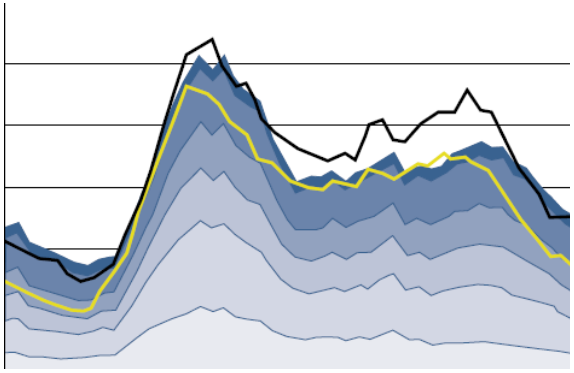
Nanoparticle Air Monitoring Workshop



# UFP Monitoring Network & Regulations in the European Union

**Jeff Baker**

**March 3, 2009**

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# New European Standards for Air Quality Based on Ultrafine/Nano Particle Count

00:00 – 00:05 1. Why is the EU Monitoring Ultrafines?
-Objectives of the UFIPOLNET within the EU
00:05 – 00:10 2. Measurement Criteria Desired and Why They Were Deemed Important for Human Health
00:10 – 00:15 3. Practical Field Solutions to Meeting Criteria
- Designed to Meet EU UFIPOLNET Criteria
00:15 – 00:20 4. Demonstration Station & Test Results from Initial Sites
00:20 – 00:25 5. Summary & Next Steps for the EU
00:25 – 00:30 6. Questions

# 1. Why does the EU Want to Monitor UFP's?

- *"In laboratory animal studies, it has been shown that on average, 24% of inhaled TiO2 particles under 100nm in size had penetrated cells through the lung and bloodstream in less than 1 hour.*
- *In a second set of experiments, nanoparticles of 78nm and ultrafine particles of 200nm had been found to penetrate human red blood cells."*

- *How Ultrafines Disseminate in the Body (EHP 113:1555-1560)*

# 1. Why does the EU Want to Monitor UFP's?

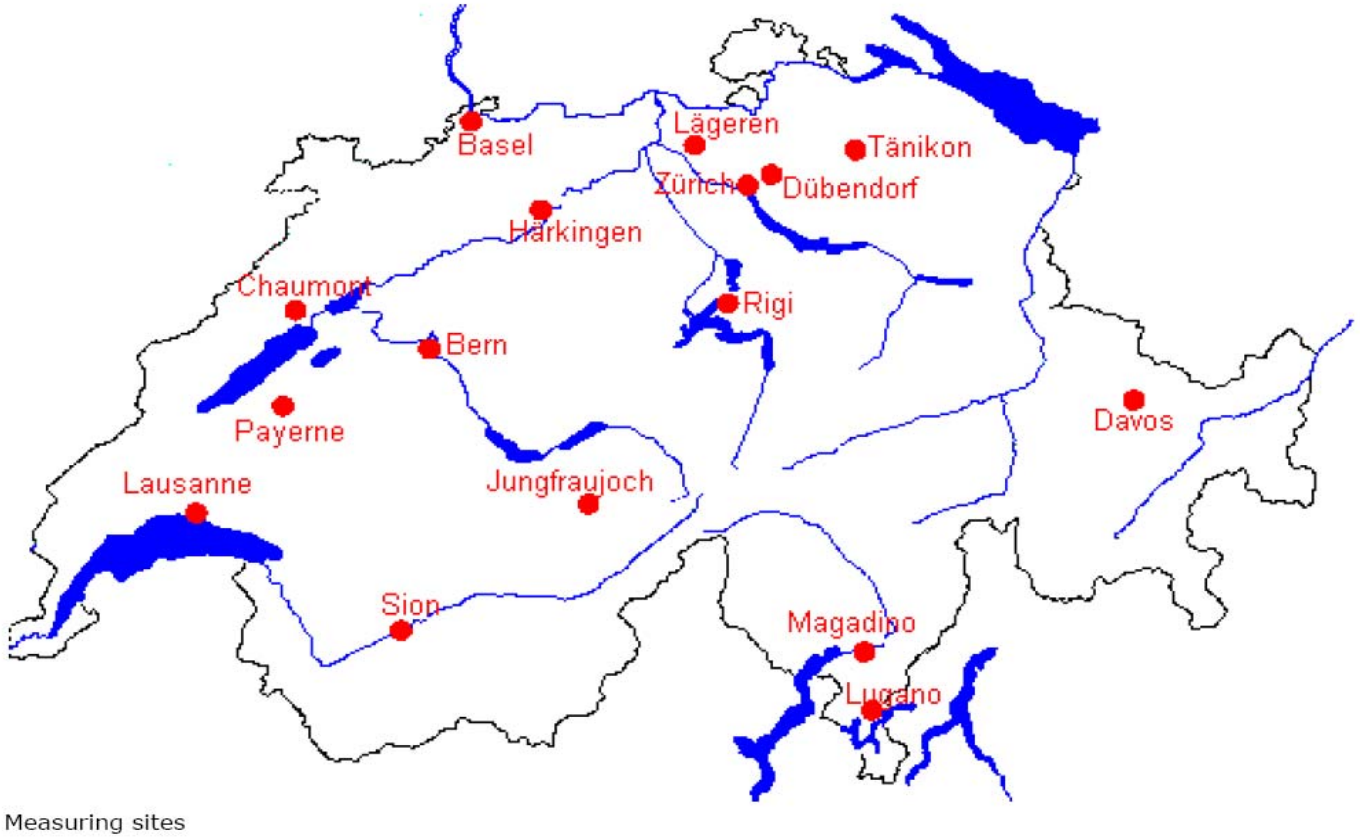
*" While there is considerable toxicological evidence of the potential detrimental effects of UF particles on human health, the existing body of epidemiological evidence is insufficient to conclude on exposure/response relationship to ultrafine particles"*

*- World Health Organization, 2005*

# Why is the EU Monitoring UFP's? - Background and History

- Decided to start with on road vehicles as this was seen as most affecting human exposure (dense populations are in dense traffic areas).
- Early on, UFP number concentration and size distribution measurements were limited to atmospheric research and epidemiologic studies:
  - ACE I, ACE II, GSF study in Erfurt etc.
- Since 1998, several UK monitoring sites are recording UFP number concentration/and or size distribution.
- Since 2001, Switzerland pioneered (unregulated) UFP number concentration monitoring in their 16 NABEL (National Air Pollution Monitoring Network) monitoring stations
  - 12 out of 16 stations routinely run CPCs (TSI model 3022A)
  - EMPA has established calibration routines for NABEL CPCs

# Ultafine Particle Monitoring Sites in Switzerland




Meanwhile, 12 stations monitor total UFP number concentration with CPCs



Source: http://www.empa.ch/plugin/bean/empa/Article_PrintArticle?pr_artid=13204&wo=1

