

# Indoor Exposure to Particles from Cooking, Cleaning and Smoking

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# Today's Focus: Contributions to Indoor Ultrafine Particle (UFP) Exposure

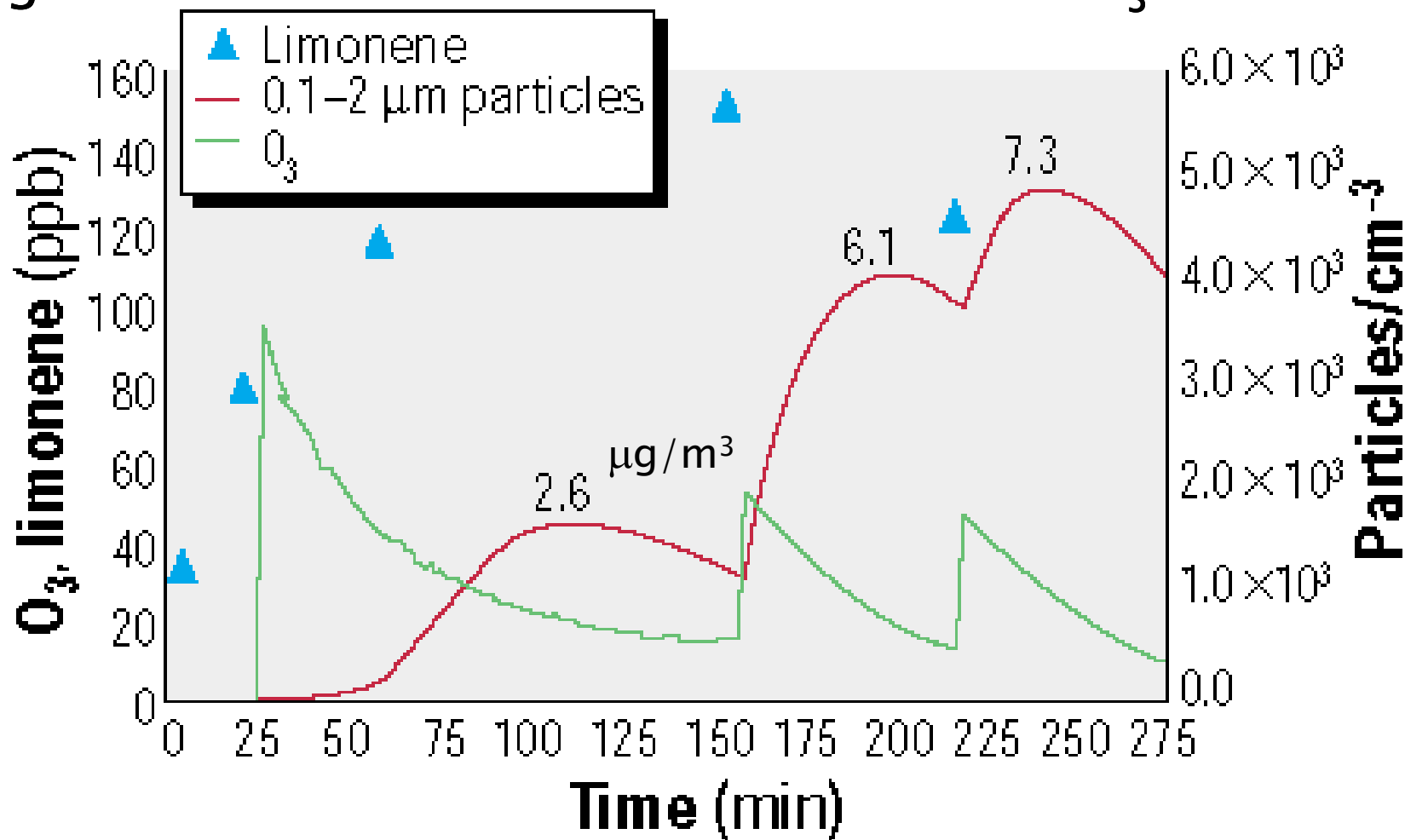
- 1) Cleaning products that contain pine or citrus scents
- 2) Indoor combustion sources
  - (a) clothes dryers
  - (b) cigarette smoking
  - (c) cooking
- 3) Proximity to the source



# 1) Cleaning Product Emissions:

Can chemically react to form UFP

e.g.: Lemon-scented solid air freshener +  $O_3 \rightarrow$  UFP



[T Wainman et al, Env Health Pers. 108:1139, 2000]

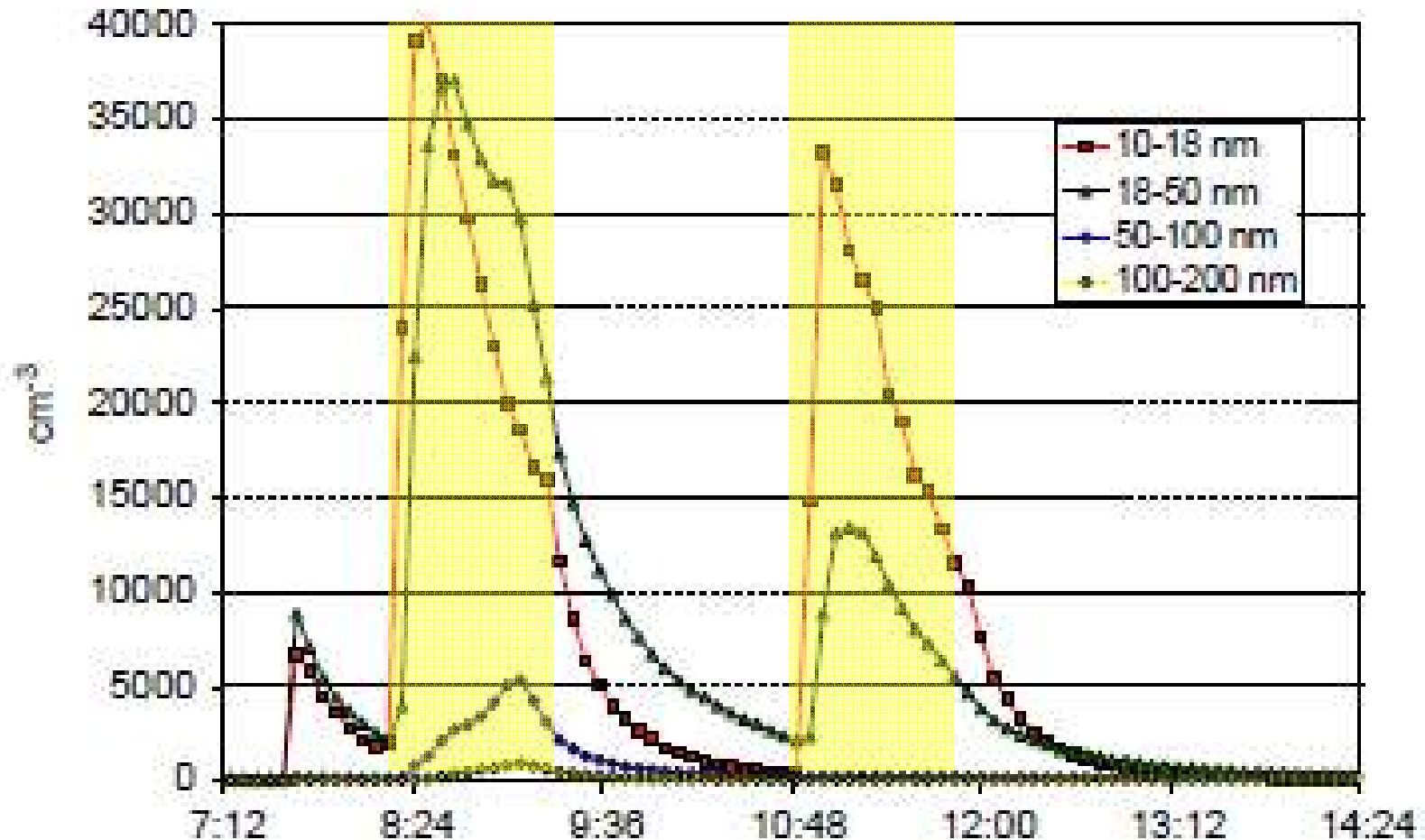


# 1) Cleaning Product Emissions (cont.)

- ▶ Terpenes (often used to give a pine scent) also react with ozone to form UFP.
- ▶ Terpene or limonene is found in:
  - hand soaps
  - laundry detergents, fabric softeners
  - dishwasher detergents
  - glass cleaning solutions
  - air fresheners
  - etc.



## 2) Combustion Emissions (a) Clothes Dryer



Gas clothes dryer on from 8:20–9:20 (medium setting), and from 10:45–11:45 (hot setting).

