A&WMA International Specialty Conference

Continuous, Long Term Monitoring of Ultrafine Particles (UFP) in Urban Air

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Tim Johnson, Kathy Erickson, Robert Zhou

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Leapfrogging Opportunities for Air Quality Improvement

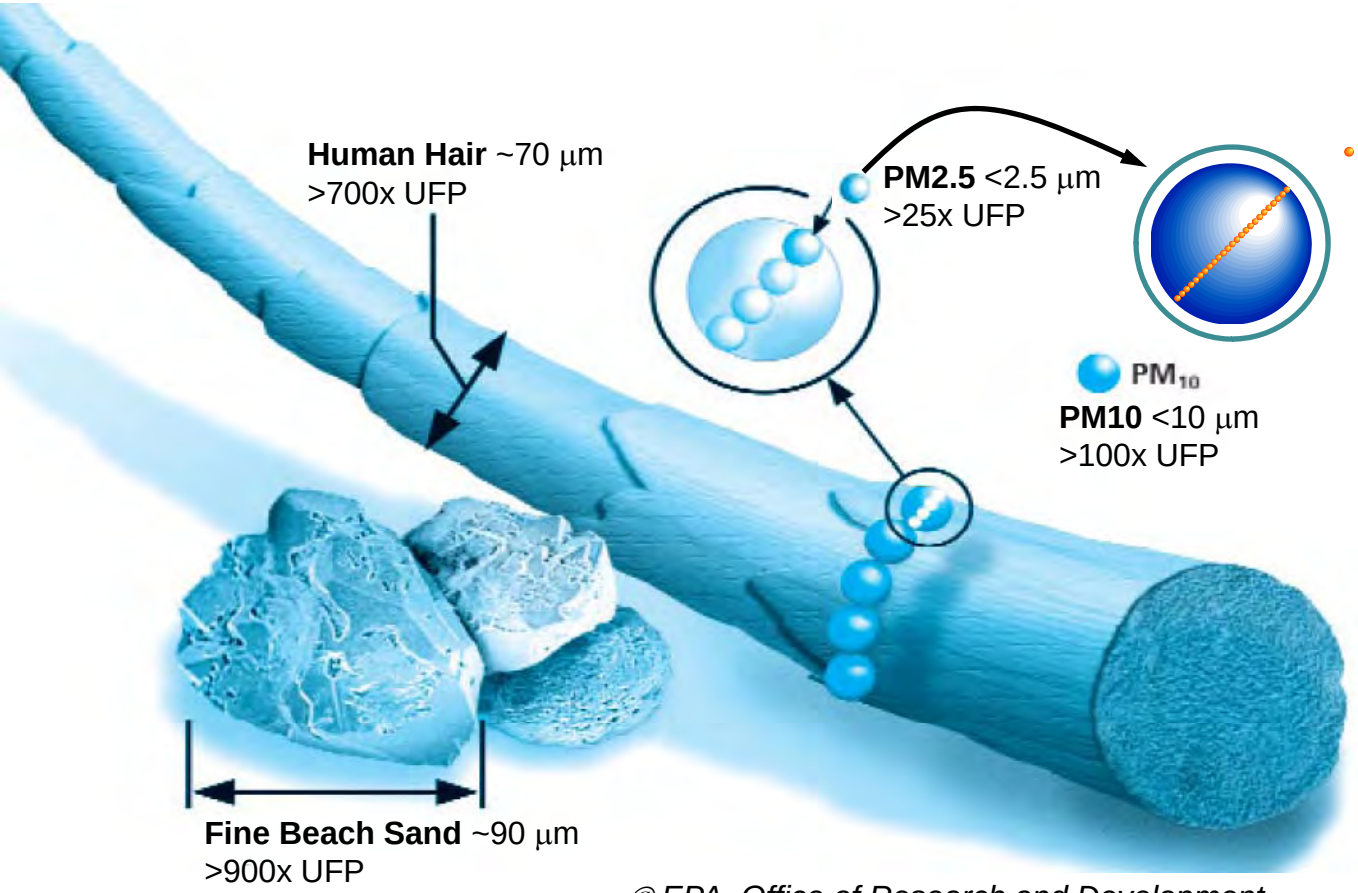
Xi'an, Shaanxi Province, China

Outline

- What are Ultra-fine Particles (UFP)?
- Why Monitor UFP?
- European Regulatory Activity
- Ways to Measure Ultra-fine Particles
  - Total Concentration
  - Size Distribution
- Instrumentation

What are Ultra-Fine Particles?

1. US EPA definition: Particles with a diameter <100nm
2. UFPs occur in massive numbers in urban air but essentially have no measurable mass
3. Most common source in urban environment is vehicle exhaust

