Collection efficiency of SP-AMS for internally mixed particulate black carbon

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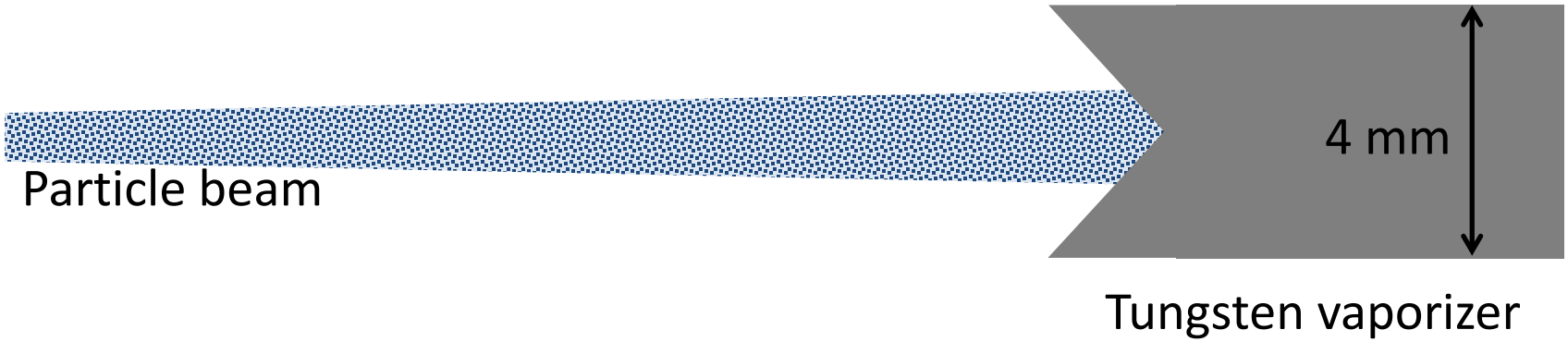
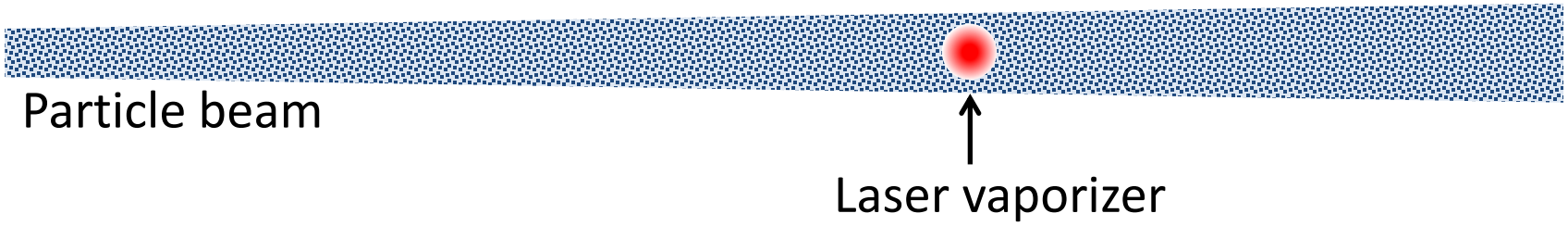
CE issue: Tungsten vaporizer vs. laser vaporizer

CE issue: Particle bounce off from tungsten vaporizer



CE issue: Particle beam – SP laser overlap



$d_{PB} > d_{LB}$ → What is the collection efficiency of laser vaporizer for BC?

Objectives of this work

- To understand the effects of mixing state of aerosol particles (bare BC vs. internally mixed BC) on the quantification of atmospheric BC using SP-AMS.

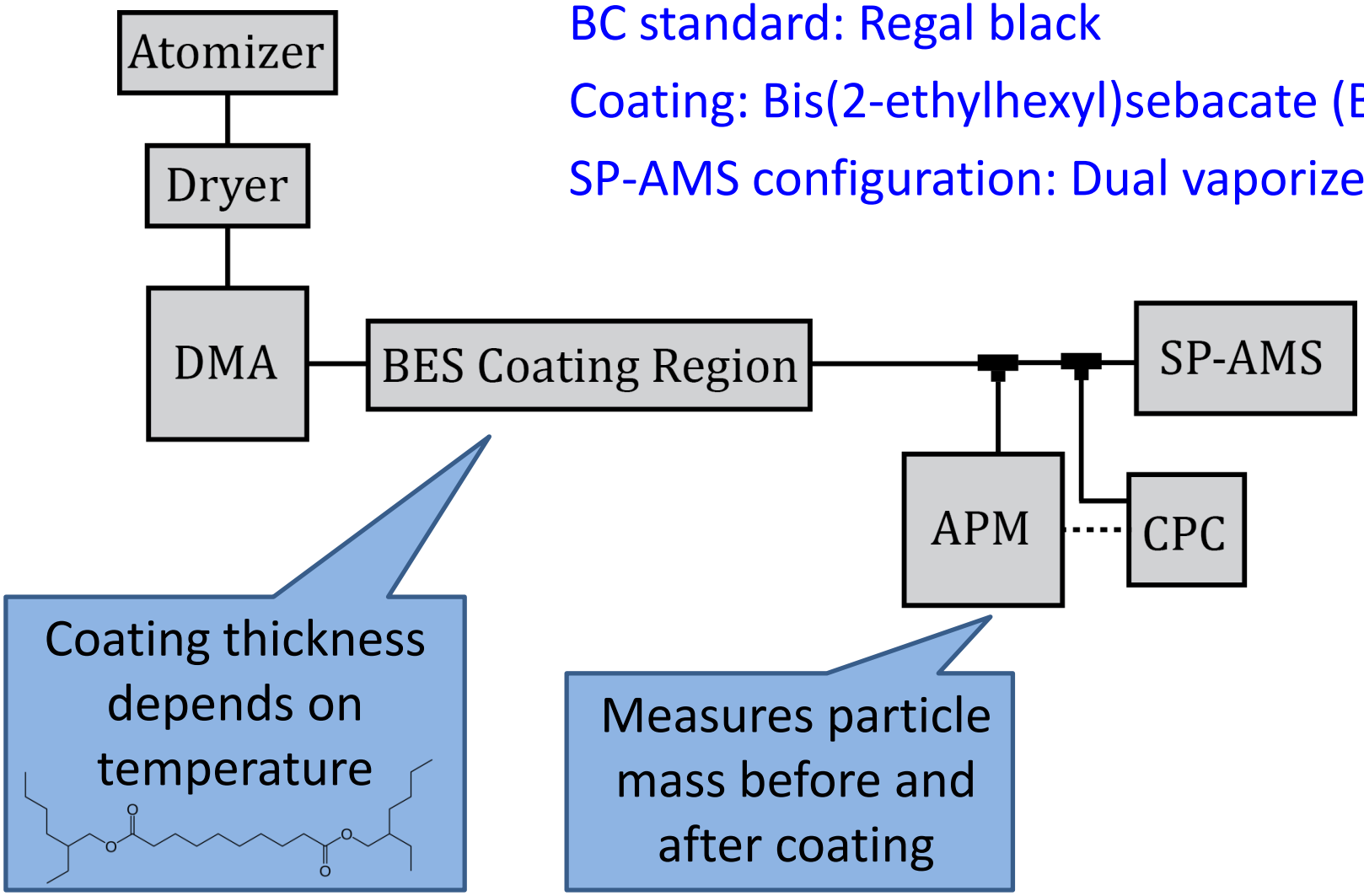
- To provide insights for evaluating the current calibration procedure for atmospheric BC quantification.

