D. Dahmann

Institut für Gefahrstoff-Forschung der BBG
Bochum
Germany

Nanoparticle emission measurement at the working place

Nanoparticle measurement in workplace air

Dirk Dahmann, Bochum

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- Current state of particle measurement in the workplace
  - sampling and measurement procedures
  - standardisation
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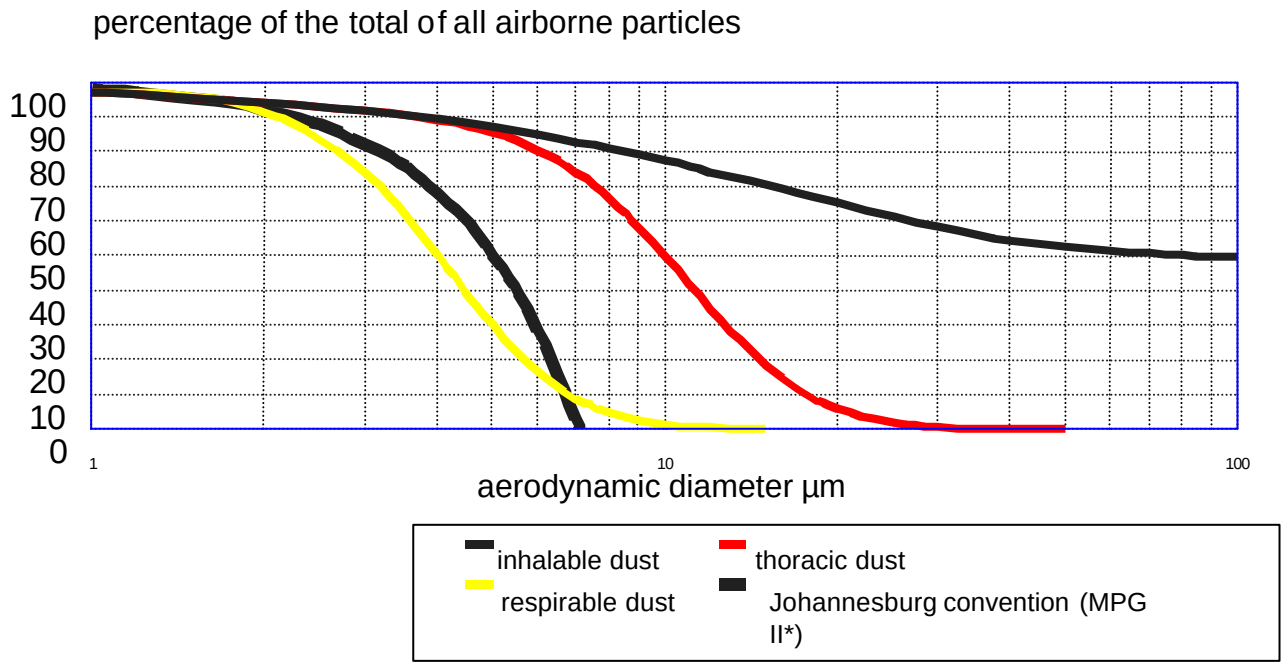
Particle measurement in workplaces - current state

- A very detailed landscape of mass-based threshold limits (particles and „chemical contents“) as well as sampling and measurement procedures
- A well developed standardization scene (CEN, ISO)
- A wealth of experience (exposure data, sampling and measurement know-how, health effects, etc.)