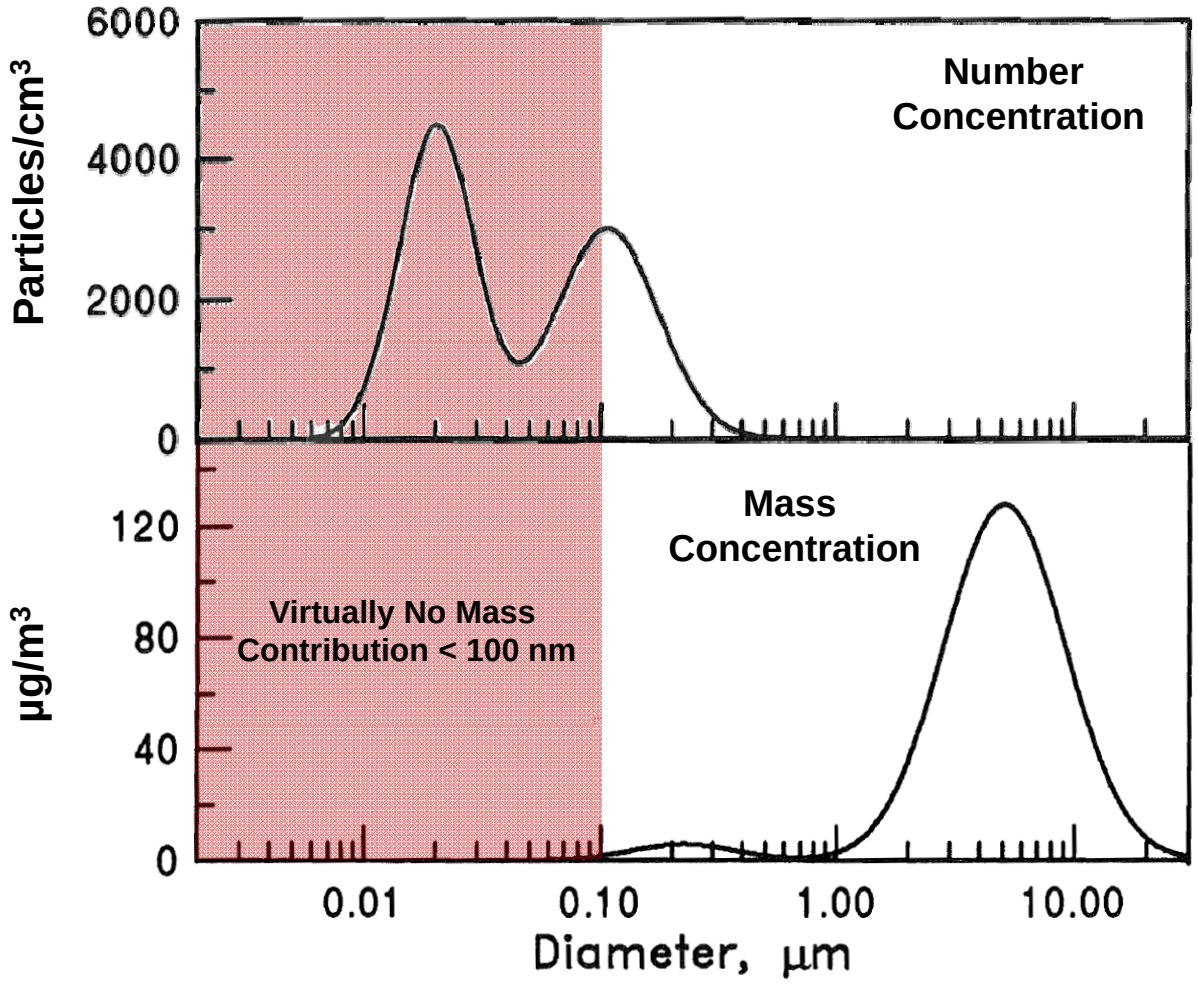


© EPA, Office of Research and Development

Why Monitor UFP?

1. Potential Health Effects
   - 2008 UCLA Study: How UFP in Air Pollution May Cause Heart Disease
   - 2004 Oberdörster Study: Evidence of UFP Accumulation in Brain
2. Increased Exposure to Ultra-fines
   - Ultrafine Particles in Classrooms: Studied UFP in 3 elementary classrooms in Brisbane, Australia: Numerous occasions where UFP levels were significantly higher than outdoor air.
   - Ultrafine Particles in Tunnels: Measured UFP concentration levels outside a vehicle traveling through the M5 East tunnel in Sydney, Australia: at times the levels are up to 1000 times higher than in urban ambient conditions.
   - Ultrafine Particles Near Airports: Measured range of air pollutants near Santa Monica Airport: Found that emissions of (UFP) were significantly elevated, up to 10 times higher at a downwind about 100 yards and 2.5 times higher at distance of about 600 yards.
3. Air Quality Effects
   - Ultra-fine particles from combustion sources are frequently hygroscopic
   - At high relative humidity, condensing water enlarges UFPs to a size that is efficient at scattering light and interferes with visibility.
   - UFPs are primarily responsible for urban smog

UFP: Mass or Number?



Traditional mass based measurements like PM_{10} and $PM_{2.5}$ severely underestimate contribution of UFPs

	Total Particle Mass		Total Particle Mass	
UFP	**1,000,000 @ 0.1µm**	=	**1 @ 10µm**	PM_{10}

Adapted from: Seinfeld, J. H.; Pandis, S. N. *Atmospheric Chemistry and Physics;* John Wiley and Sons, 1998.

