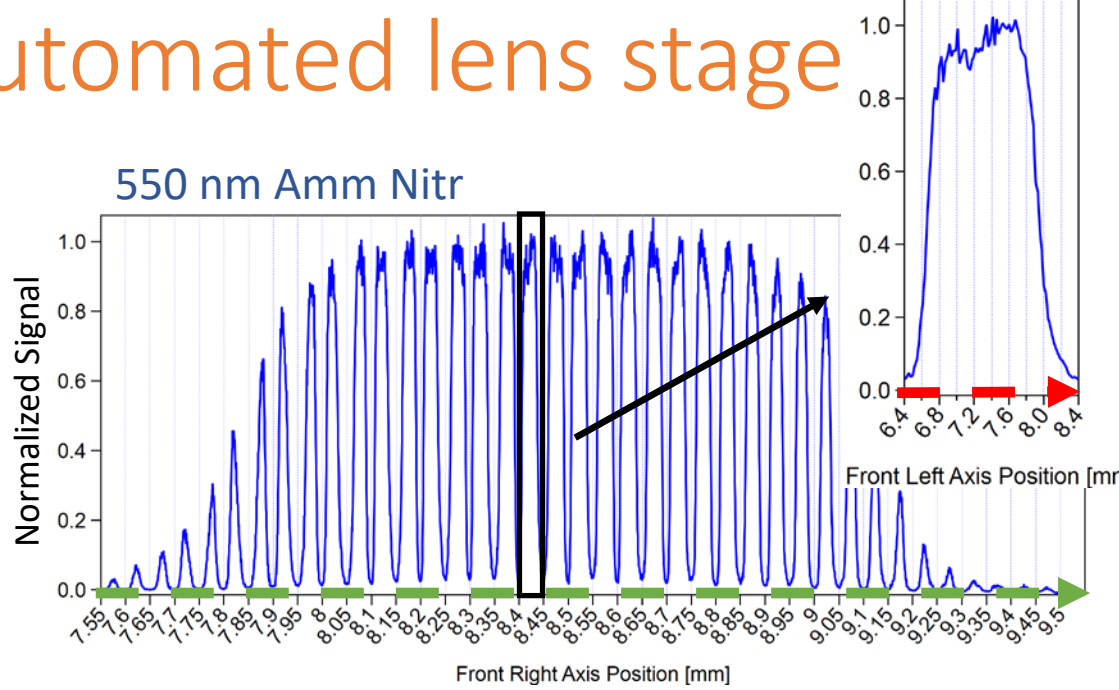
Iterative process, until both beam widths are about the same

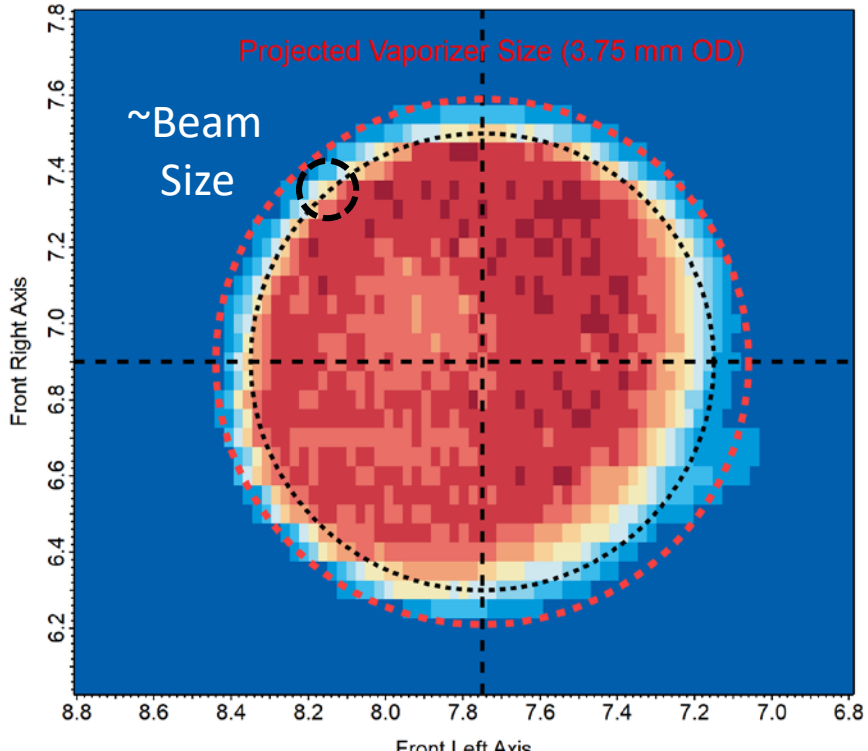
- Time consuming, prone to vaccuum accidents
- Fairly low spatial resolution
- For aircraft instruments, particularly painful