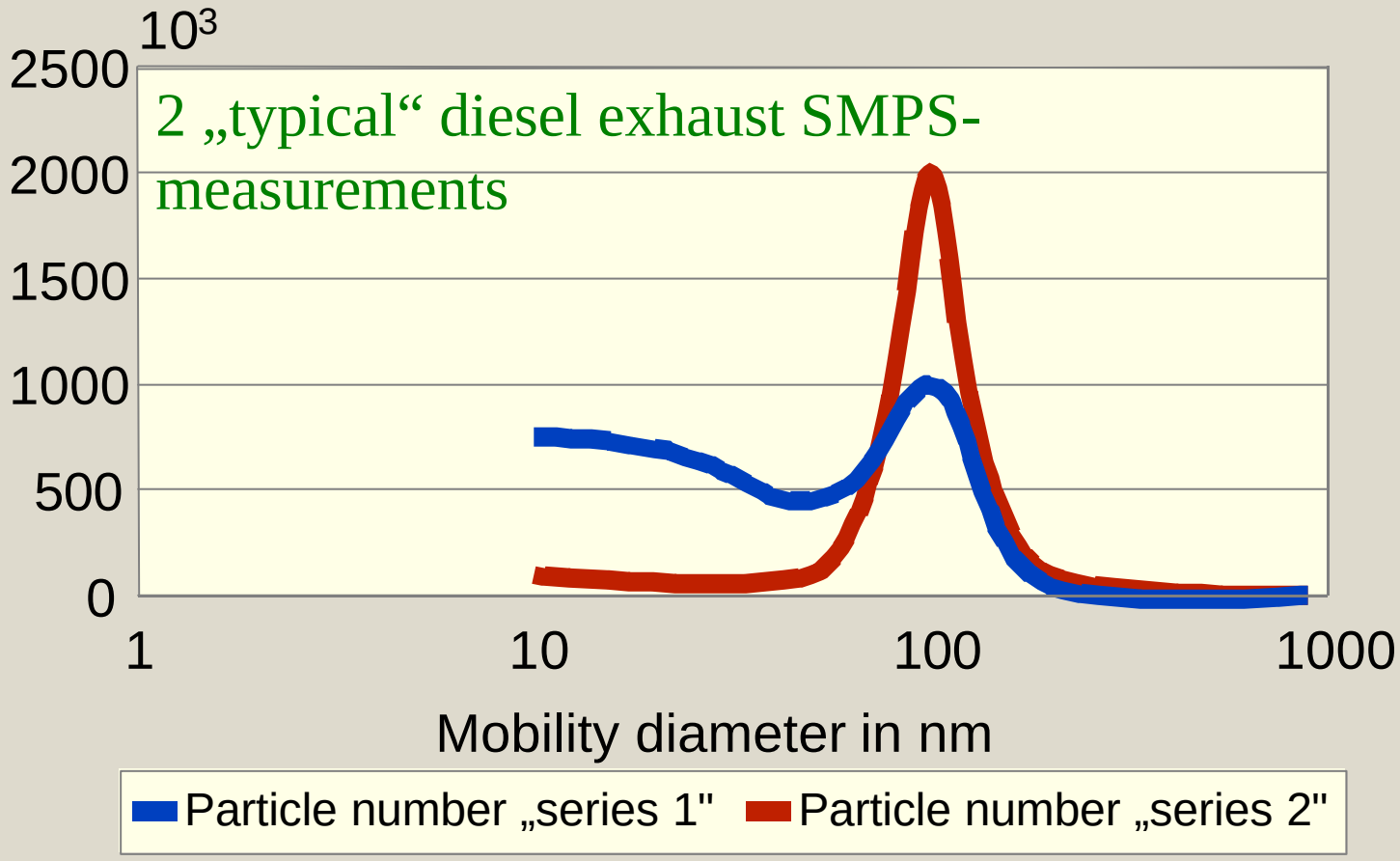
Sampling Conventions (EN 481)



Samplers

- Respirable dust
  - stationary (elutriators, cyclones, special cases)
  - personal (mostly cyclones)
- Inhalable dust
  - stationary
  - personal
- Standards
  - EN 481 (sampling conventions)
  - prEN 13205 (sampler performance requirements)

What is happening below 1 µm?



Instruments - Principles

- SMPS (DMA + CNC)
- ELPI
- PAS
- DC
- NanoMet (PAS + DC + tunable dilution)

- Standards
  - none

Problems:

- Currently diesel particulate matter (dpm) as well as welding fume in workplaces is measured with mass based procedures though there is a lot of evidence that particle mass may not be the relevant property with respect to health problems
- The particle number based procedures are currently not as well developed with respect to standardization as the mass based ones.