European Particle Number Regulatory Activity

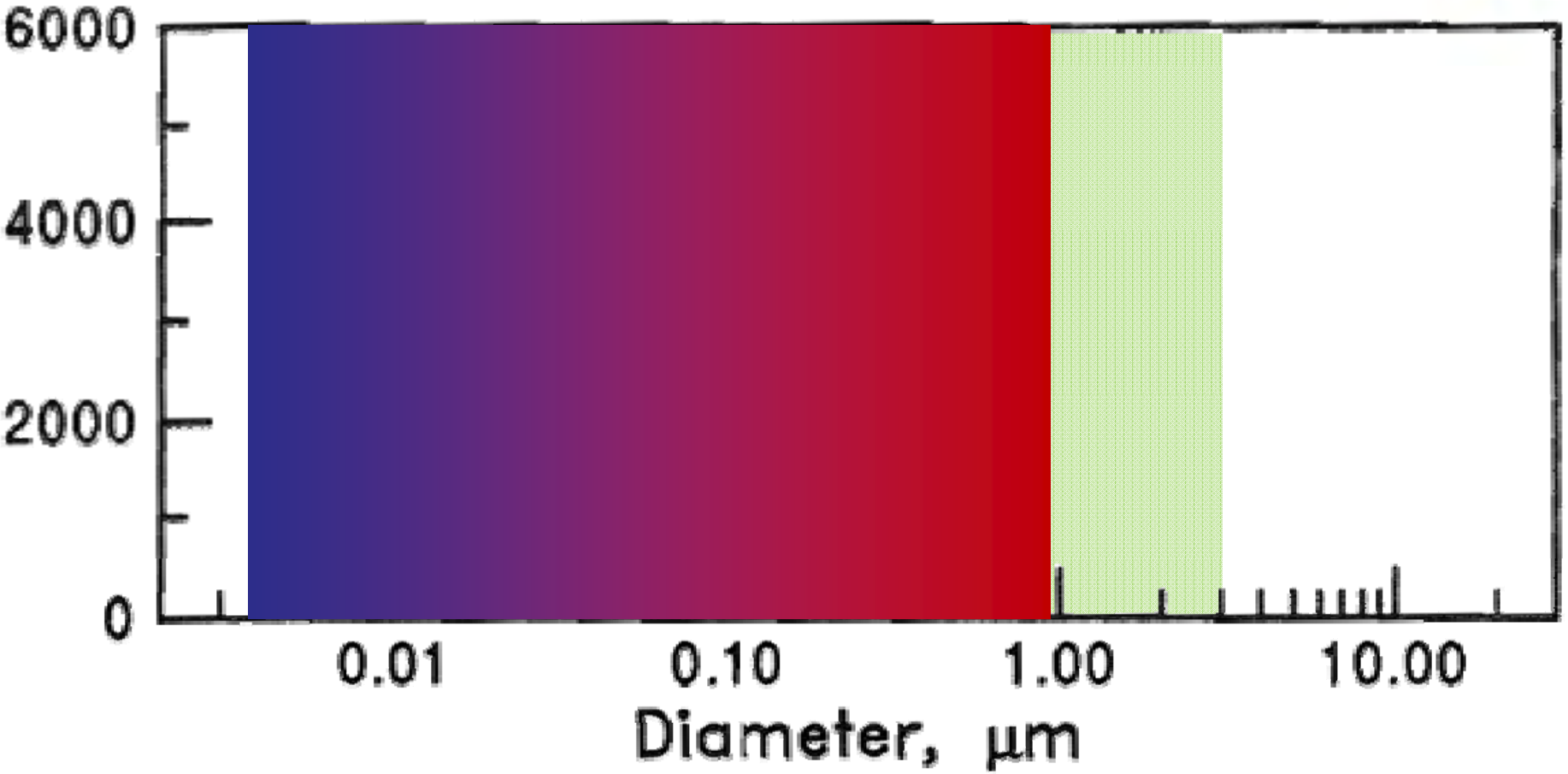
1. **Euro 5/6:** First regulation to restrict the number (not mass) of UFP in light duty diesel vehicle emissions.
2. Clean Air Commission of VDI/DIN* is preparing German national guidelines for particle number concentration and size distribution measurements in air quality monitoring networks.
3. CEN/TC** 264/WG 32 is working on technical recommendations for number concentration and size distribution measurement of UFP in air quality monitoring
4. Clean Air for Europe (CAFE)
   - Thematic Strategy on Air Pollution
   - Program to improve data quality for advanced environmental monitoring, including UFP number concentration and size distribution.
5. UFIPOLNET† project initiated to develop an affordable, low maintenance monitor for UFP number and size.

* VDI is the Association of German Engineers; DIN is the German Institute for Standardization

** CEN is the European Committee for Standardization; TC is an Independent Technical Committee for air quality control

† UFIPOLNET: UltraFIne Particle Size Distributions In Air POLlution Monitoring NETworks

How to Measure Ultra-Fine Particles



1: Condensation Particle Counter

2: Scanning Mobility Particle Sizer

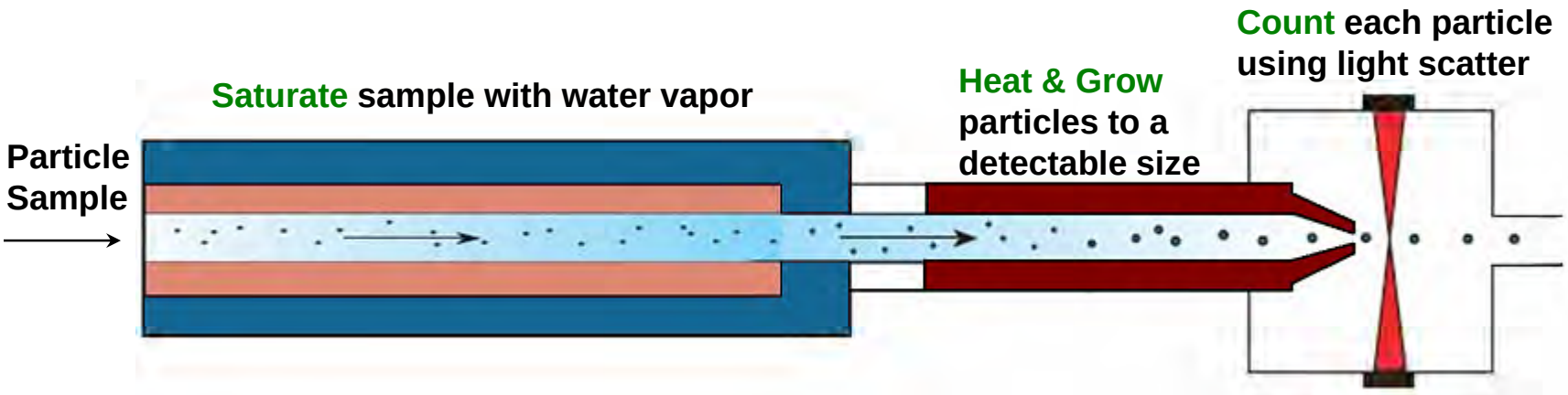
3: Ultra Fine Particle Monitor

Adapted from: Seinfeld, J. H.; Pandis, S. N. *Atmospheric Chemistry and Physics;* John Wiley and Sons, 1998.