A more user-friendly approach: automated lens stage better than 50 µm resolution

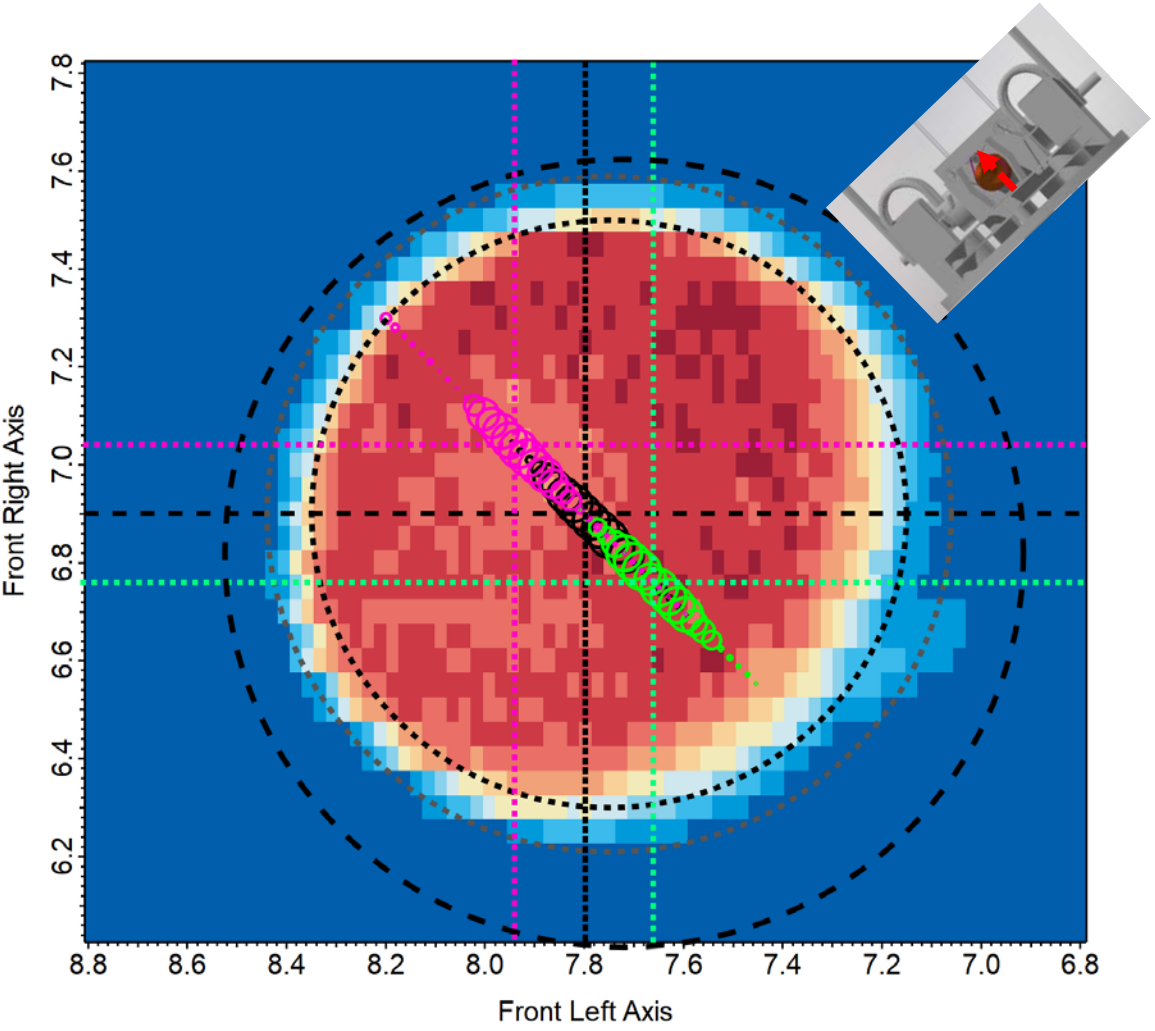
Actual Geometry

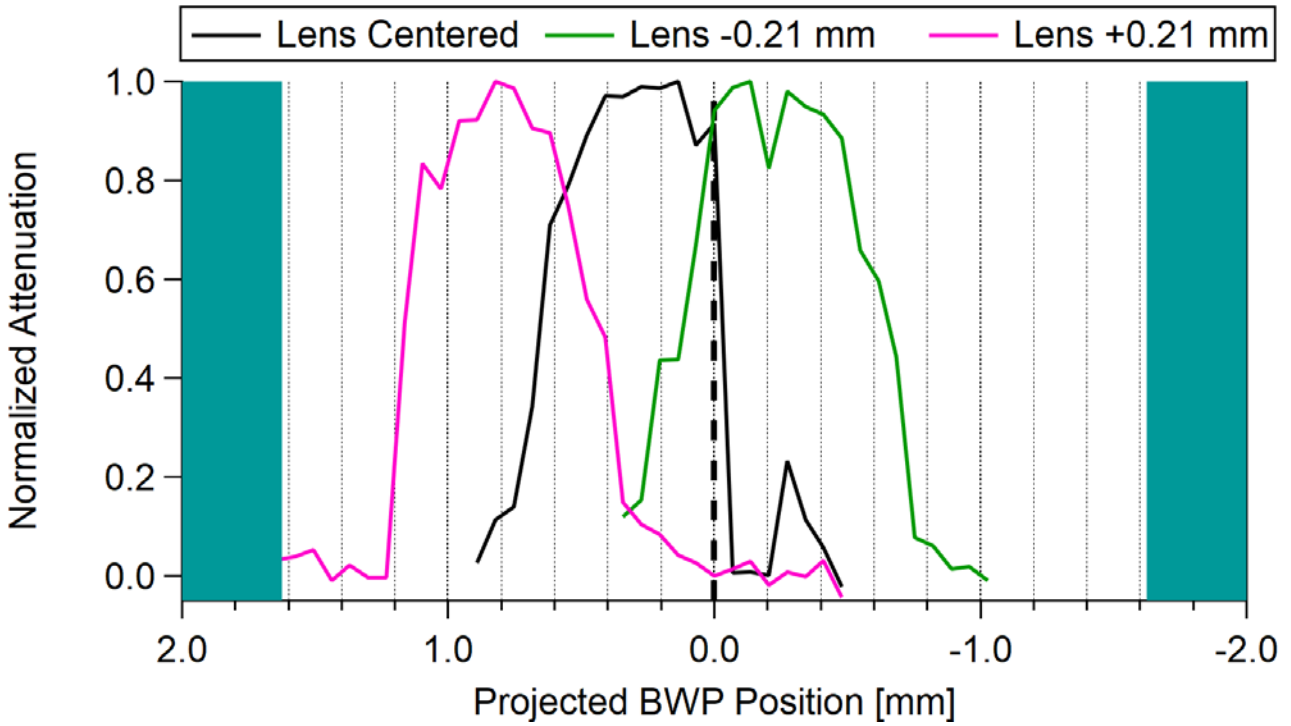


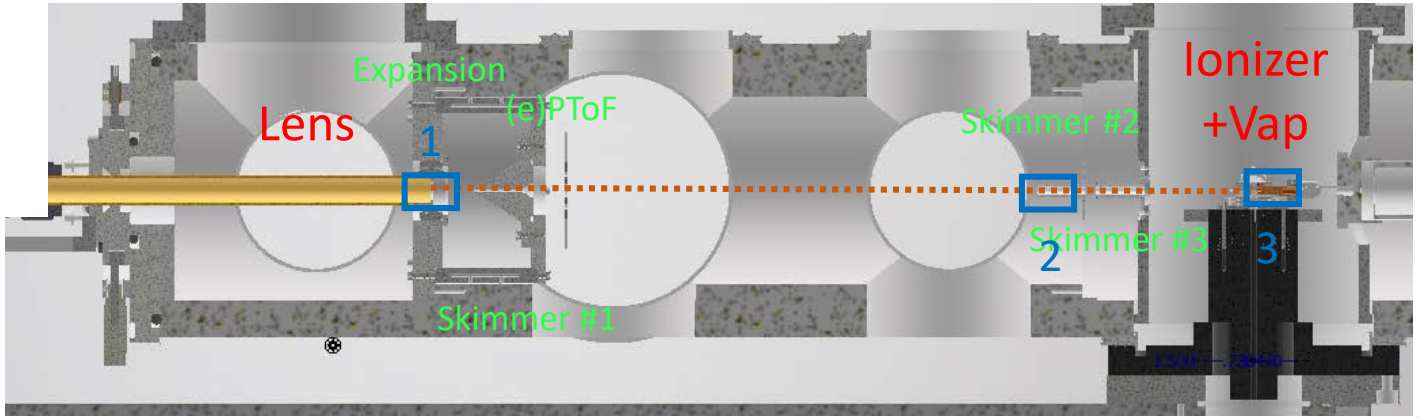




