Exposure to Ultrafine Particles on and Near Roadways

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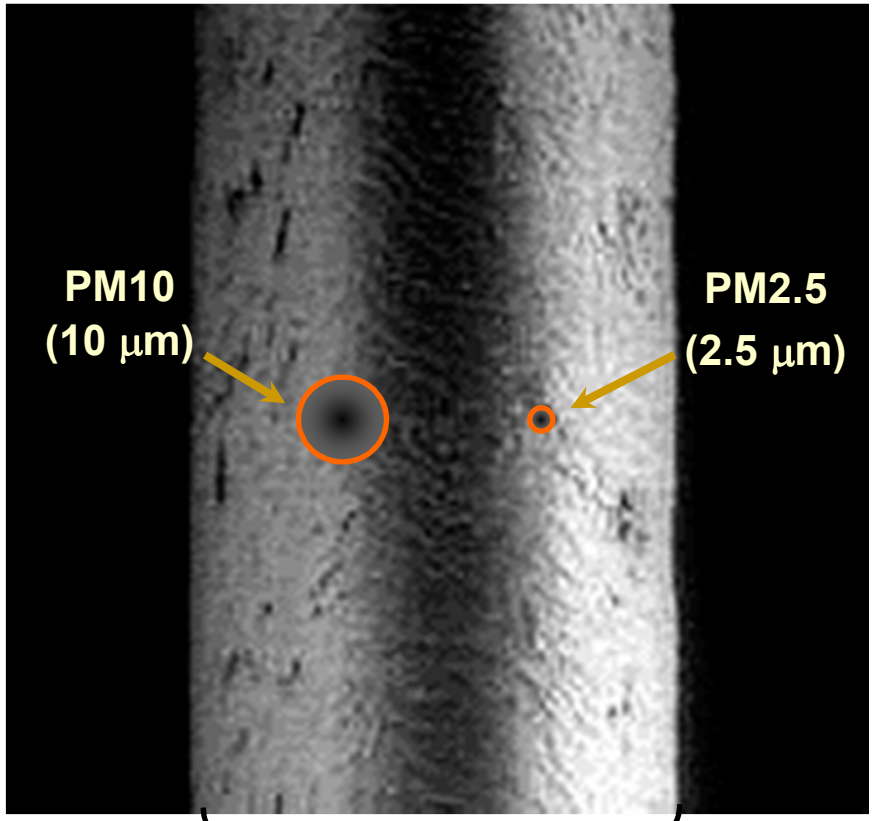
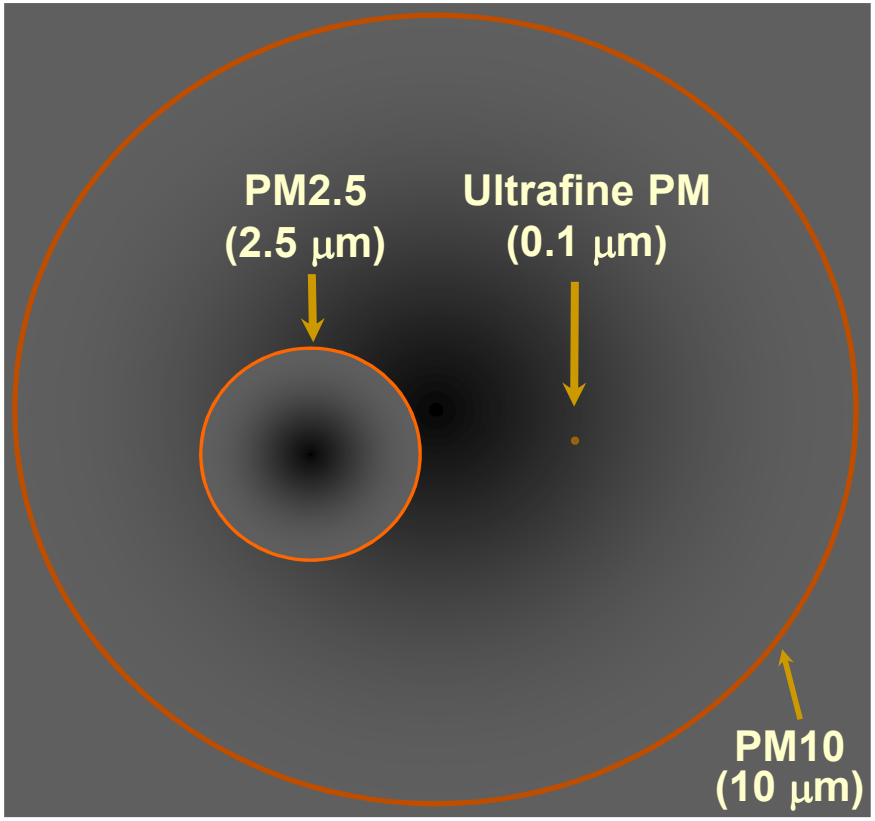
Comparison of PM_{10}, $PM_{2.5}$, and Ultrafine PM

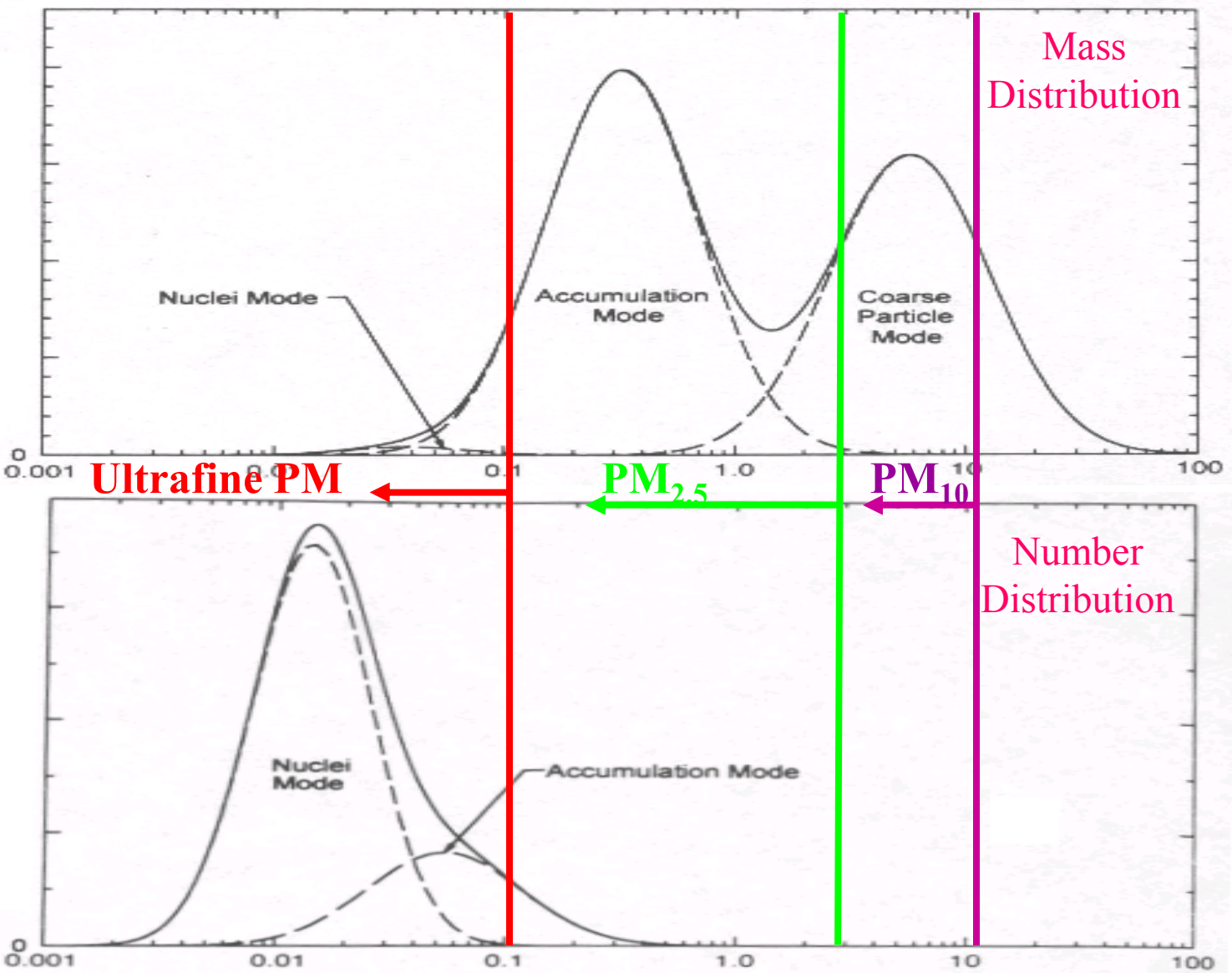


Human Hair
(60 μm diameter)



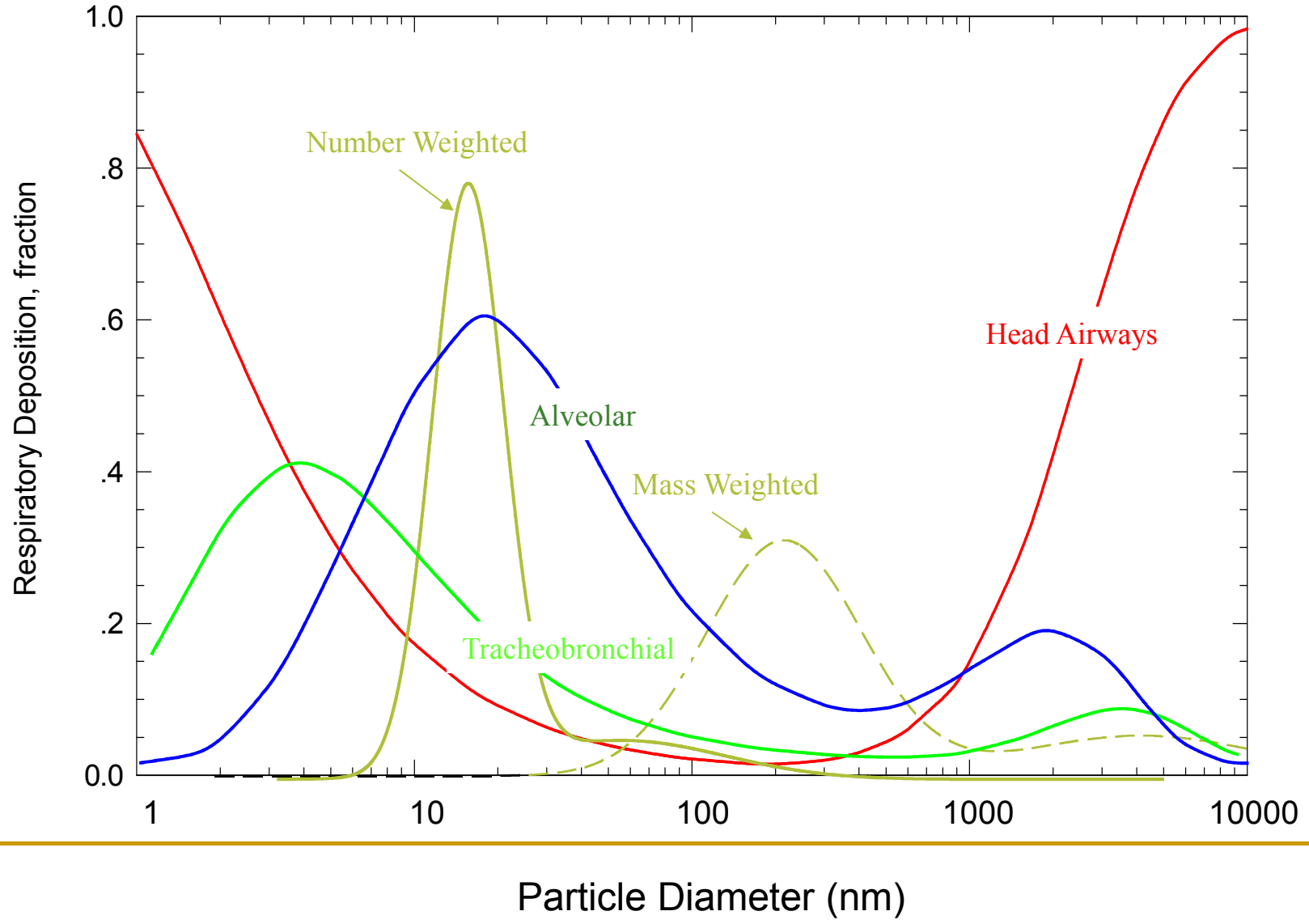
Relative size of particles

Atmospheric Aerosols: Particulate Matter (PM) Size Distribution



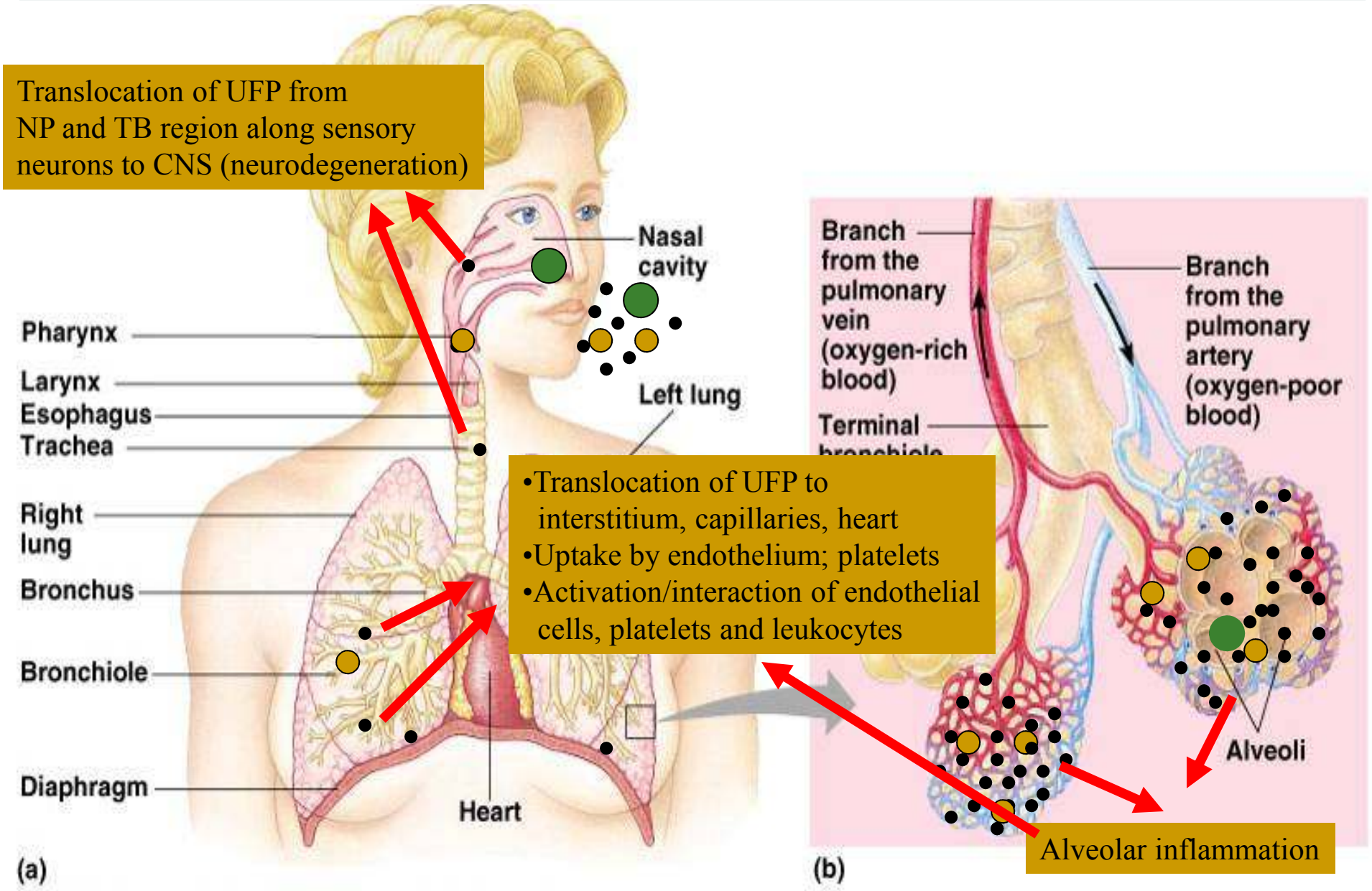
Hinds, 1999, "Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles", 2nd edition.