Important questions for workplace exposure monitoring:

- Are existing threshold limits exceeded or not? (Compliance)
- What is the level of exposure in comparison to health effects observed in exposed workers? (Epidemiology)
- What are „low“ („high“) levels of exposure with respect to the state of art of emission control or personal protective devices? (Prevention and Compensation)

To answer these questions measurement has to be:

- ... true
  (as close as possible to the „true“ value, whatever this is)
- ... reliable
  (with as few as possible random deviations)
- ... comparable
  (give „very similar“ results if done the same way by different people)

Additionally:

- ... attempts should be made in order to show how „new“ techniques are related to existing data in order not to lose available information!
  - Example: A huge amount of conimetric data existed in the German uranium mining of the former GDR. How do they „translate“ into gravimetric ones?
  - Example II: Are measurements of respirable dust related to PM 10 measurements and if ‚yes‘ how?

Problems with this approach:

- Sometimes there is (or seems to be) no physical correlation between the two principles.
  - Example: conimetry and cyclone or elutriator pre-separation
- Nevertheless, under very similar circumstances (like in one specific mining environment) it may be possible to find emiprical „recalculation functions“ and thus use the existing data.

What does this mean for diesel particles?

- Is mass-based measurement (like respirable dust sampling in connection with coulometry) really obsolete and irrelevant?

Answer:

- Maybe!
- But maybe not!
  - In cases of very similar particle number distributions mass based sampling would give very comparable answers to the question of „high“ or „low“ exposure compared to number based one.

Coulometry

- Also, coulometry is the reference method.
  - It is extremely well validated and will even be standardized in a short time.
  - It did provide a wealth of data which have successfully been used for prevention purposes.
  - The initial objections against it with respect to engine development seem to have been premature! (Modern engine do have low mass emissions AND low particle number emissions)

Current activities

- Use SMPS to measure typical exposure levels in workplaces to get basic ideas about possible problems (BIA, IGF, AUVA, ETH etc)
- Evaluate SMPS for possibilities of standardization (interlaboratory test in September 2000 with 10 different SMPS-devices in a diesel test stand in Dortmund)
- Evaluate PAS-systems in comparison to coulometric data (same test stand as above)

Project: PAS-evaluation

- Sponsored by Hauptverband der Gewerblichen Berufsgenossenschaften, St. Augustin, Germany
- How do PAS results compare to those of coulometry?
- Do recalculation algorithms to the coulometric results exist?
- Are the sensors behaving reliably in different workplace environments?
- How independent of the type of diesel source are their signals?
- Duration: Two years
- Partners:
  - ETH, Zürich, Switzerland and IGF, Bochum, Germany