Are we centered (I)? : Combining 1D-BWP and lens scans



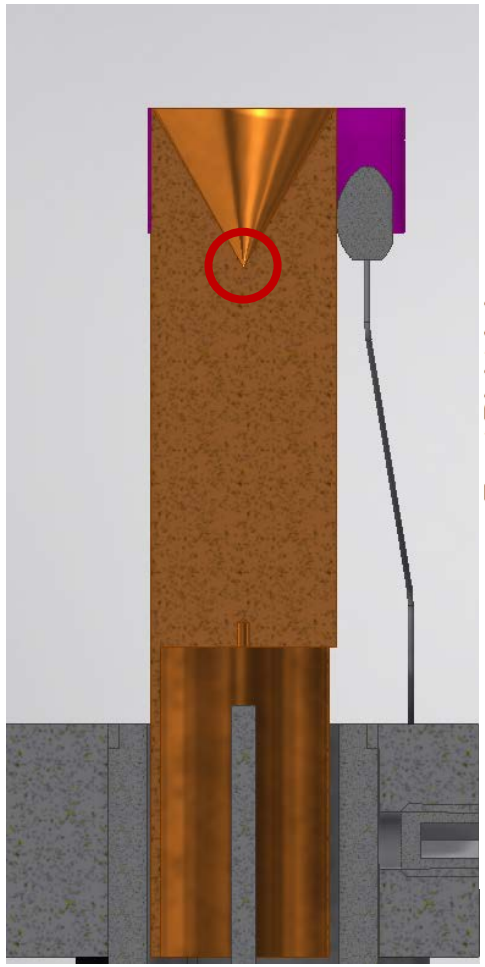




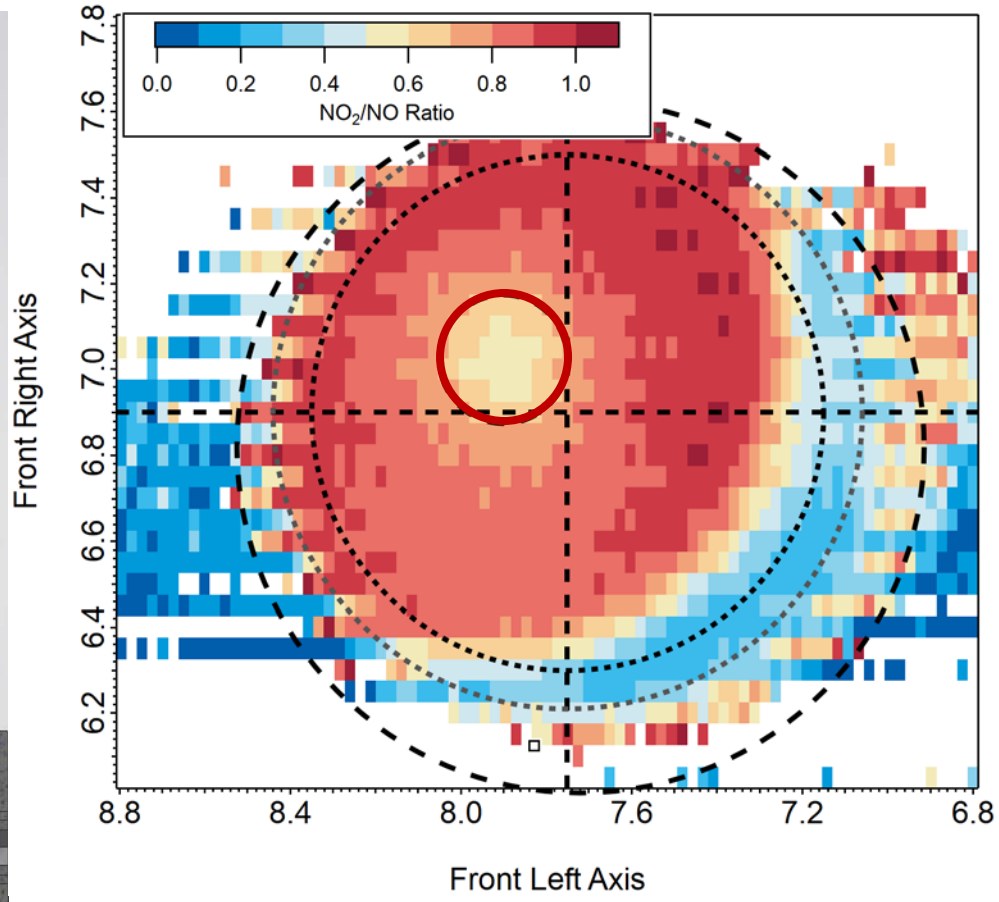
So the vaporizer is sitting high. Can we get additional confirmation

Are we centered (II)? Molecular thermometers!