[L.Wallace, Atm.Env. 39:5777, 2005]



2) Combustion (b) Cigarette Smoke  
Example: Exposure to UFP Inside a Casino

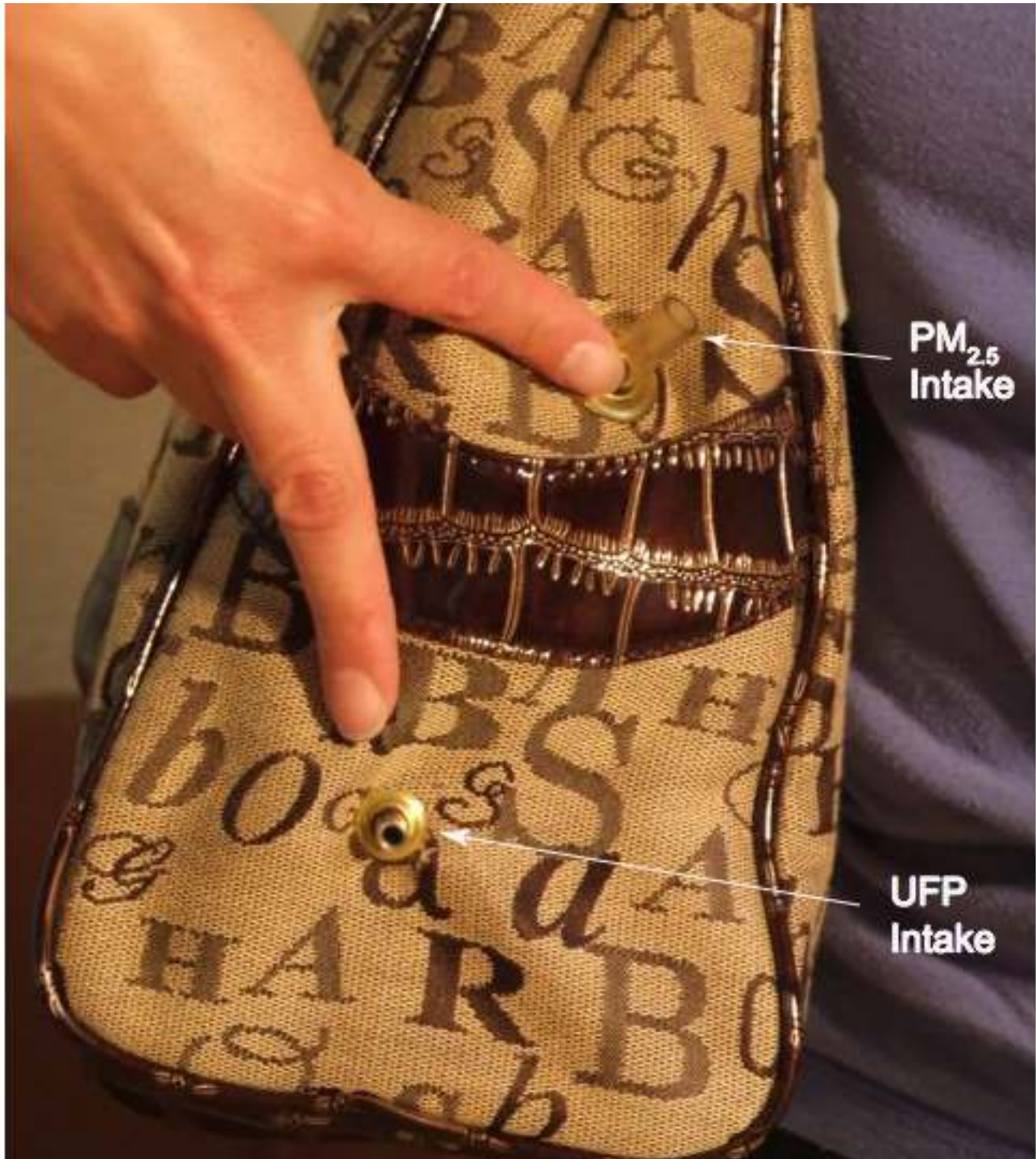




Handbag

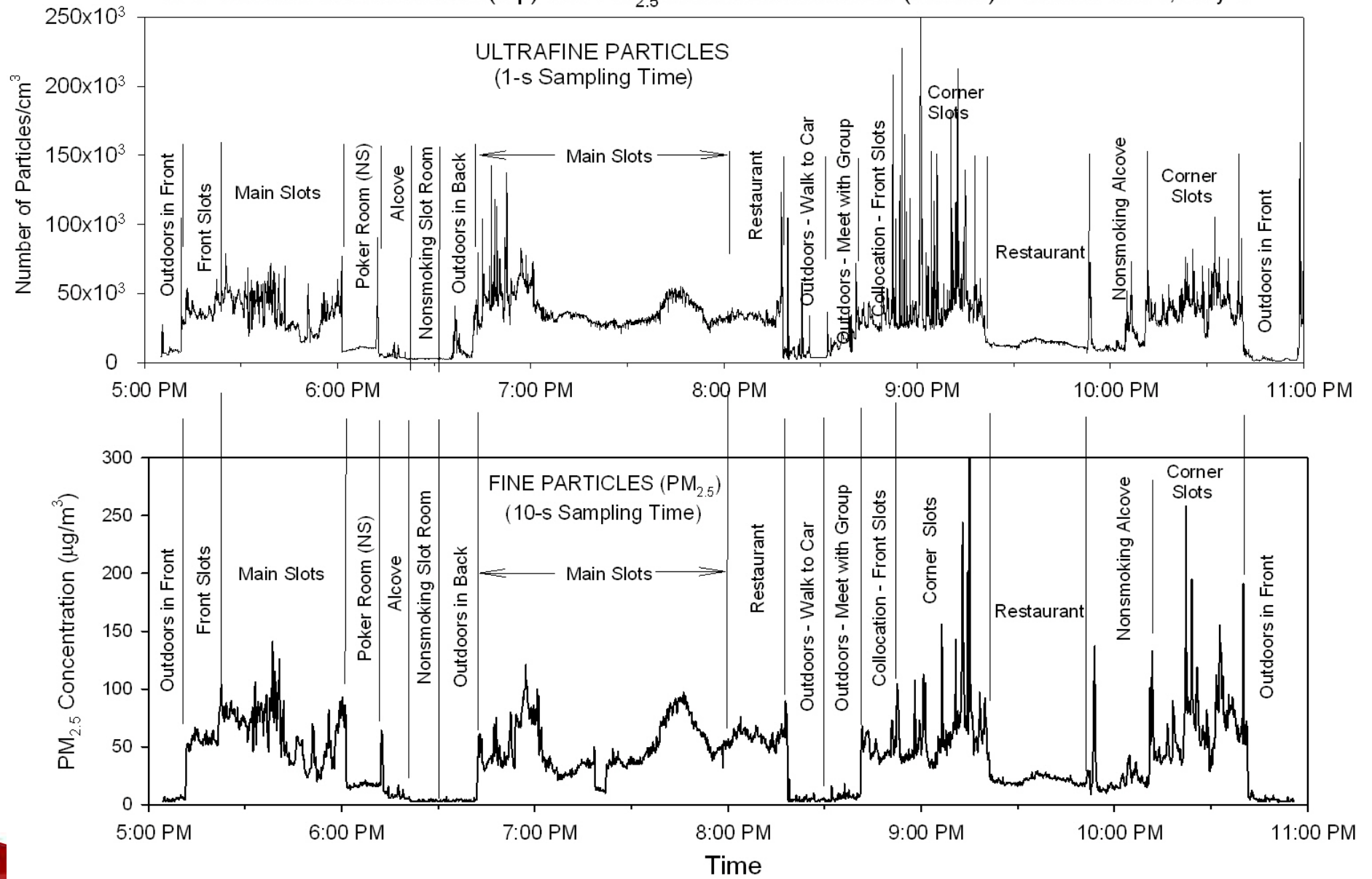
UFP Condensation  
Particle Counter

PM<sub>2.5</sub> Laser  
Photometer

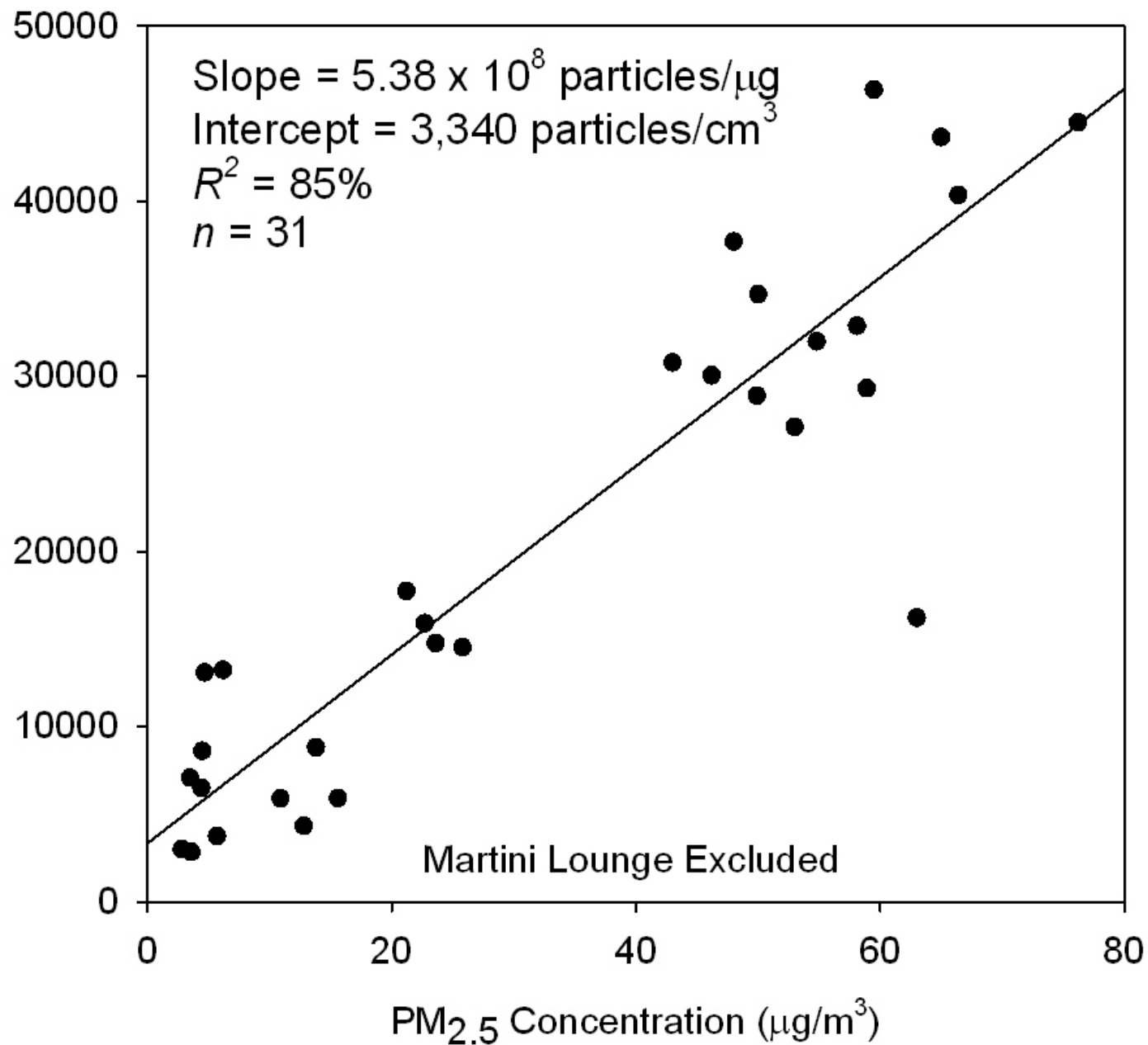




UFP Number Concentration (top) and PM<sub>2.5</sub> Mass Concentration (bottom): Casino No. 1, Day 1



UFP Concentration (particles/cm<sup>3</sup>)



# Summary of Measurements for Casino

Location (# of 10+min visits)	Avg Ultrafine PM, #/cm <sup>3</sup>	PM2.5, μg/m <sup>3</sup>