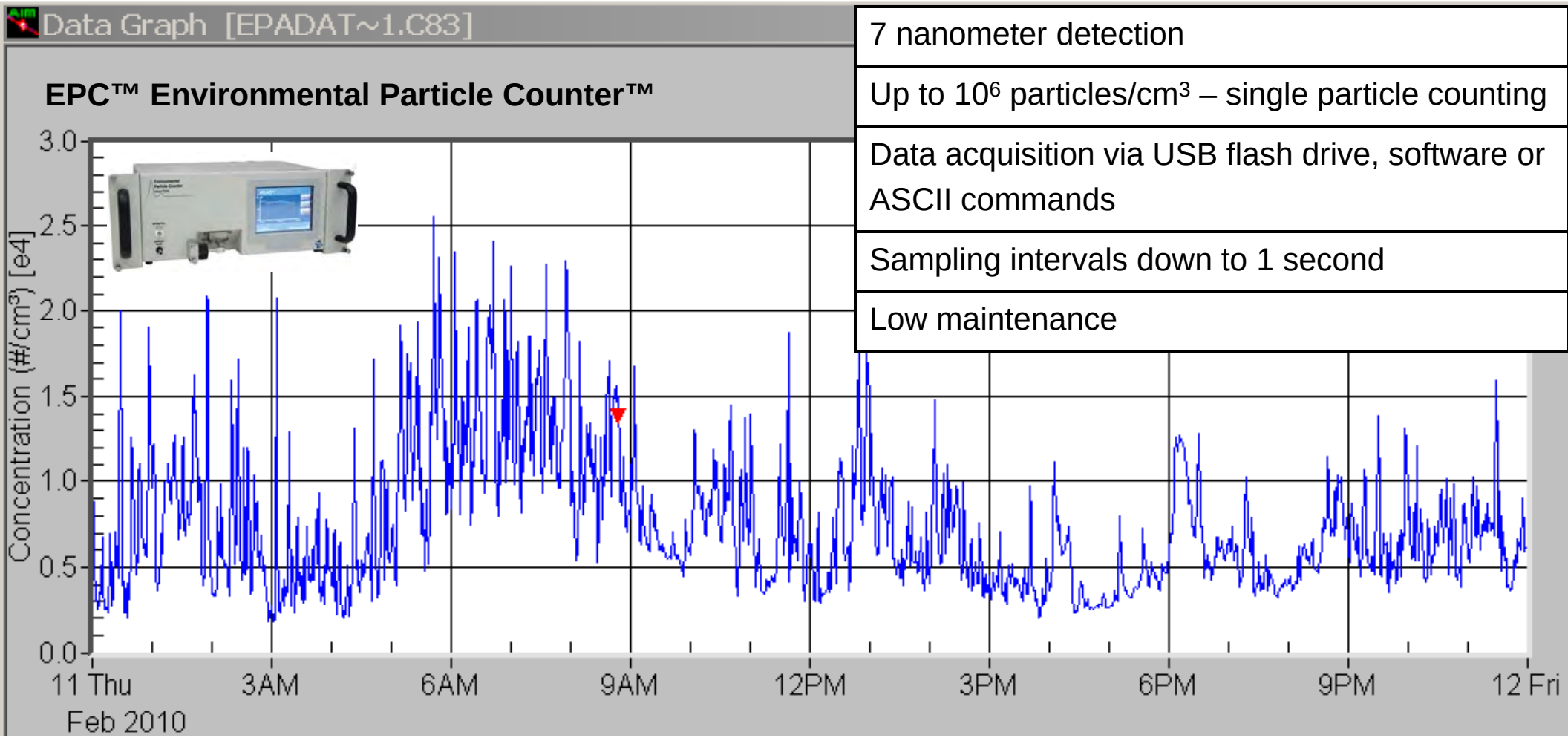
Total Number Concentration

Condensation Technique Used to Count Ultra-Fine Particles

- Standard method used by government agencies (NIOSH, EPA, etc.) and air quality measurement experts to measure UFP concentrations.
- Single particle counting: particles are counted individually, significantly increasing concentration accuracy.



UFP Particle Number (PN) Concentration



7 nanometer detection
Up to 10^6 particles/cm^3 – single particle counting
Data acquisition via USB flash drive, software or ASCII commands
Sampling intervals down to 1 second
Low maintenance

Data from US EPA Roadside Study Site – Las Vegas, NV

UFP Size Distributions

UFP Monitor

- Developed by UFIPOLNET team
- Designed for 24/7 Air Quality monitoring
- Continuous particle size and concentration measurements
- Standardized measurement method
- Extensive field validation
- No working fluids; no radioactive source

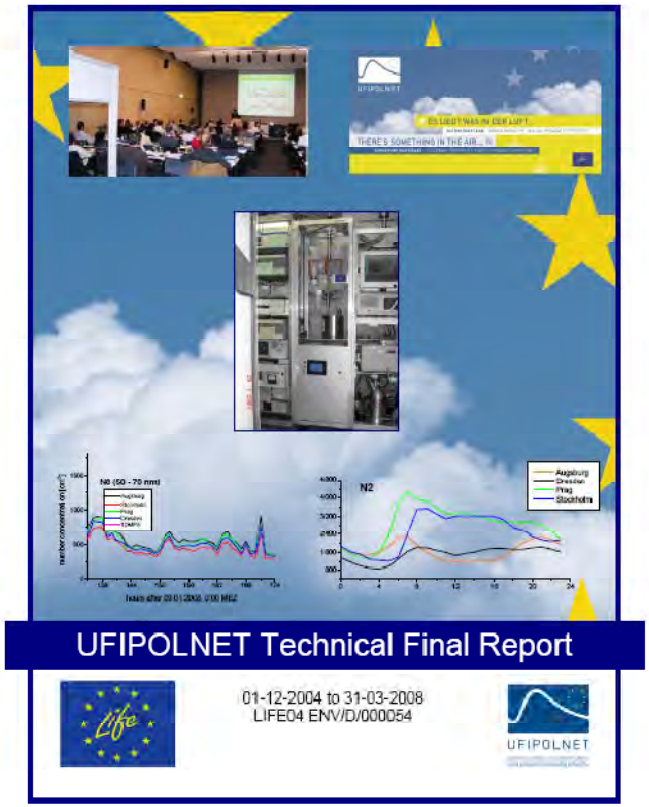
Specifications

20 nm to ~800nn
6 size channels
Concentration up to 10^6 particles/cm^3
15 minute data sets
Data Interfaces: Ethernet, RS-232, USB

UFIPOLNET Design Criteria

Affordable price/low cost of ownership
Low cost of ownership
Easy integration into monitoring systems
Manageable data sets
Reliable, sensitive and accurate data