Experimental setup

BC standard: Regal black

Coating: Bis(2-ethylhexyl)sebacate (BES)

SP-AMS configuration: Dual vaporizers



Summary of coating experiments

Lens transmission ≈ 1

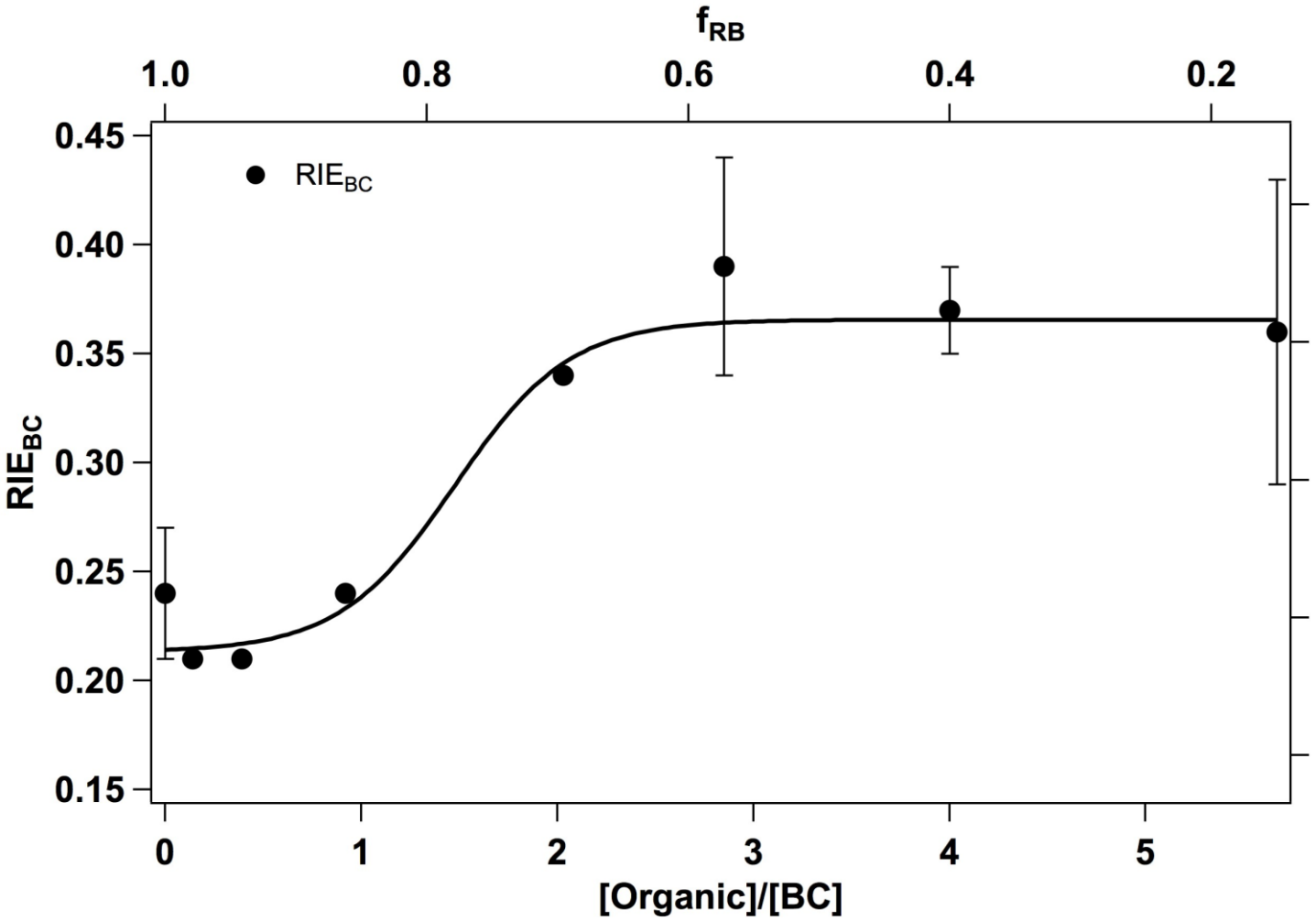
Regal Black Core Size (d_m, nm)	Final d_{va} (nm)	f_{RB}
250, 300, 400	180, 205, 255	1.0
300	222	0.88
300	255	0.72
300	313	0.52
300	355	0.33
200	285	0.26
150	275	0.20
75	250	0.15

f_{RB} = mass of black carbon/total mass of black carbon and organics

Sensitivity to Regal Black (RIE_{BC})