EcoChem
PAS 2000
EcoChem
PAS 2000

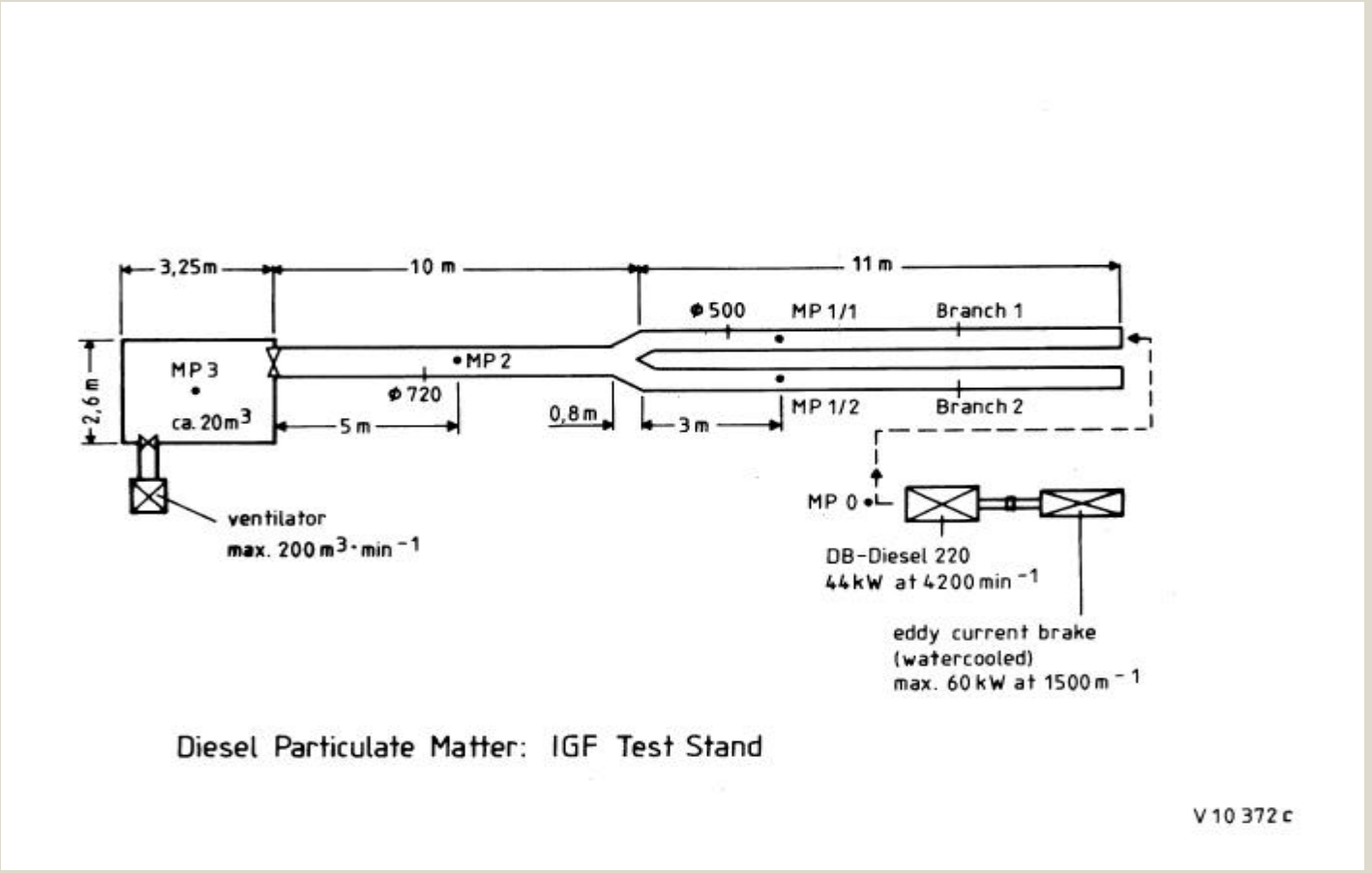
Principle methods:

- Field tests!
  - Parallel sampling and measurements in real workplaces
- Test chamber measurements!
  - Controlled conditions
  - stepped approach by variation of selected aerosol properties
- Both test methods should interact!

Test chamber:

- diesel engine: (45 kW at 4200rpm, aspiration, eddy current brake)
- flow partitioning of raw exhaust
- y-shaped duct system (21 m, addition of different aerosol components possible)
- measuring chamber
  (20 m^3, <0.1 m/sec flow)
- ventilator (adjustable, <250 m^3/min)