UFIPOLNET - Project

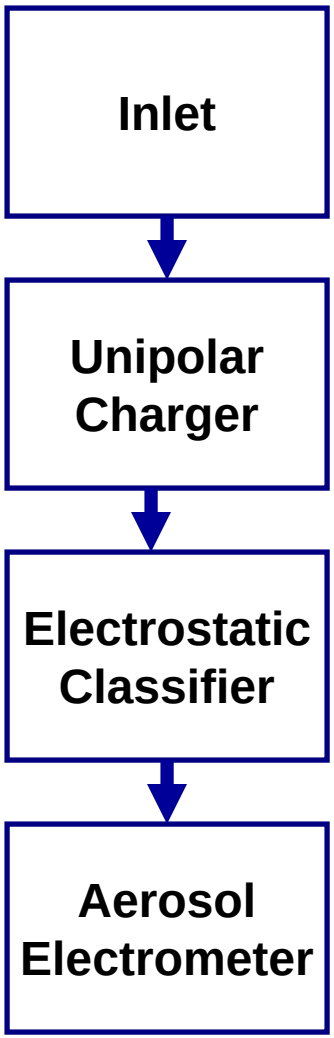


Freistaat Sachsen

Saxon State Agency for Environment and Geology (LfUG)

- UFIPOLNET Technical Final Report is public on the UFIPOLNET web site www.ufipolnet.eu