Increasing coating thickness

Increasing sensitivity



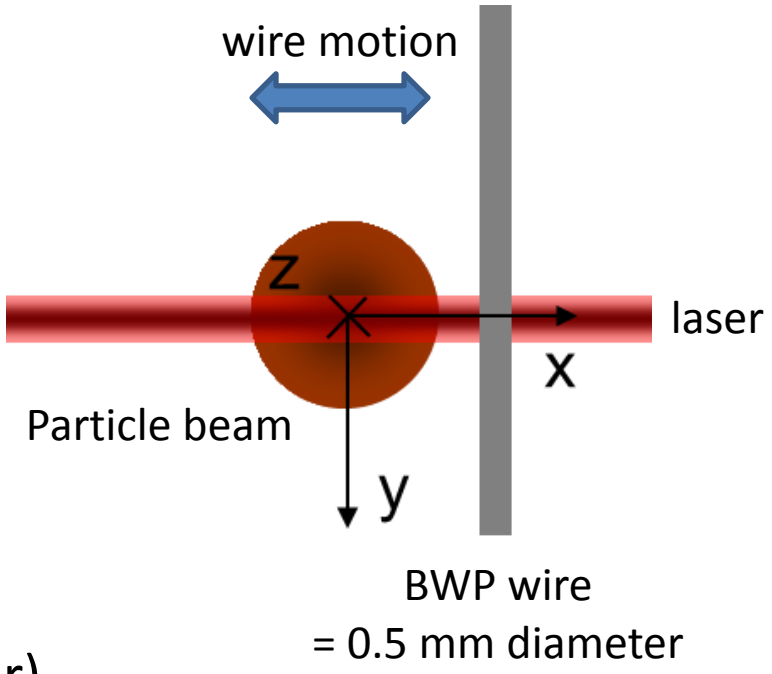
Beam Width Probe (BWP) Measurement

Mass concentration of species "s"

$$C_s = \frac{1}{CE_s \cdot RIE_s \cdot mIE_{NO_3} \cdot Q} \sum_i I_{s,i}$$

$$CE = E_L \cdot E_S \cdot E_B$$

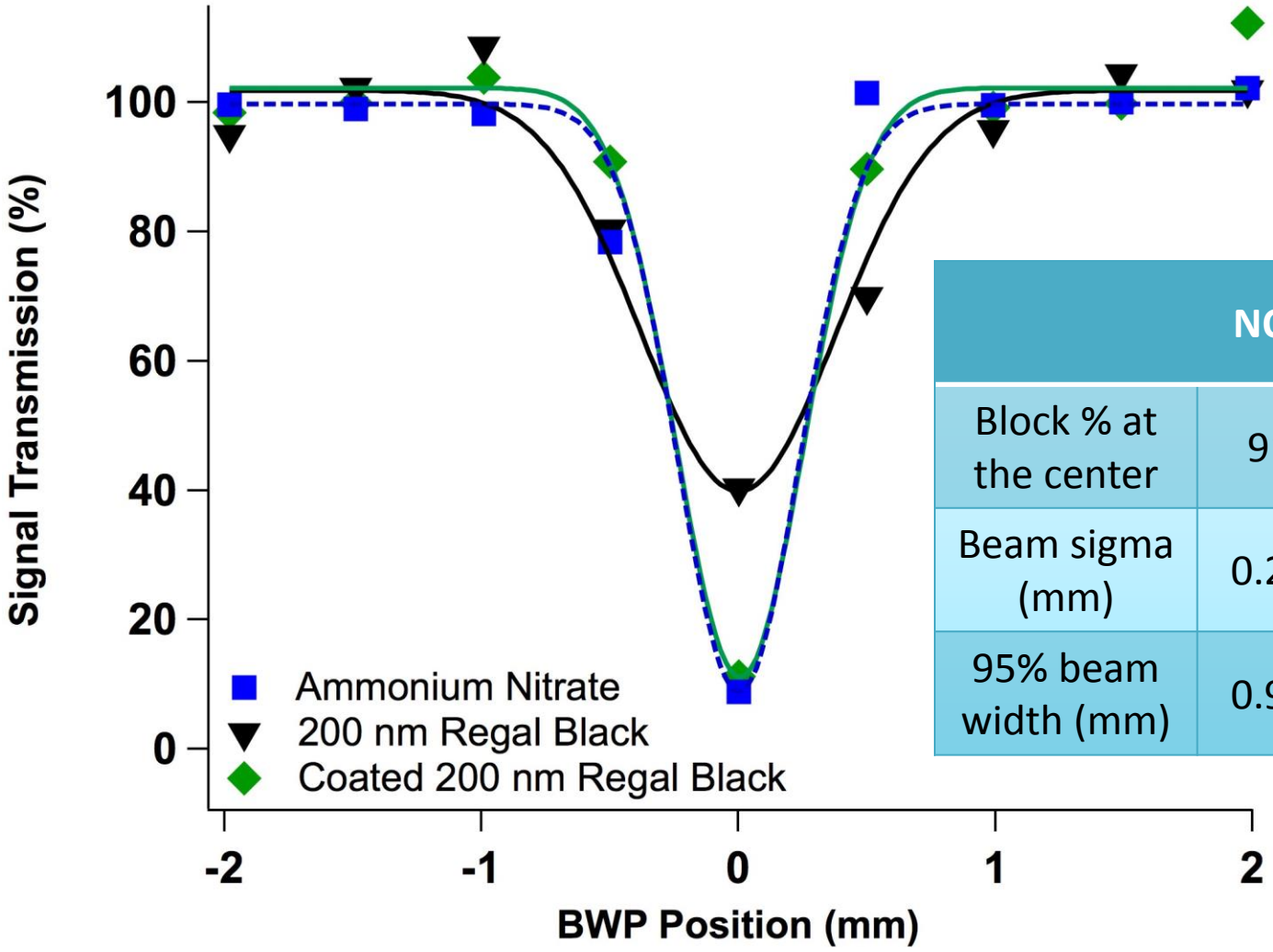
E_L = Aerodynamic lens transmission
E_B = Particle bounce off the vaporizer
E_S = Particle beam divergence