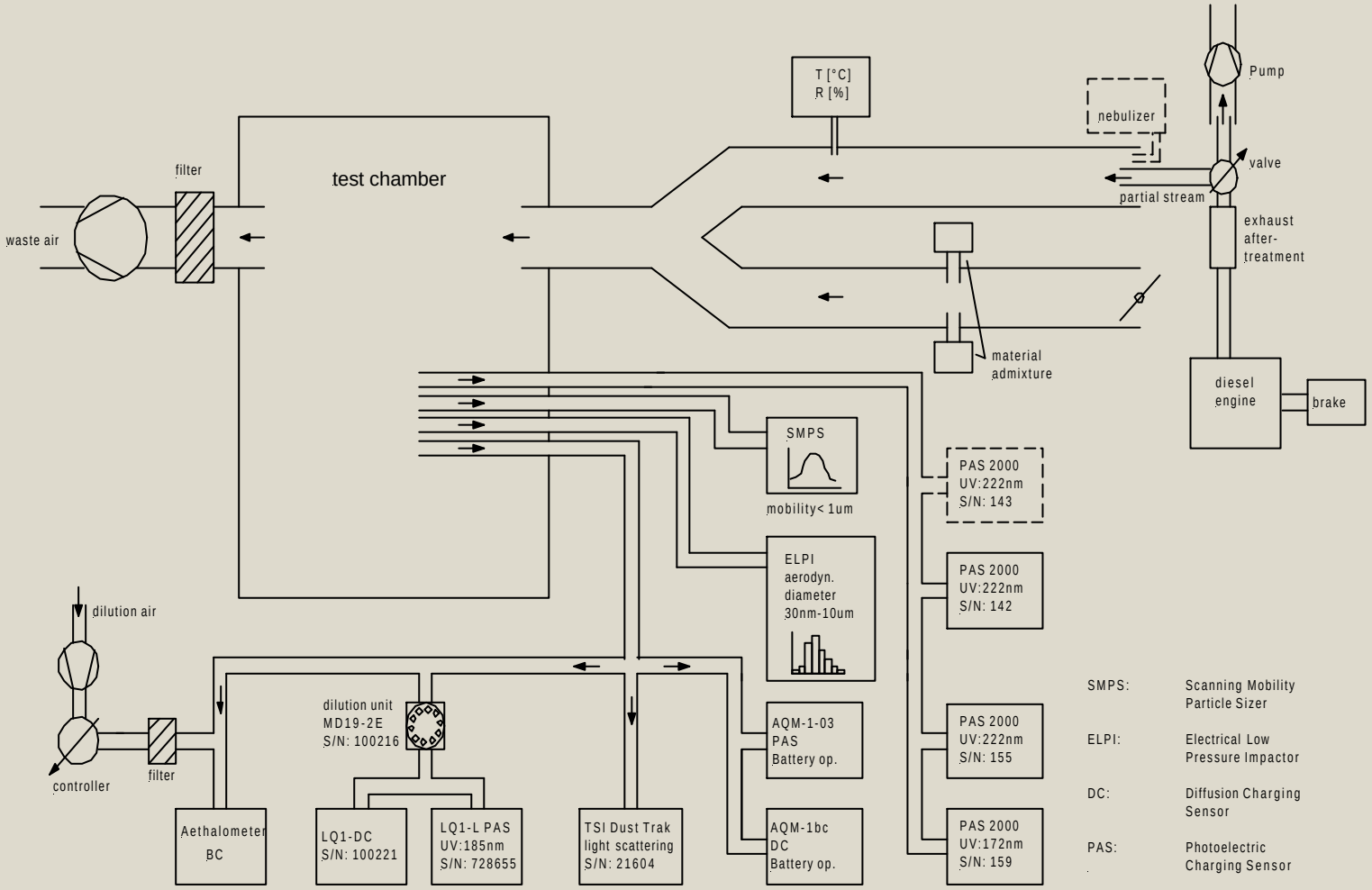
Test channel - principle setup



Instruments and Samplers in the Tests

Samplers	**PAS-Sensors**	**Others**
2x MPG II static samplers (46.5 l/min)	172 nm	2x DC
2X PM4 F static samplers (4 m^3/h)	185 nm	ELPI
2 PGP FSP pds, 2 l/min	208 nm	SMPS
	2x 222 nm	Aethalometer Dust Trak Light scattering

Measurement systems in the Tests



Work programme: test chamber

- Verify homogeneity and stability of aerosol generated
- Measure the performance of the filter samplers and decide on the reference method
- Compare the signals of the PAS-sensors with the coulometrically determined ec-concentrations at varying levels

