

Tobacco smoke measurement using fast electrical mobility spectrometers

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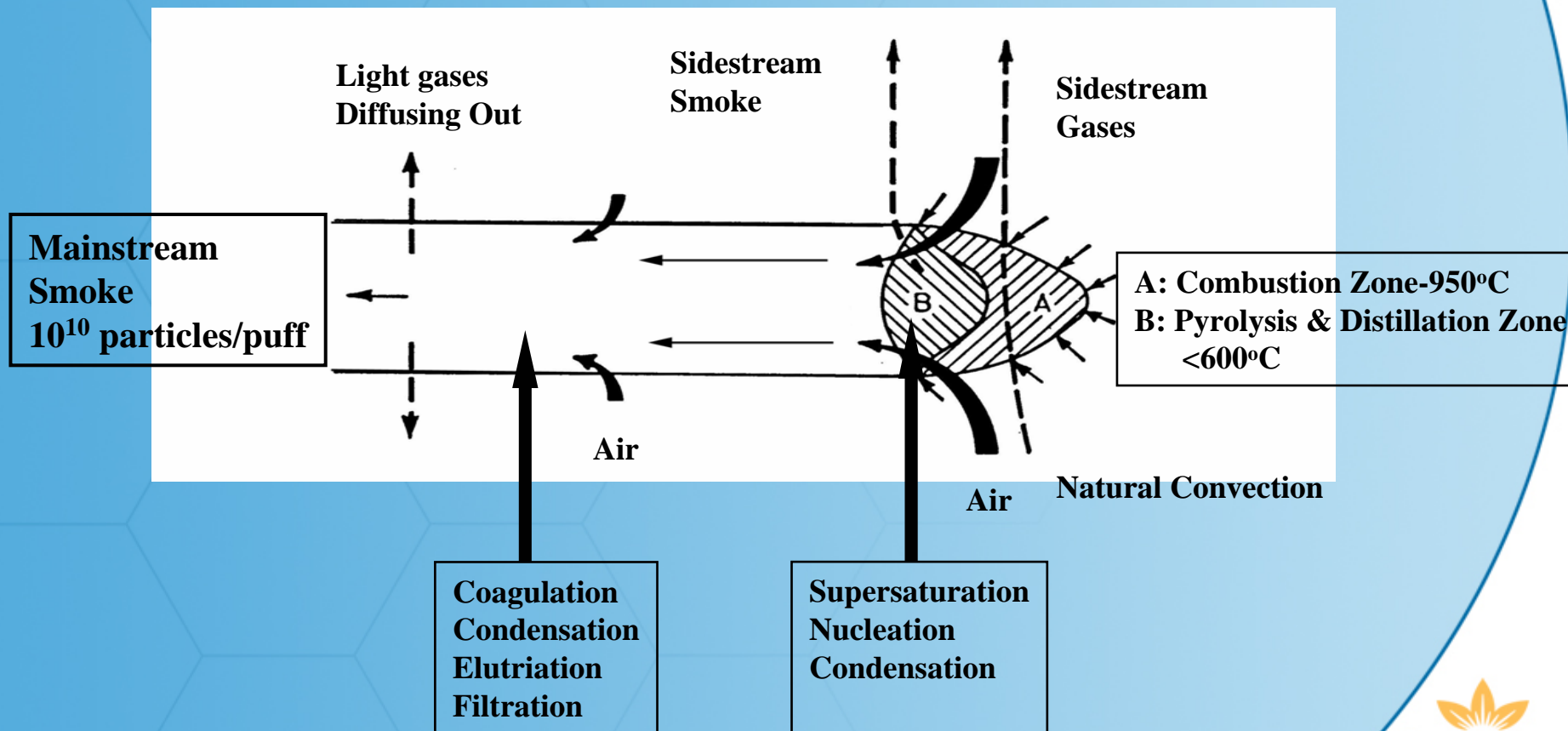
Study Objectives - Tobacco

- Impact of cigarette design parameters on cigarette yields e.g. tar, nicotine, CO, Hoffmann analytes
- HA : list of 44 key combustion-derived toxins including nitrosamines, PAHs, aromatic amines
- Improved predictive capability to design progressively reduced delivery products for existing smokers
- Aerosol measurement incorporated into design matrix of filter ventilation, filter pressure drop and paper permeability