# 1. Why Measure UFP's? - Background and History

- To coordinate different EU country activities, in 2005 the European Union adopted the *"Thematic Strategy on Air Pollution"* - part of the "Clean Air for Europe (CAFE)" program
- This strategy calls for member countries to increase their research activities and to identify the impact of air pollution on human health and the environment.
- Furthermore, the EU has also established a starting point for particle number based limits for emission of UFP's from light duty vehicles with diesel engines
  - (Euro 5: 6 x $10^{11}$ particles/km - phased in - 2010 to 2012)

# 2. Measurement Criteria: EUSAAR

## (European Supersites for Atmospheric Aerosol Research)

### Objectives of EUSAAR

- **Objective 1**: Ensure measurements and QA/QC of aerosol chemical, optical and physical properties
- **Objective 2**: Ensure dissemination of data and capacity building
- **Objective 3**: Develop future tools for aerosol monitoring and dissemination of information
- **Objective 4**: Ensure trans-national access of research infrastructures


*The EUSAAR network*

**The EUSAAR network runs 34 stand alone CPCs and 19 SMPS systems for total particle number concentration and number-size distribution, resp.**



Ref: Paolo Laj; EUSAAR contribution to the 2008-2009 EMEP intensive field campaigns

# 2. The EUSAAR Project - Objectives into Action

- As a part of the EUSAAR project, the need for a uniform UFP monitoring network was identified as a goal.
- Commercial SMPS and CPC's are seen more as laboratory instruments than typical year round environmental monitors with remote capabilities. Therefore, the EU included UFP monitoring aspects in research programs, e.g.:
  - EU-Life program developed UFIPOLNET (Ultra FIne Particle Size Distributions in Air POLlution Monitoring NETworks) to develop an affordable, low maintenance, networkable monitor for UFP number and size.

# 2. The EU-Life UFIPOLNET Project

- Objectives
  - Design a new UFP monitor for air quality networks
    - Affordable (initial cost & total cost of ownership)
    - Easy to install, use and maintain
    - Easy to integrate into existing station data acquisition
    - Well suited for continuous monitoring (24h/365days)
  - Test 4 prototypes of the new monitor for 12 months under realistic conditions
    - Four European sites with different particle characteristics were chosen:
      - Street Canyon in Stockholm, Sweden (very high PM concentration)
      - Street tunnel entrance in Prague, Czech Republic (medium PM concentration)
      - Street intersection in Dresden, Germany (medium PM concentration)
      - Urban park in Augsburg, Germany (urban background)

UFIPOLNET
ultrafine particle size distributions in air pollution monitoring networks

Life

# 2. Regulatory and Guideline Activities

- Meanwhile, the clean air commission of VDI/DIN in Germany is writing guidelines for particle number concentration and size distribution measurements in air quality monitoring networks – release late 2009.
- CEN (European standards organization) started a new work group in late 2008 to work on technical recommendations for number concentration and size distribution measurement of UFP in air quality monitoring.
- The new UFP monitor will be included in both activities.

# 3. Practical Field Solutions: Design Considerations

- Available technology:
  - Sizing: DMA, ~~Diffusion Battery~~, ~~LPI~~
  - Detection: ~~CPC~~, Aerosol Electrometer
- DMA & electrometer need charger
  - ~~Radioactive, corona bipolar~~, corona unipolar

Low maintenance

Reasonable size resolution & ability to measure bimodal distributions

Best possible sensitivity

Reliable & affordable

- Use as many existing, proven parts as possible

# 3. Practical Field Solutions: UFP Monitor Principle

**Inlet**

Sampling the particles

**Unipolar Charger**

Charging the particles

**Electrostatic Classifier**

Classifying into size fractions

Quantifying the concentration

**Aerosol Electrometer**

# 3. Practical Field Solutions: UFP Monitor

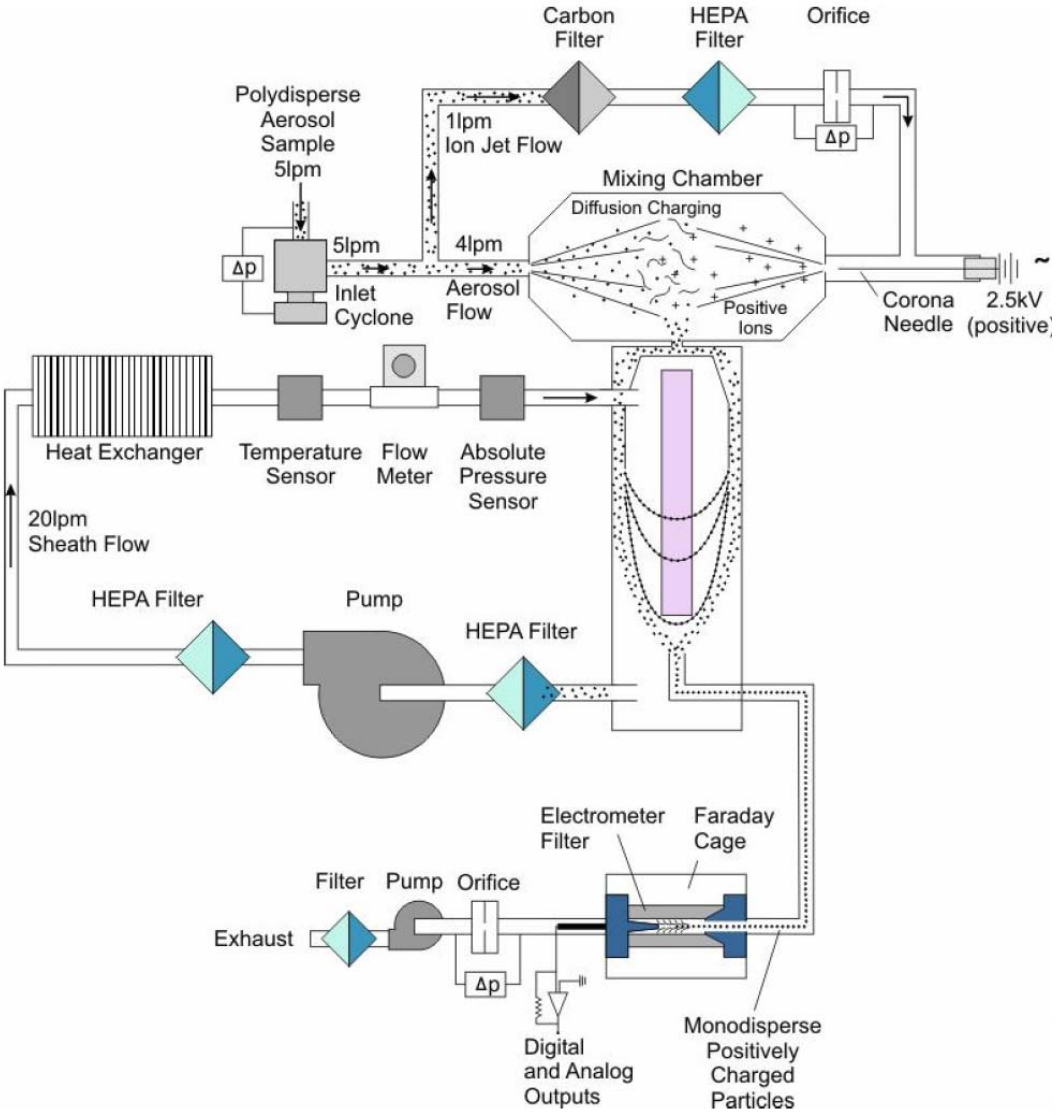



Figure 4: Flow scheme

The “engine” of the four UFP Monitor prototypes.