$E_L \approx 1$ (Dva = 180-355 nm)
$E_B = 1$ (no bouncing issue on laser vaporizer)

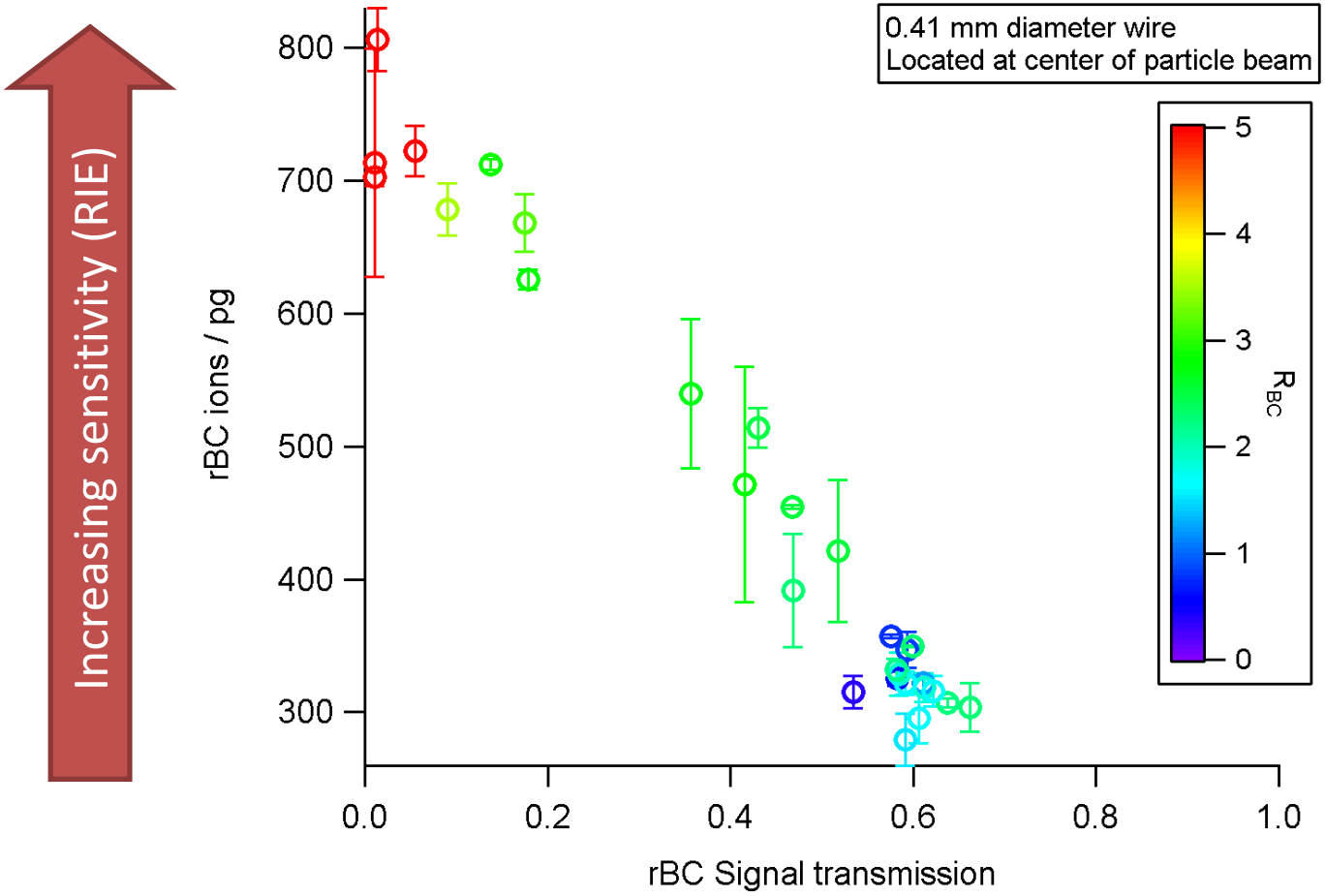
E_S governs the overall CE for black carbon
→ Beam width probe measurement