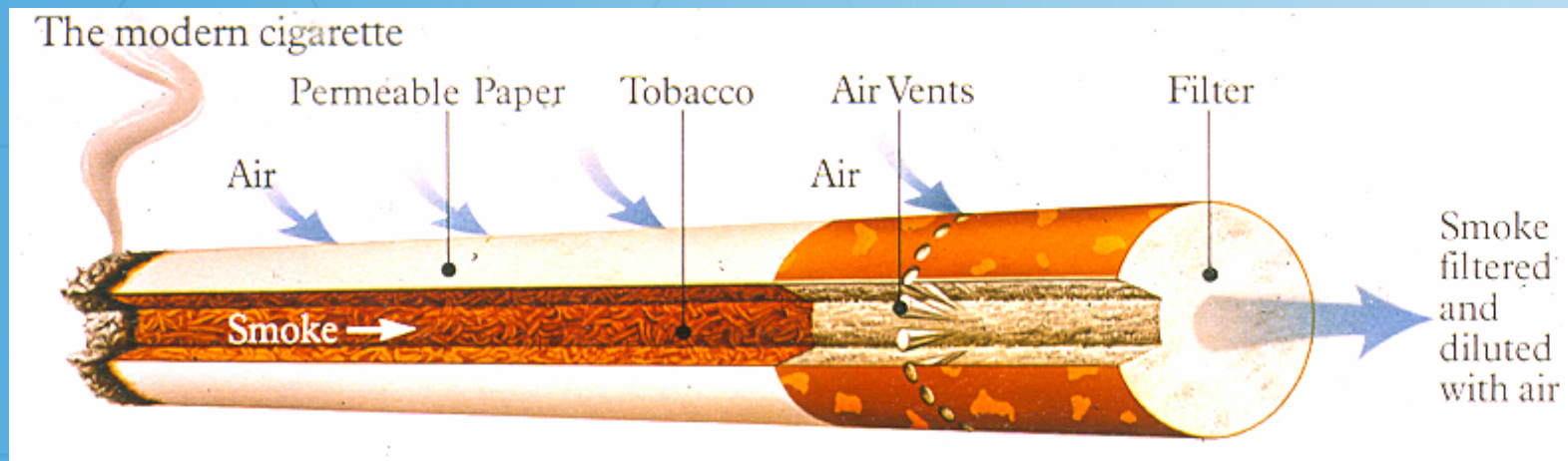
Study Objectives - Aerosol

- Tobacco smoke diameters 180 – 860 nm in literature (e.g. Ingebrethsen (1986), McRae (1990), Bernstein(2005))
- Improve time-resolved measurement of mainstream tobacco smoke particles – by puff ?
- Address existing measurement issues
 - Light scattering intensity $\propto d^{-6}$ and $d \ll \lambda_{\text{vis}}$
 - Condensation & evaporation effects
 - Coagulation effects

Thermal and Physical Processes Inside a Burning Cigarette

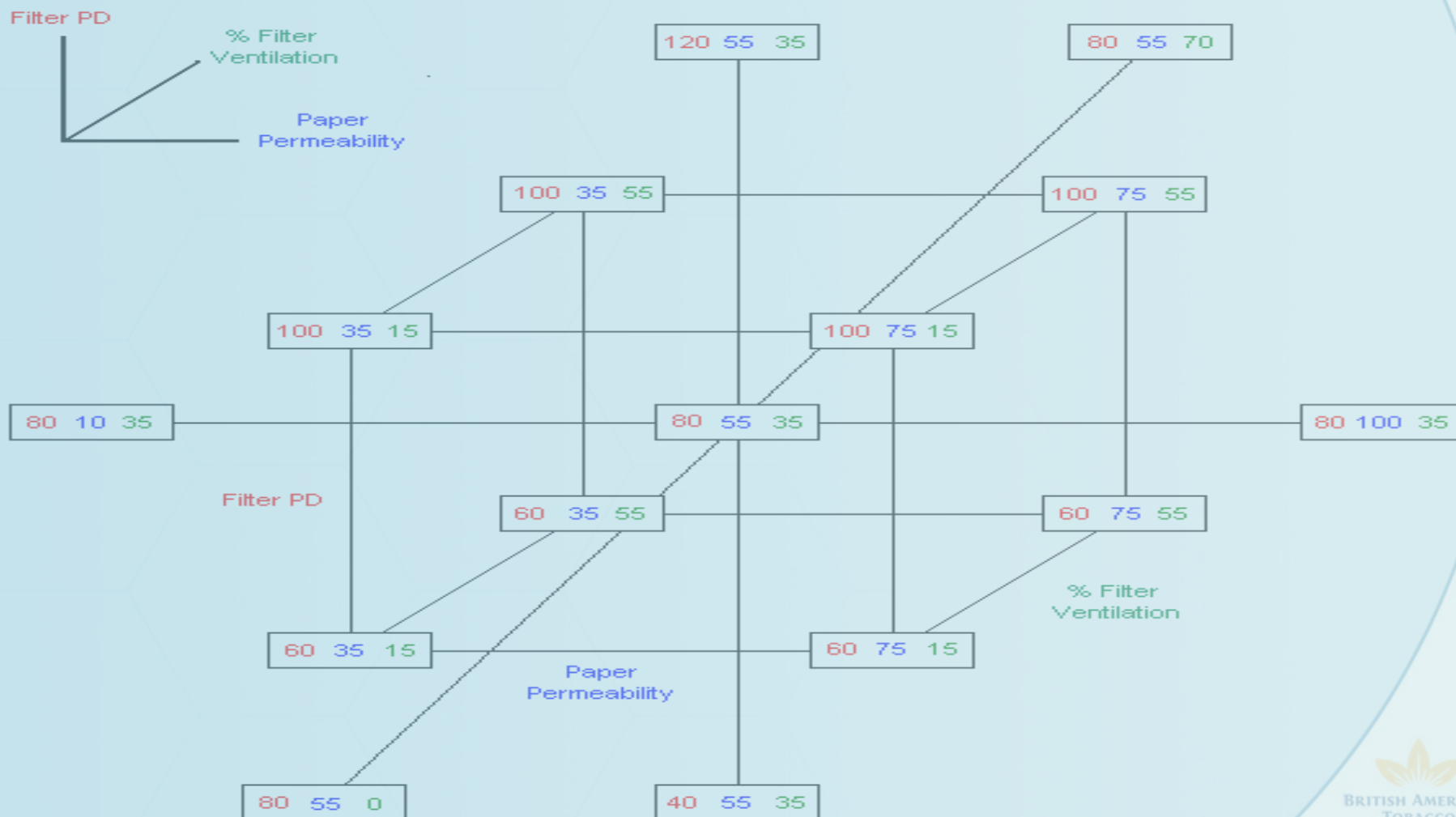


Cigarette Design Parameters



- Filter Ventilation ▲, smoke yields ▼
- Paper Permeability ▲, smoke yields ▼
(but small magnitude effect)
- Filter Pressure Drop ▲, smoke yields ▼