All parts shown in this diagram are standard TSI components.

# 3. Practical Field Solutions: Data Acquisition & Processing

- Electrometer current is measured for 32 steps of electrical mobility (DMA voltage steps)
- Based on the instrument response matrix, these currents are deconvoluted. The result is a monomodal or bimodal size distribution, described by 2 x [D50, GSD, total number concentration]
- Both the raw data and the deconvolution fit are stored in the instrument data base
- The reported size channel data are calculated from the fitted data.

# 3. Practical Field Solutions: Reported Data

- At first, the user team requested a size range from 10 nm to 1000 nm
- Data reliability considerations lead to the final size range of 20 nm to inlet size allowed (1um with sampler inlet).
- Particles between 10nm and 20nm (nucleation mode) have a high volatility, and a long term monitoring instrument with 15 minute reporting intervals is not the best tool to measure these volatiles.
- There are instruments with faster time resolutions that are better suited for measuring these volatiles.

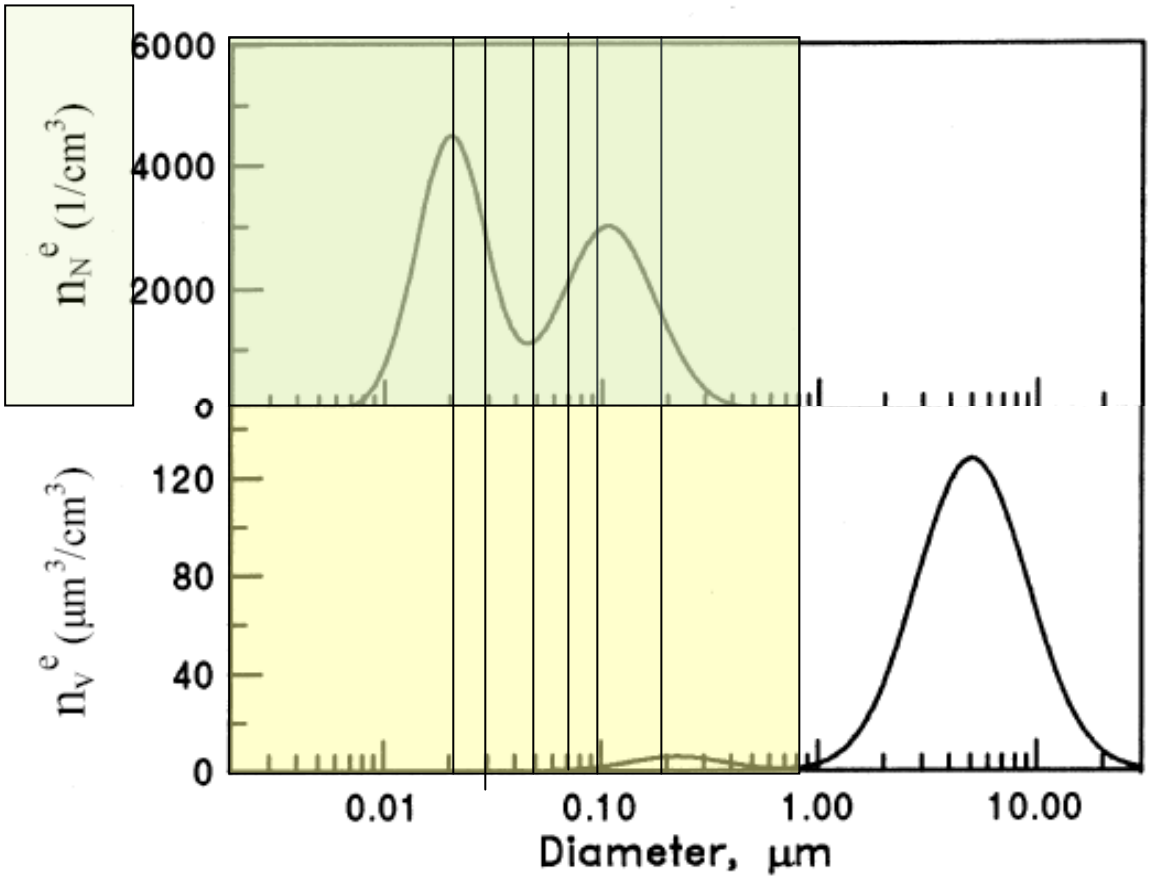
# 3. Practical Field Solutions: Reported Data

There was consensus to limit the reported data to number concentration in 6 size classes plus all necessary instrument status information.

- Comparison of already established data base structures finally lead to the size boundaries:

**I 20nm-30nm I 30nm-50nm I 50nm-70nm I 70nm-100nm I 100nm-200nm I >200nm I**

# Typical Urban Aerosol Distribution




**Number Concentrations**

**Mass Concentrations**

Ref: Seinfeld and Pandis

# 4. Initial Testing

- Compare the response of the UFP prototypes to lab-generated aerosols with SMPS
- Compare the response of the UFP prototypes to real-world urban aerosols with IfT-DMPS*)
- 1 month of co-located measurements of the UFP prototypes under real-world urban conditions

*) The IfT-DMPS was chosen here because it is a well characterized instrument already installed in the Dresden monitoring station

# 4. Initial Testing: Lab Testing

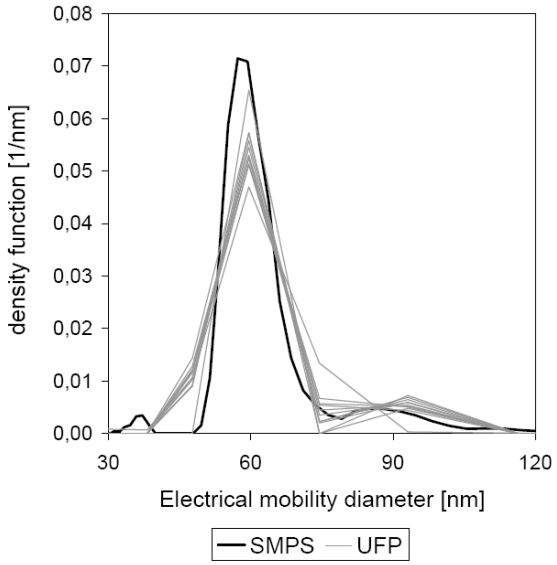



Fig. 6. Size distribution of a 60-nm-testaerosol recorded by SMPS in comparison to 12 results of UFP at concentrations between 500 - 8000 $cm^{-3}$