Particle Regional Deposition for Light Exercise



Pathways of Particle Translocation Within and Outside Respiratory Tract

Translocation of UFP from NP and TB region along sensory neurons to CNS (neurodegeneration)



- Translocation of UFP to interstitium, capillaries, heart
- Uptake by endothelium; platelets
- Activation/interaction of endothelial cells, platelets and leukocytes

Alveolar inflammation

Vehicular emissions usually constitute the most significant source of UFPs in an urban environment.

Recent Traffic-Related Health Studies

- **Cardiac and Pulmonary Health Risks from Near-Highway Exposures**

  Environmental Health – Tufts Univ. School of Medicine (Brugge 2007)

- **Adverse Effects of Traffic Exposure on Children's Lung Development**

  The Lancet – USC School of Medicine (Gauderman 2007)

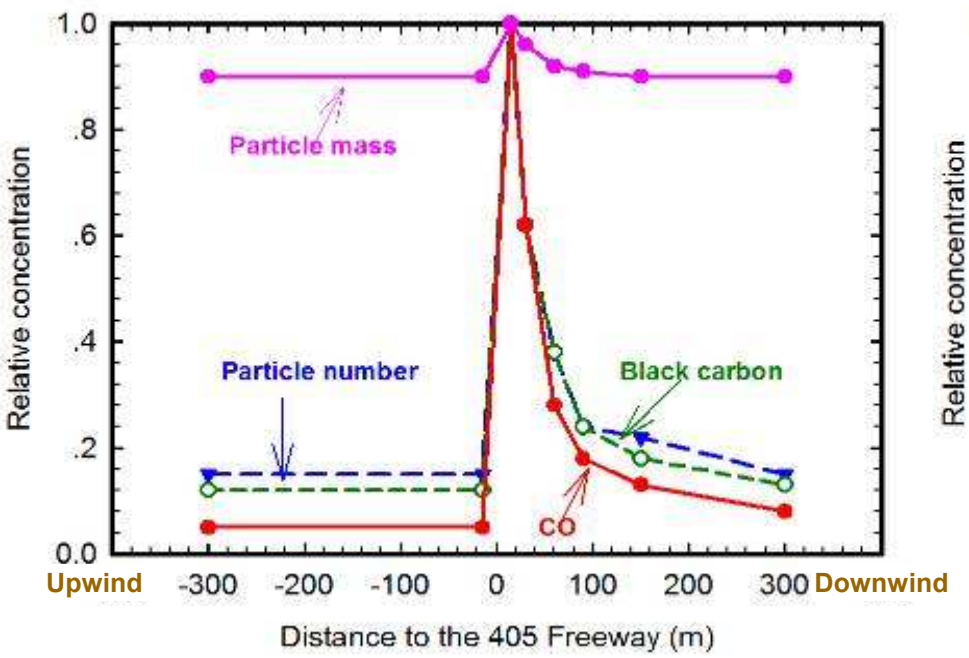
- **Traffic Exposure and Decreased Lung Function in Adults with Asthma**

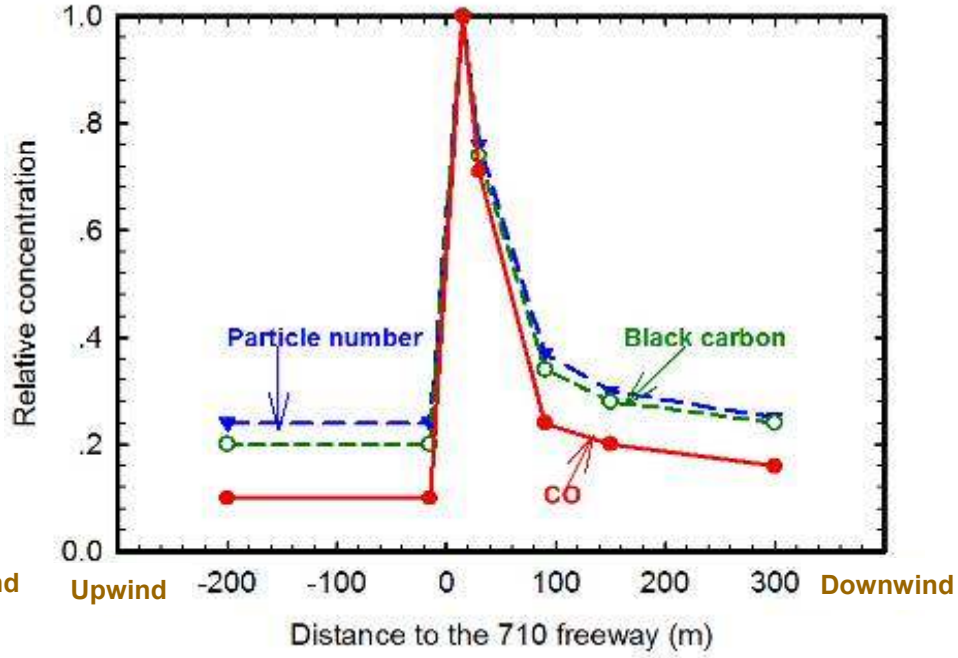
  A,. Academy of Allergy, Asthma & Immunology – UCSF (Balmes 2009)

- **Residential Proximity to Freeways and Autism in the CHARGE Study**

  Environmental Health Perspectives – USC School of Medicine (Volk, 2011)

Near Roadways





Zhu et al., 2002 "Concentration and size distribution of ultrafine particles near a major highway", *J. of Air and Waste Management Association*, 52:1032-1042.

Zhu et al., 2002 "Study of Ultrafine Particles near a Major Highway with Heavy-duty Diesel Traffic", 2002, *Atmospheric Environment*, 36: 4323-4335.

Key point

UFP concentrations decay exponentially downwind of freeways.

SENATE COMMITTEE ON EDUCATION
Jack Scott, Chair
2007-2008 Regular Session

BILL NO: SB 1468
AUTHOR: Oropeza
AMENDED: March 24, 2008
FISCAL COMM: Yes HEARING DATE: April 16, 2008
URGENCY: No CONSULTANT:Kathleen Chavira

SUBJECT : Location of School Sites

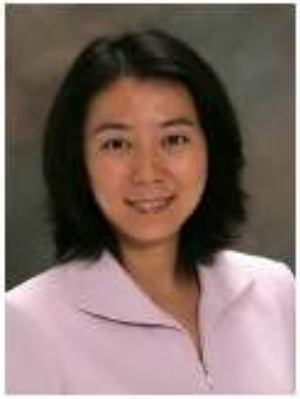
SUMMARY

This bill deletes the current authority of a school district to locate a school within 500 feet of the edge of the closest traffic lane of a freeway or other busy traffic corridor if certain conditions are met and instead, prohibits the location of a school site within one-fourth of a mile from the edge of the closest traffic lane of a freeway or other busy traffic corridor under any conditions.

2011 Haagen-Smit Prize Winners

The Executive Editors and the Publisher of *Atmospheric Environment* take great pleasure in announcing the 2011 "Haagen-Smit Prize", designed to recognize **outstanding papers published in *Atmospheric Environment***. The Prize is named in honor of Prof. Arie Jan Haagen-Smit, a pioneer in the field of air pollution and one of the first editors of the *International Journal of Air Pollution*, a predecessor to *Atmospheric Environment*.

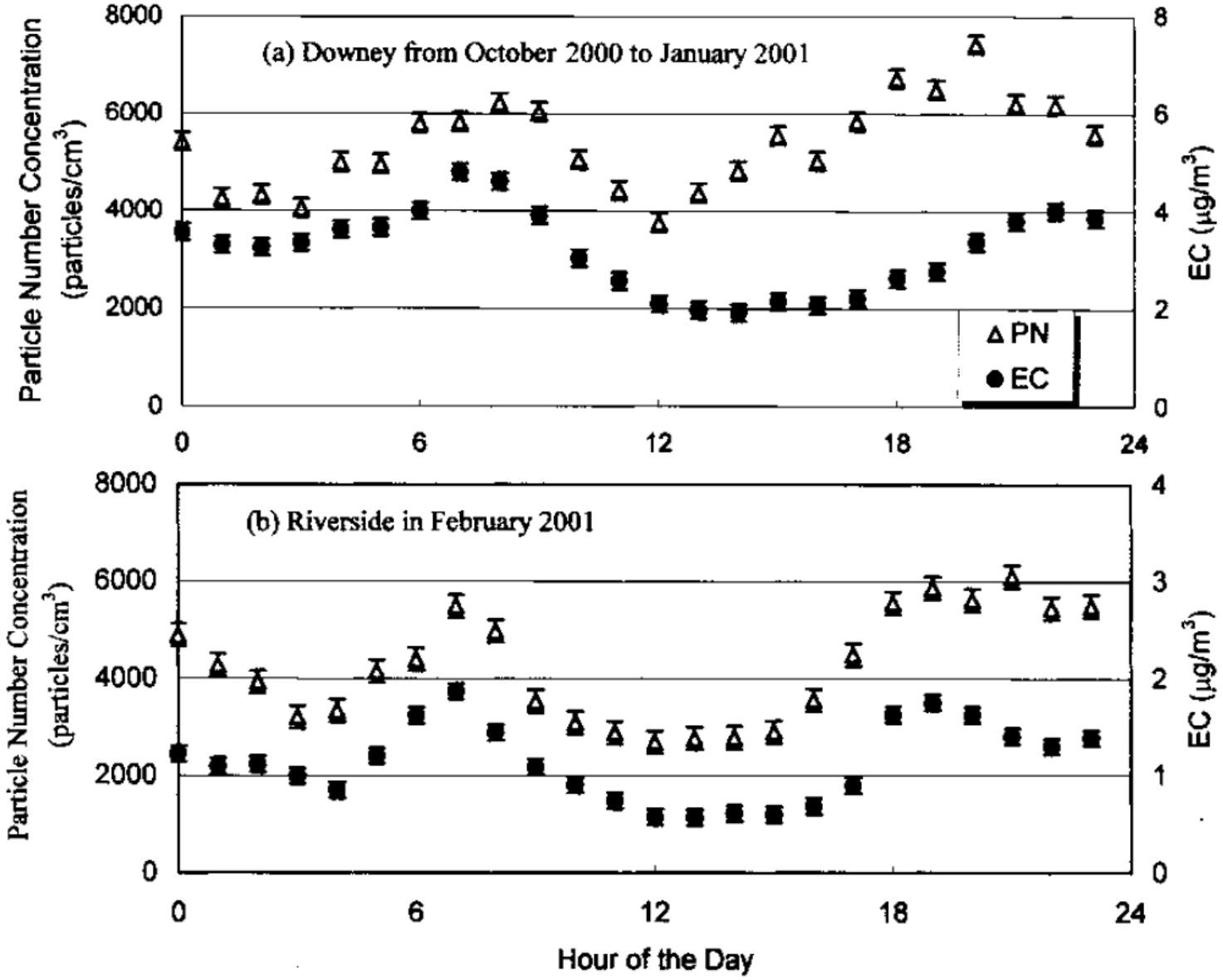
The "Haagen-Smit Prize" is given annually to **two papers** previously published in *Atmospheric Environment* and covering different science areas. Additional information about this award and the selection committee members can be found at http://geo.arc.nasa.gov/sgg/singh/. The nominating letters printed below describe the two 2011 winning papers.



Y. F. Zhu, W. C. Hinds, S. Kim, S. Shen and C. Sioutas. Study of ultrafine particles near a major highway with heavy-duty diesel traffic. *Atmos. Environ., 36*, 4323-4335, 2002.

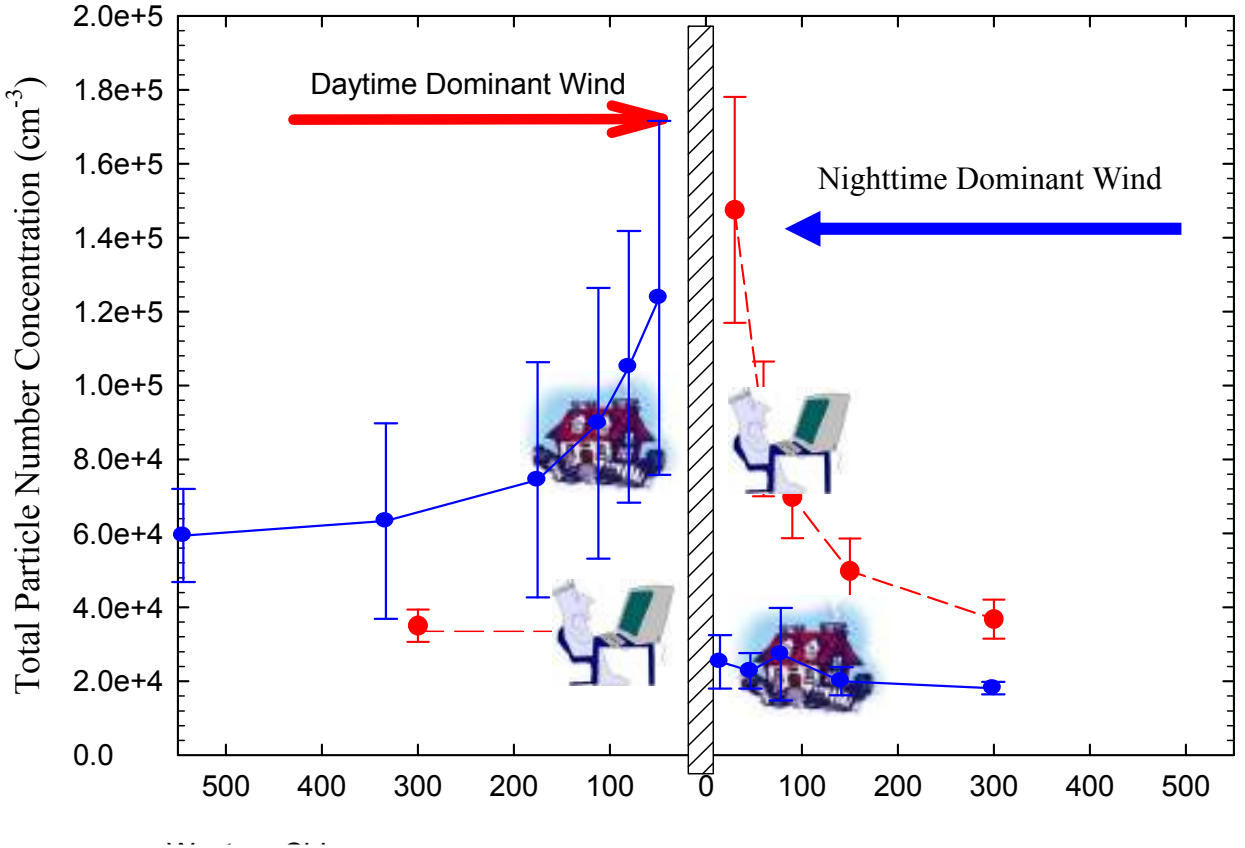
Zhu et al. (2002) reported measurements of ultrafine particles downwind of the Interstate 710 freeway in Los Angeles. This highway, on which 25% of the traffic is heavy-duty diesel trucks, is one of the most heavily traveled in the nation. This paper was ground-breaking in obtaining data on the particulate air quality, especially particle number concentrations, in the vicinity of a major roadway containing substantial diesel traffic and has been cited more than 300 times since its publication.