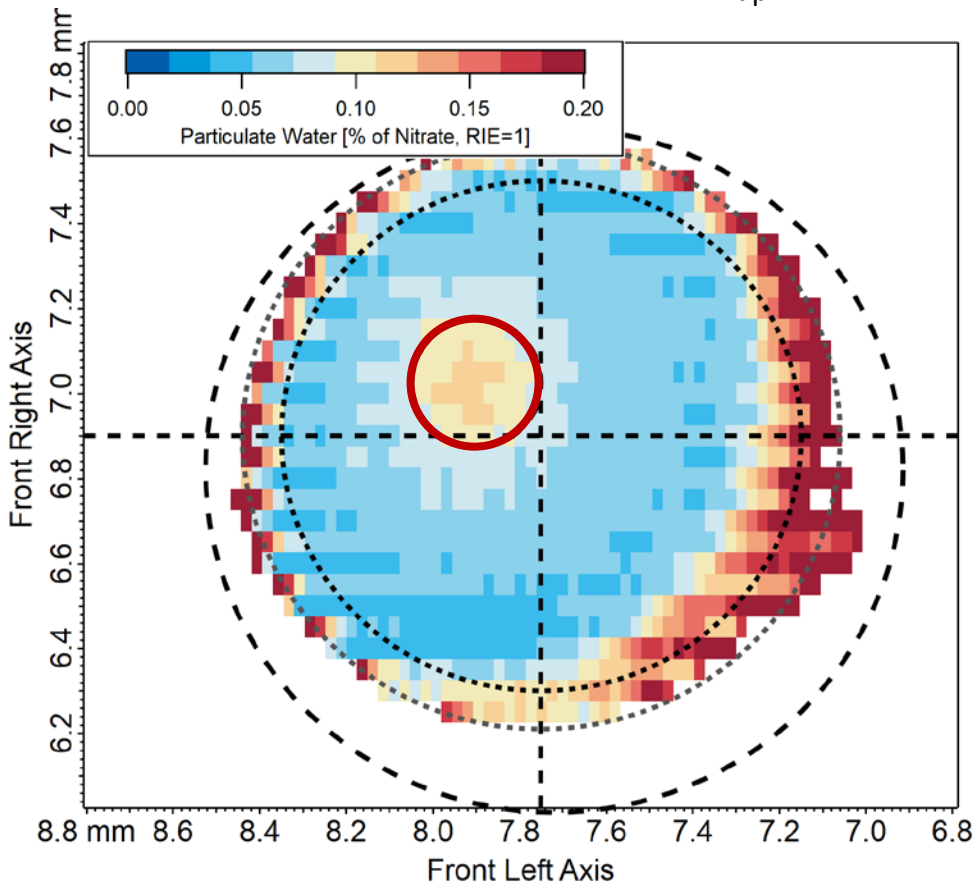
Cross Section
Standard Vaporizer



NO_2^+/NO^+ Ratio for nitrate
Ratio DECREASES with T_{vap}



Particulate Water/Nitrate
Ratio Increases with T_{vap}

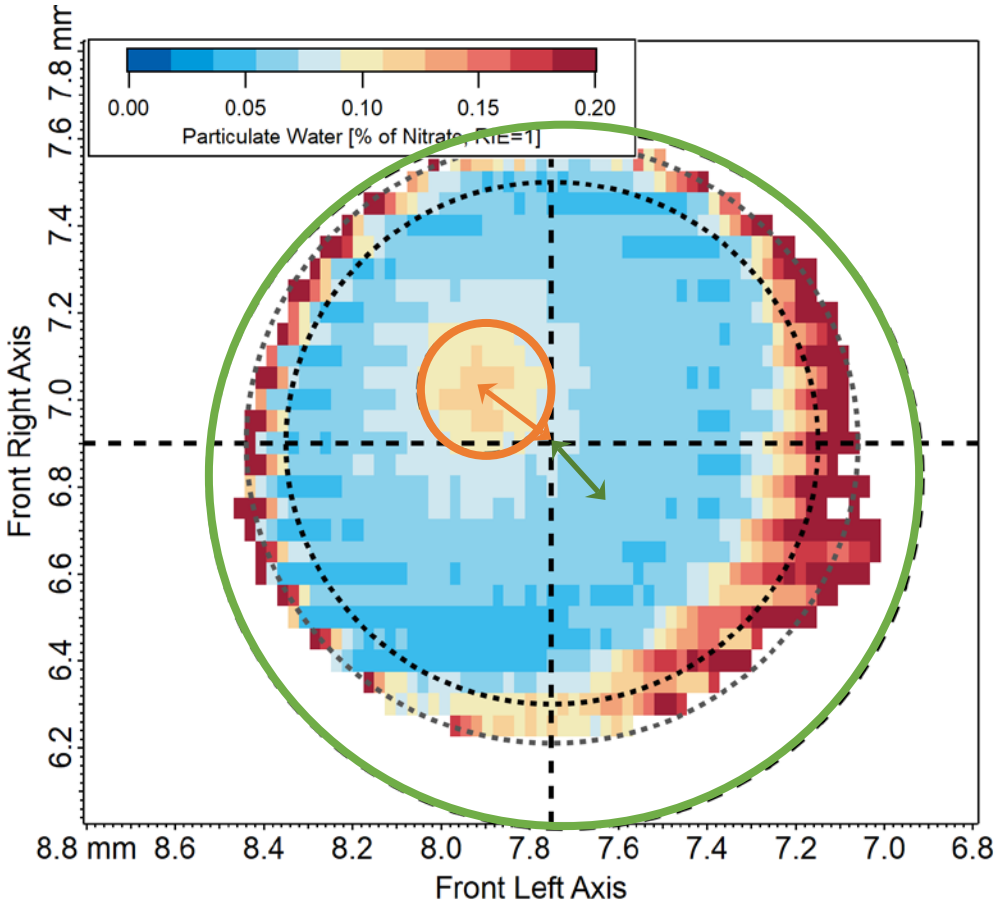


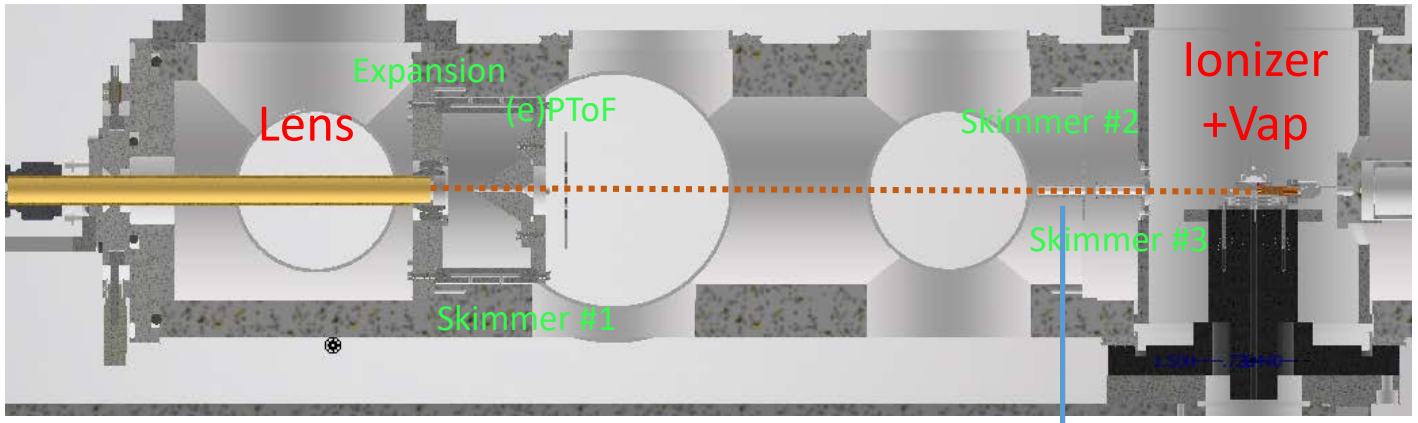
So this clearly confirms that the vaporizer is actually NOT aligned with instrument axis
Can we quantify that?

So how much off-center is this vaporizer?