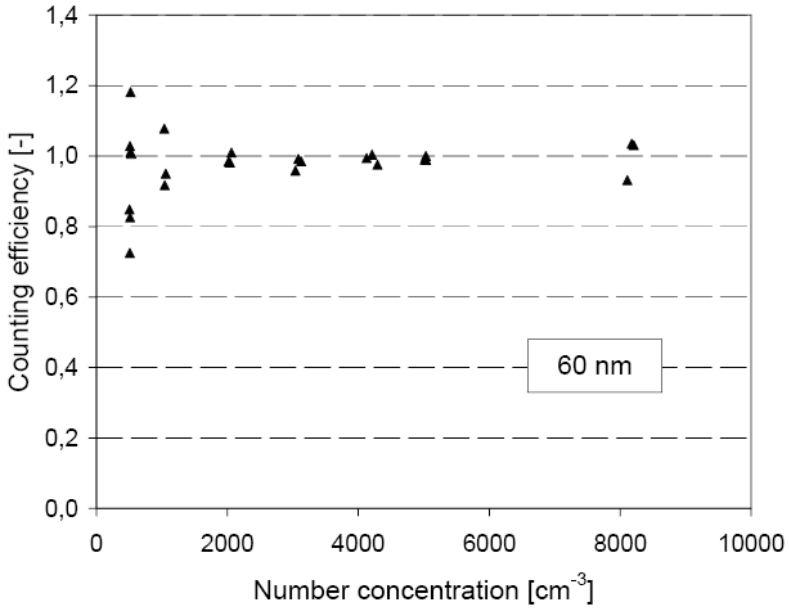



Fig. 5. Counting efficiency of the developed spectrometer

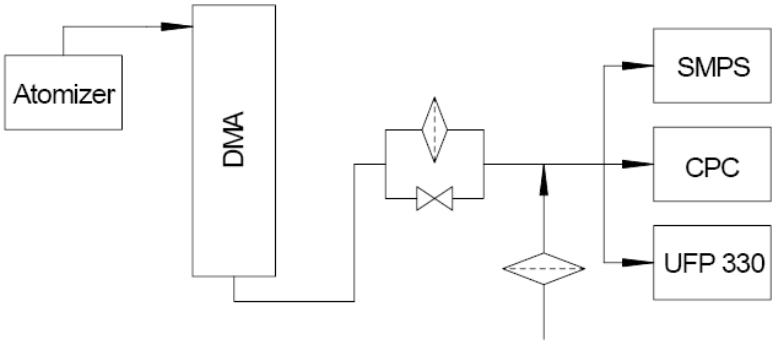



Fig. 4. Experimental setup for the calibration of the developed spectrometer



Ref: A novel device to quantify ultrafine particles in urban air; L. Hillemann et al.

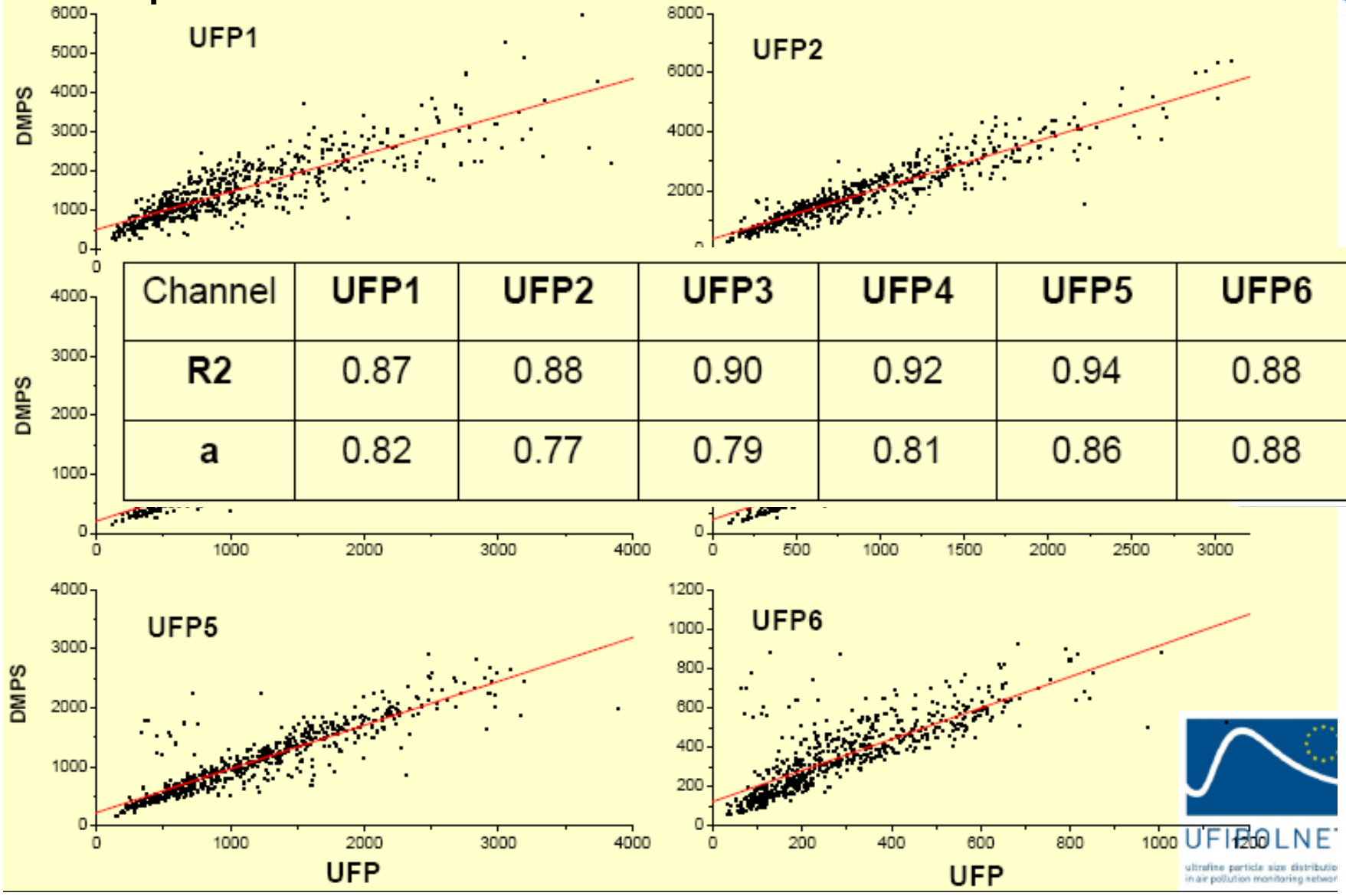
# 4. Initial Testing: Field Validation




**fig. 7.1a, b** Photos of the 4 prototypes UFP 330 Sep-2006 at the common IfT/ UfZ (Helmholtz Zentrum für Umweltforschung – UfZ) calibration test laboratory in the Eisenbahnstr. in Leipzig situated in a flat. High polluted ambient air of a street canyon was measured. (Photo: TOPAS)

# 4. Initial Testing: Field Validation Data (2)

## Comparison of UFP Monitor size classes with data from IfT-DMPS




| Channel | UFP1 | UFP2 | UFP3 | UFP4 | UFP5 | UFP6 |
|---|---|---|---|---|---|---|
| **R2** | 0.87 | 0.88 | 0.90 | 0.92 | 0.94 | 0.88 |
| **a** | 0.82 | 0.77 | 0.79 | 0.81 | 0.86 | 0.88 |