UFP Monitor Principle

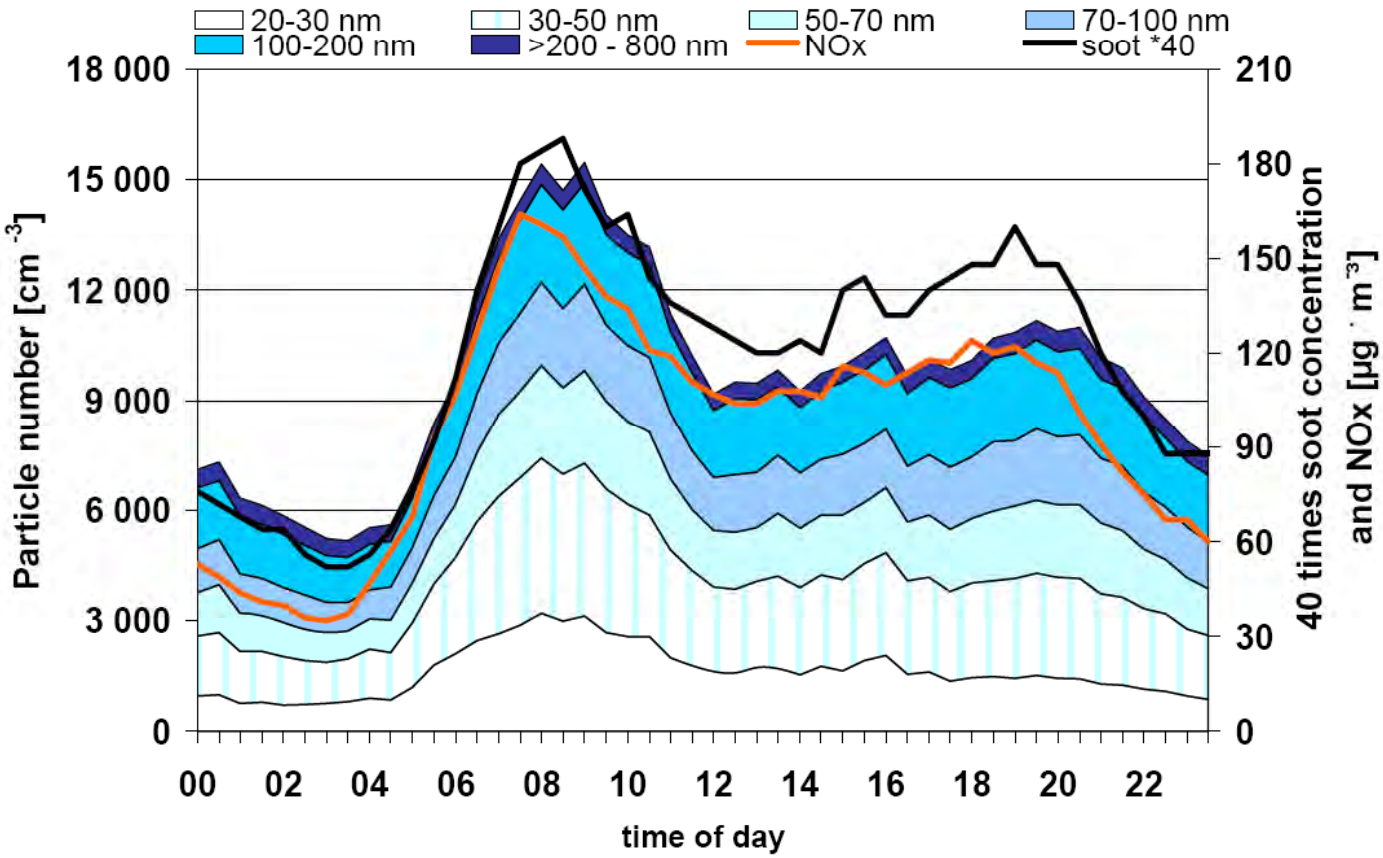


Sample the particles

Charge the particles

Classify into size fractions

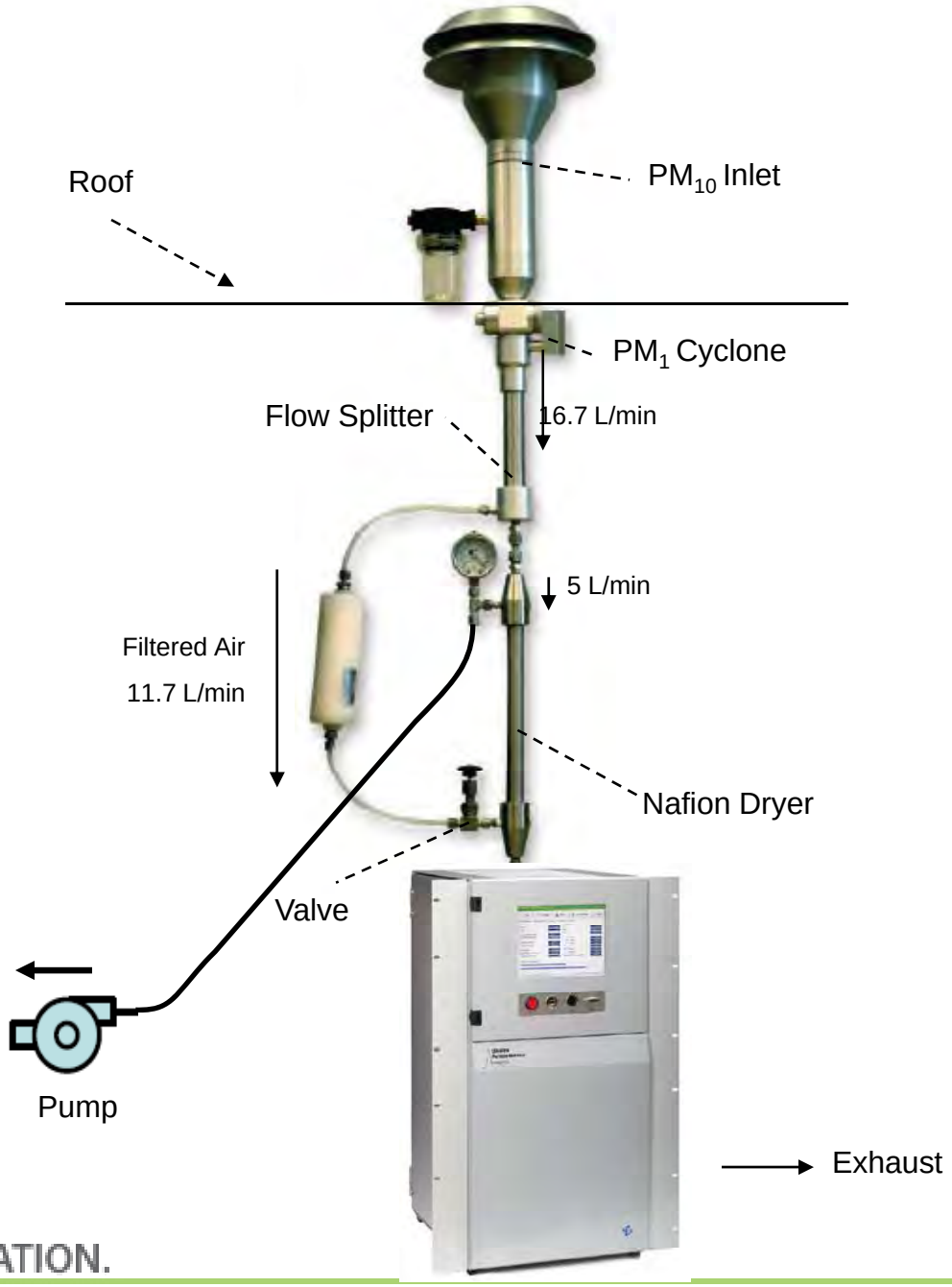