Diurnal Pattern of Pollutant Concentration in LA



Kim S, Shen S, Sioutas C. 2002, Size distribution and diurnal and seasonal trends of ultrafine particles in source and receptor sites of the Los Angeles basin, J Air Waste Manag Assoc. Mar; 52(3):297-307.

Near Roadways



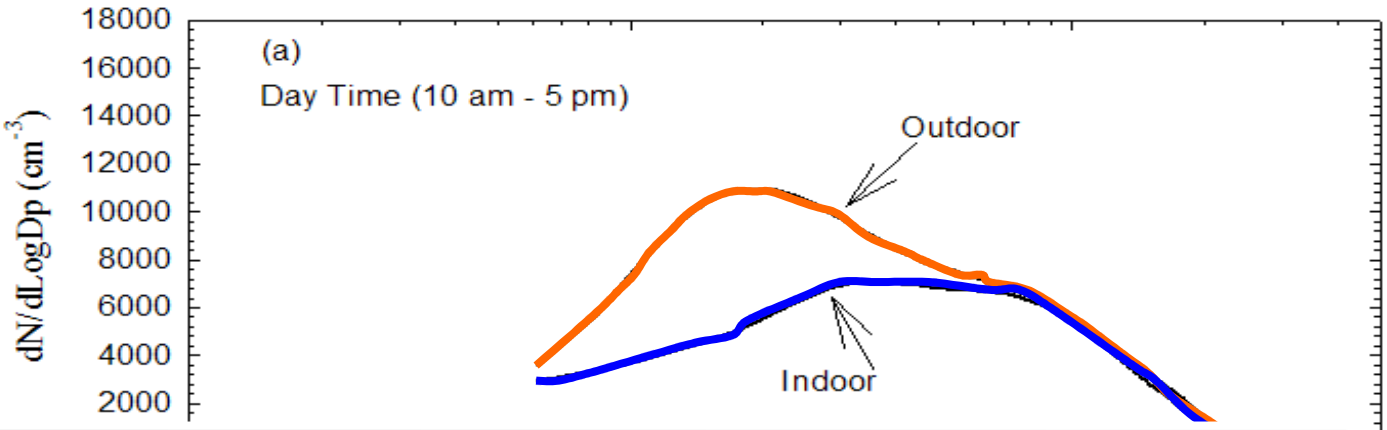
Key point

Daily exposure to UFPs: Three folds of difference between the two cases.

Zhu et al., 2006, "Comparison of Daytime and Nighttime Concentration Profiles and Size Distributions of Ultrafine Particles near a Major Highway" *Environmental Science and Technology* 40: 2531-2536.

Indoor near Roadways

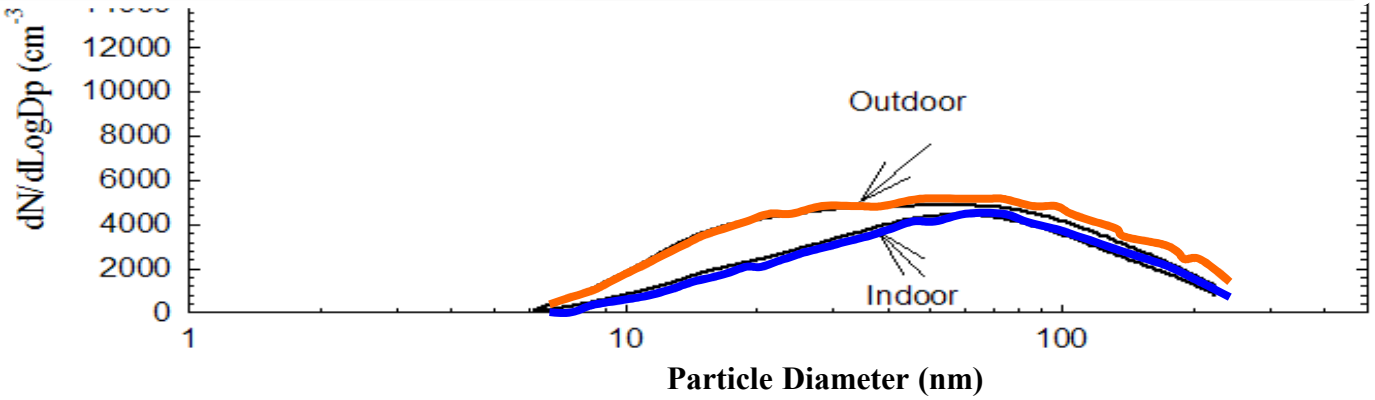
◆ Apartment 1



◆ Apar

Key point

Significant amount of freeway UFPs penetrate into indoor environments.



Zhu et al., 2005 "Penetration of freeway ultrafine particles into indoor environments", 2005, *Journal of Aerosol Science,* 36: 303-322.

In-Cabin on Roadway

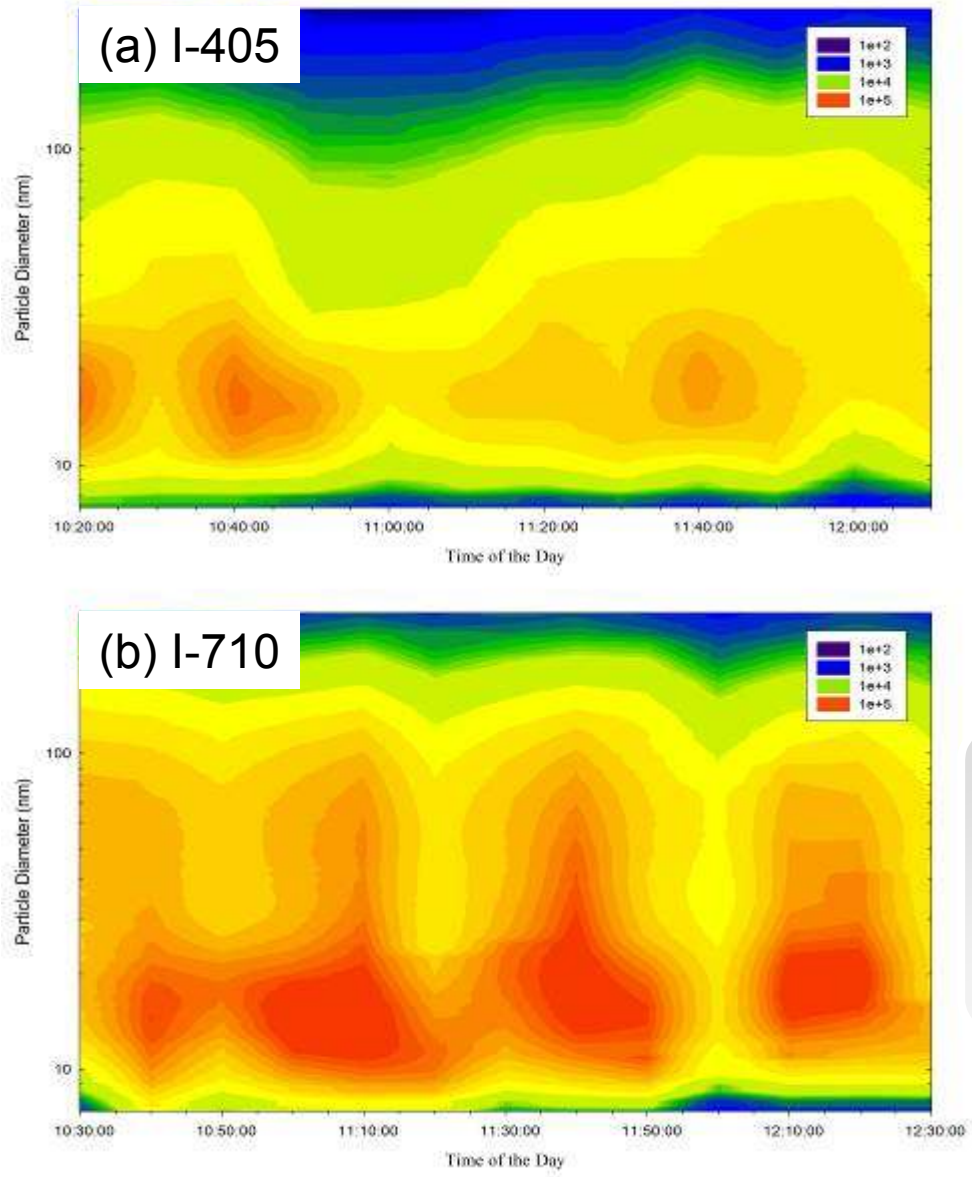
Jetta (2002)

Audi A4 (2004)

PT Cruiser (2005)

Zhu et al., 2007 , "In-cabin commuter exposure to ultrafine particles on Los Angeles freeways". *Environmental Science and Technology*. 41: 2138-2145.

In-Cabin on Roadway



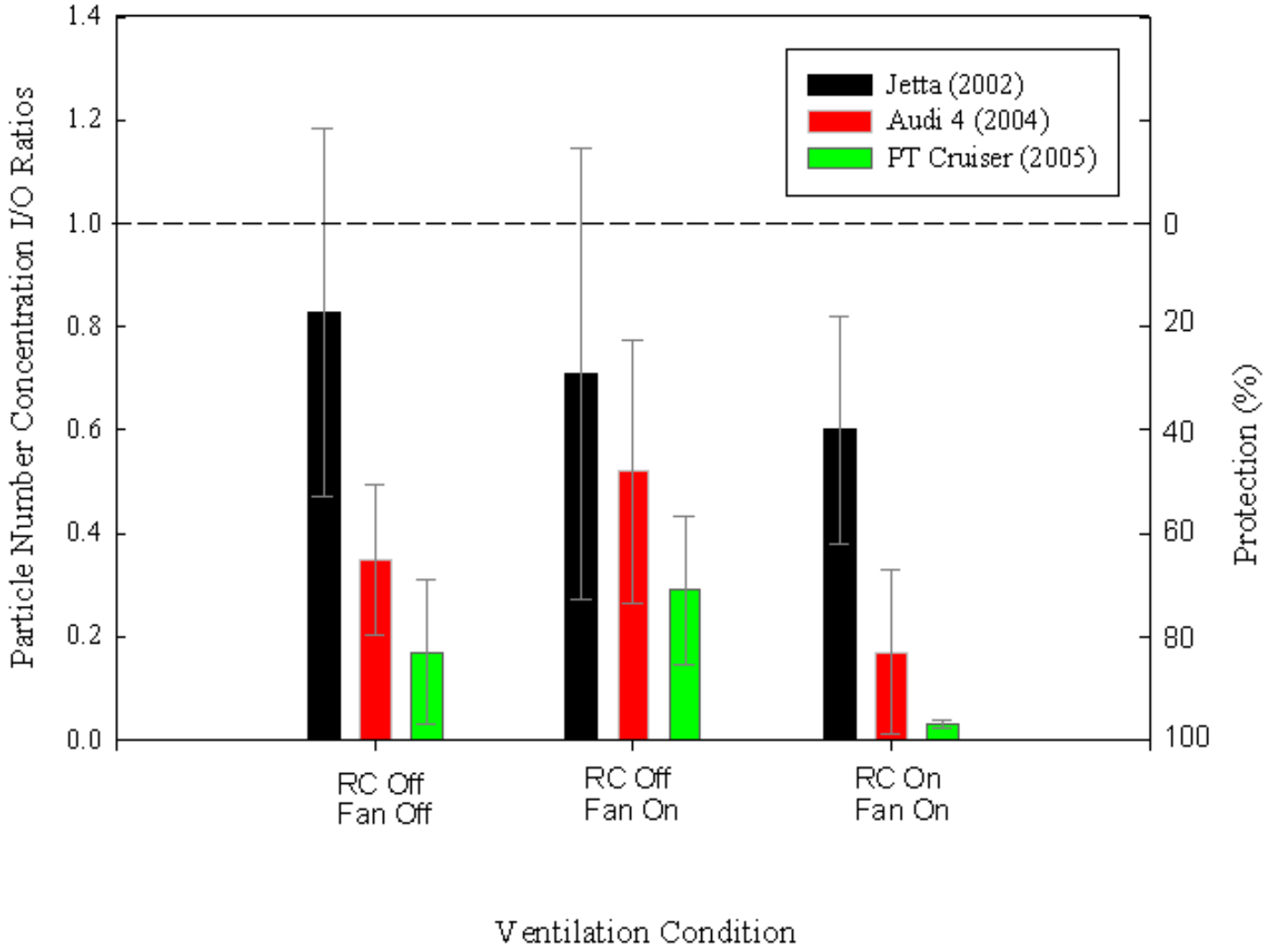
Typical contour plots of particle number based size distributions inside a test vehicle driving on freeways.

Key point

Greater particle number concentrations were observed on I-710, a diesel vehicle dominated freeway.

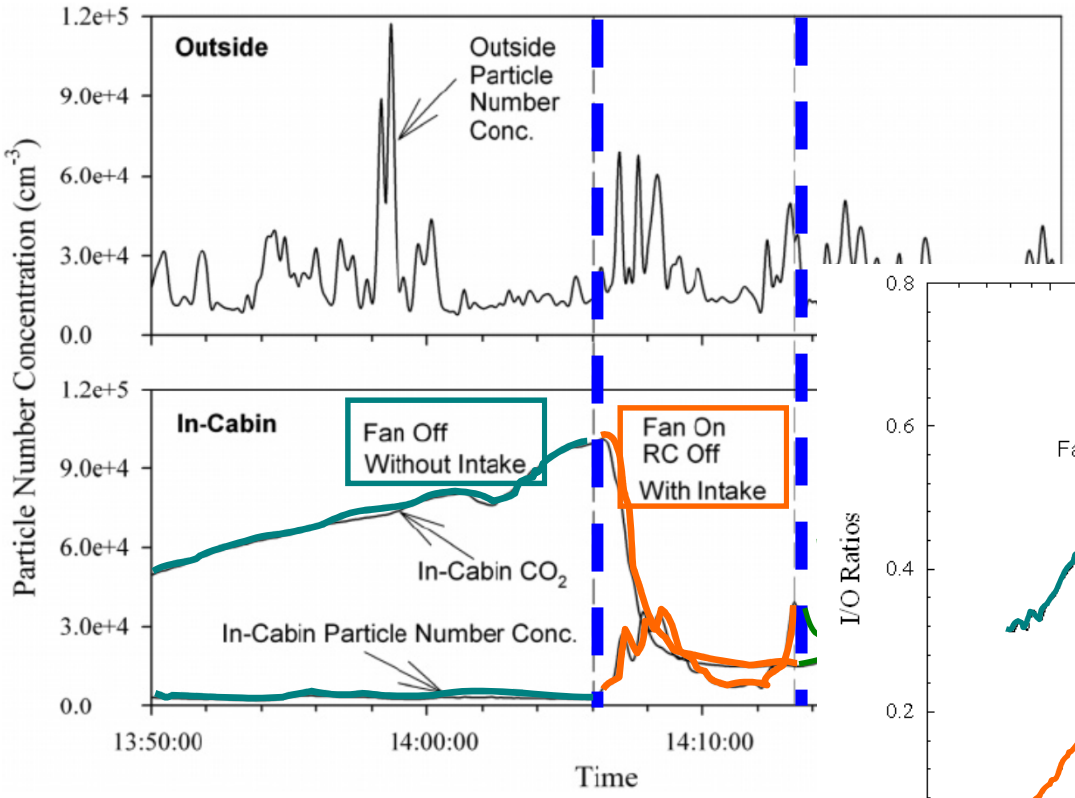
Zhu et al., 2008 "Measurements of Ultrafine Particles and Other Vehicular Pollutants inside a Mobile Exposure System on Los Angeles Freeways" *J. of Air and Waste Management Association*, 58: 424-434.