Outdoors (n=4)	7000–13,000	4–11
Indoor Areas, smoking (n=8)	30,000–46,000	43–76

→ UFP in Casino Smoking Areas >3 Times  
as High as UFP Outdoors



## 2) Combustion

## (c) Cooking



# Types of Sources Tested

Source (# of experiments)	Duration (mins)
Cooking 2 lean Hamburgers (n=3)	8-9
Frying chicken thighs (4 thighs) (n=1)	22
Stir-frying chicken(lean) & vegetables (n=2)	15-17
Frying 5 strips of Bacon (n=2)	9-10
1 Smoked Cigarette (n=4)	5-6
Burning 1 stick of Incense (n=1)	10



# Oct 19 am Cooking Bacon

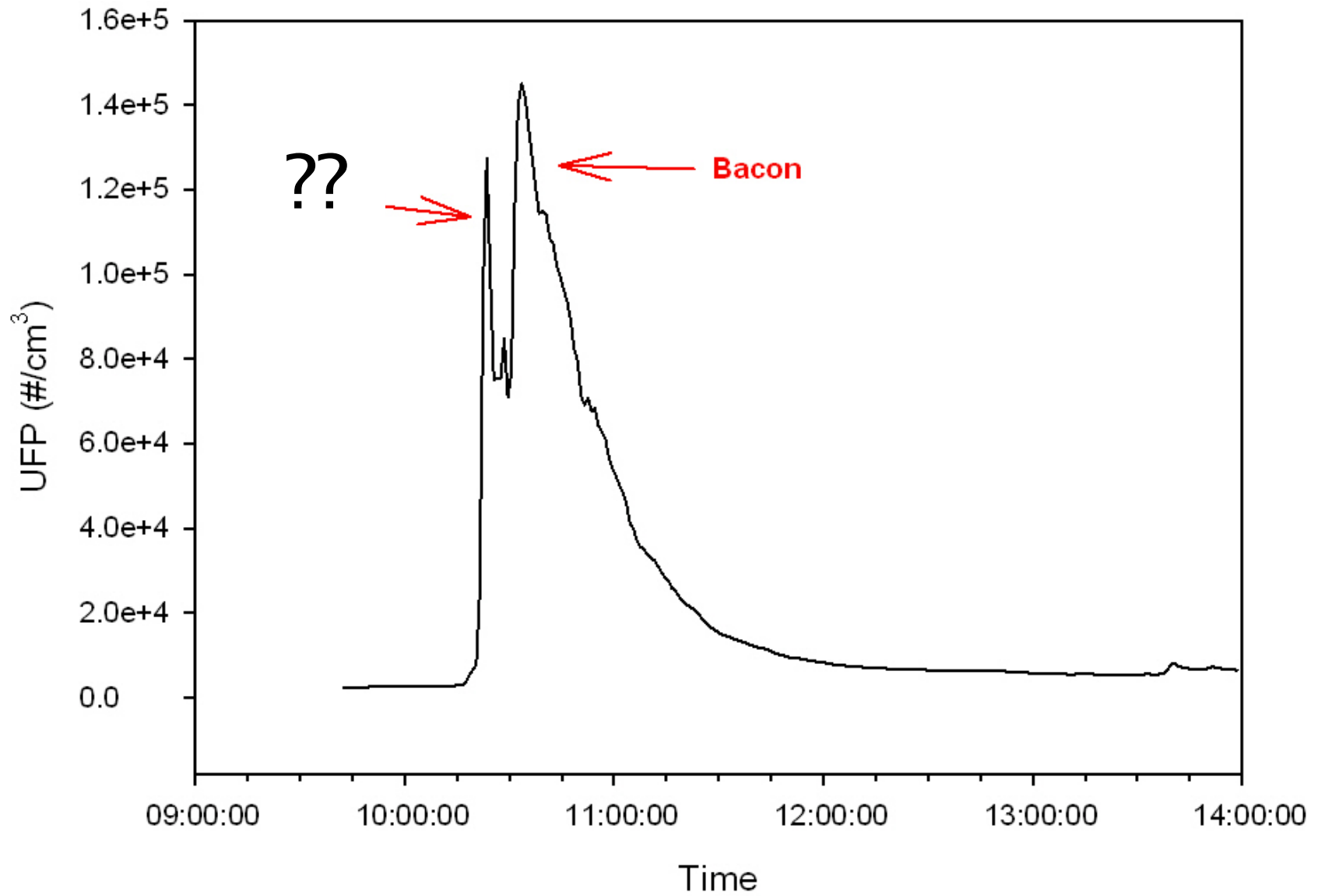
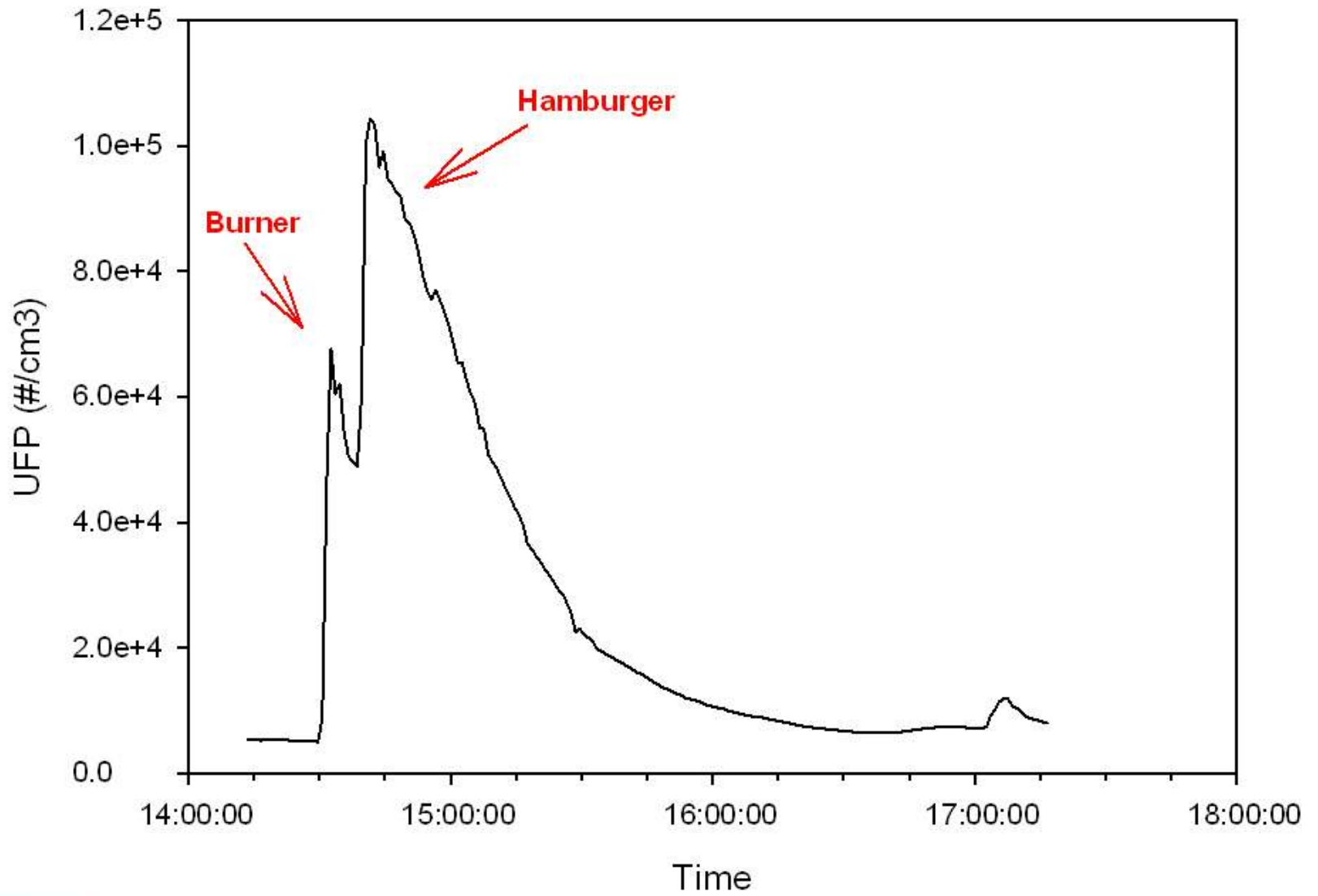