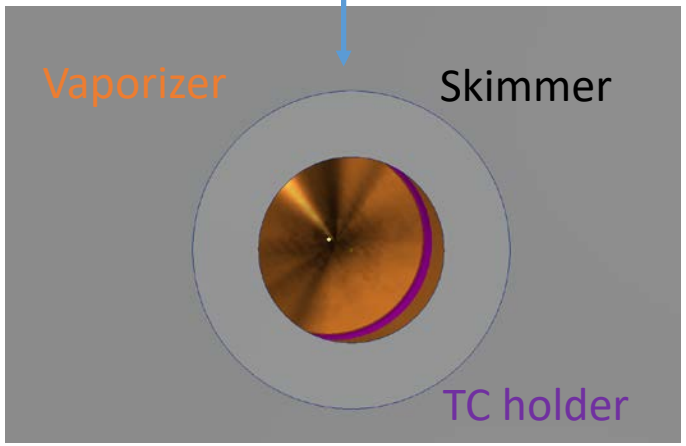
Two independent measurements:

- Skimmer suggests vaporizer +0.12 mm (projected) in the vertical (=>0.32 mm on the vap)
- Molecular thermometer suggest +0.18 mm, nearly vertical (=>0.45 mm on the vap)

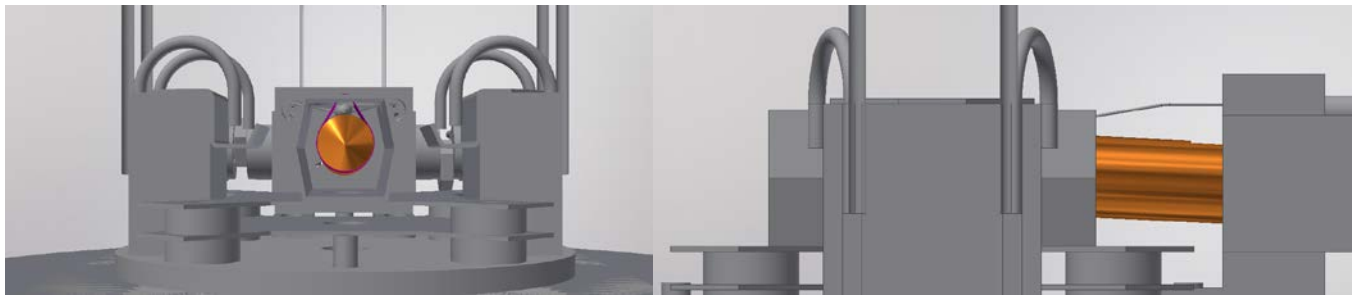




Taking the more robust measurement (+0.18 mm) results in a vertical angular deviation of the vaporizer of +2.75 degrees