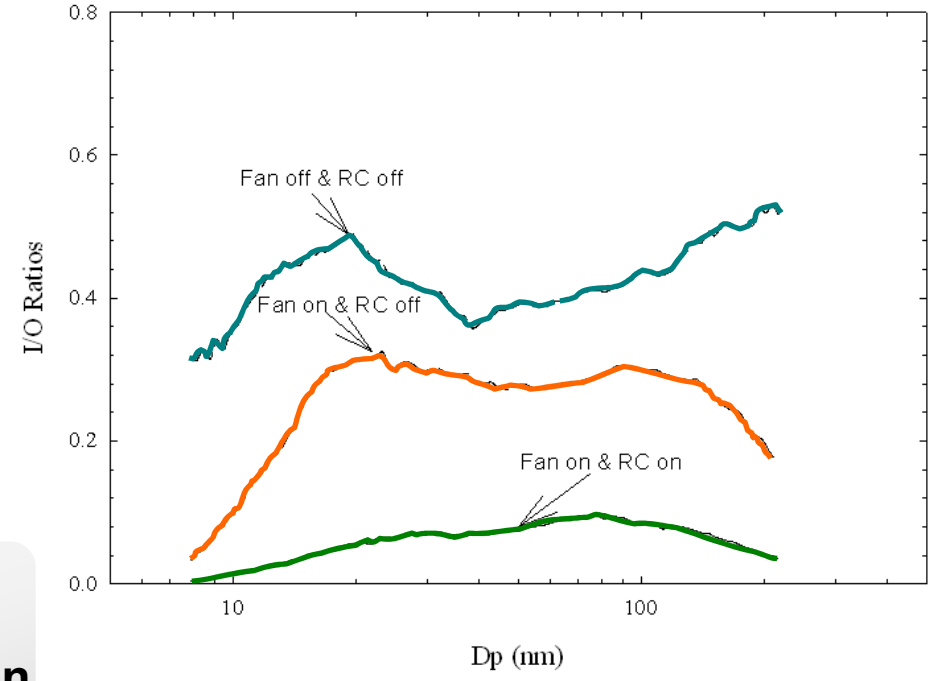
In-Cabin on Roadways



Zhu et al., 2007 , "In-cabin commuter exposure to ultrafine particles on Los Angeles freeways". *Environmental Science and Technology*. 41: 2138-2145.

In-Cabin on Roadways





Key point

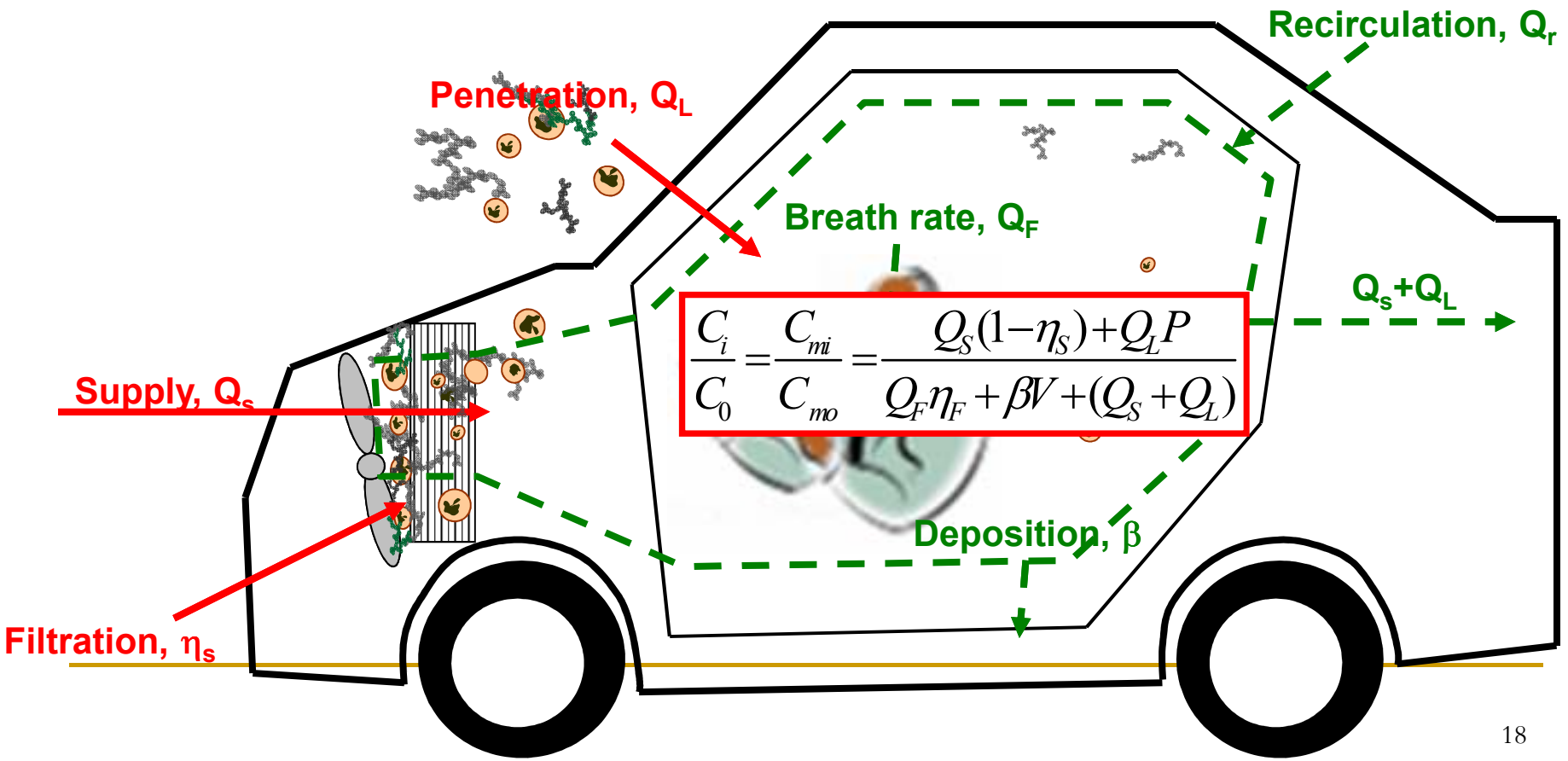
Fan on & Recirculation on provides the best protection for UFP exposures.

Zhu et al., 2007 , "In-cabin commuter exposure to ultrafine particles on Los Angeles freeways". *Environmental Science and Technology*. 41: 2138-2145.

In-Cabin Model

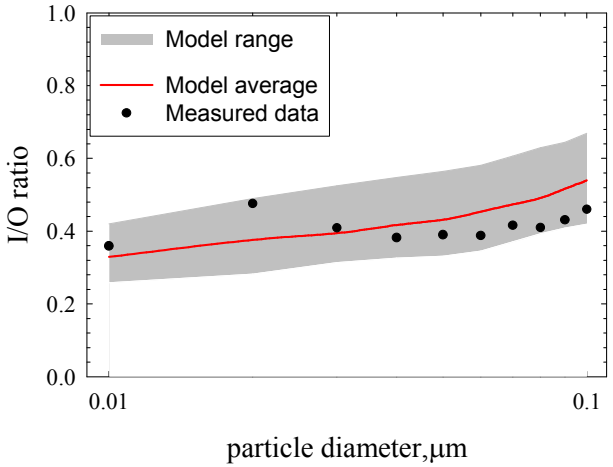
Source Penetration Filtration

Sink Recirculation Inhalation Coagulation Deposition

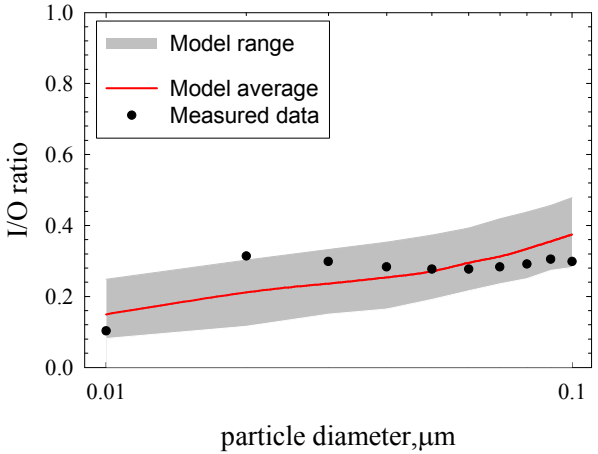


In-Cabin Model

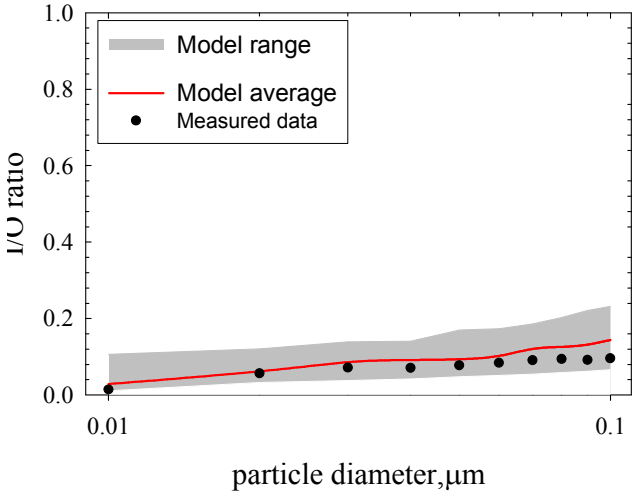
Model performance under steady-state conditions