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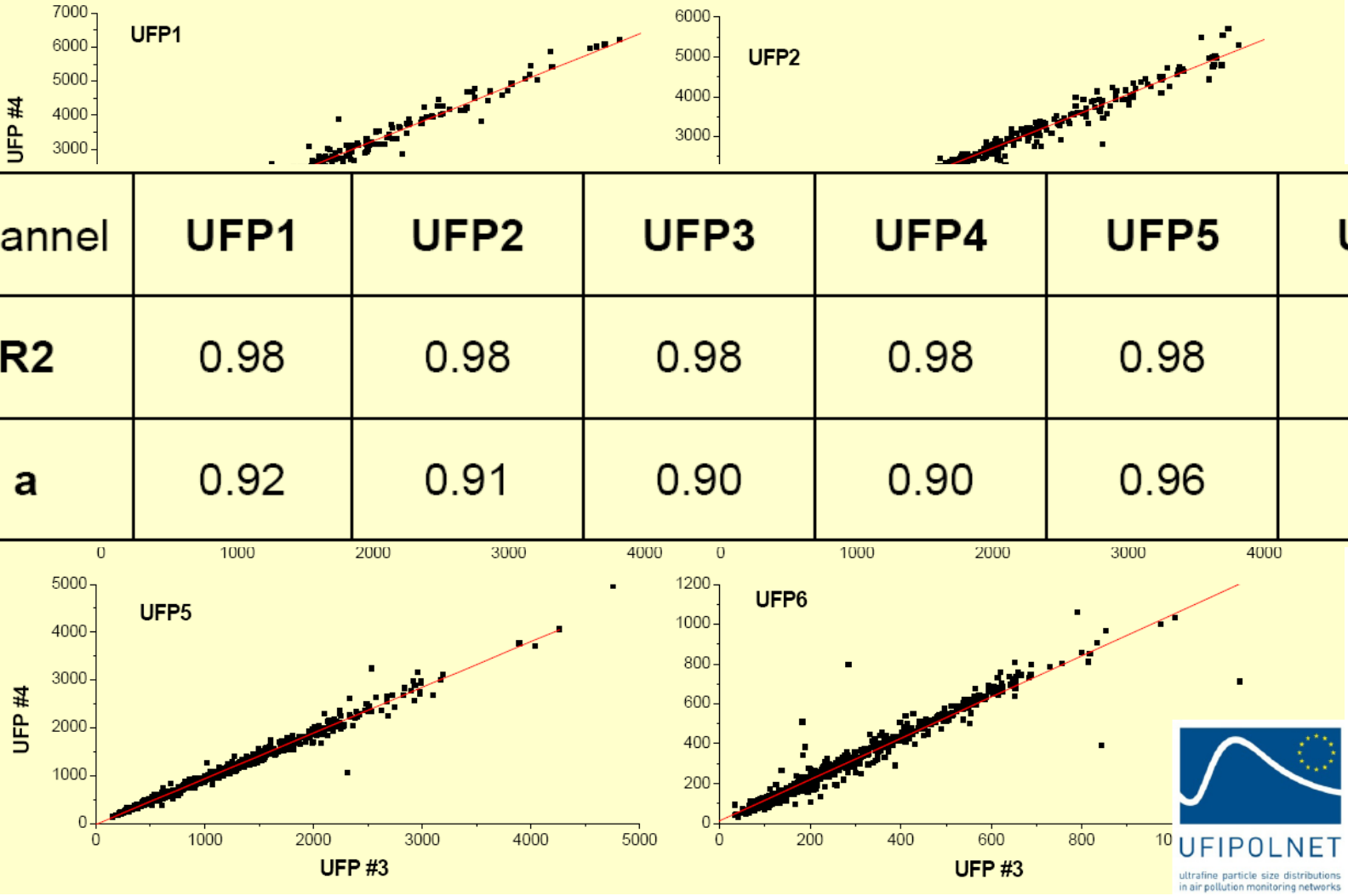
# 4. Initial Testing: UFP Co-Located Instruments

## Comparison of two UFP Monitors for six size classes




| Channel | UFP1 | UFP2 | UFP3 | UFP4 | UFP5 | UFP6 |
|---|---|---|---|---|---|---|
| **R2** | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.94 |
| **a** | 0.92 | 0.91 | 0.90 | 0.90 | 0.96 | 1.04 |

*Source: Wehner, et. al., 2007*

# 4. Initial Testing: Field Evaluation at 4 locations in Europe


**Stockholm**:
Hornsgatan (street canyon)

**Dresden**:
Schlesischer Platz (main crossing)

**Prague**:
Strahovský tunnel (above tunnel exit)

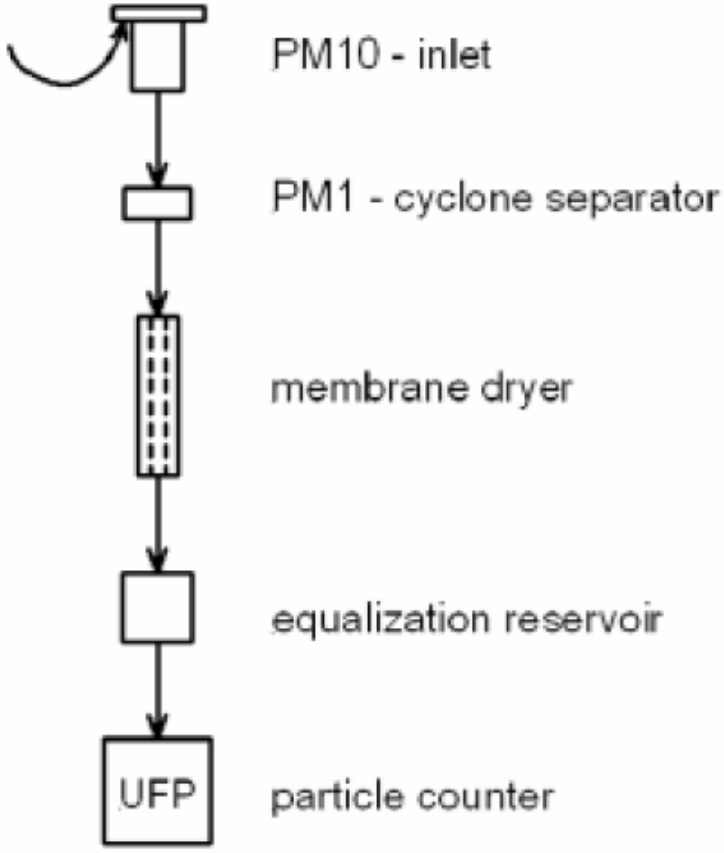
**Augsburg**:
Friedberger Straße (urban background)

# 4. Initial Testing: June 2007 to June 2008 Period

- The 1 year of testing was designed to…
  - Demonstrate data availability of the devices
  - Learn as much as possible about necessary maintenance and make recommendations
  - Collect data for a correlation analysis with other measured contaminants
- 1 instrument (Dresden) was monthly maintained and re-checked in the lab
- 3 other instruments were “left alone” without any maintenance