Quantify the concentration



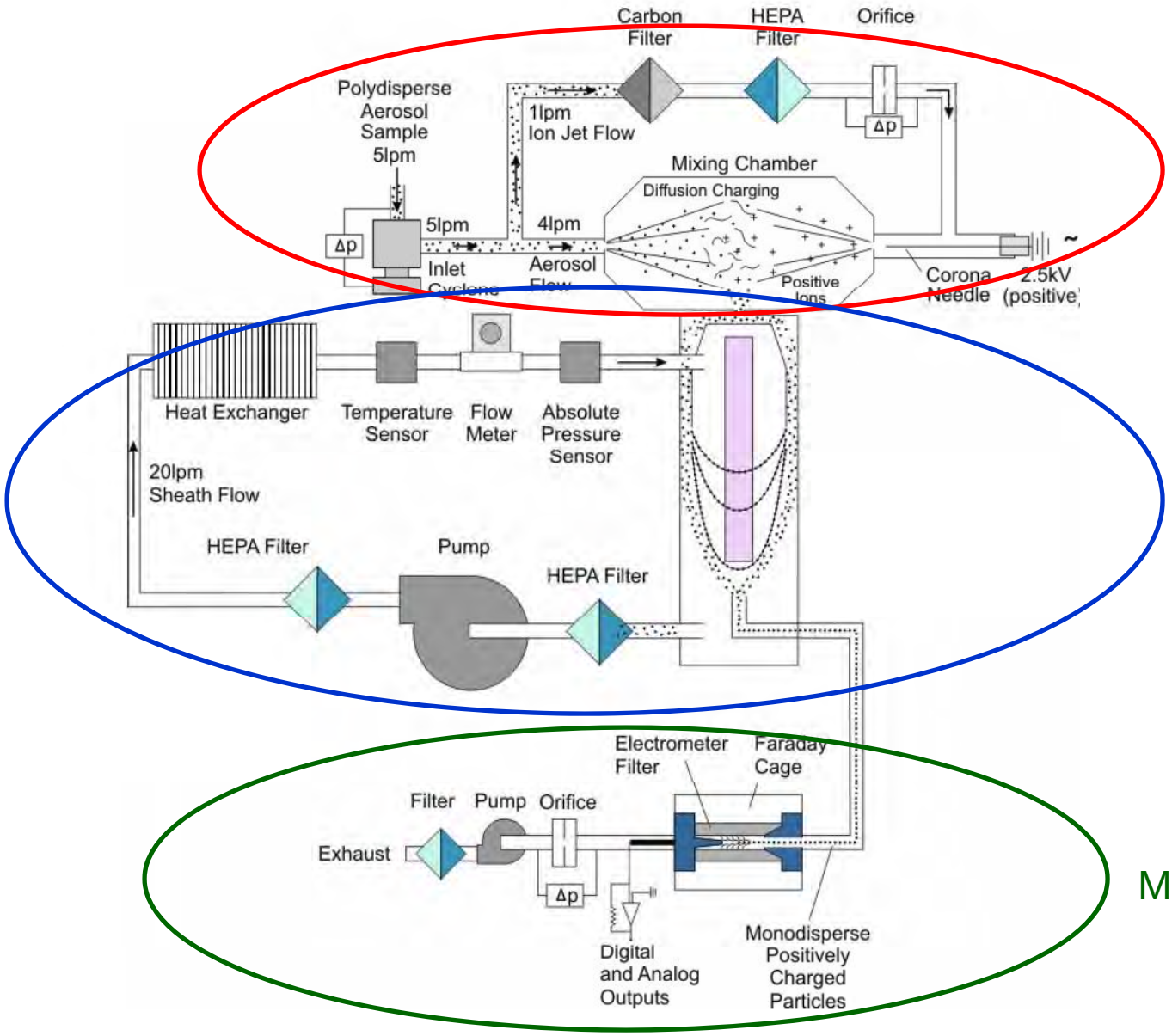
Average Weekday Concentrations of UFP, NO_x and Soot in Dresden, Germany, 1/24 – 3/19/2007