Fan off, RC off



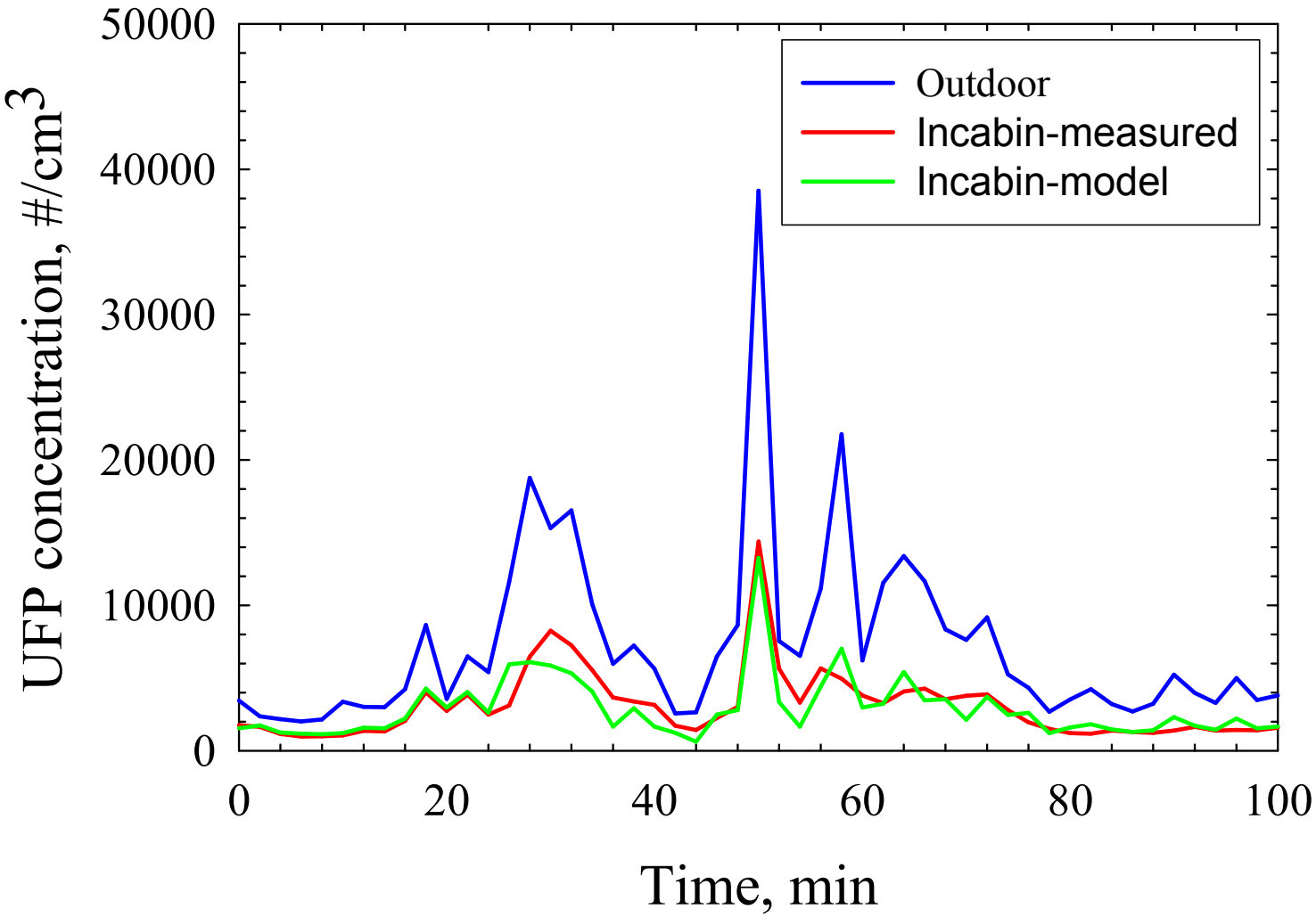
Fan on, RC off



Fan on, RC on

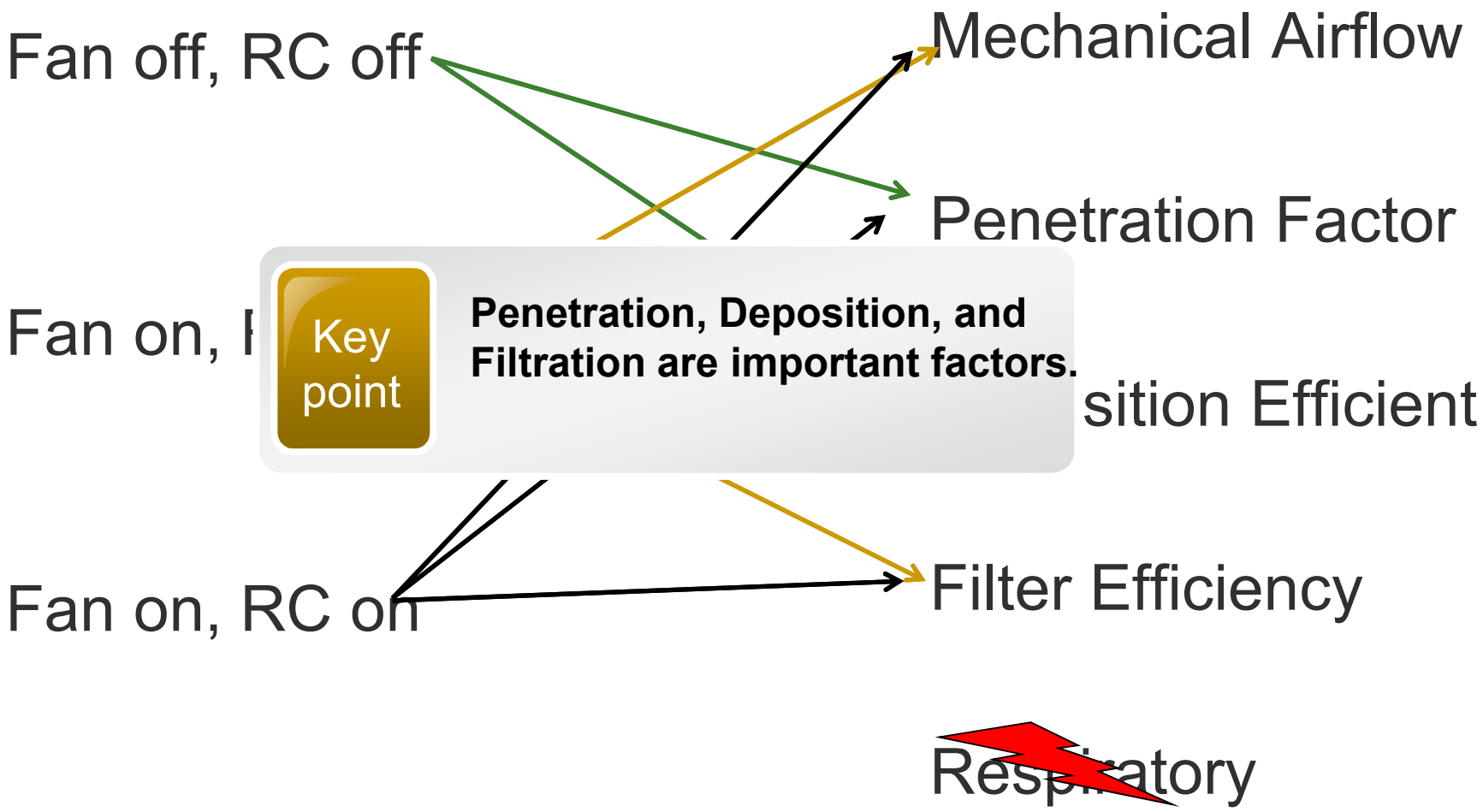
Bin Xu and **Yifang Zhu** "Quantitative analysis of the parameters affecting in-cabin to on-roadway (I/O) ultrafine particle concentration ratios", 2009, *Aerosol Science and Technology*, 43: 400-410.

Model performance under dynamic conditions



Bin Xu and **Yifang Zhu** "Quantitative analysis of the parameters affecting in-cabin to on-roadway (I/O) ultrafine particle concentration ratios", 2009, *Aerosol Science and Technology*, 43: 400-410.

In-Cabin Model



Xu and **Zhu 2009** "Quantitative analysis of the parameters affecting in-cabin to on-roadway (I/O) ultrafine particle concentration ratios", *Aerosol Science and Technology*, 43: 400-410.

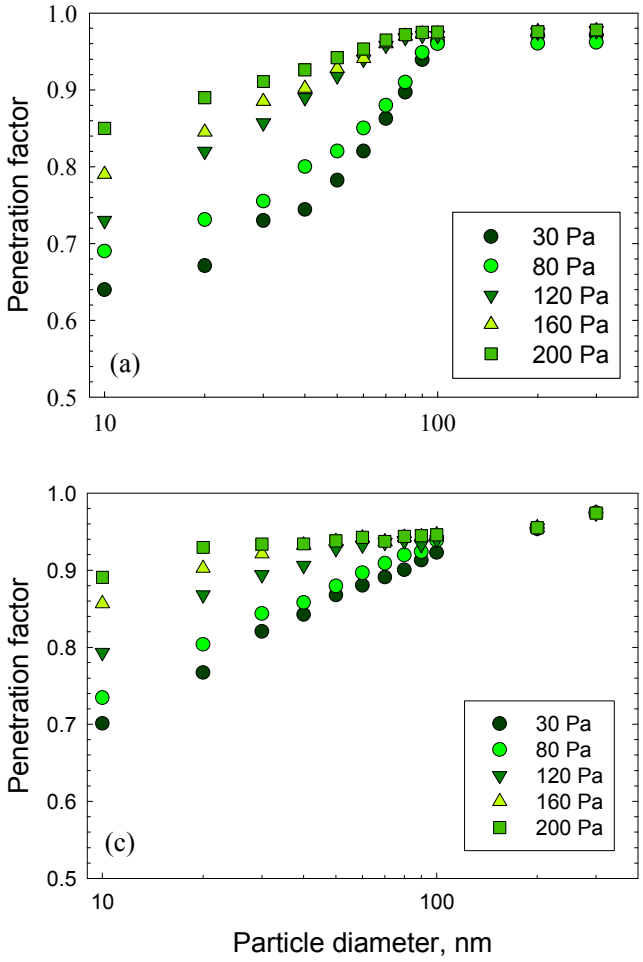
Penetration

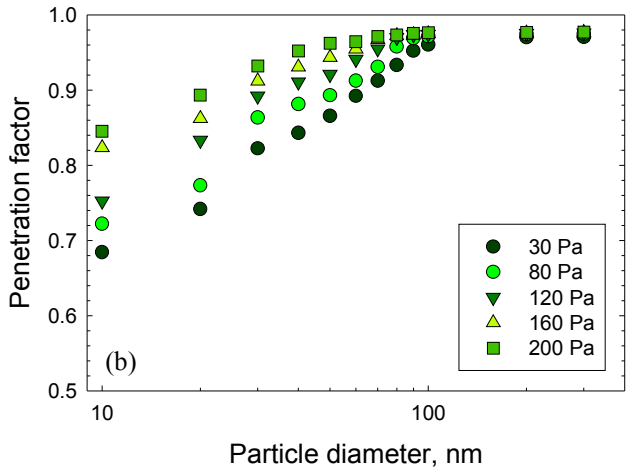
❖ Apparatus Configuration

Material	Size	Configuration
Rubber-Steel	0.8 mm height, 9.5 mm length	straight-through
	0.8 mm height, 28.5 mm length	straight-through
	1.6 mm height, 9.5 mm length	straight-through
	1.6 mm height, 28.5 mm length	straight-through
Rubber-Rubber	0.8 mm height, 9.5 mm length	straight-through
	0.8 mm height, 28.5 mm length	straight-through
Rubber-glass	0.8 mm height, 28.5 mm length	double-bend

Penetration

Penetration factors as a function of particle size under various differential pressures





Key point

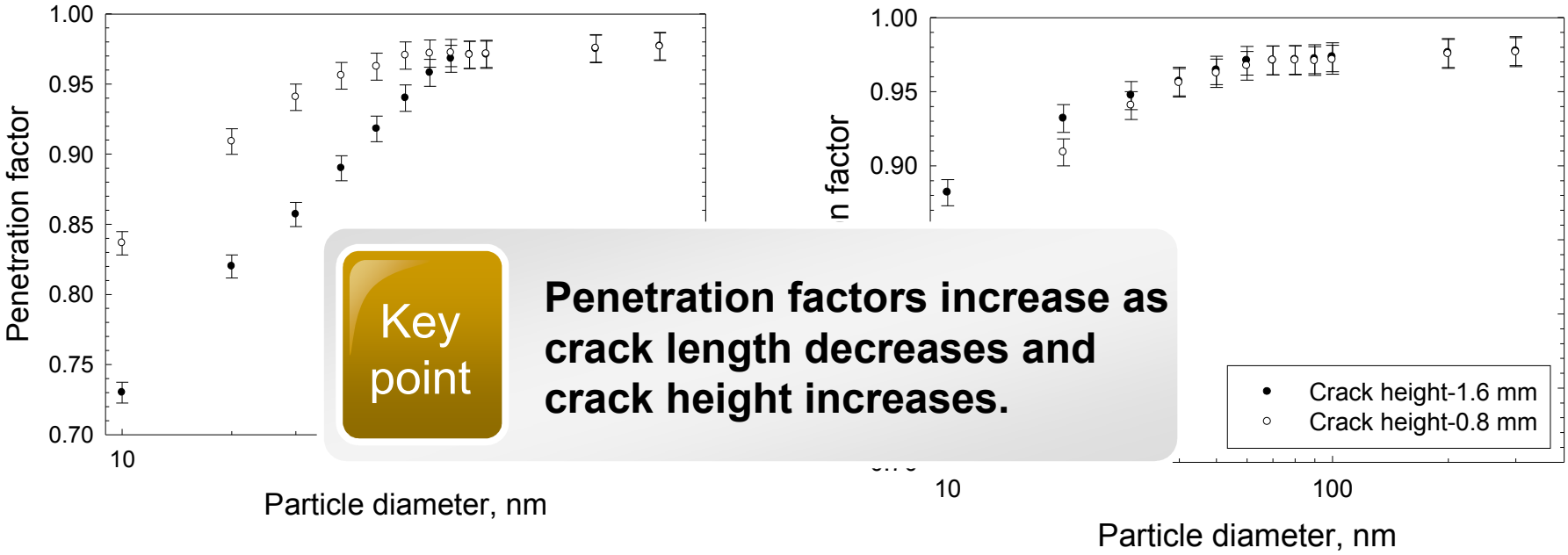
Penetration factors increase as particle size and differential pressure increase.

Bin Xu, Shusen Liu, and **Yifang Zhu** "Ultrafine particle penetration through idealized vehicle cracks", 2010, *Journal of Aerosols Science*, 41(9) 859-868.

Penetration

❖Particle penetration factor for different crack lengths

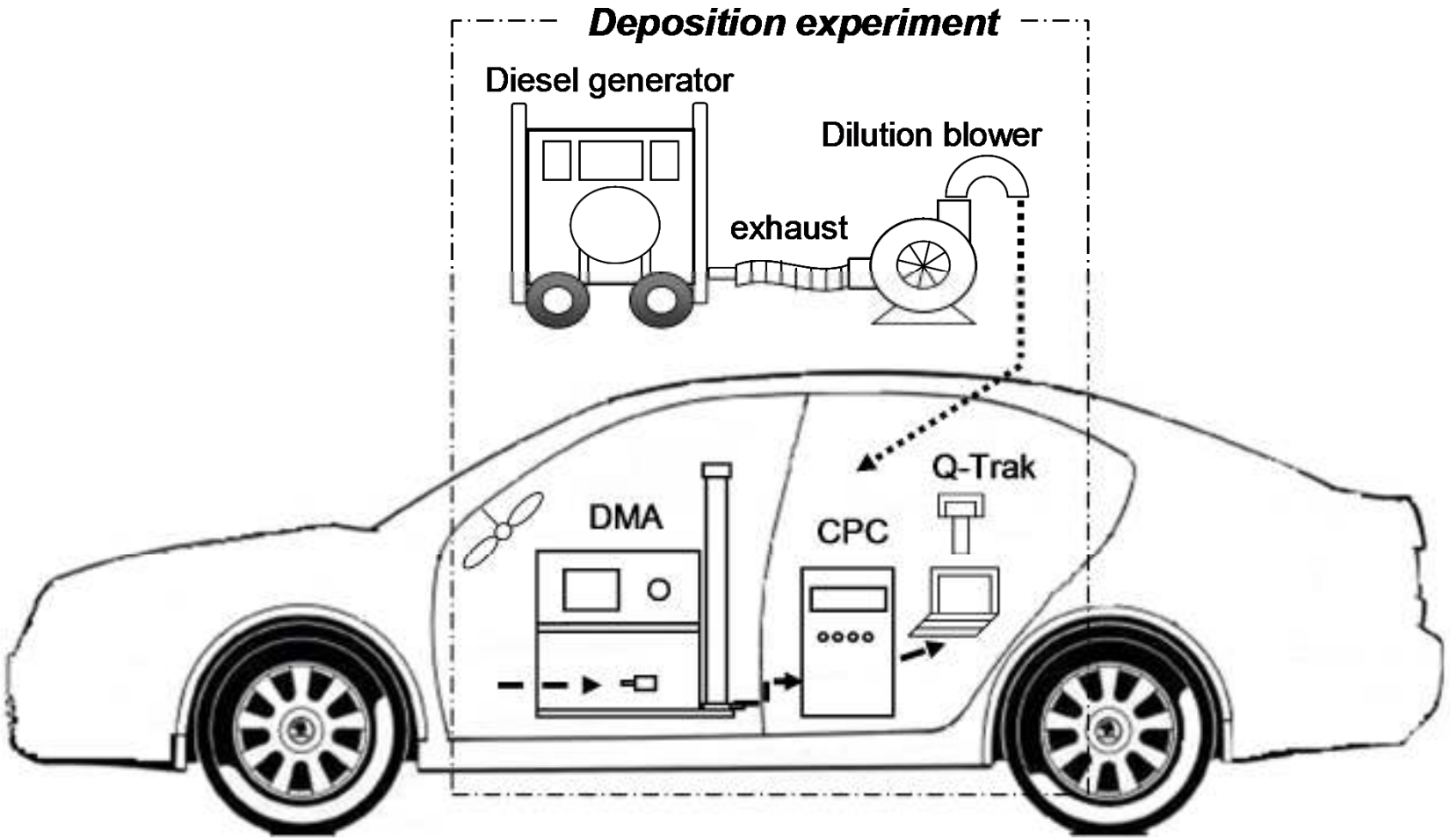
❖Particle penetration factor for different crack heights



Bin Xu, Shusen Liu, and **Yifang Zhu** "Ultrafine particle penetration through idealized vehicle cracks", 2010, *Journal of Aerosols Science*, 41(9) 859-868.