Figure 4 OCT19PM Hamburger



Source (# of exps)	Source Emission Rate of UFP*
Cooking 2 lean 4–5oz Hamburgers (n=3)	~ 0.4–0.5 x 10 <sup>12</sup> UFP /min /hamburger
1 Smoked Cigarette (n=4)	~ 0.4 x 10 <sup>12</sup> UFP/min /cigarette
Burning 1 stick of Incense (n=1)	~ 0.2 x 10 <sup>12</sup> UFP/min /stick of incense
Frying chicken thighs (4 thighs; 23 oz) (n=1)	~ 0.1 x 10 <sup>12</sup> UFP/min/ 6oz (=1 chicken thigh)
Stir-frying chicken (lean) & vegetables (11 oz) (n=2)	~ 0.1 x 10 <sup>12</sup> UFP/ min /6oz of chicken
Frying 5 strips of Bacon (n=2)	~ 0.1 x 10 <sup>12</sup> UFP/min /strip of bacon

\*UFP emission estimates are lower bounds.





### 3) The Effect of Proximity on Exposure in the Home: *Example of Scripted Activity*

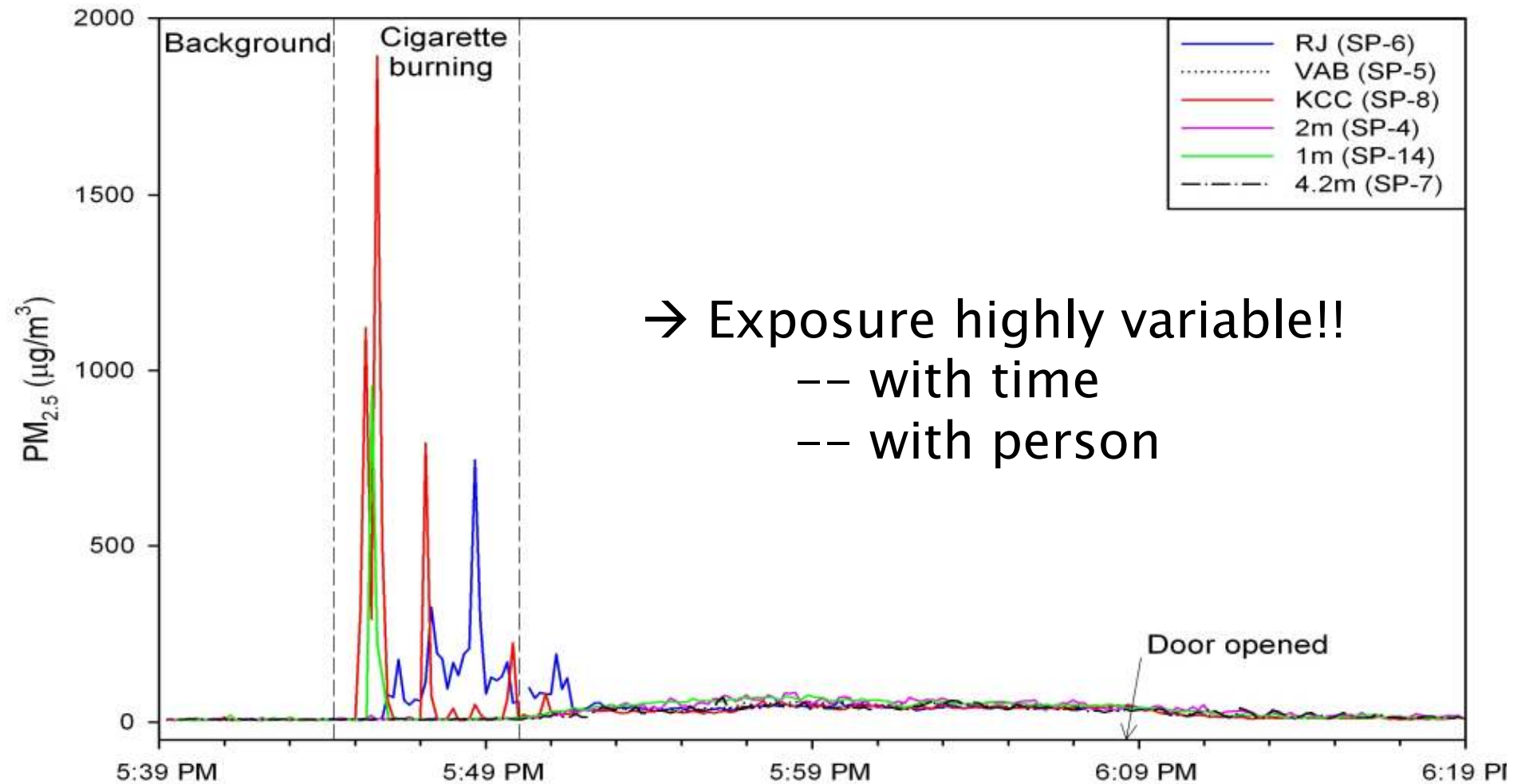


- ▶ One smoker
- ▶ Two nonsmokers
- ▶ Three more monitors representing other “nonsmokers”
  - 1 m
  - 2 m
  - 4.2 m (“well-mixed”)

➔ Monitor inlets located close to breathing zone



# Real-time PM<sub>2.5</sub> Data from Scripted Activity



# Average Exposures to SHS ( $\mu\text{g}/\text{m}^3$ $\text{PM}_{2.5}$ )

	Well-mixed (4.2 m)	2 m	1 m	VAB (0.5m)	RJ (0.5m)	KCC (smoker)
Background (6 mins)	8	8	8	7	8	7
Average over 40 mins	26	33	38	27	44	47
Source period (5 mins)	9	10	51	8	129	182

- ▶ VAB's exposure to SHS resembled well-mixed case
- RJ's exposure during source period almost as high as smoker's