Beam Width Probe (BWP) Measurement



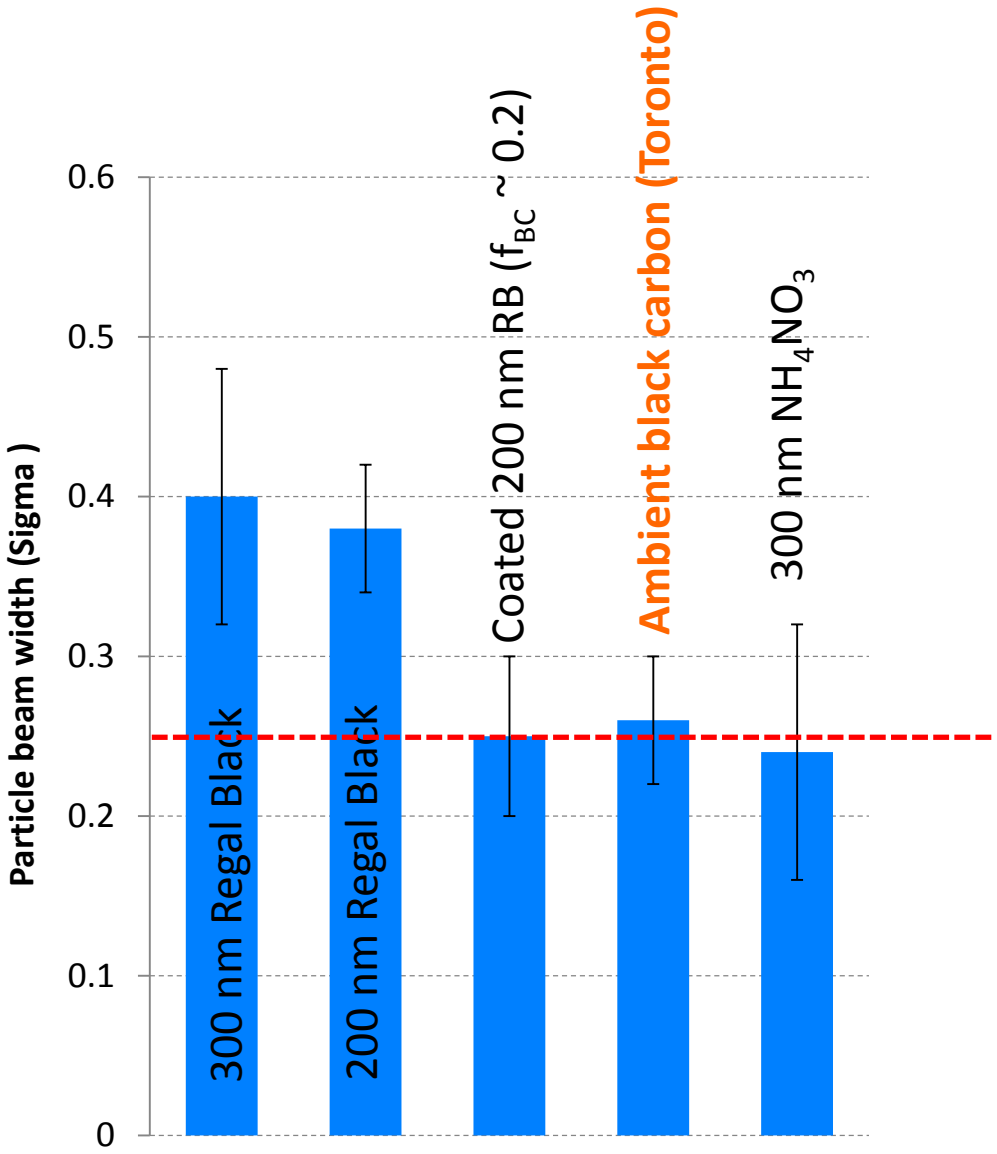
	NO_3	RB	RB with coating
Block % at the center	91	60	89
Beam sigma (mm)	0.24	0.38	0.25
95% beam width (mm)	0.94	1.51	0.99

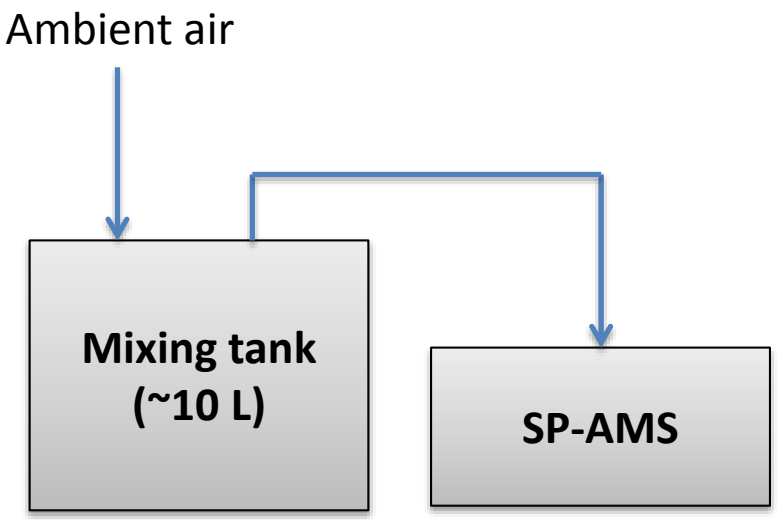
BWP Measurement (from Aerodyne)