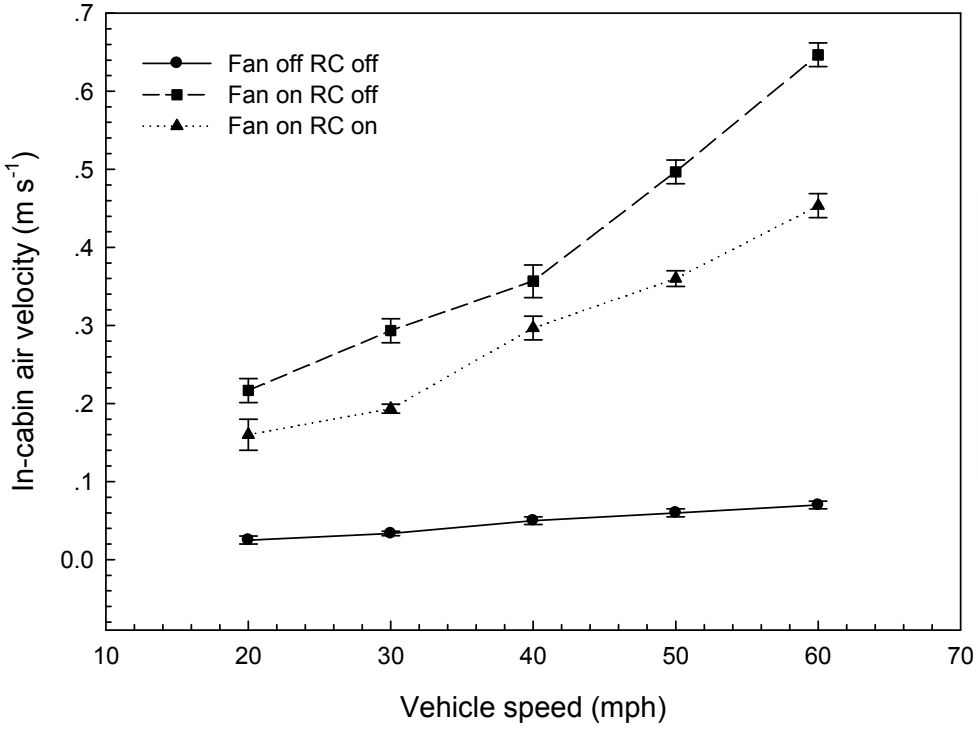
Deposition

❖ Experimental Setup: Particle generation and measurements



Deposition

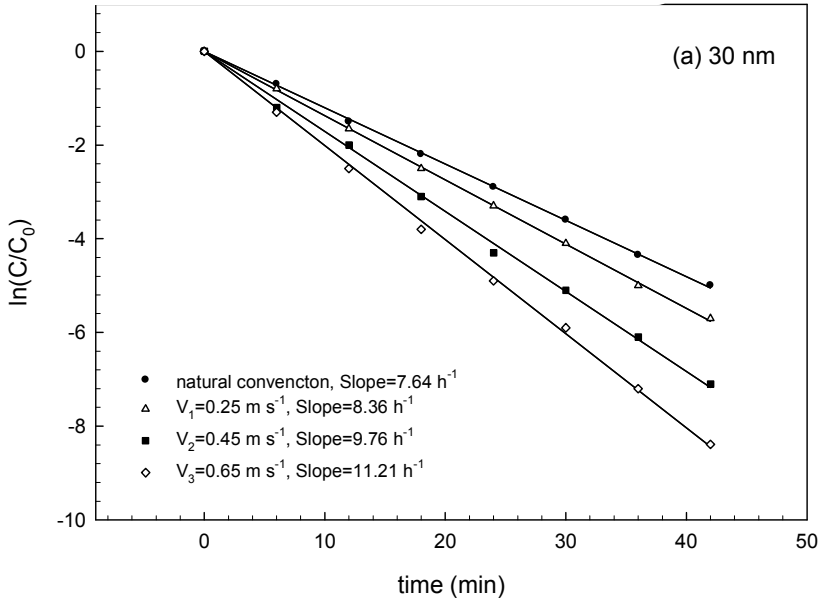
❖In-cabin air velocity under various vehicle speeds and ventilation settings.

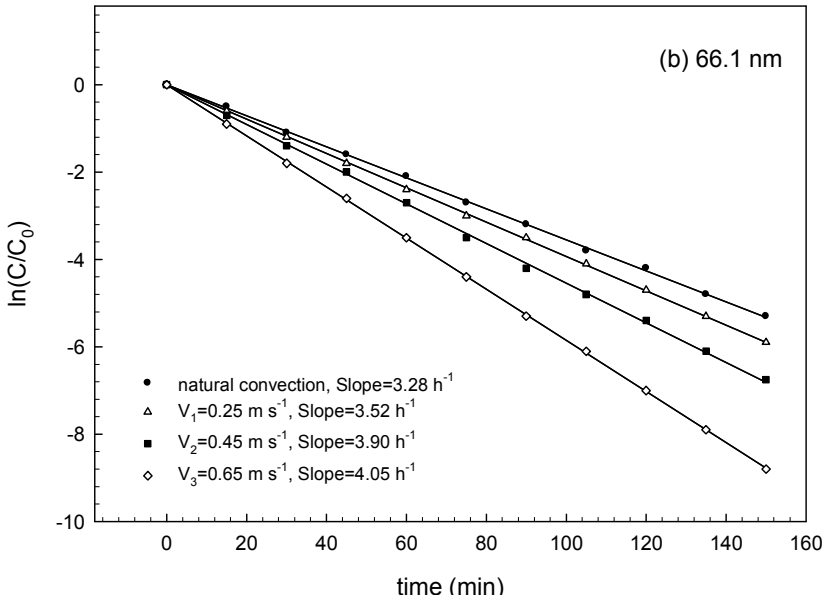


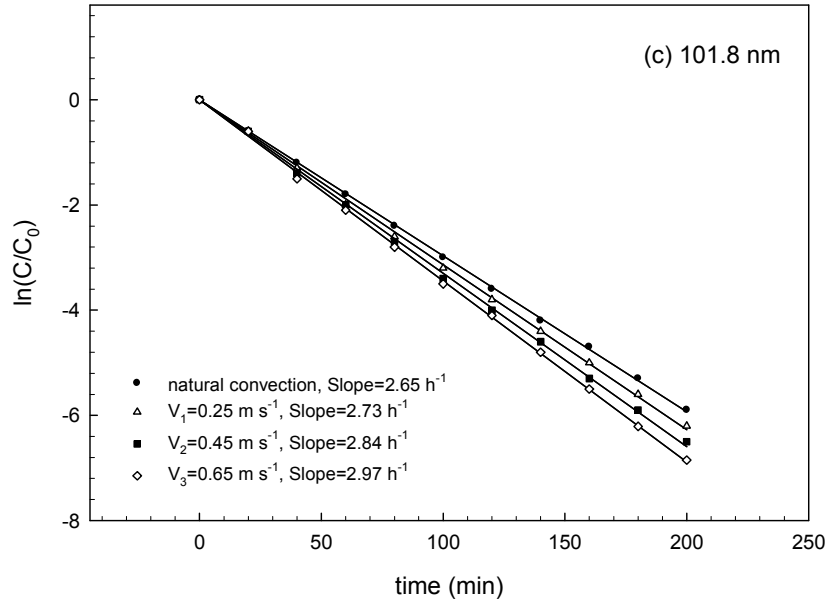
Key point

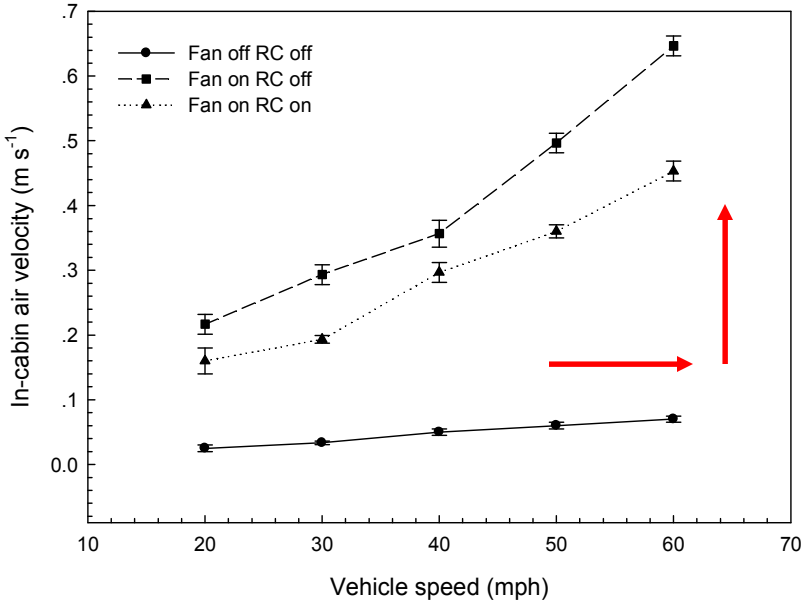
In-cabin air velocity increases as vehicle speed increases. Fan off/RC off has the lowest in-cabin air velocity.

Deposition

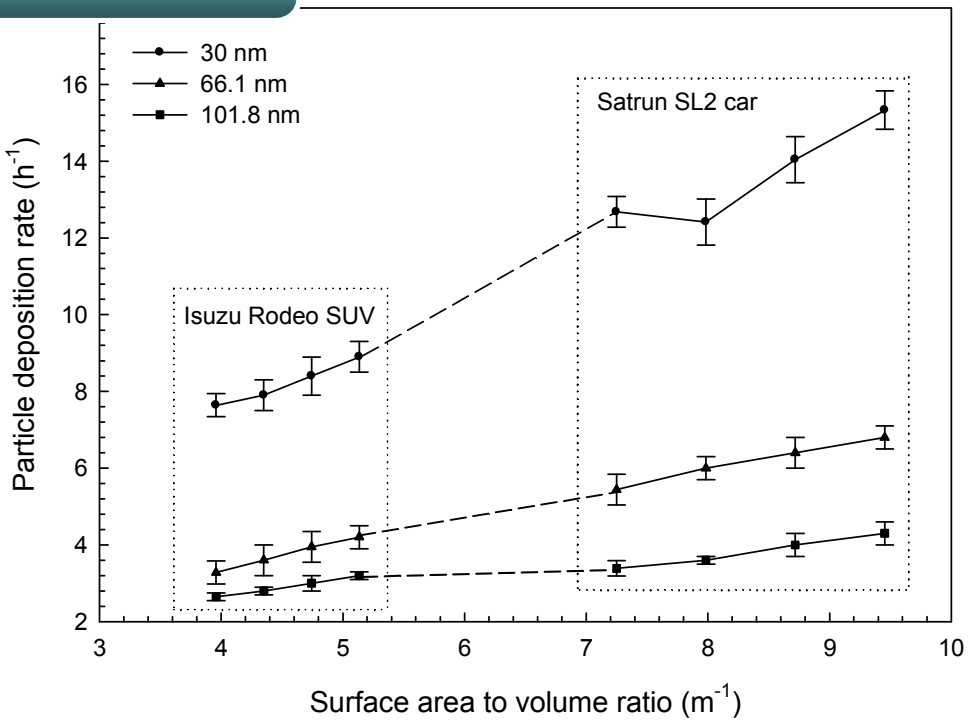

(a) 30 nm
ln(C/C0)
time (min)
natural convencton, Slope=7.64 h-1
V1=0.25 m s-1, Slope=8.36 h-1
V2=0.45 m s-1, Slope=9.76 h-1
V3=0.65 m s-1, Slope=11.21 h-1


(b) 66.1 nm
ln(C/C0)
time (min)
natural convection, Slope=3.28 h-1
V1=0.25 m s-1, Slope=3.52 h-1
V2=0.45 m s-1, Slope=3.90 h-1
V3=0.65 m s-1, Slope=4.05 h-1


(c) 101.8 nm
ln(C/C0)
time (min)
natural convection, Slope=2.65 h-1
V1=0.25 m s-1, Slope=2.73 h-1
V2=0.45 m s-1, Slope=2.84 h-1
V3=0.65 m s-1, Slope=2.97 h-1


Fan off RC off
Fan on RC off
Fan on RC on
In-cabin air velocity (m s-1)
Vehicle speed (mph)

Deposition



The particle deposition rates as a function of surface area to volume ratios for 30, 66.1, and 101.8 nm particles inside two test vehicles.

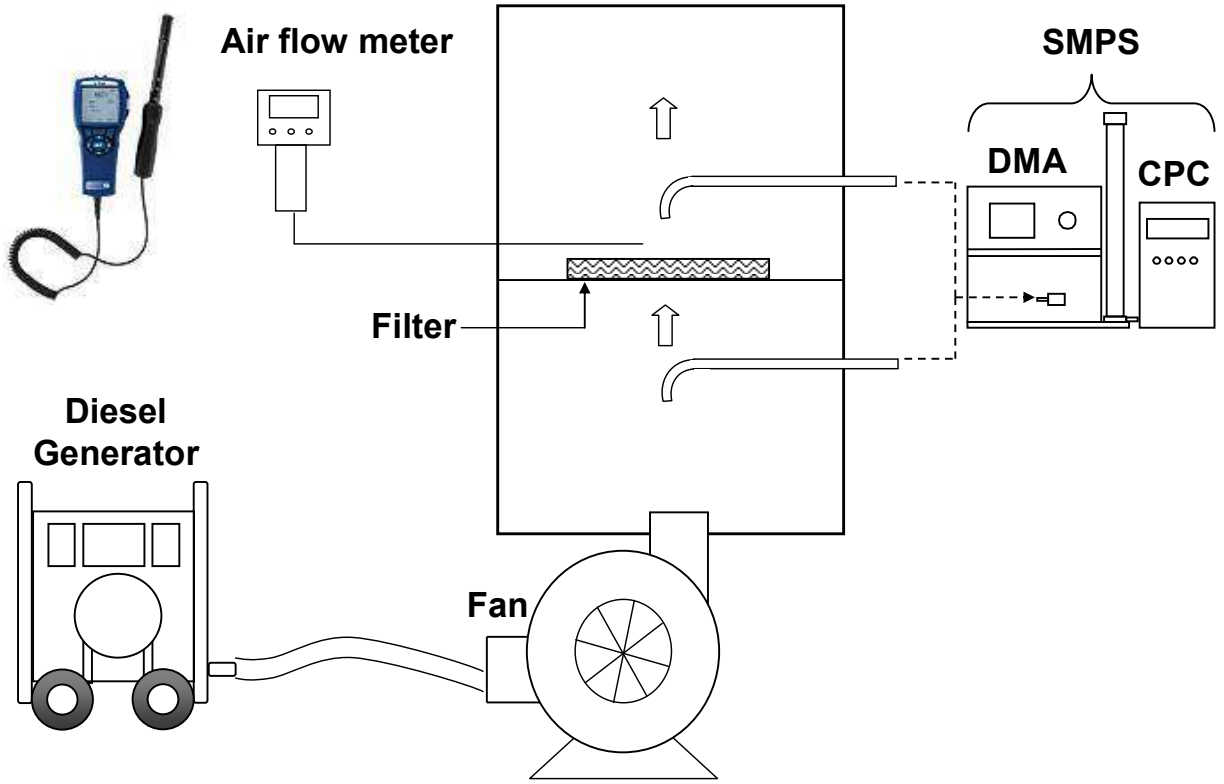
Key point

There is a positive correlation between surface area to volume ratios and ultrafine particle deposition rates. Greater surface area to volume ratio results in higher deposition rate for ultrafine particles.

Longwen Gong, Bin Xu and **Yifang Zhu** “Ultrafine Particles Deposition inside Passenger Vehicles", 2009, *Aerosol Science and Technology*, 43: 544-553.