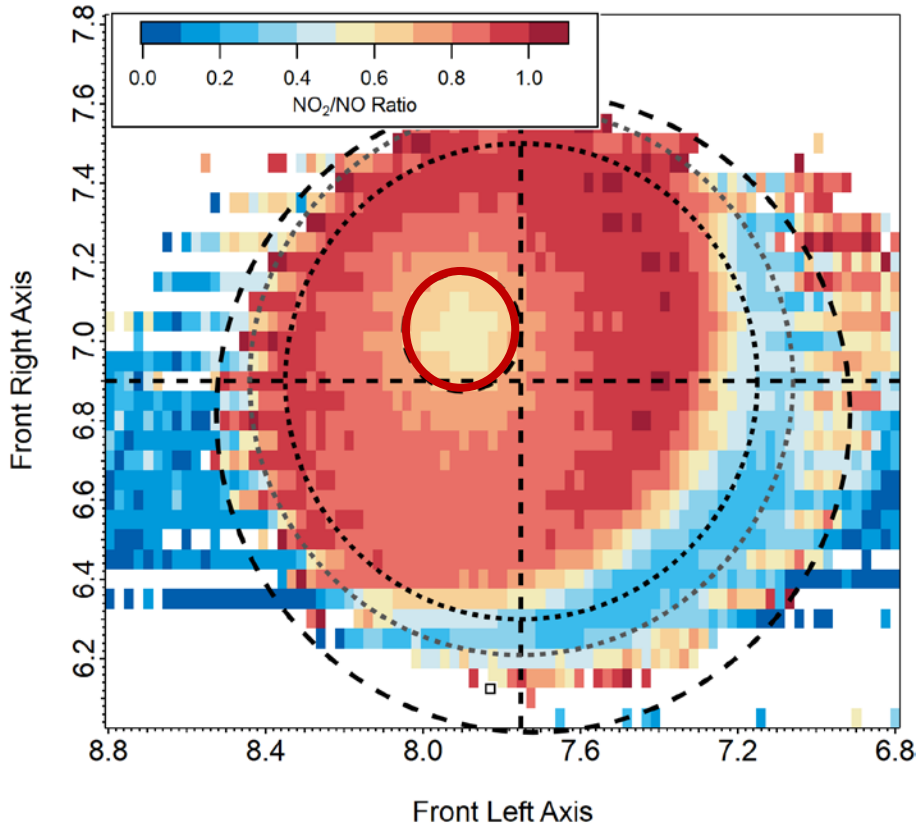
This mostly within the installation tolerances!



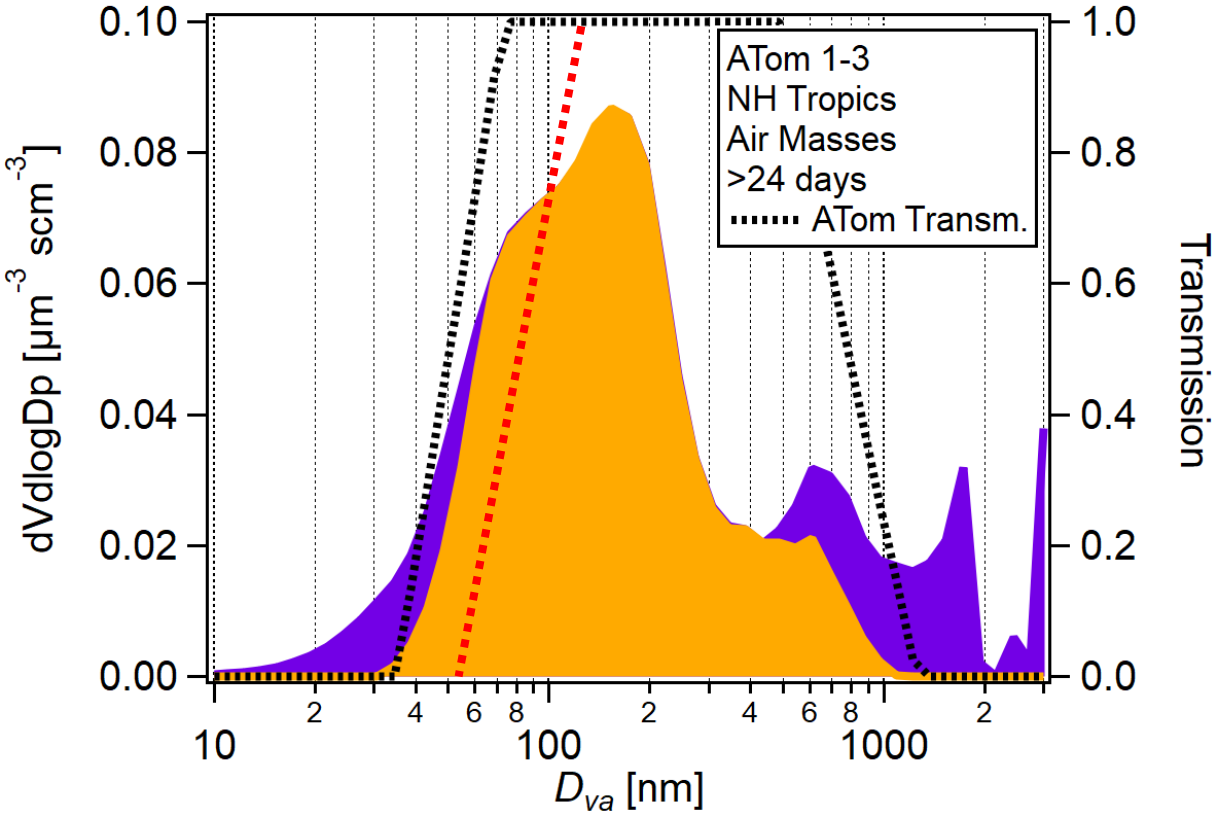
So should you worry about such misalignments?