Decreasing particle beam width/
Increasing particle – laser beam overlap

Particle beam width comparison

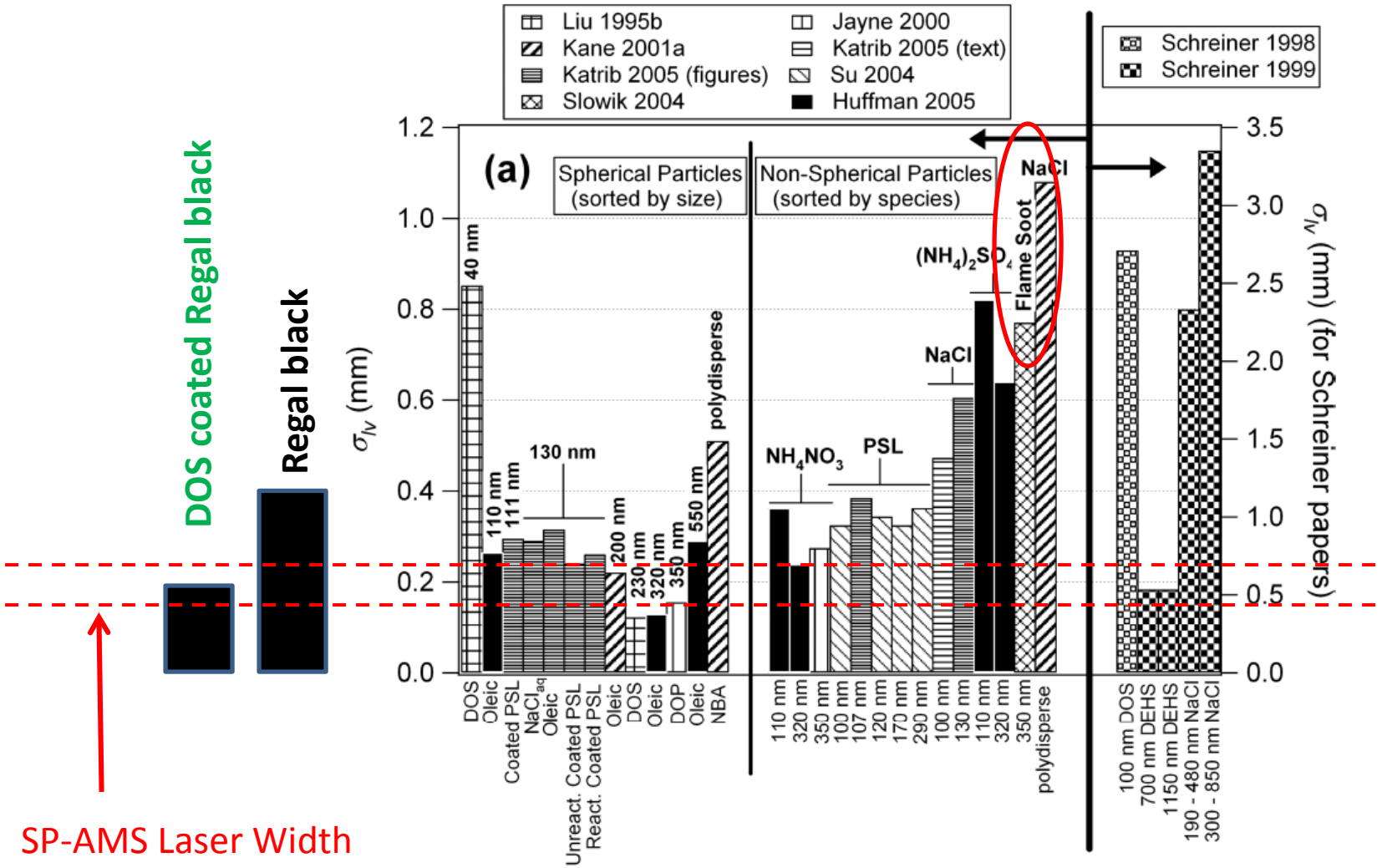




Laser beam width $\sigma < 0.25$ mm
Note: RIE saturated for $f_{BC} < 0.6$

Particle beam width of ambient BC is similar to that of coated 200 nm regal black.

Particle Beam Width Comparisons



- Particle beam widths: DOS coated RB ~ pure DOS/AN particles
- Laser beam width is <= σ ~ 0.1 to 0.25 mm

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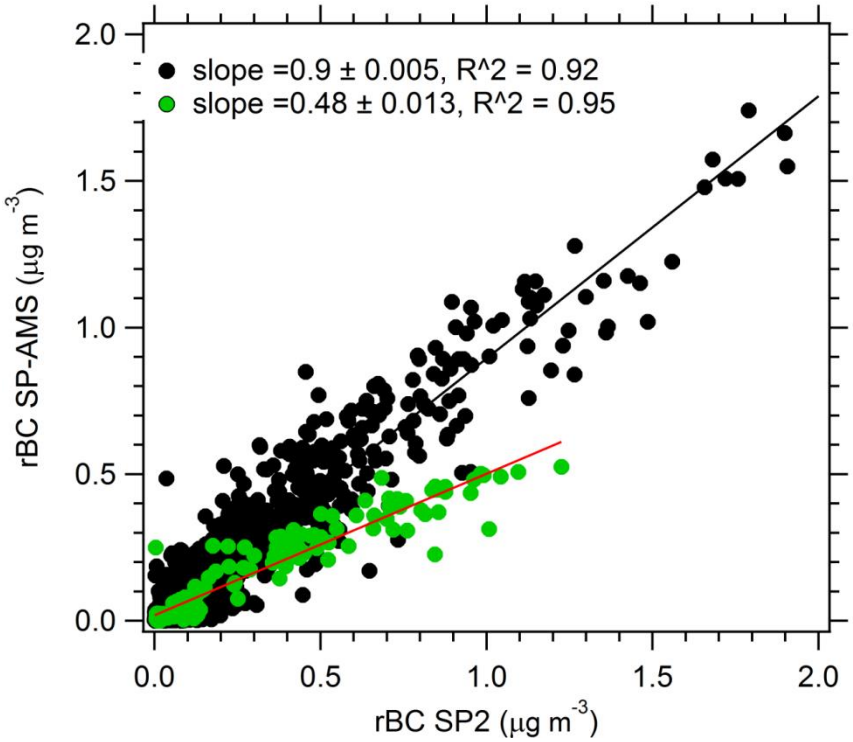
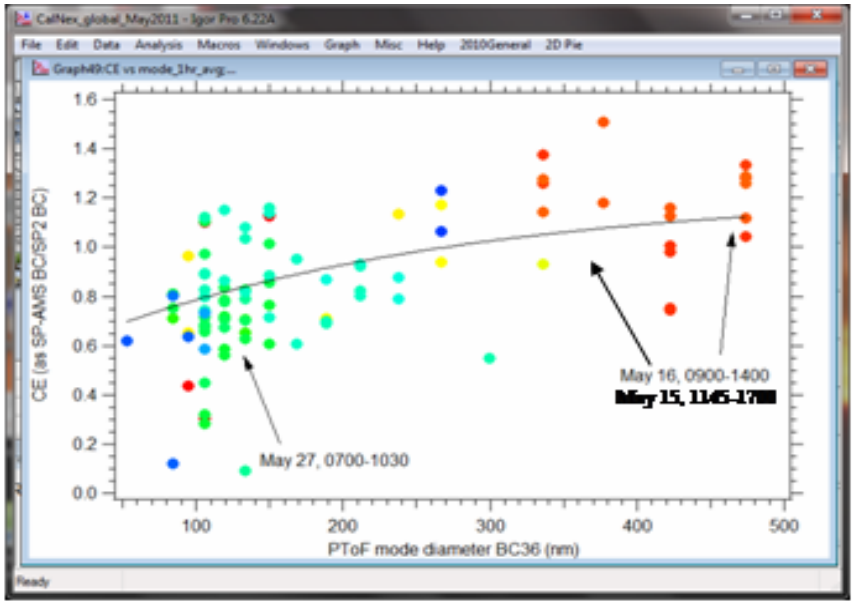
SP-AMS vs. SP2 Mass Loadings