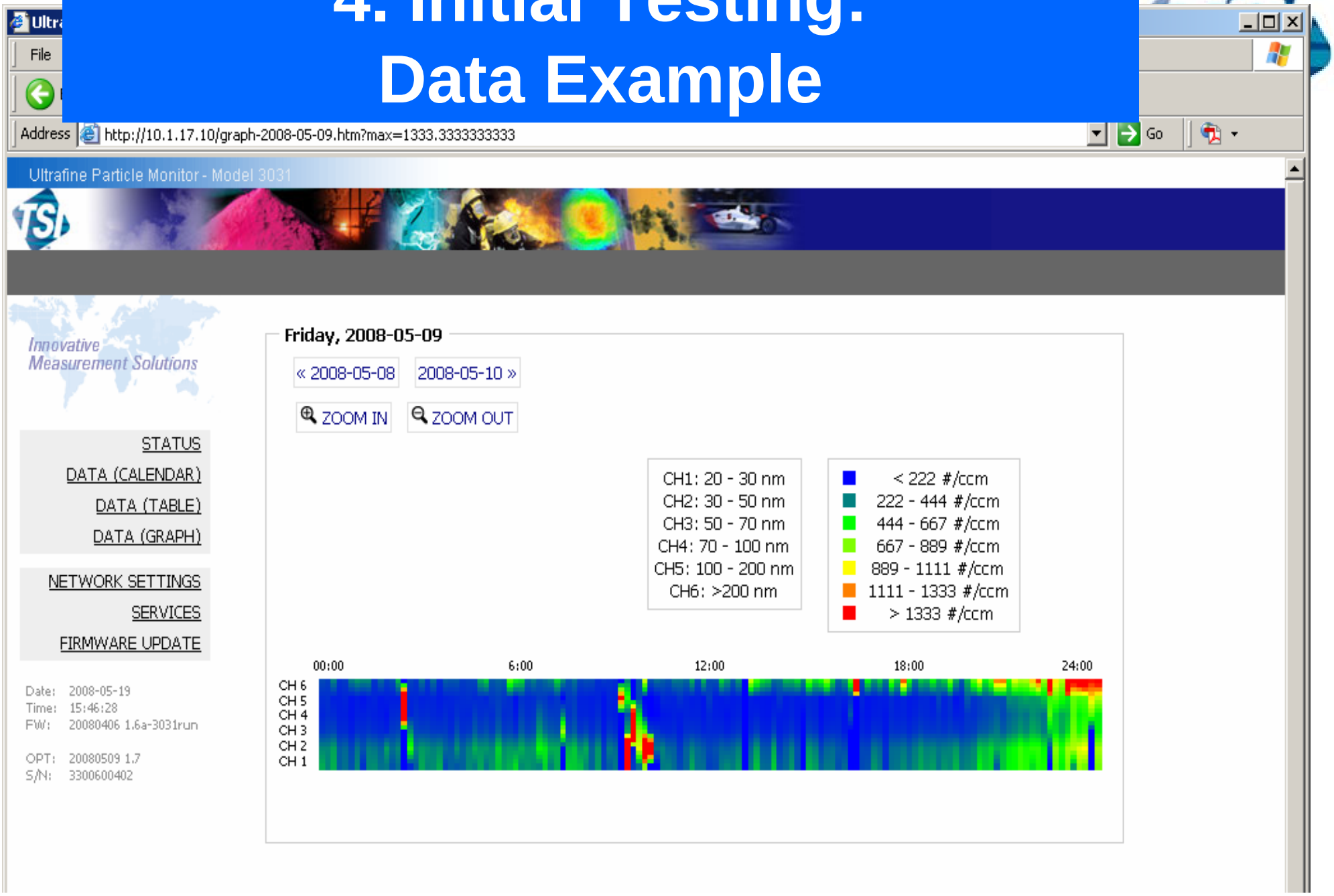
# 4. Initial Testing: UFIPOLNET Sampling

**To ensure best possible data comparability, all four sites used identical sampling systems**




Sampling system of UFP 330 implemented at all 4 stations (Hillemann/Wehner)

# 4. Initial Testing: Data Example






Ref: UFIPOLNET Final Report

# 4. Initial Testing: Data Example

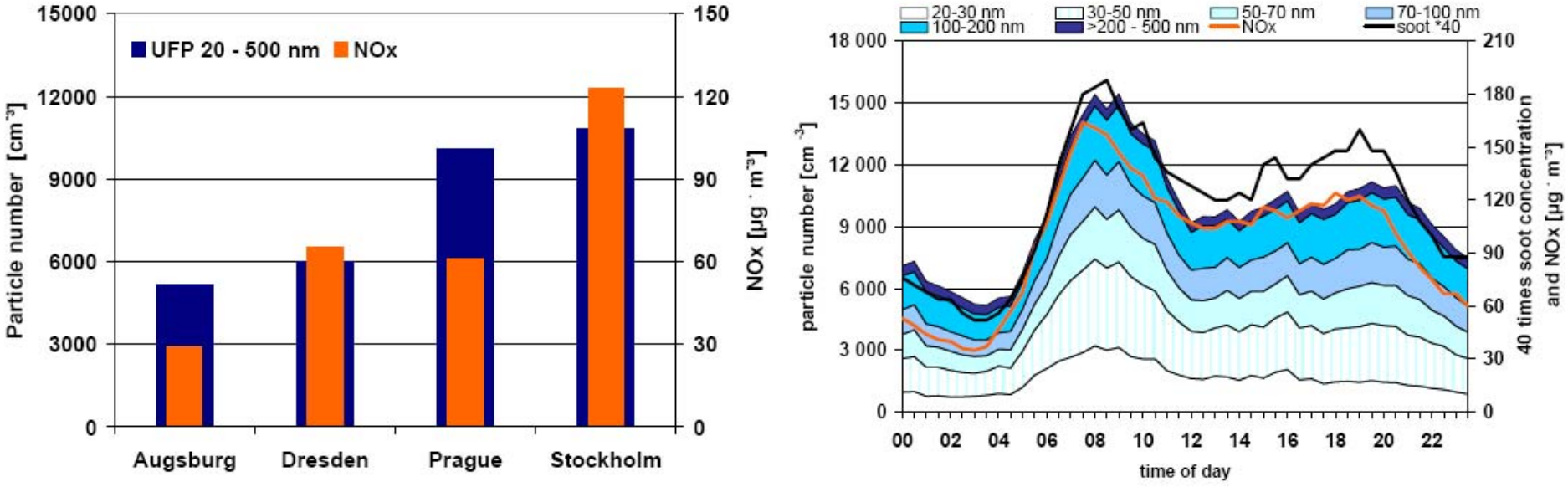



**fig. 7.3** **a** Comparison of 4 measuring stations: Jun/07 averages of particle numbers and NOx. **b** Dresden half hour average particle number concentrations UFP 330 compared to NOx, soot b average weekday 24/1 – 19/Mar/07

As expected, UFP and NOx correlate well for Stockholm and Dresden, where traffic is the main source of UFP. For urban background (Augsburg), the correlation is poor.