Normally not, except if you care about:

pRONO2 quantification for small particles/with PM2.5 lens



Accurate AMS transmission (CE_L) of small particles (especially for PM2.5 lens)

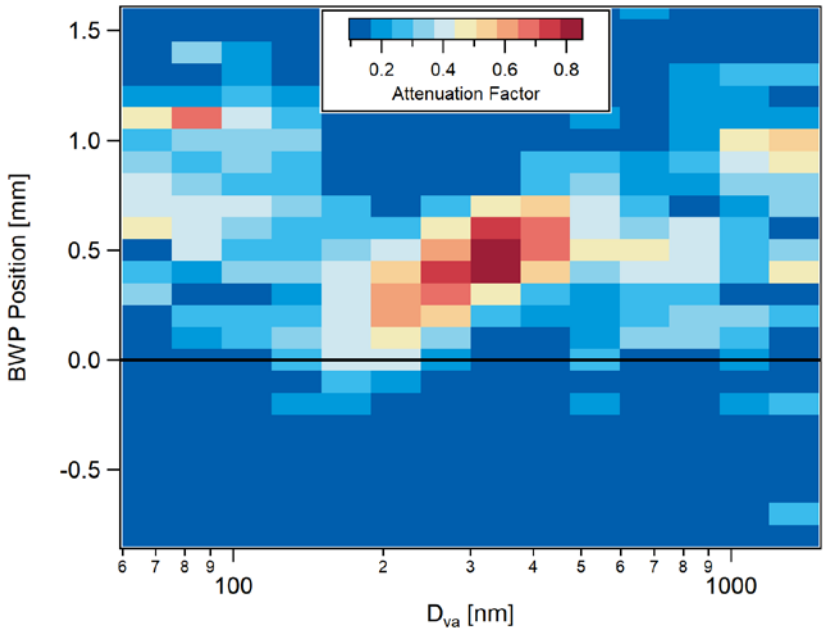


Also if you modify the inlet flow field of your lens (e.g. for aircraft measurements)
For some more examples, please attend Dongwook's talk tomorrow

In Summary:

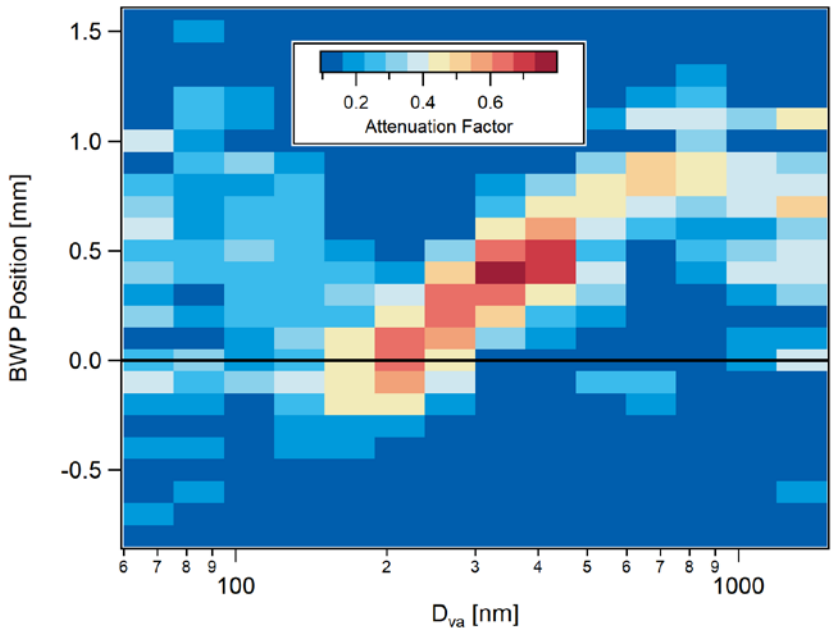
1. 2D Beam Width Probing

45 degree angle

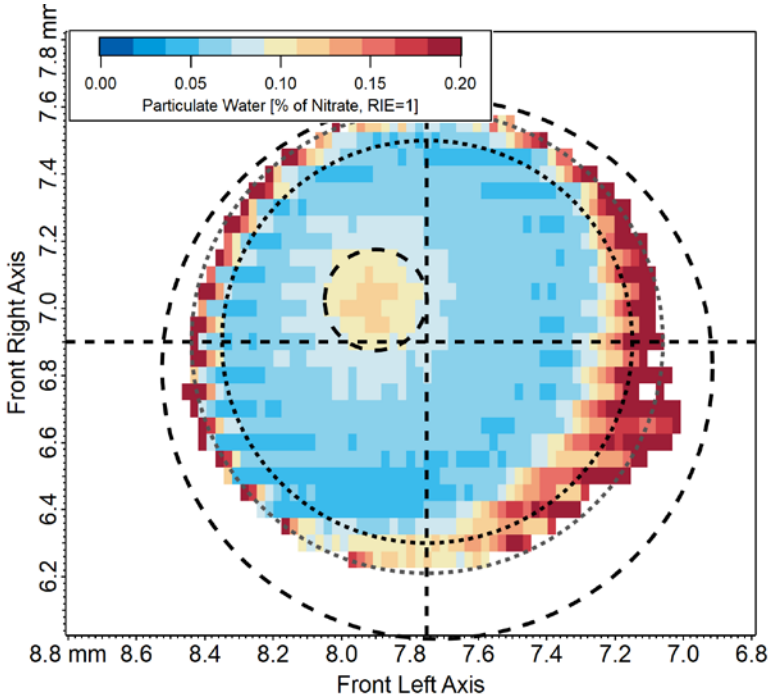


2. 3D Beam Width Probing

"vaporizer left/right"