CalNex2010

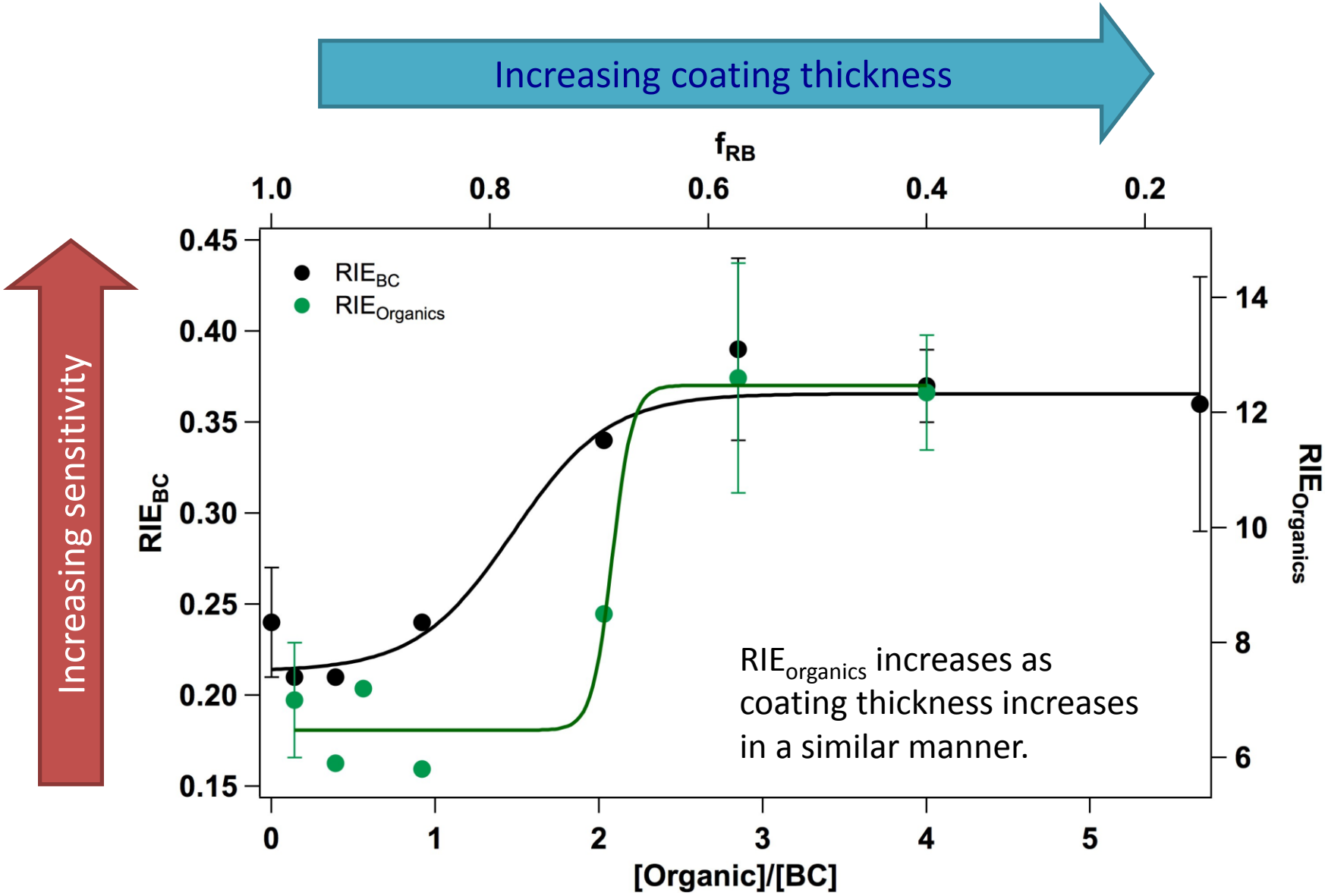




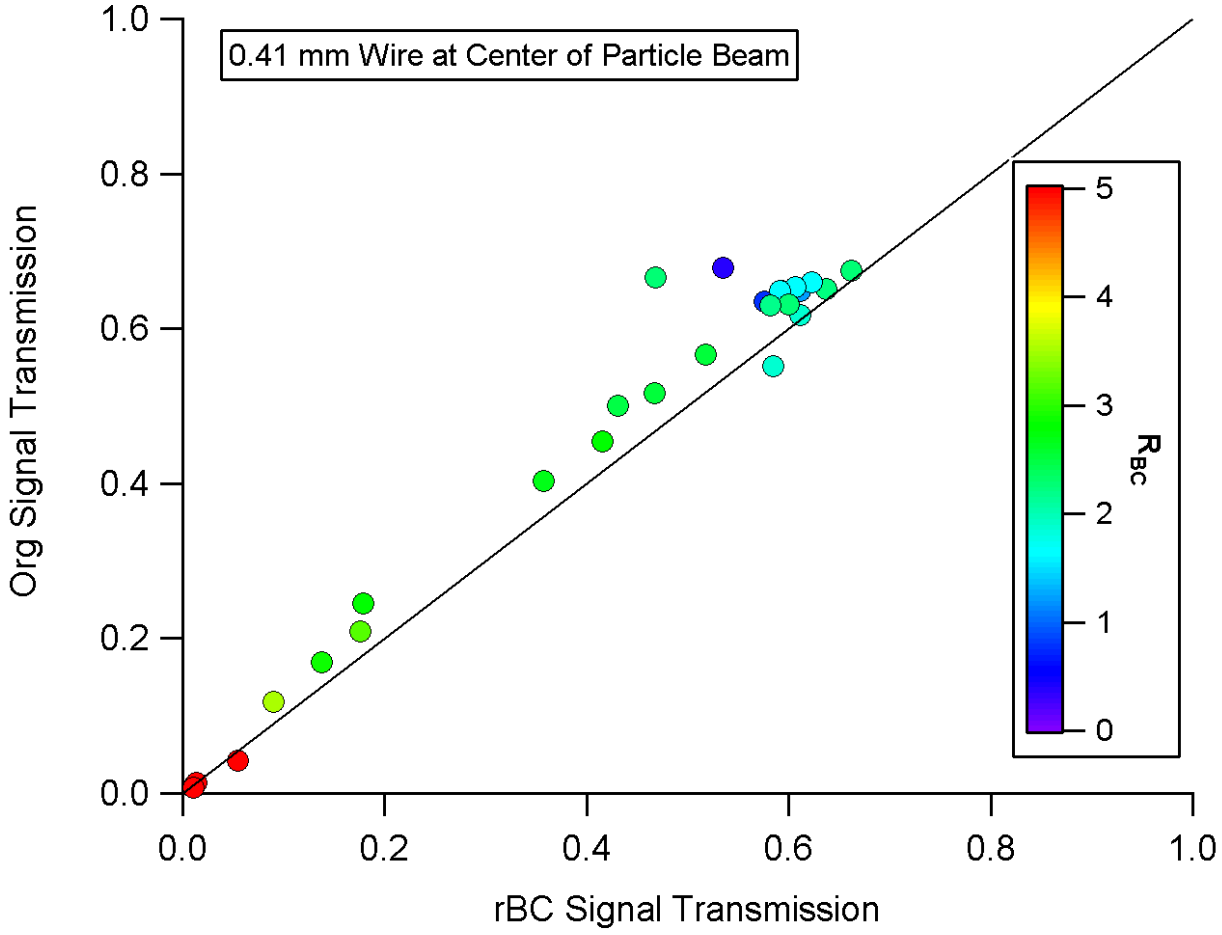
The CE is low when size is small.