Gerwig, H. *et al.*, "UFIPOLNET: Concentration of Particle Number Distributions at 4 Stations in Europe, Poster Presentation, Particle and Photo-oxidants in Europe, Sep 25-27, 2007, Prague, Czech Republic

Typical Field Setup



3031 Flow Schematic



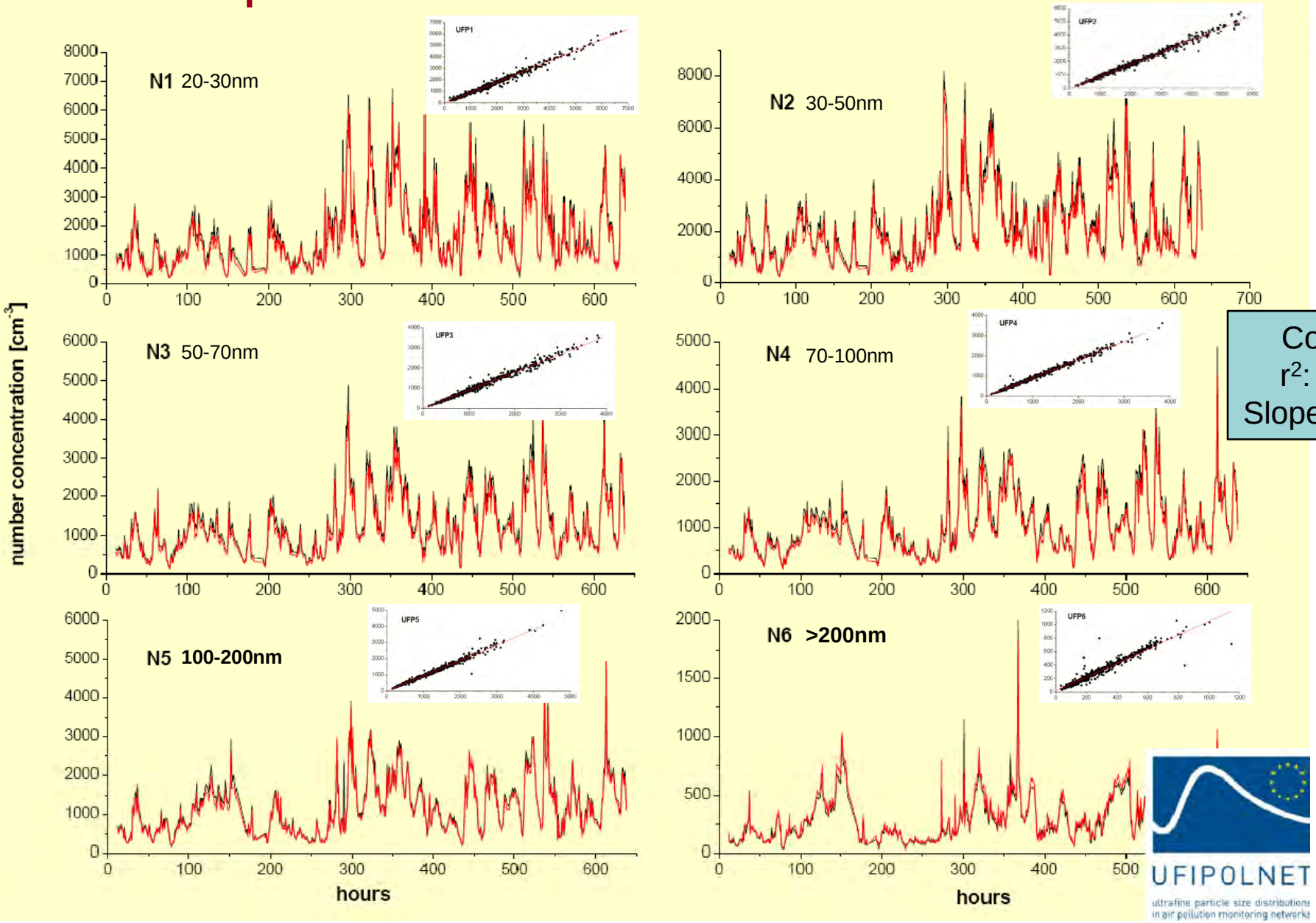
Charge the Particles

Select Particles by Size

Measure the Concentration

Validation: Co-Located Instruments

Comparison of two UFP Monitors for six size classes



Correlations:
r^2: 0.94 -0.98
Slope: 0.90 – 1.04

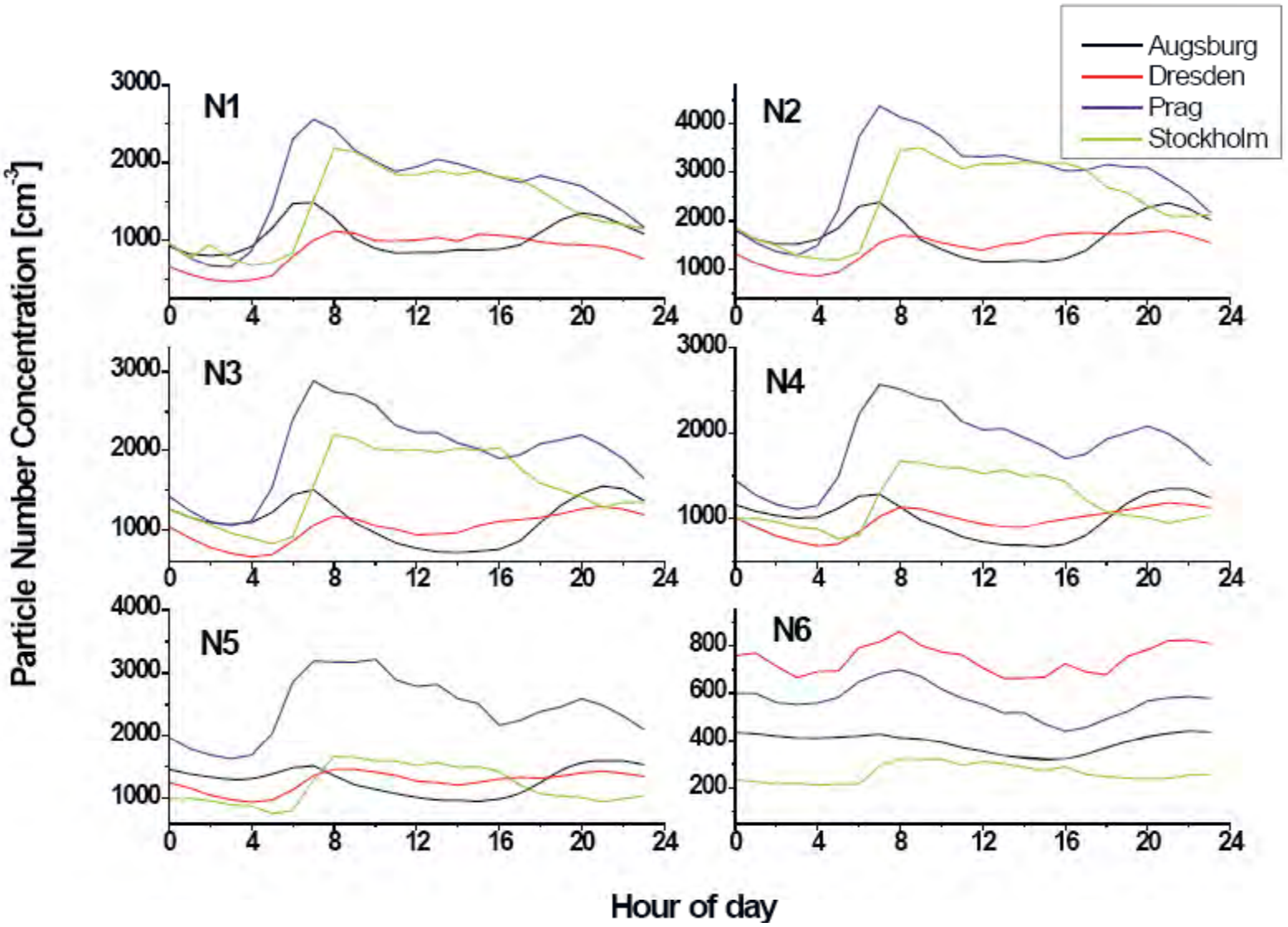
UFIPOLNET
ultrafine particle size distributions in air pollution monitoring networks

Wehner, B., *et al.*, "The new UFP 330: Comparison with a DMPS for ambient aerosols", Poster Presentation, European Aerosol Conference, Salzburg, Austria, 2007

Field Evaluation at 4 locations in Europe

- The 12 months of continuous operation
  - Demonstrate data availability of the devices
  - Determine optimal maintenance scheme
  - Correlation analysis with other measured contaminants
- All four prototype units achieved data availability >90%
- No reliability problems reported during entire period (>12 months)

Diurnal Variations



N1	20 – 30 nm
N2	30 – 50 nm
N3	50 – 70 nm
N4	70 – 100 nm
N5	100 – 200 nm
N6	> 200 nm

Wehner, B., *et al.*, "The new UFP 330 (TSI 3031): One year of continuous measurements", Poster Presentation, European Aerosol Conference, Karlsruhe, Germany, 2008

Field Measurements of UFP Size Distributions

- Beijing Olympics: Researchers from Cornell University used a 3031 to monitor UFP in Beijing during August 2008 Olympic Games.
- USEPA: Las Vegas Roadside Study – Designed to Evaluate UFP in the Near-Roadway Environment
- Delaware Department of Natural Resources and Environmental Control: New Air Quality Project to Monitor Nanoparticles http://www.awm.delaware.gov/Pages/AirQuality.aspx
- Other Agencies
  - Ontario Ministry of Environment & Department of the Environment
  - Environmental Protection Agency Air Sciences: Queensland, Australia

The 3031 TSI Ultrafine Particle Monitor used by AQM to continuously monitor particles in nanometers.

From TSI Specification Sheet for 3031 Ultrafine Particle Monitor

plete picture of how nanoparticles may affect our everyday lives, give clues for identifying their source, gain understanding on particle behavior and chemistry, learn whether any patterns or trends exists and whether they should be regulated. For more information on air quality and monitoring, please visit:
http://www.awm.delaware.gov/Pages/AirQuality.aspx.

Article by J. Martini, AQM

Small particle concentrations have been a health concern due to the relationship with the increased incidence of asthma and other related health conditions. DNREC has been monitoring particle concentrations for many years as part of an ambient air monitoring network. The focus to date has been on total mass of the particles in a given volume of air, but there is evidence indicating that the number of particles making up that mass may also be a major concern. Now Delaware will be one of a few states taking a lead in this research.

The shelter used to house the new Ultrafine Particle Monitor located near MLK Blvd in Wilmington.

Thank You for your Attention