Filtration

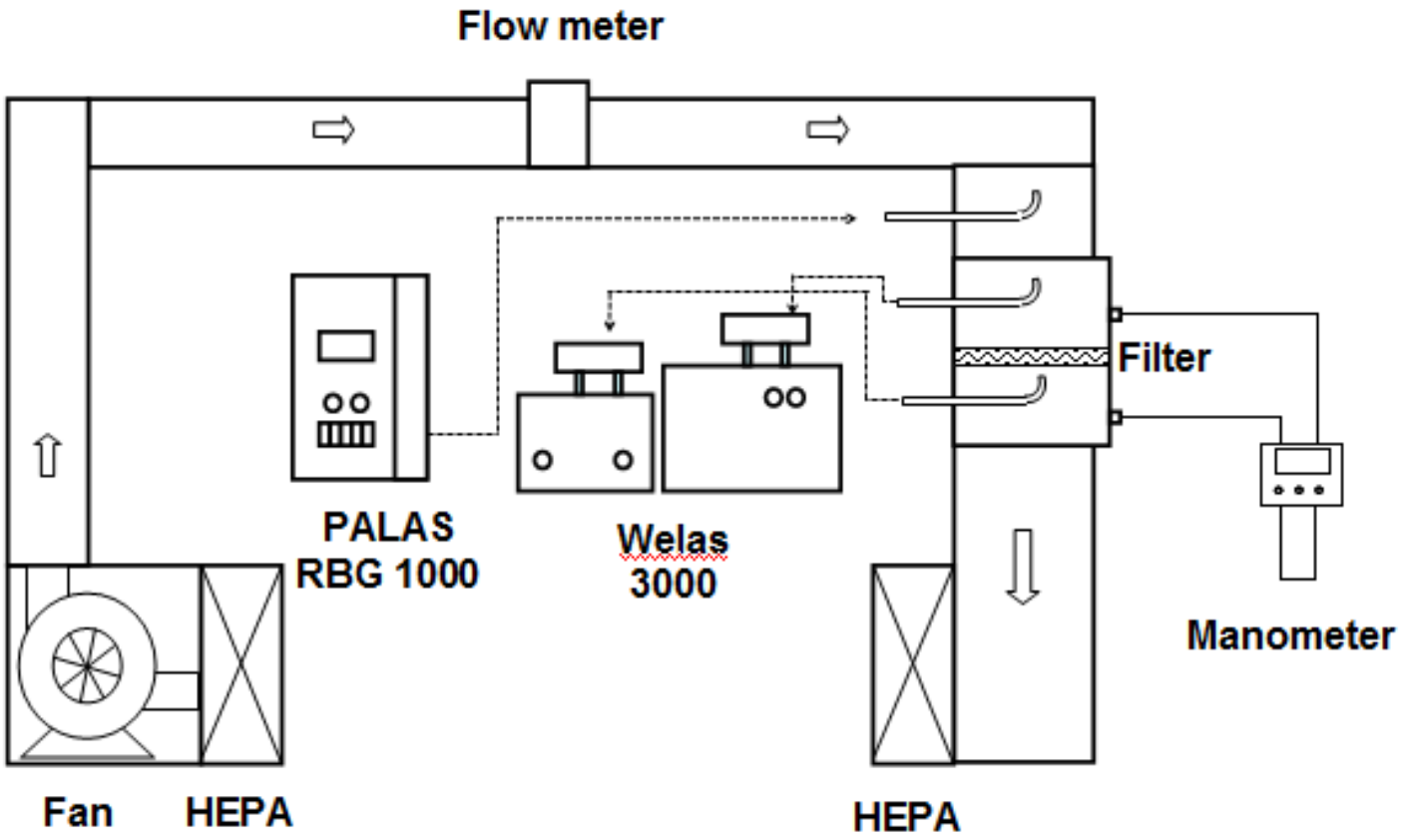
❖Ultrafine Particle Filtration Efficiency Measurements



$$Filtration\ Efficiency = 1 - \frac{downstream\ \ concentrat\ ion}{upstream\ \ concentrat\ ion}$$

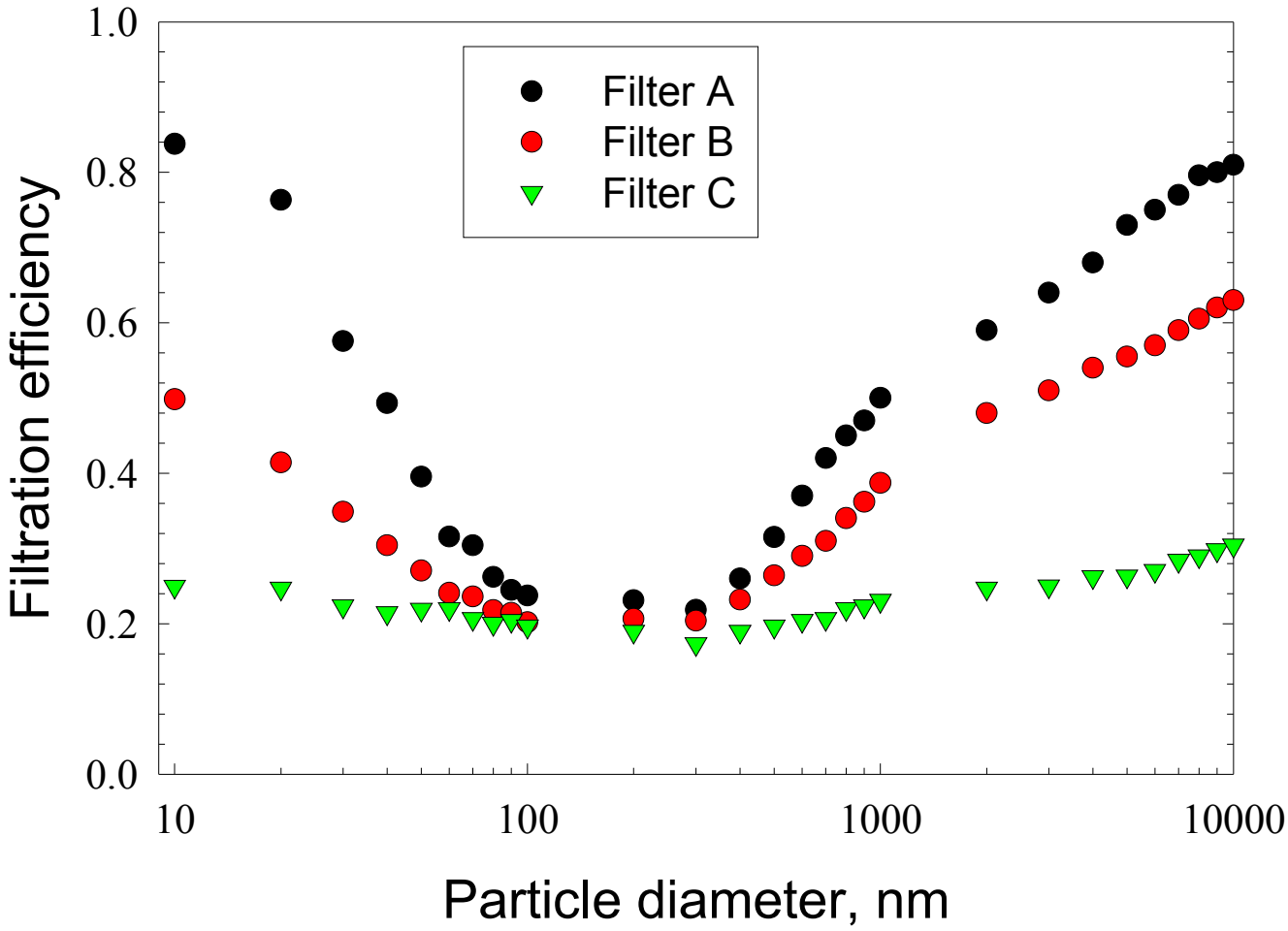
Filtration

❖Coarse Particle Filtration Efficiency Measurements



Filtration

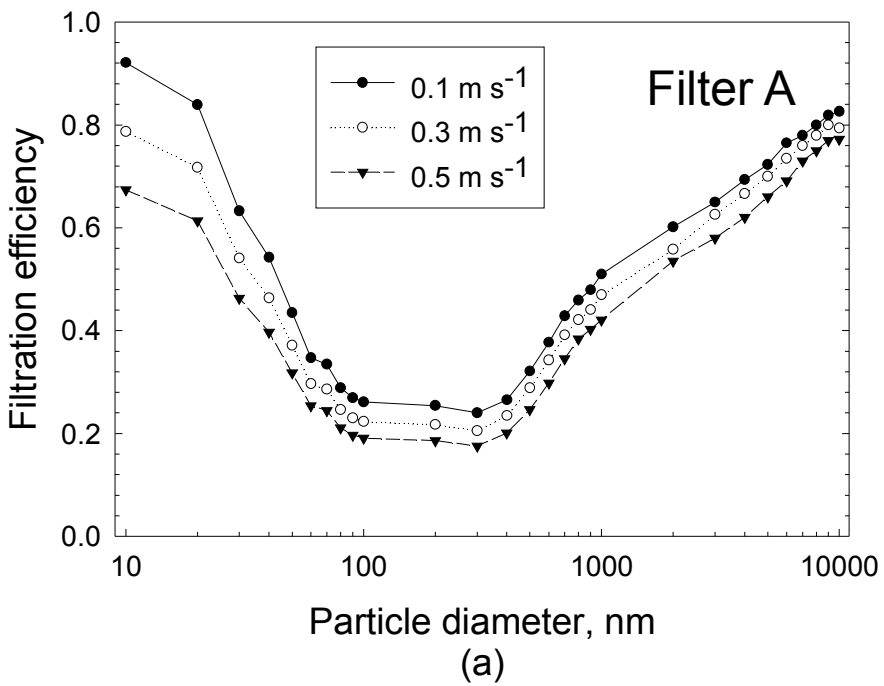
Cabin Filter Performance: The Good, the Bad, and the Ugly

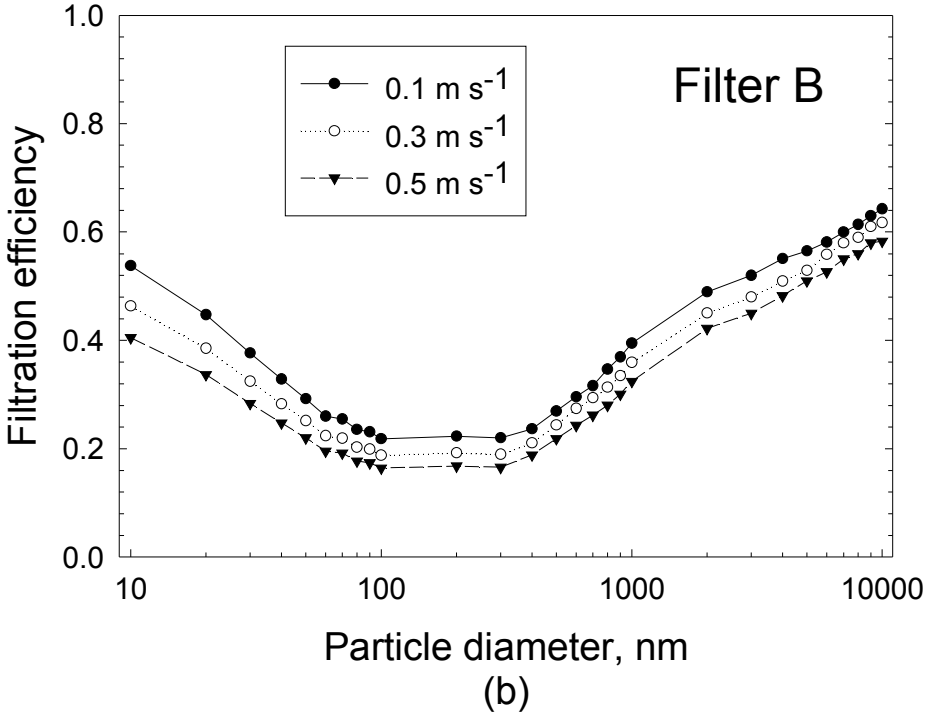


Xu, Liu, Liu, and **Zhu, 2010** 'Effects of cabin filter on in-cabin to on-roadway ultrafine particle ratios' *Aerosol Science and Technology*, *Aerosol Science and Technology*, 45:215–224.

Filtration

Particle filtration efficiencies as a function of particle size under various filter face velocities





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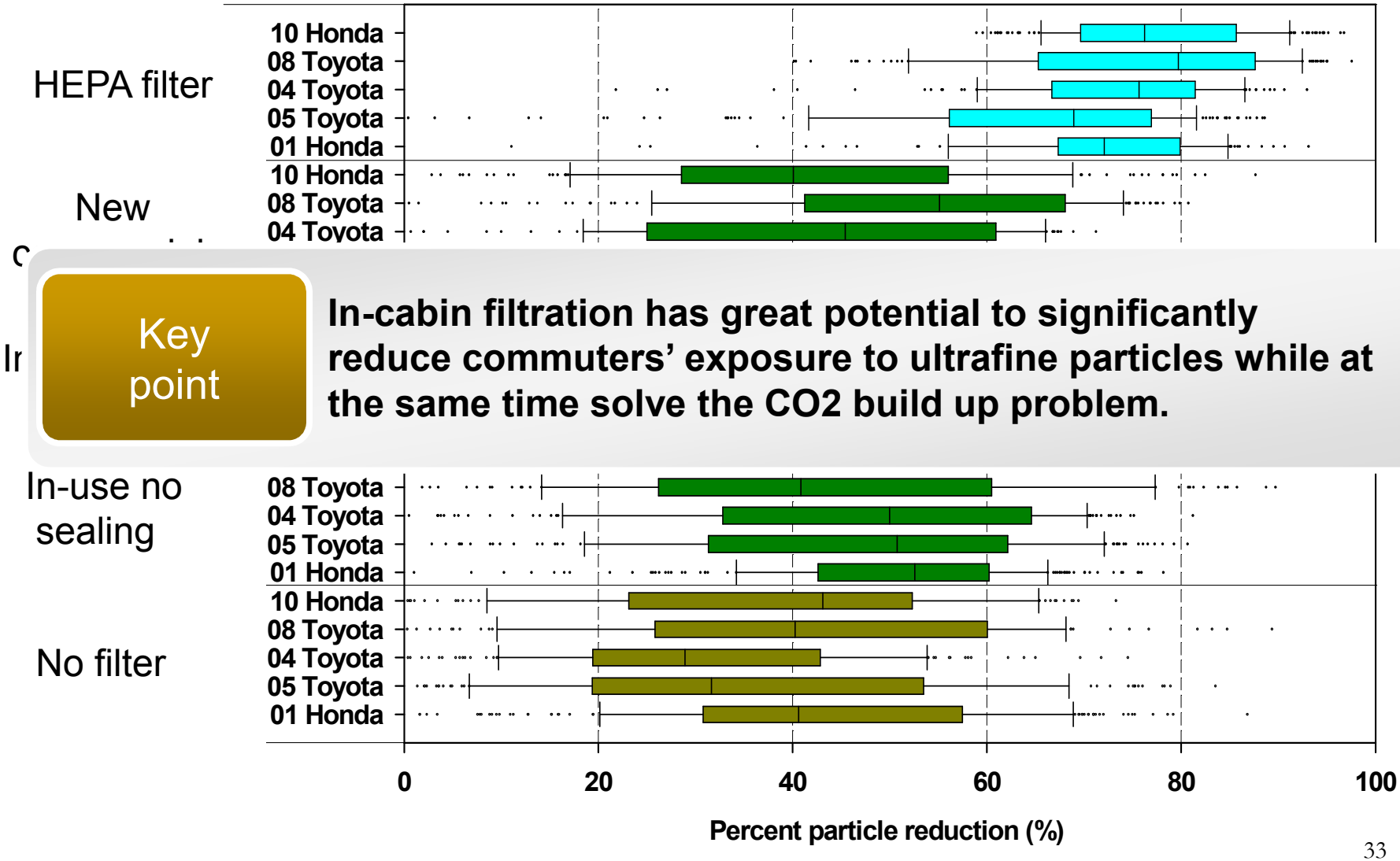
Filtration