# Proximity: Sitting at a table



Monitor inlet

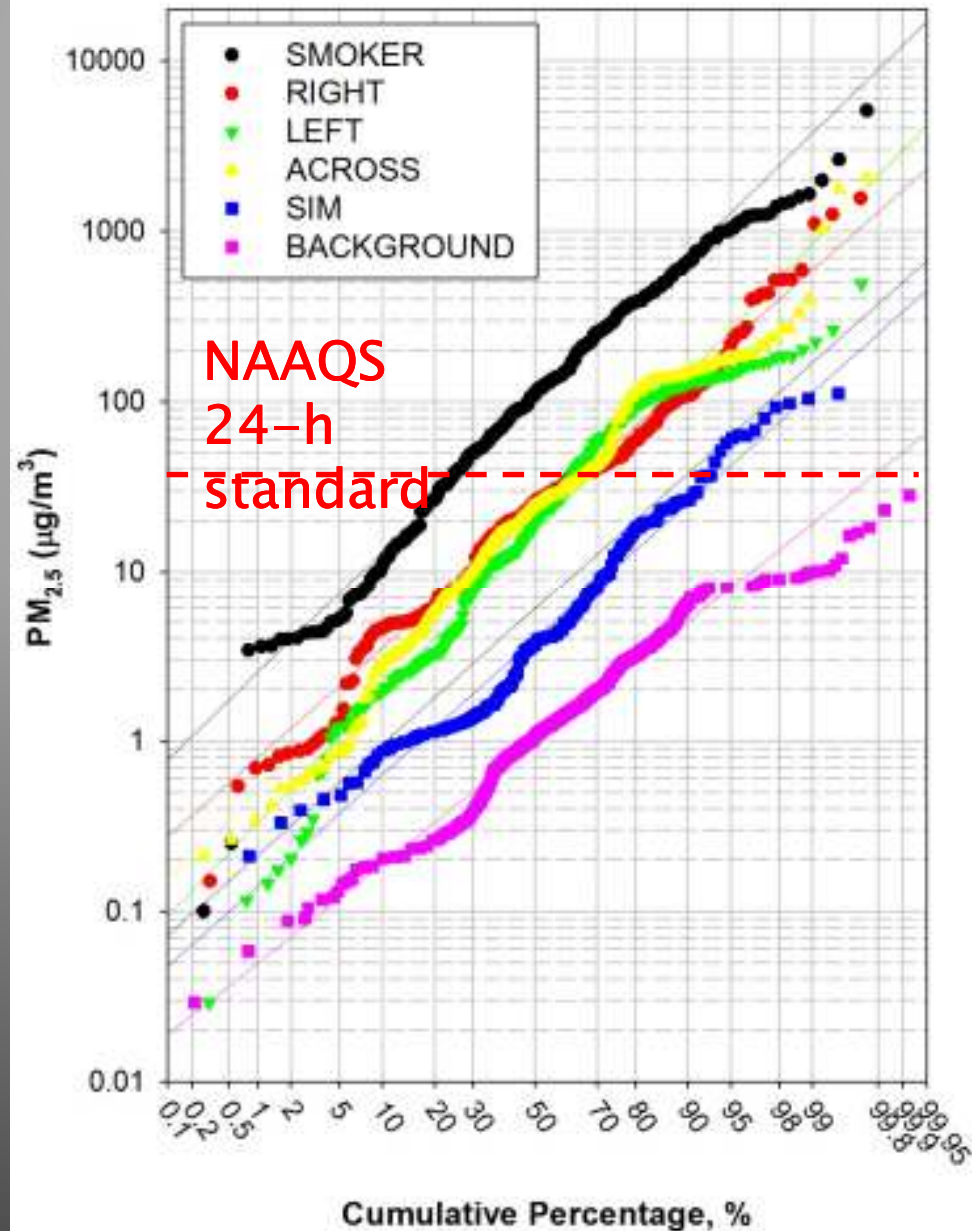
- ▶ 8 total experiments at a dining table or a card table in garage



# Frequency Distributions

## Summary Statistics (10-s averages) [ $\mu\text{g}/\text{m}^3$ ]

	Median
Smoker	113
Right	26
Left	20
Across	25
SIM	4
Background	1

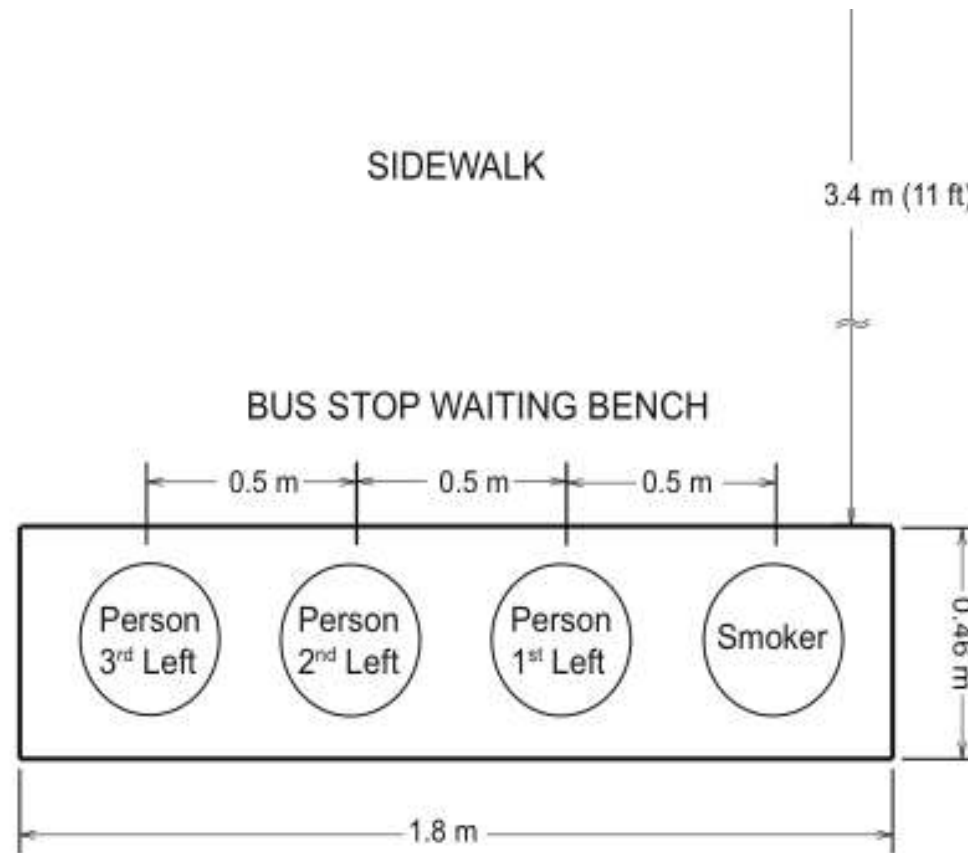


How does cigarette smoke compare with motor vehicle emissions for UFP exposure?





# How does cigarette smoke compare with motor vehicle emissions for UFP exposure?





# PM<sub>2.5</sub> Exposure to SHS vs. Exposure to Traffic while Waiting for a Bus El Camino & Cambridge Bus Stop: 1 Person Standing and 4 Persons Sitting