Massoli et al., 2012

Sensitivity to BES coating ($RIE_{organics}$)

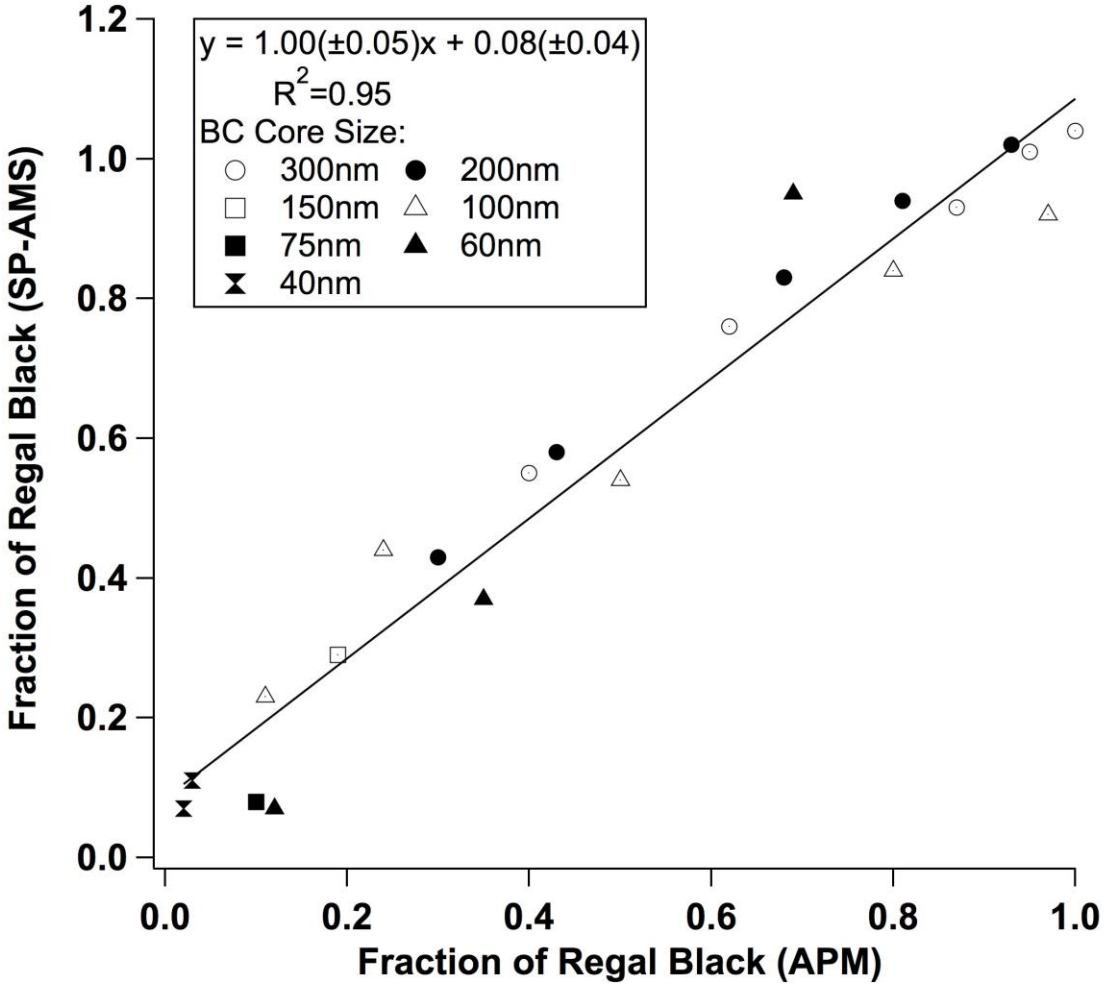


$RIE_{organics}$ vs. RIE_{BC} (from Aerodyne)



- Org and rBC signal transmissions decrease together with increasing DOS coating and narrowing of particle beam, suggesting that the effective particle beam widths for rBC and DOS are similar

f_{BC} relationship: SP-AMS vs. APM



Taking into account changing RIE for rBC and BES as the particle beam becomes narrower. SP-AMS can provide an accurate quantification of rBC down to 5% by mass for internally mixed particles.

Summary

- The collection efficiency of the SP-AMS is a function of the mixing state of rBC particles. Organic coating can narrow the particle beam width of BC, increasing the degree of laser beam – particle beam overlap.
- Ambient black carbon and thickly coated regal black particles have similar particle beam width, highlighting the importance of evaluating the current calibration procedure for rBC quantification.
- BWP measurements suggest that the effective SP-laser beam width (sigma) is ≤ 0.25 mm. Further investigation is required.
- Given accurate RIE values for lab-generated rBC particles and organic coating, the SP-AMS can provide an accurate quantification of rBC down to 5% by mass for internally mixed particles.