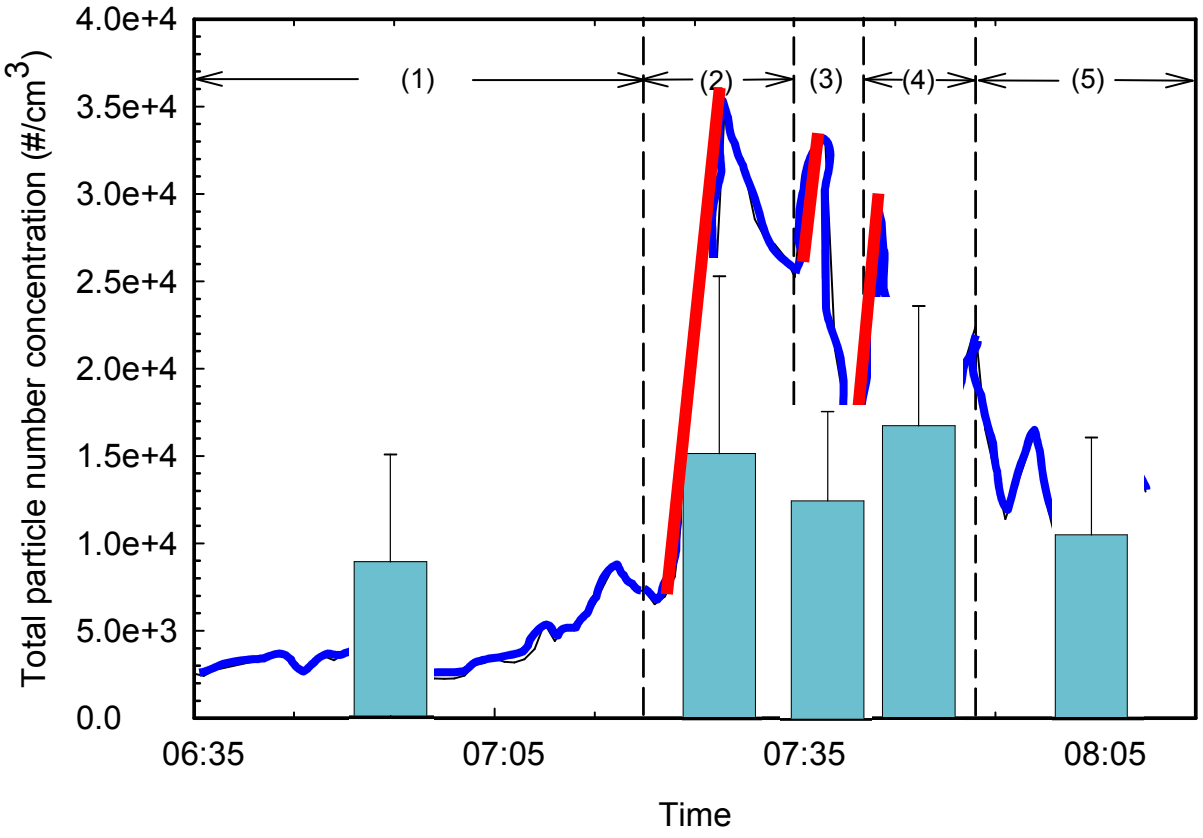


Key point

In-cabin filtration has great potential to significantly reduce commuters' exposure to ultrafine particles while at the same time solve the CO2 build up problem.

School Bus Test

Effect of route



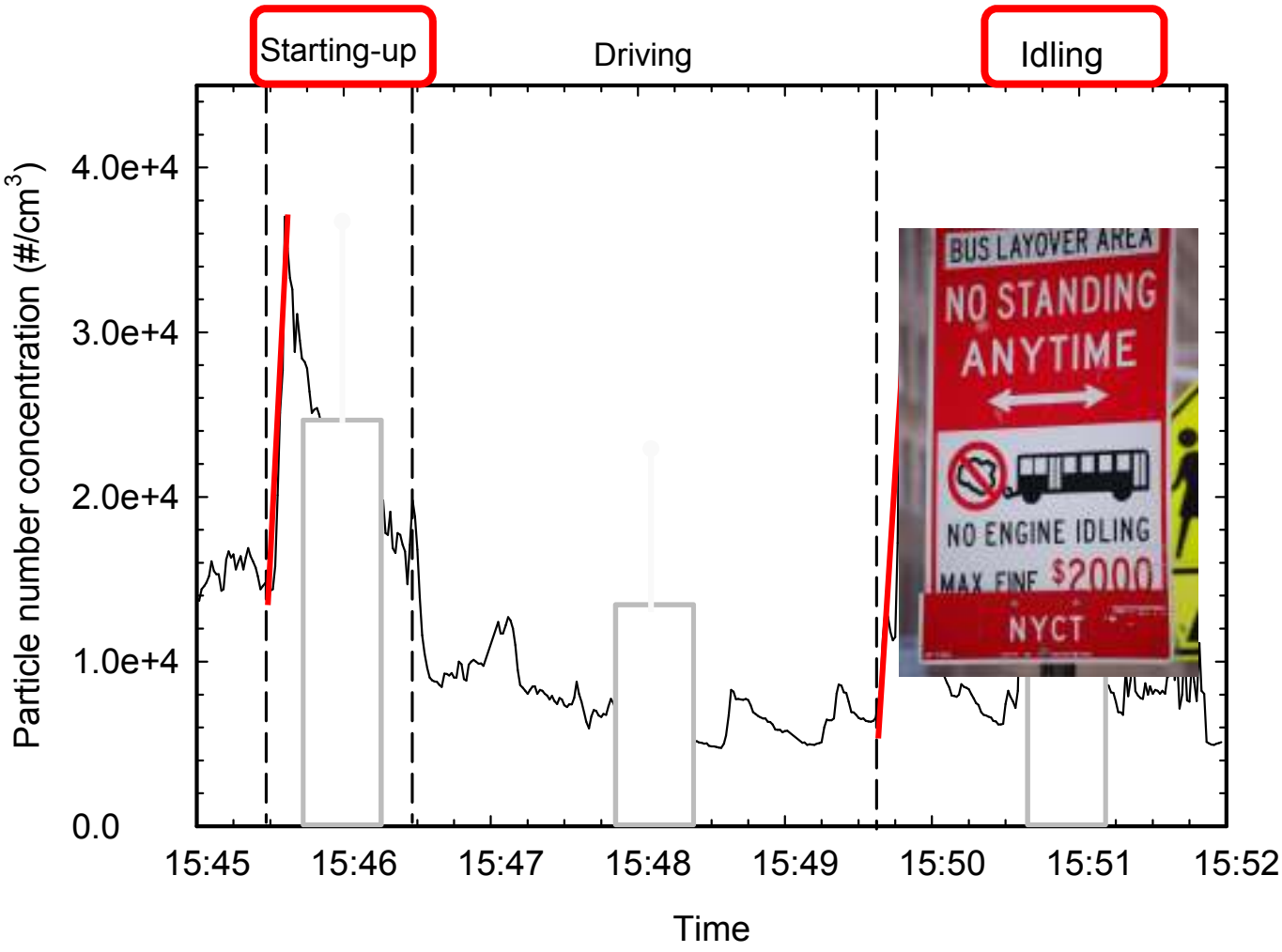
(3) Line-up with other school buses leaving the transfer station

(4) School parking lot

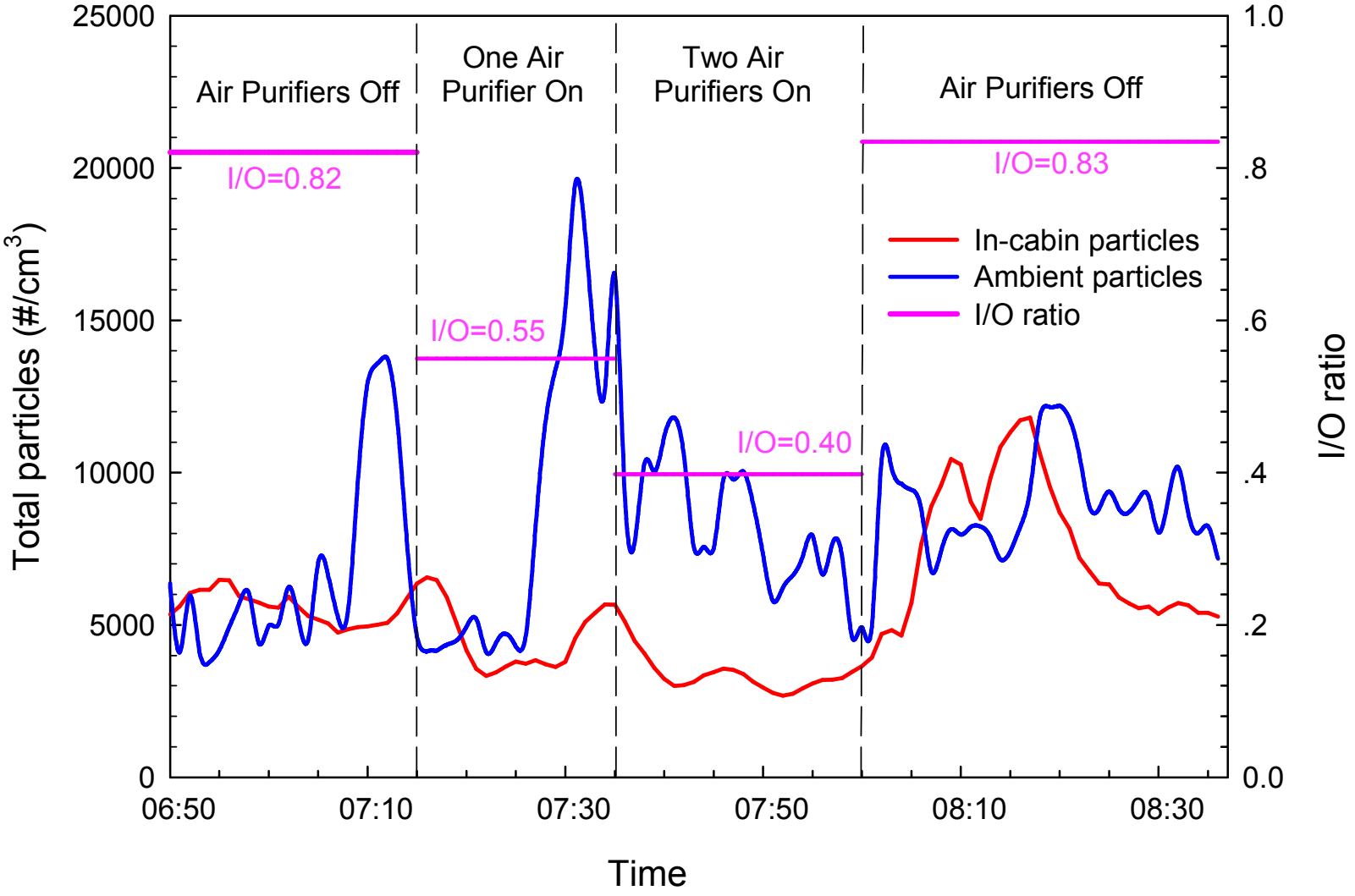
(5) Town route

School Bus Test

Effect of operation

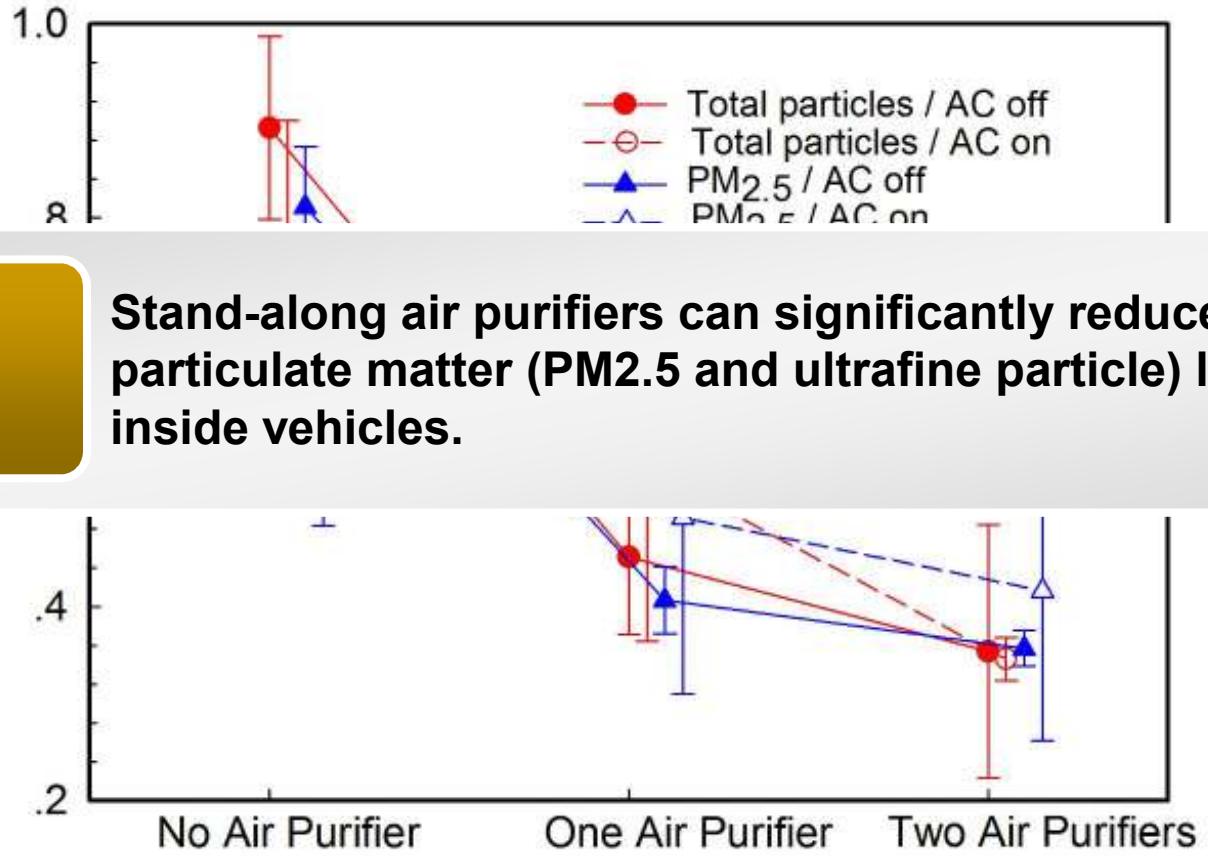


School Bus Filtration



School Bus Filtration

I/O ratio inside school buses without/with air purifiers



Key point

Stand-along air purifiers can significantly reduce particulate matter (PM2.5 and ultrafine particle) levels inside vehicles.

Zhang and **Zhu 2011** "Performance of School Bus Retrofit Systems: Ultrafine Particles and Other Vehicular Pollutants", 2011, *Environmental Science and Technology*, 45: 6475–6482.

Summary

Reducing UFP Exposure Near Roadways:

- **Meteorology: stay on the upwind side of major roadways;**
- **Spatial Profile: stay away from major roadways;**
- **Temporal Profile: avoid heavy traffic hours**

Reducing UFP Exposure inside Vehicles:

- **Route: avoid heavy-duty vehicle route**
- **Driving: avoid idling**
- **In-Cabin Ventilation : close window and turn on recirculation**
- **In-Cabin Filtration: use HEPA filter/air purifier**

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