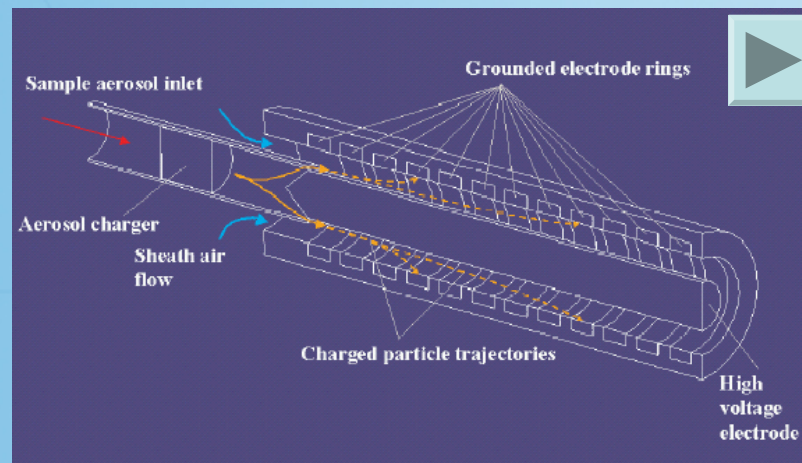
Central Composite Design



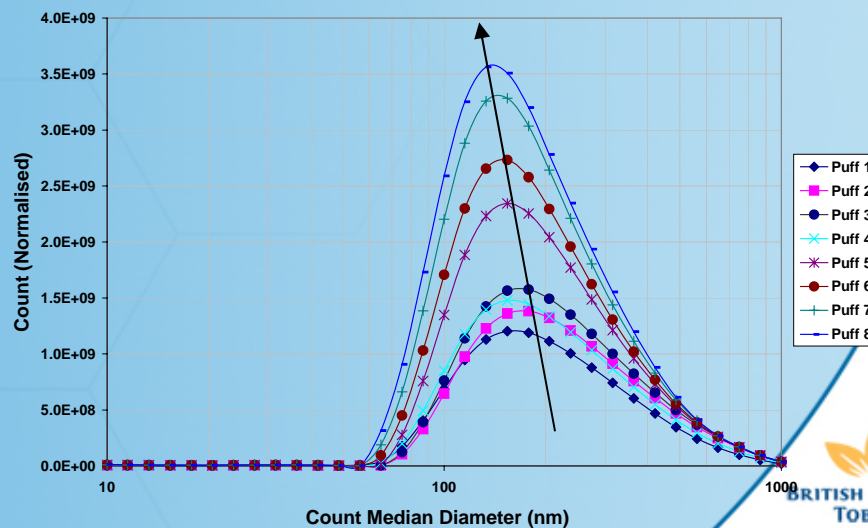
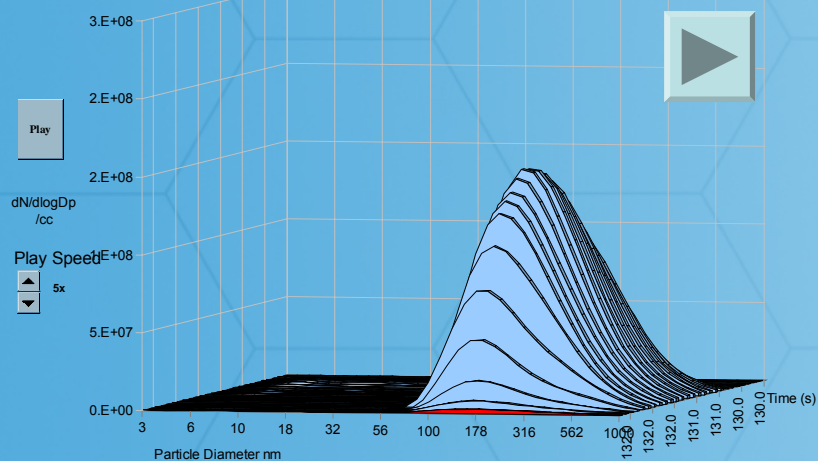
Measurement Campaign

- Cigarette
 - 24.6 mm circumference
 - 84 mm rod
 - 27 mm filter
 - Lamina (Virginia, Burley, 1:1, Oriental)
- Smoking
 - 35 ml puff
 - 2 s duration
 - 60 s interval
 - **8 puffs**
 - 4 replicates
- Dilution
 - **50:1** Dilution ratio
- Measurement
 - diameter by Cambustion DMS-500
 - 10 Hz resolution
 - 10-1000 nm range
 - - 1E+08 concentration
 - number concentration by TSI Model 3022 CPC
 - calibration with PSL standards