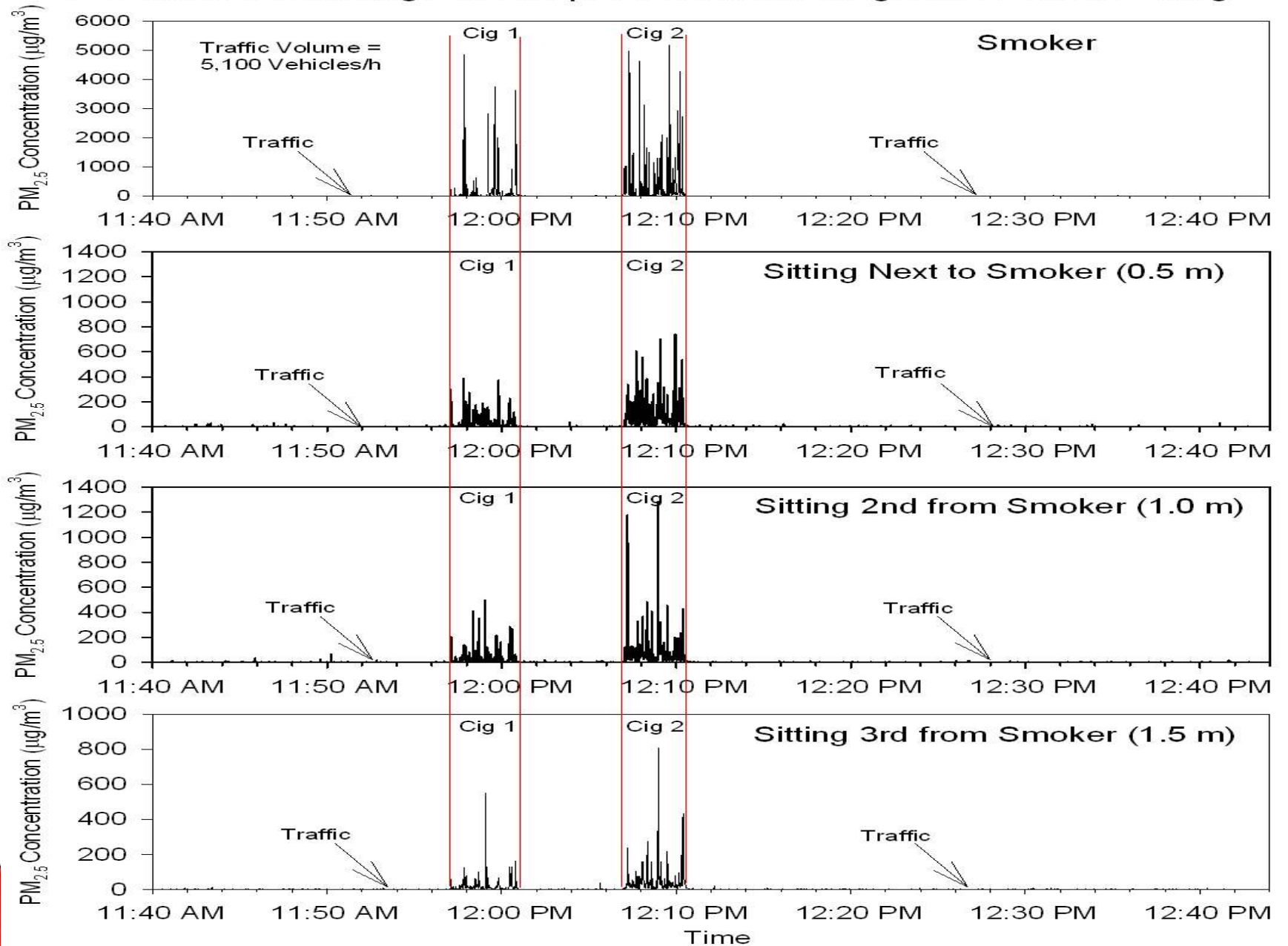
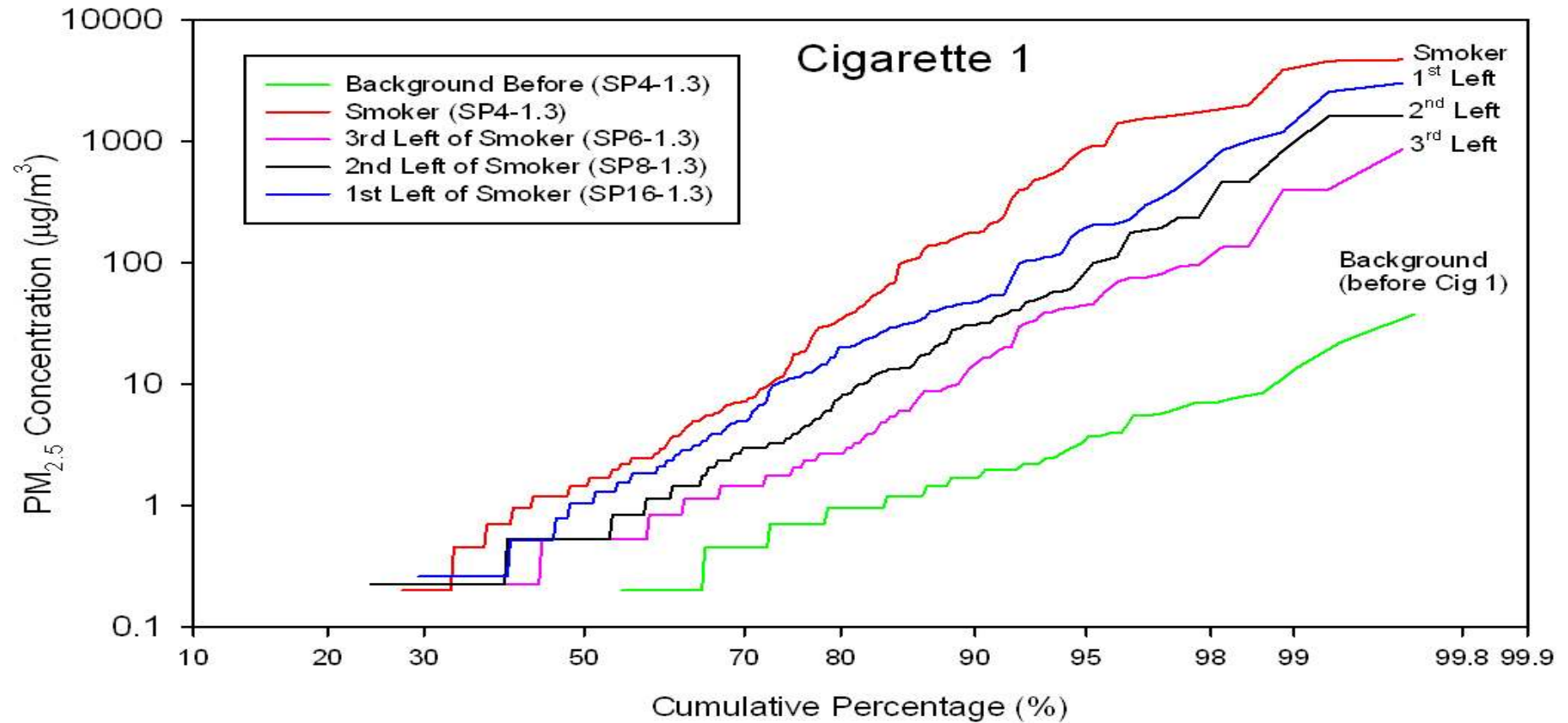


Table 2. PM<sub>2.5</sub> personal exposure of 1 smoker and 3 nonsmokers sitting on bus stop benches during smoking period ( $\mu\text{g}/\text{m}^3$ ).

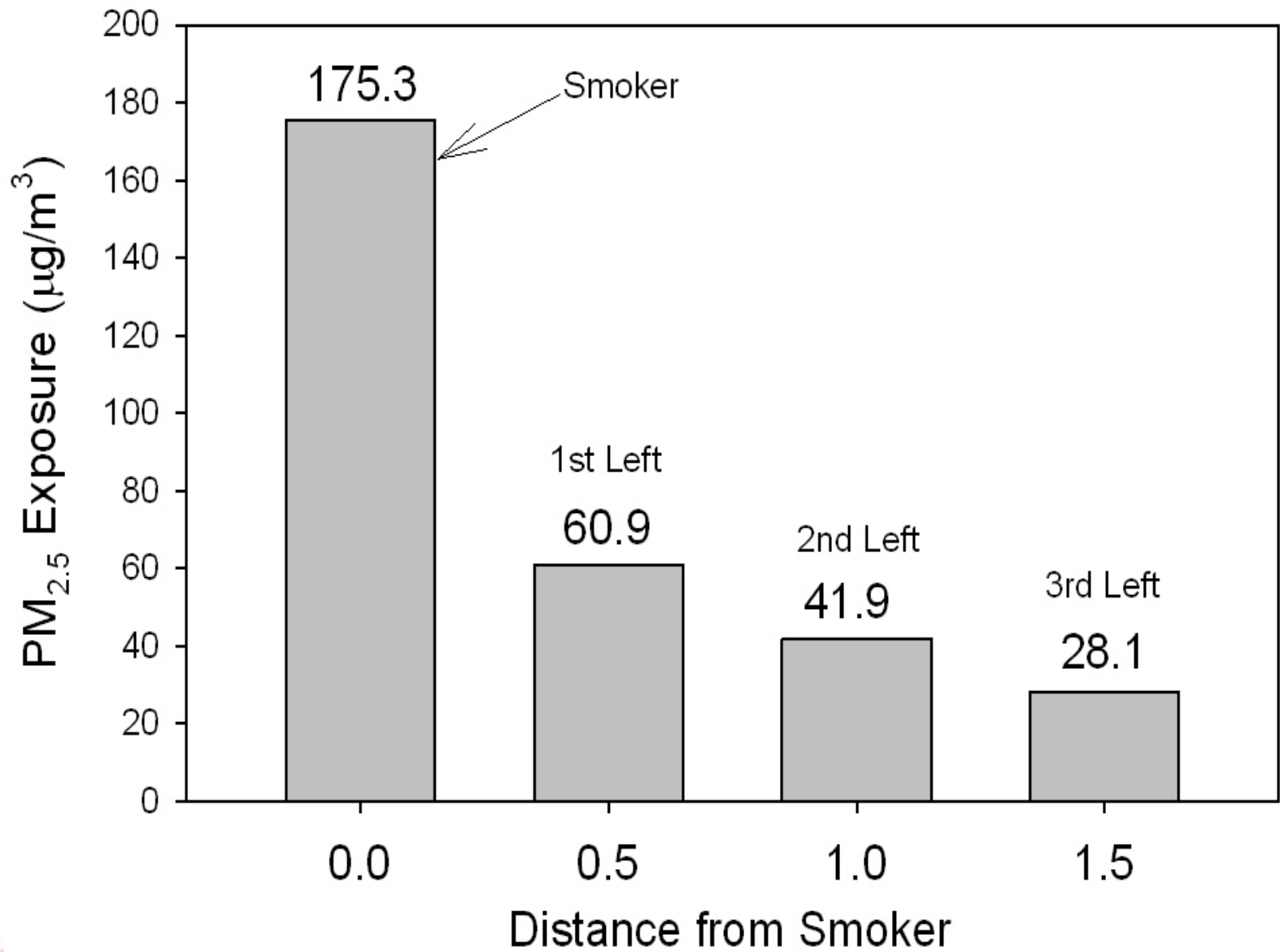
Cigarette No.	Bus Stop	Duration (min)	Back-ground	Smoker's Exposure	Exposure of Nonsmokers		
					0.5 m	1.0 m	1.5 m
1	A <sup>a</sup>	4.55	1.9	422	102 <sup>b</sup>	1.9	--
2	A	5:08	1.2	417	153	173	83
3	A	4.75	1.2	118	24	12	11
4	A	6.05	1.9	89	17	17	16
5	B	4.50	1.9	138	51	29	13
6	B	4.95	1.6	42	15	5	3
7	C	3.92	2.5	76	46	24	28
8	C	4.25	1.3	211	59	28	32
9	D <sup>c</sup>	5.27	1.3	26	70	44	24
10	D <sup>c</sup>	5.00	1.5	88	138	49	33
11	E <sup>c</sup>	3.75	1.9	192	37	66	21
12	E <sup>c</sup>	3.48	1.9	424	96	78	48
13	F <sup>c</sup>	4.67	2.1	283	59	16	--
Mean	--	4.63	1.7	192.0	59.0	39.7	28.0
SD	--	0.69	0.5	145.7	46.0	45.0	22.1