Surprisingly, Prague also fell out of this pattern. This will be further investigated.



Ref: UFIPOLNET Final Report

# 4. Initial Testing: Important Findings

- All data were collected in a central data base at IfT Leipzig
- The systematic data correlation analysis for the four sites is underway and will be published by the UFIPOLNET team.
- All four UFP prototypes reached data availability of more than 90%
  - Dresden: corrected for planned laboratory checks
- No reliability problems were reported during the 12 months

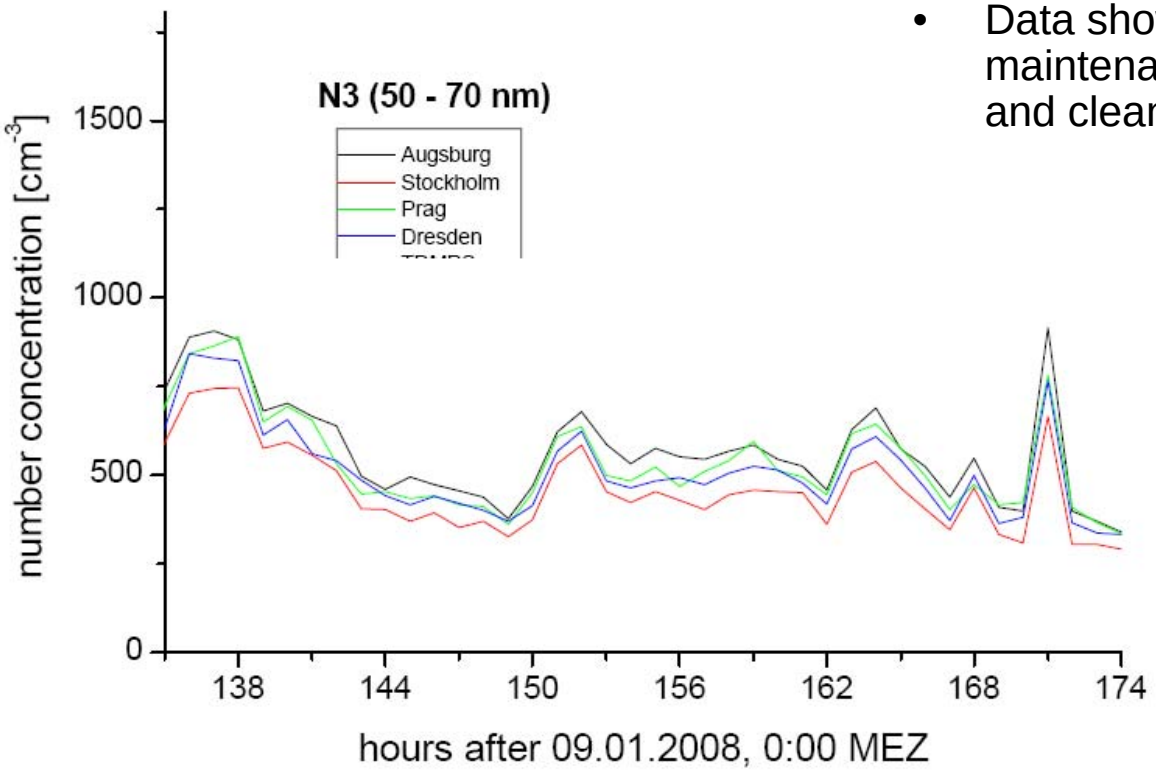
# 4. Initial Testing …After 12 Months in the Field

- The Augsburg instrument (urban background) still compared well (+/- 10%) to the Dresden instrument (monthly check and maintenance)
- The Stockholm instrument (very high UFP concentration) showed approximately 50% decrease in sensitivity
  - Reason was identified in internal soiling of HV connections plus break through of carbon filter
- The Prague instrument (medium UFP concentration) showed some decrease in sensitivity
  - Reason was identified in internal soiling of HV connections

# 4. Initial Testing: Maintenance

- The identified problems (soiled HV connections, carbon filter) were corrected
  - This brought all instruments into +/- 20% agreement
- All other filters were exchanged and the DMA columns were cleaned
  - After this maintenance, the all instruments were back to their initial +/- 10% agreement

# 4. Initial Testing: Final Comparison




- Data shown are after maintenance (filter exchange and cleaning, no adjustments)

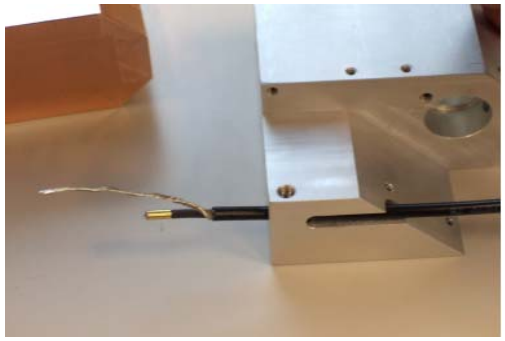
Comparison of 4 UFP 330, particle number concentrations 50 - 70 nm Jan/08 showing comparable results +/- 10%.

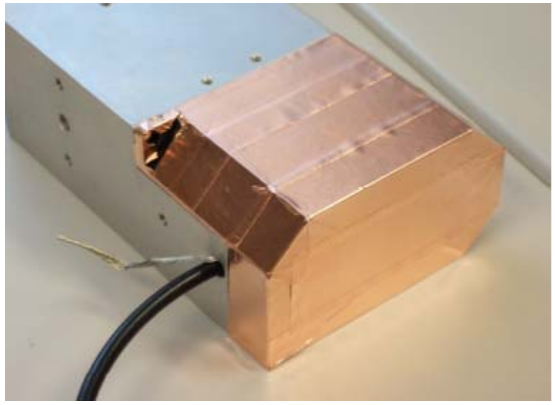
# 5. Summary & Next Steps: UFP Monitor Meets Design Objectives

- Long-term, unattended operation
- Low start-up and operating costs
- No working fluids, no radioactive source
- Continuous monitoring with output every 15 min
- Convenient data management with remote access via the Internet
- Comprehensive environmental sampling system

# 5. Summary & Next Steps: Updates Based on What Was Learned

- Design changes were made to avoid problems with HV connections
- Finally, the 12 month experience resulted in recommendations for preventive maintenance
- SOPs were corrected to reflect experience including an Annual Consumables Kit (Filter changes) ⟶





# 5. Next Steps: Based on What Was Learned

-The four sites will continue to collect data with the UFP prototypes for at least 5 more years.