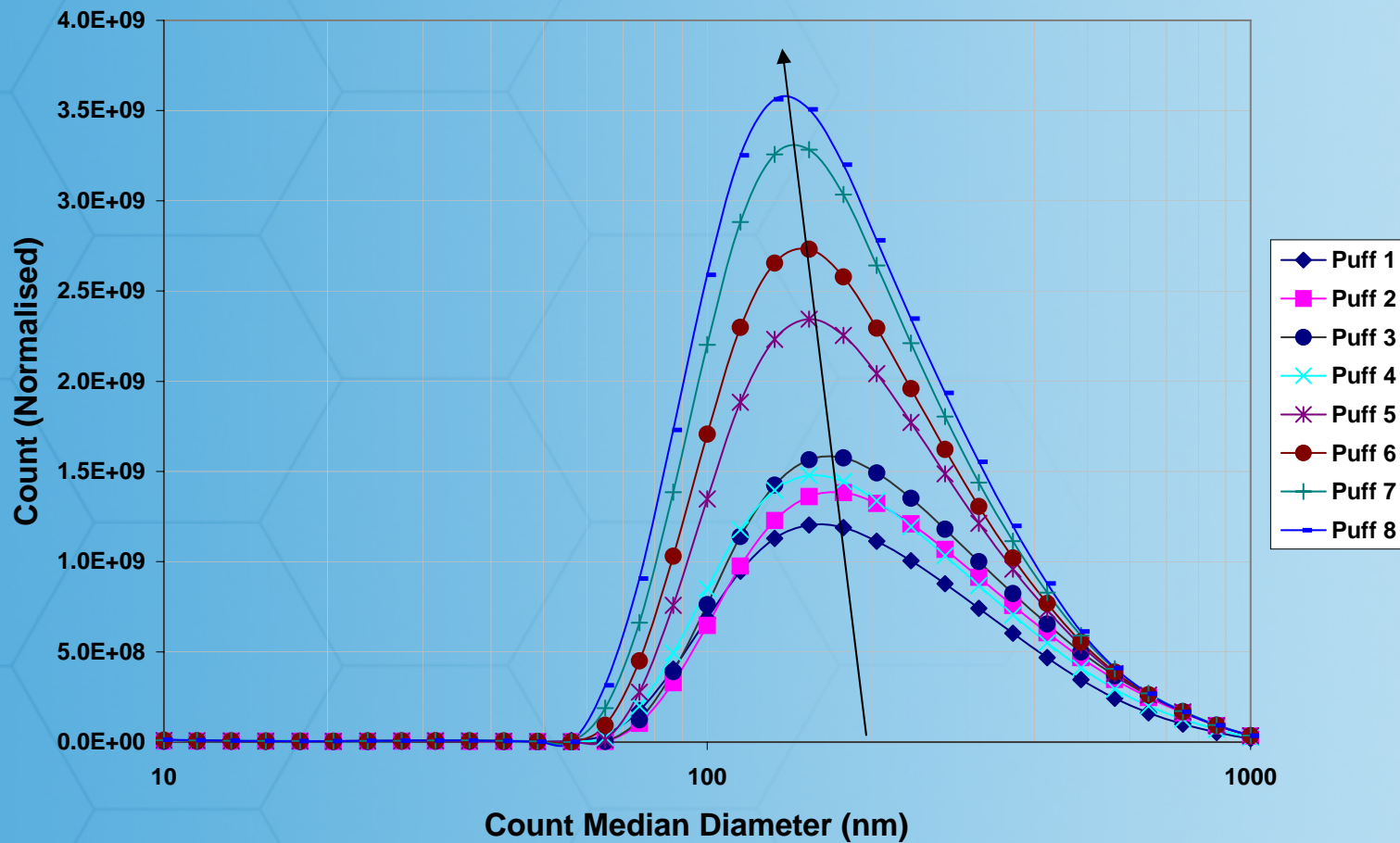
Measurement Sequence



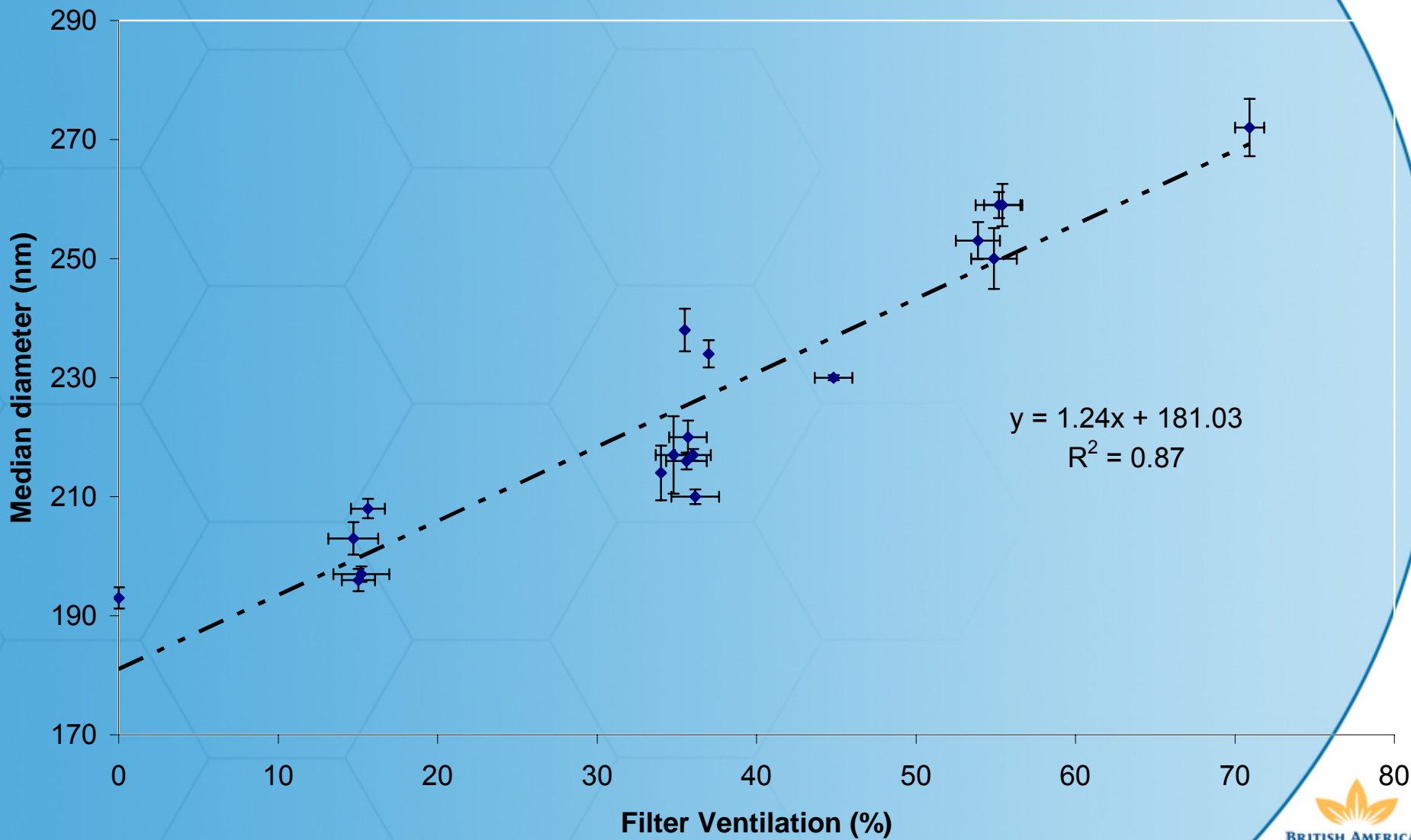
DMS500 Dynamic Particle Spectrum



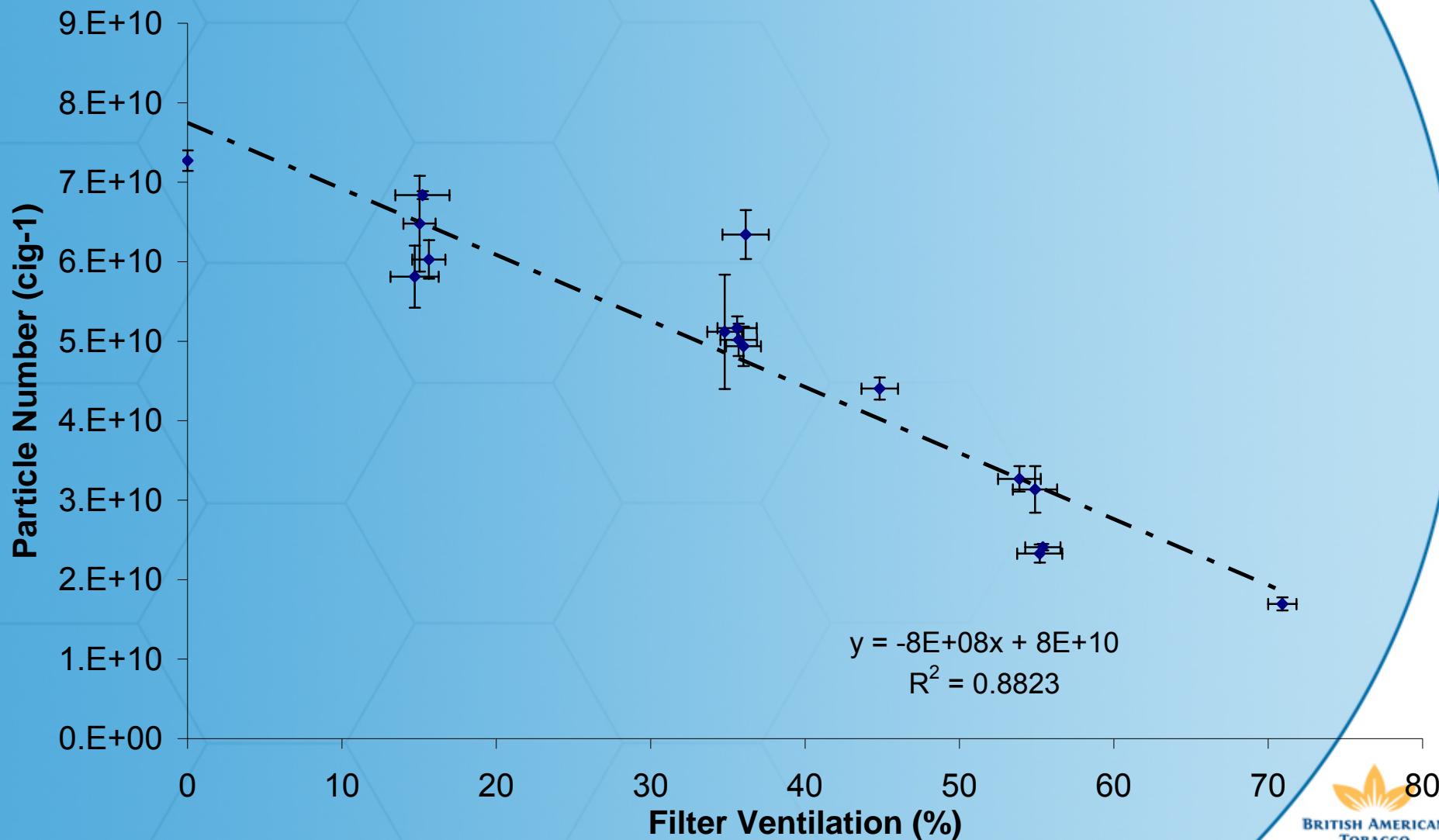
Puff Analysis



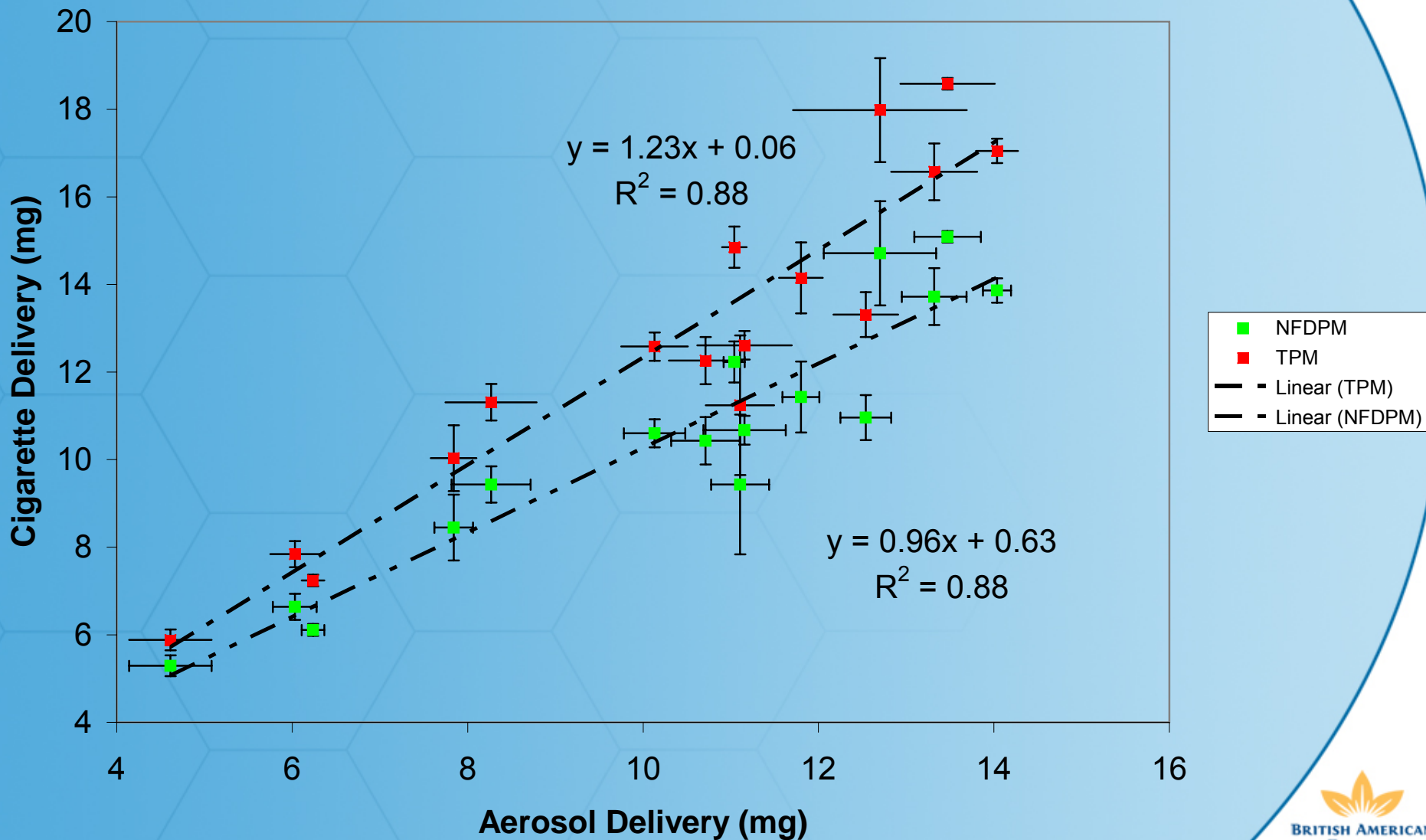