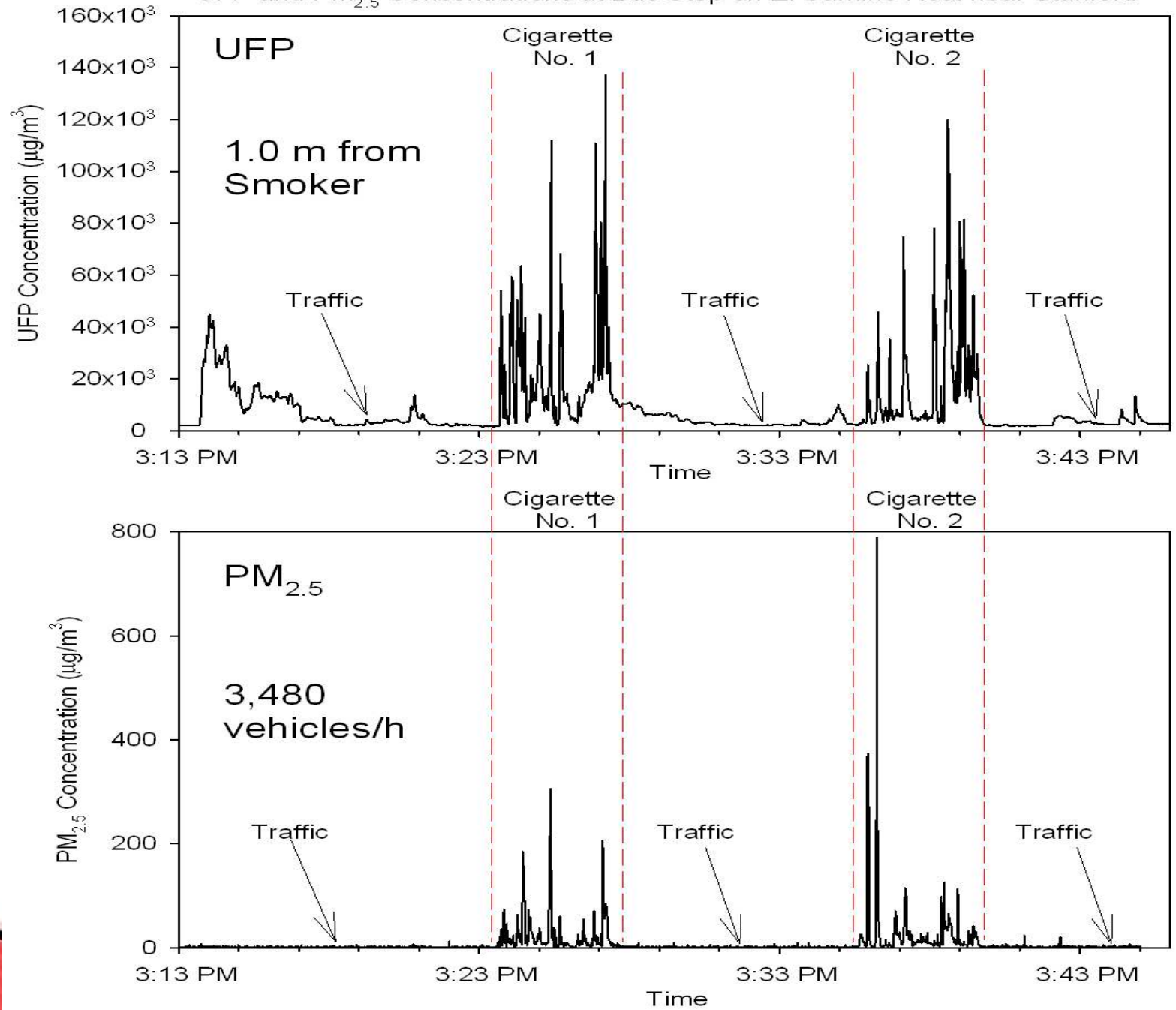
# Frequency Distributions of 1-s $PM_{2.5}$ Exposures of 4 Persons at a Bus Stop

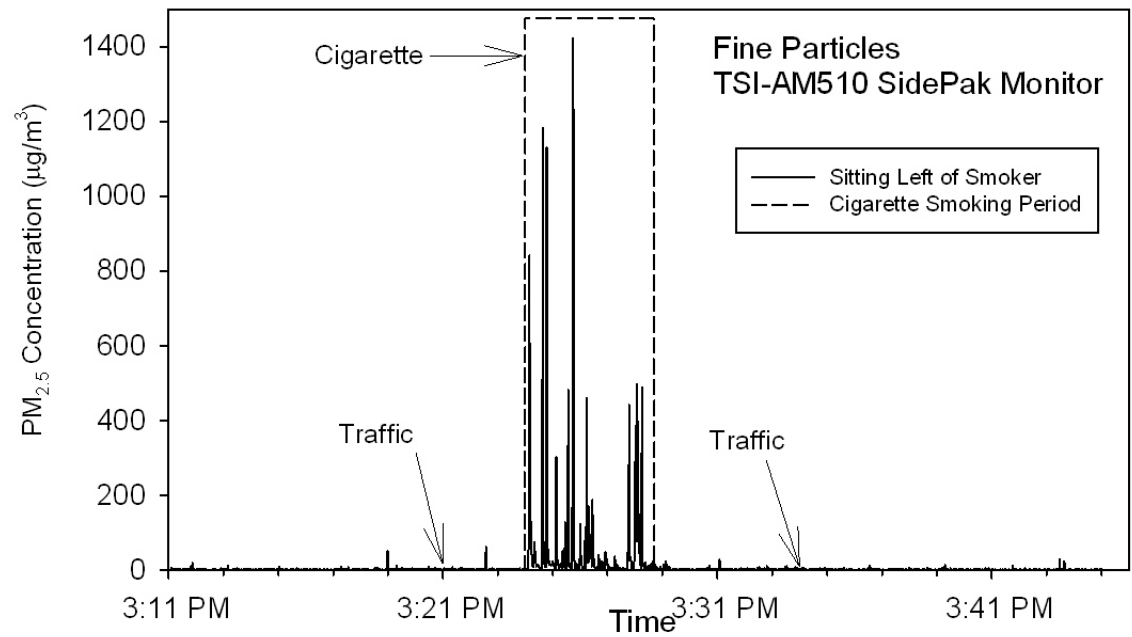
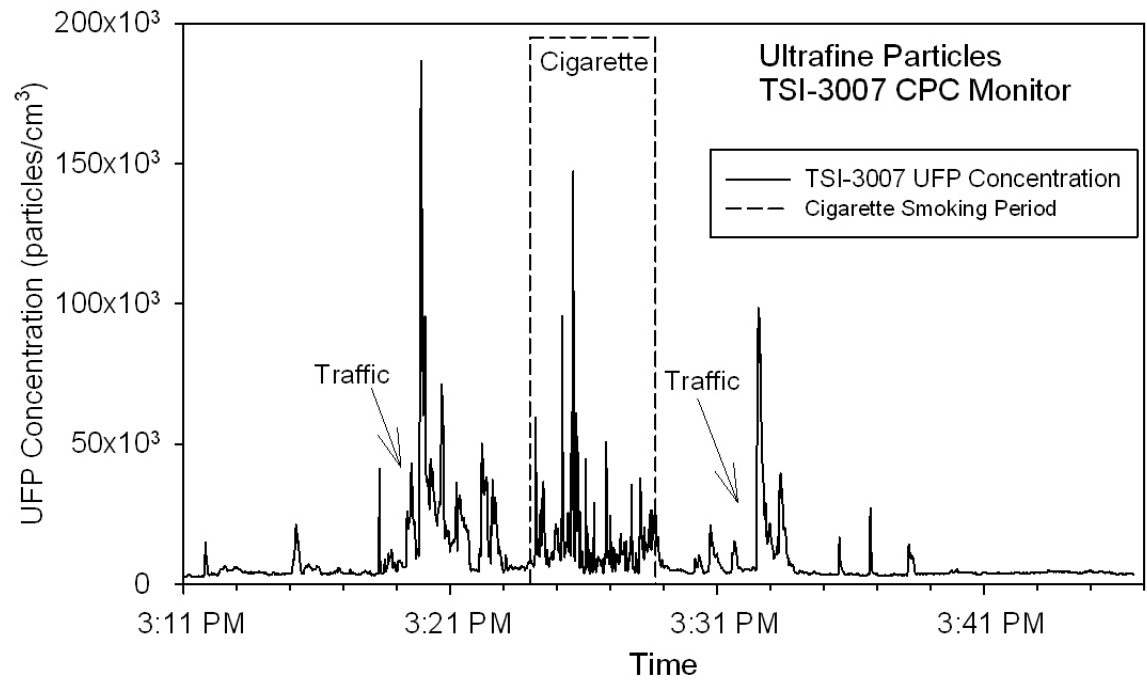