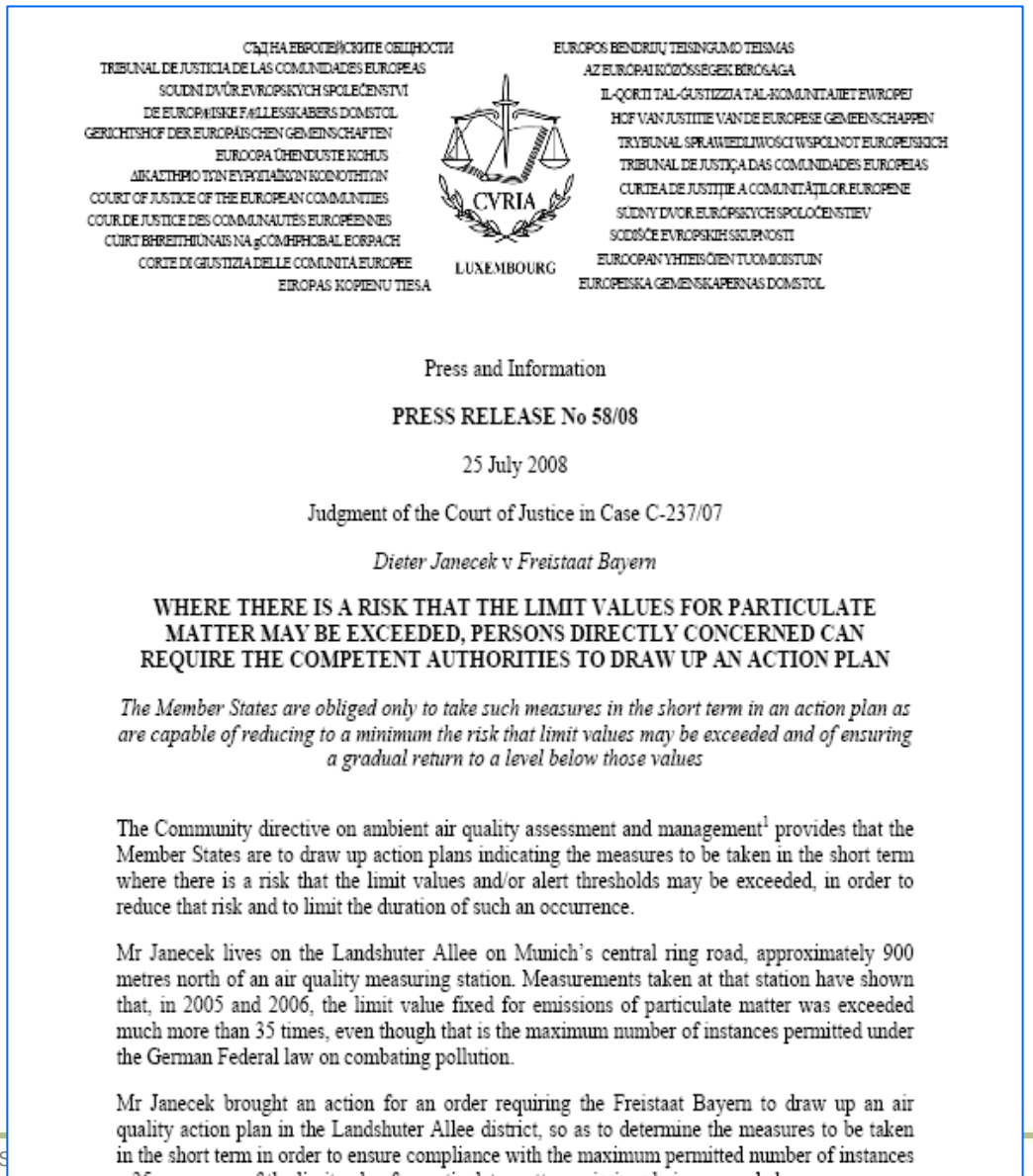
- Additional Sites will be installed over the next 2 years to collect further data.

- The EU has established the starting point for particle number based limits for emissions of UFP's from light duty vehicles with diesel engines
(Euro 5: 6 x 1011 particles/km – phased in – 2010 to 2012)

- As this change is phased in over the next three years, the new UFP monitoring network will be used as a tool to measure the improvement in air quality.

# UFP Monitor Already Spurs Public Interest in Germany

- July, 2008 - The European Court of Justice was asked to rule on the right of an EU citizen to expect EU directives to deliver action and improvement where exceedences are found. In a landmark ruling the Courts ruled that a citizen may require the competent authorities to draw up an action plan to resolve the situation.
- In other words EU citizens, individually or collectively have a right to demand that corrective measures be put in place. This ruling was in respect of "fine particles"



СЪД НА ЕВРОПЕЙСКИТЕ ОБЩНОСТИ
TRIBUNAL DE JUSTICIA DE LAS COMUNIDADES EUROPEAS
SOUDNÍ DVŮR EVROPSKÝCH SPOLEČENSTVÍ
DE EUROPÆISKE FÆLLESSKABERS DOMSTOL
GERICHTSHOF DER EUROPÄISCHEN GEMEINSCHAFTEN
EUROOPA ÜHENDUSTE KOHUS
ΔΙΚΑΣΤΗΡΙΟ ΤΩΝ ΕΥΡΩΠΑΪΚΩΝ ΚΟΙΝΟΤΗΤΩΝ
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HOF VAN JUSTITIE VAN DE EUROPESE GEMEENSCHAPPEN
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Press and Information

**PRESS RELEASE No 58/08**

25 July 2008

Judgment of the Court of Justice in Case C-237/07

*Dieter Janecek* v *Freistaat Bayern*

**WHERE THERE IS A RISK THAT THE LIMIT VALUES FOR PARTICULATE MATTER MAY BE EXCEEDED, PERSONS DIRECTLY CONCERNED CAN REQUIRE THE COMPETENT AUTHORITIES TO DRAW UP AN ACTION PLAN**

*The Member States are obliged only to take such measures in the short term in an action plan as are capable of reducing to a minimum the risk that limit values may be exceeded and of ensuring a gradual return to a level below those values*

The Community directive on ambient air quality assessment and management[1] provides that the Member States are to draw up action plans indicating the measures to be taken in the short term where there is a risk that the limit values and/or alert thresholds may be exceeded, in order to reduce that risk and to limit the duration of such an occurrence.

Mr Janecek lives on the Landshuter Allee on Munich's central ring road, approximately 900 metres north of an air quality measuring station. Measurements taken at that station have shown that, in 2005 and 2006, the limit value fixed for emissions of particulate matter was exceeded much more than 35 times, even though that is the maximum number of instances permitted under the German Federal law on combating pollution.

Mr Janecek brought an action for an order requiring the Freistaat Bayern to draw up an air quality action plan in the Landshuter Allee district, so as to determine the measures to be taken in the short term in order to ensure compliance with the maximum permitted number of instances

# 6. Questions ?

# Recommended Maintenance & Annual Consumables

| Description | Qty/instrument | Total Annual Usage |
|---|---|---|
| HEPA Capsule Filter<br>Change every 6 months | 2 | 4 |
| Balston DFU-BX Filter<br>Change every 3 months | 2 | 8 |
| Carbon Capsule Filter<br>Change every 3 months | 1 | 4 |
| Wire Core Micro-fiber Filter<br>Change once per year | 1 | 1 |

# EU Pamphlet


The UFIPOLNET Laymen  Report describes the project in brief

# End of Part I