Diameter v Ventilation



Particle Number v Ventilation



Measured v Predicted Tar Mass



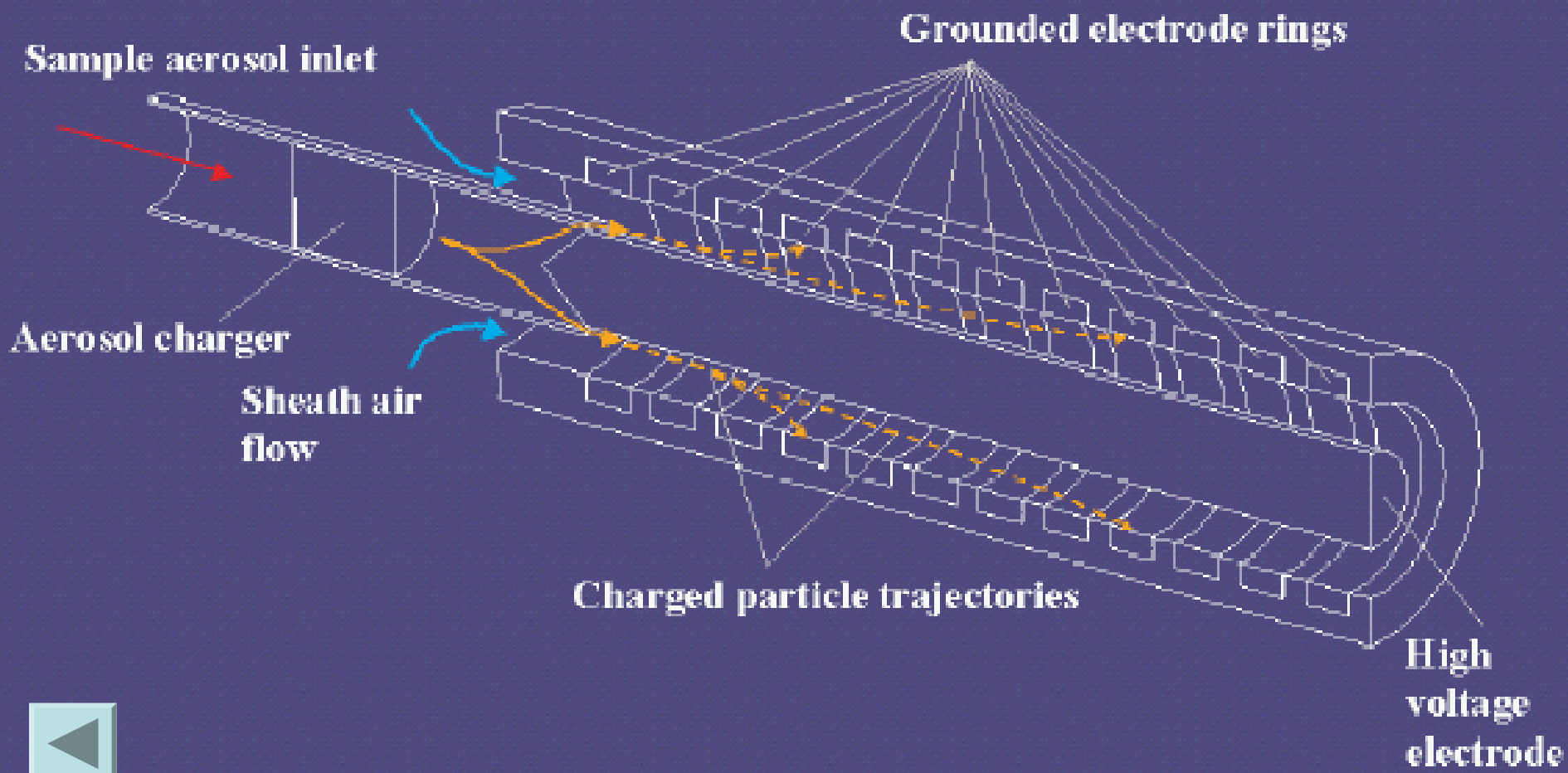
Summary

- Electrical mobility techniques have shown value in real-time smoke measurement with respect to sensitivity & time resolution at minimal transit time & dilution ratios
- Strong relationship observed for cigarette filter ventilation versus NFDPM and specific PM associated chemicals, particle diameter, number concentration
- Aerosol changes consistent with residence time changes in rod & filter, that is coagulation drives particle growth and reduction in particle number
- Calculated particle mass in good agreement with ISO machine smoking