Proximity Effect: Mean  $PM_{2.5}$  Decreases with Distance from Smoker



UFP and PM<sub>2.5</sub> Concentrations at Bus Stop on El Camino Real near Stanford





# UFP Concentrations Measured at 7 Bus Stop Experiments

	Non-Smoking Periods (n=20)	During Smoking Periods (n=13)
Min	2,000	8,000
Max	15,000	120,000
Mean	7,000	46,000
SD	3,500	37,000



# “Ingredients” for high UFP exposures

- ▶ Gaseous pollutants that want to condense  
(from combustion, or chemical reactions)
- ▶ Low PM concentrations  
(so gases will form UFP, not coatings on PM)
- ▶ Fresh emissions  
(Coagulation with larger PM reduces UFP level)
- ▶ Close proximity to source  
(Dispersion dilutes pollutant levels)



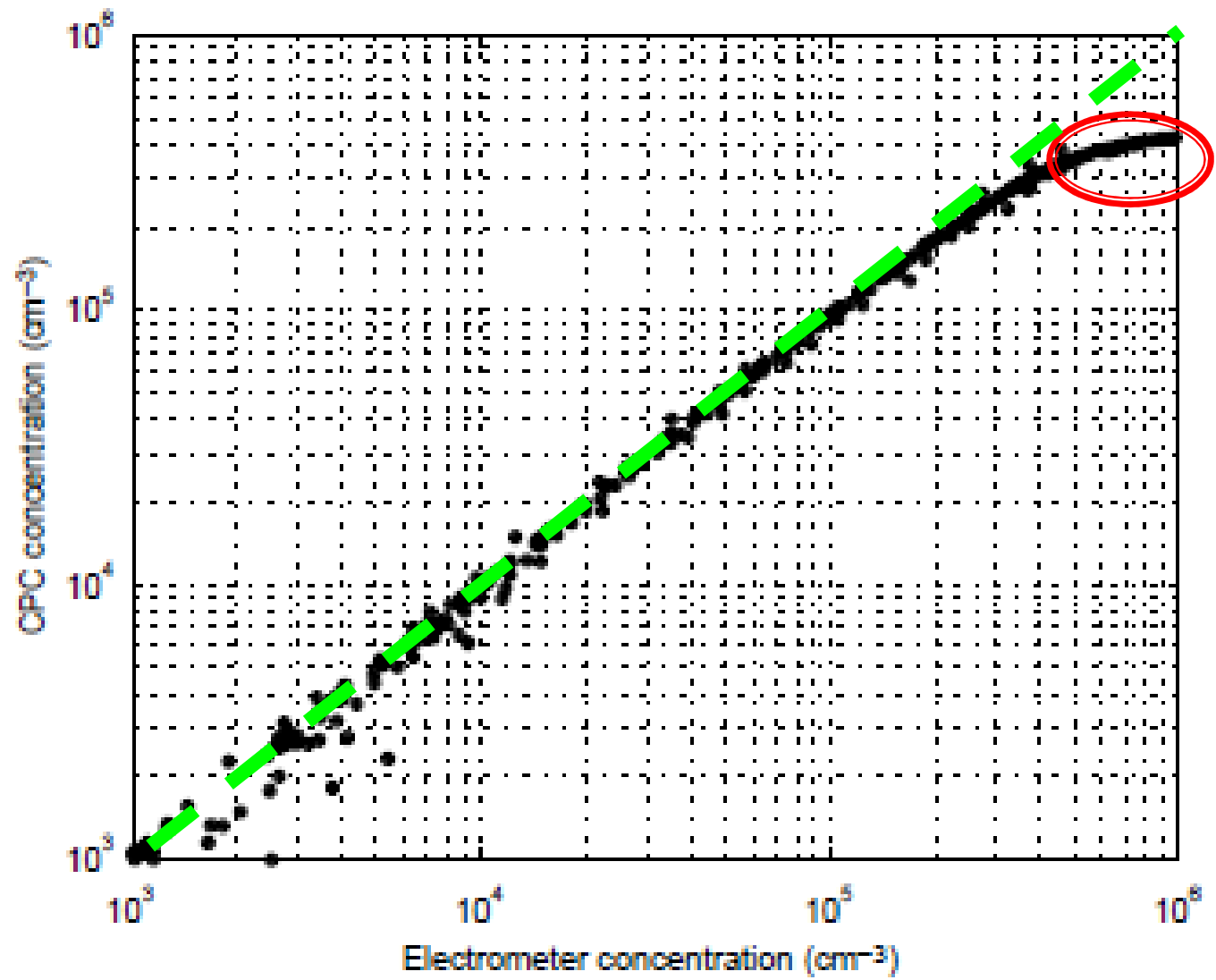


## Conclusion: What Activities /Locations Pose the Greatest Risk of Indoor UFP Exposure?

- 1) Cleaning products – pine, citrus scents react with ozone to form UFP
- 2) Combustion sources – emit condensable organics that can form UFP
- 3) Proximity to the source
  - The closer you are to the source, the higher the exposure!







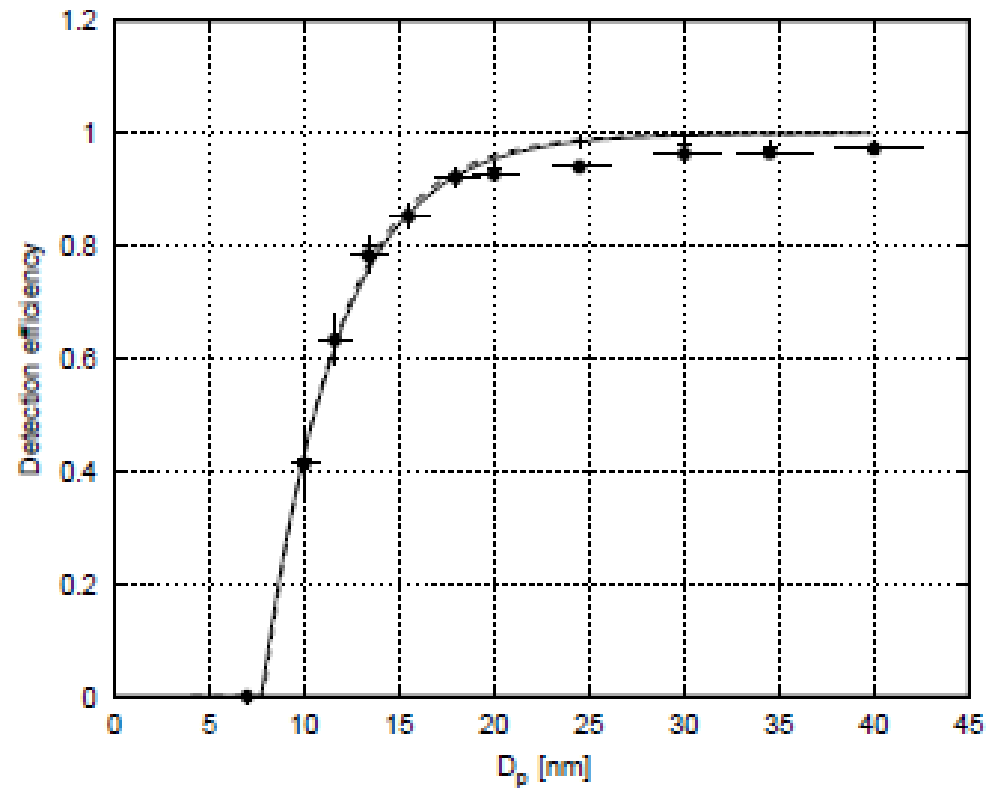


Fig. 2. Particle detection efficiency of TSI-3007 for  $(\text{NH}_4)_2\text{SO}_4$  aerosol. Experimental values (circles—unit A; crosses—unit B) are shown together with the best-fit results of Eq. (1) (dashed line—unit A; solid line—unit B). The uncertainty of the experimental data is indicated for the other data set as errorbars and it is discussed in the text.