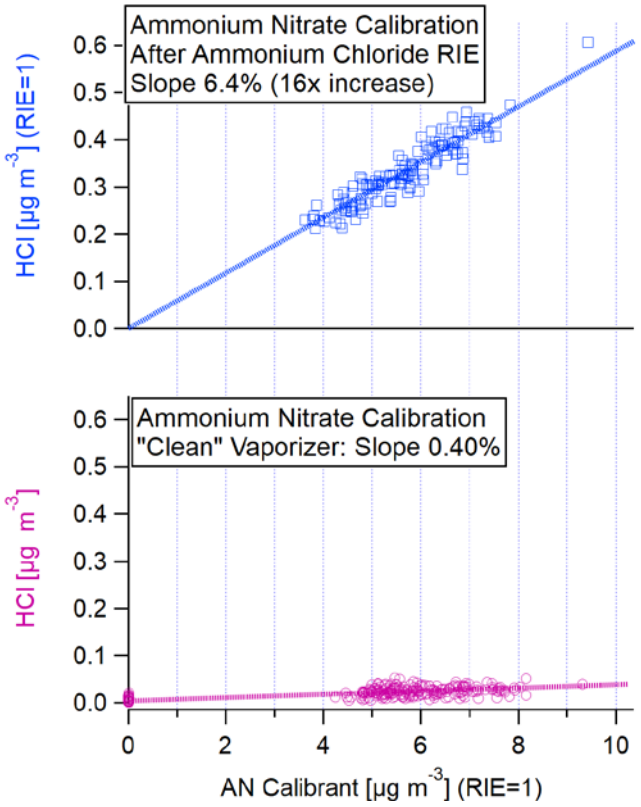


3. Automated Lens Alignment and vaporizer profiling



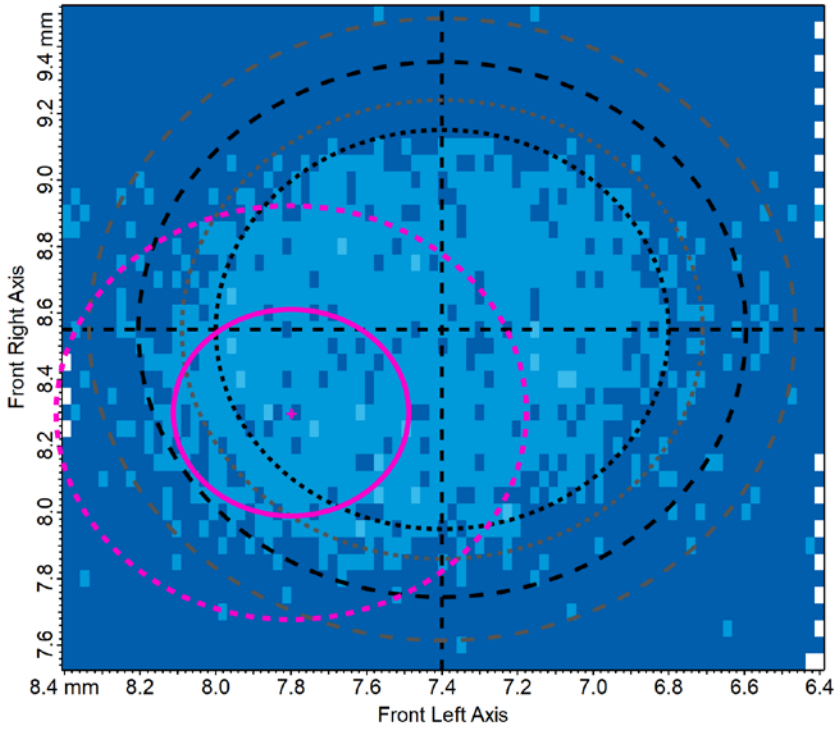
One not-CE related application: Probing the Hu effect

Hu effect:
non-particulate Cl^+ and HCl^+ signals from the vaporizer when sampling nitrate

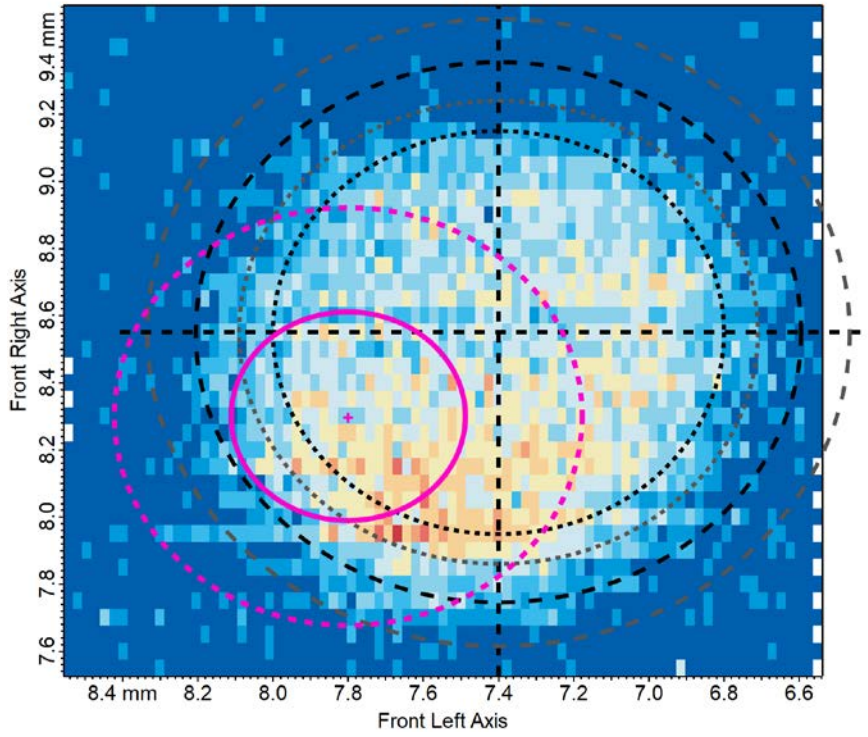


So can we see this happening on the vaporizer surface?

Chlorine Signal, pre-AChl calibration



Chlorine signal, after "etching" the vaporizer



Perform Achl "RIE Calibration" with the lens position as shown