Smoking & dilution

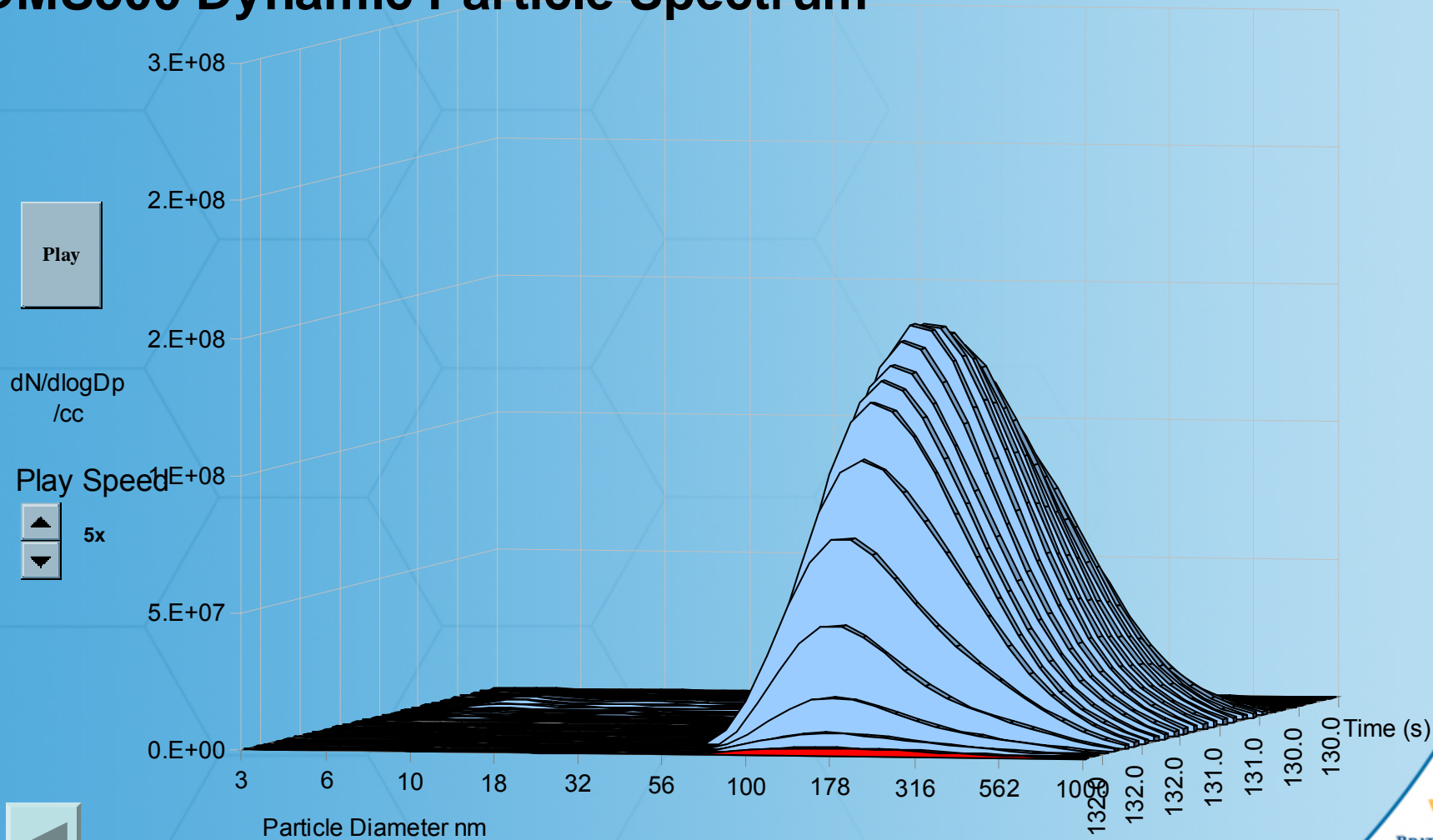


Electrical mobility spectrometer

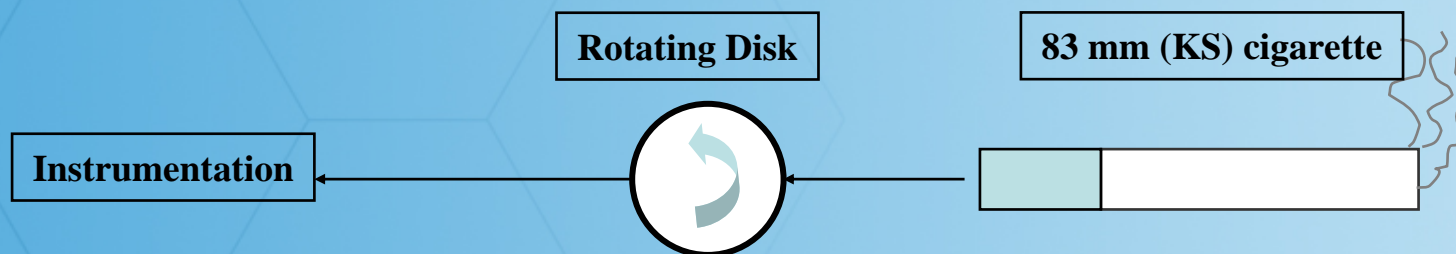


Data output – 100 ms resolution

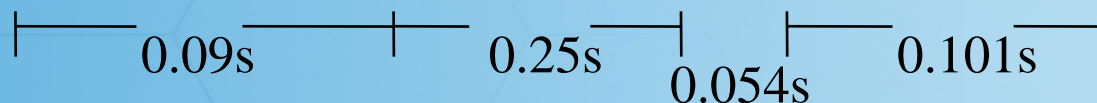
DMS500 Dynamic Particle Spectrum



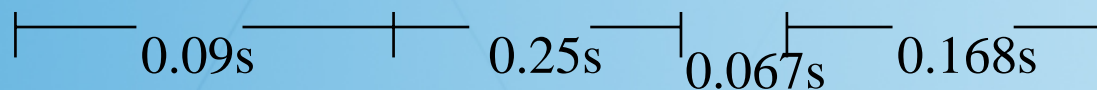
Calculated Transport Times



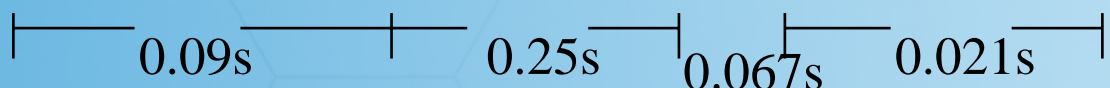
Unventilated



Ventilated – Puff 1



Ventilated – Puff 8



Flow = 1.05 l/min