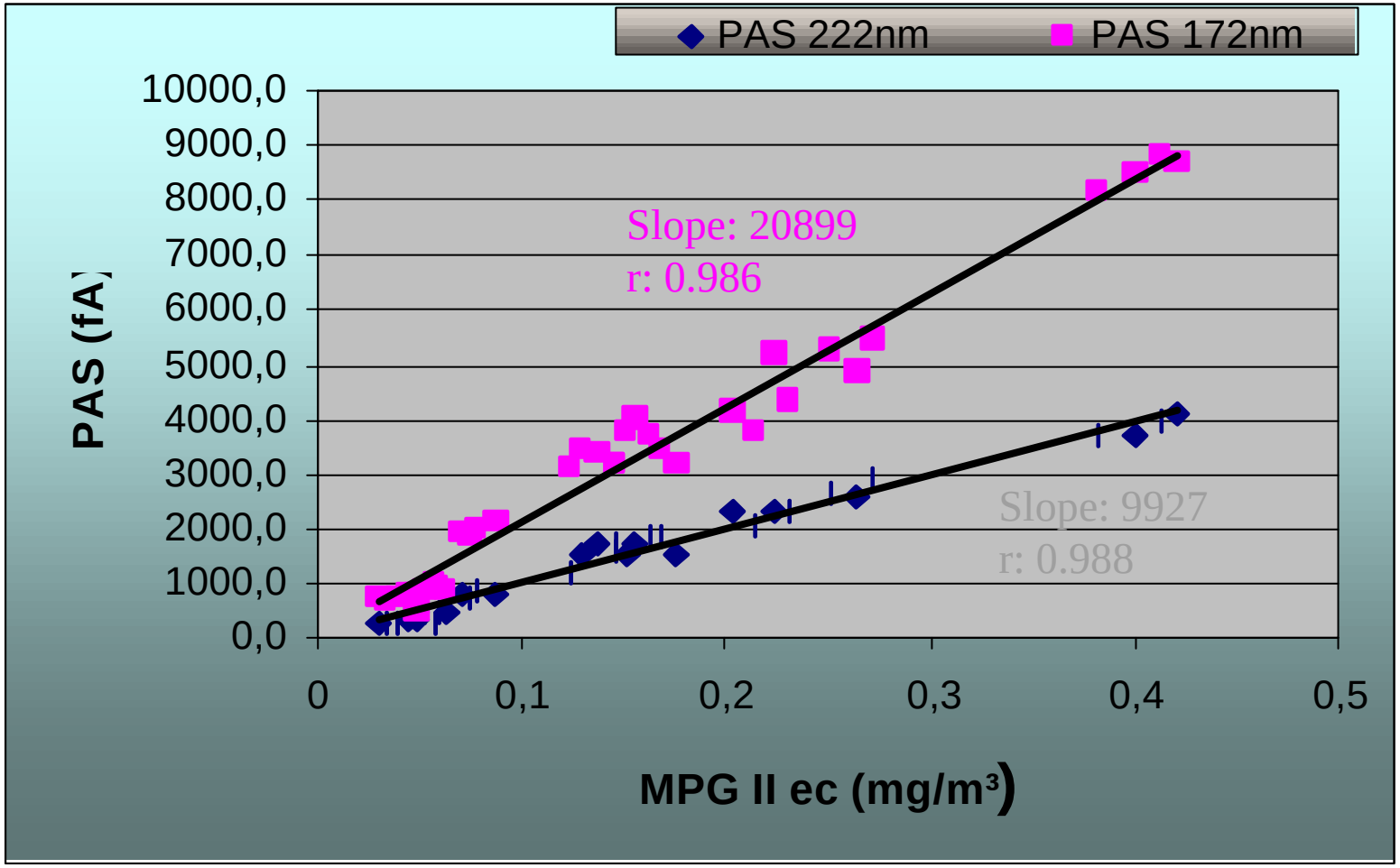
Homogeneity of the test aerosol

Overall Uncertainties (EN 482)

Conc. Levels\Samplers	**MPG II**	PM4 F
0.5 mg/m³	**7 %**	8 %
0.2 mg/m³	**3.2 %**	7 %
0.1 mg/m³	**3.5 %**	7 %
0.05 mg/m³	**13 %**	14 %

1. The sampling works surprisingly well
2. The test aerosol is sufficiently stable

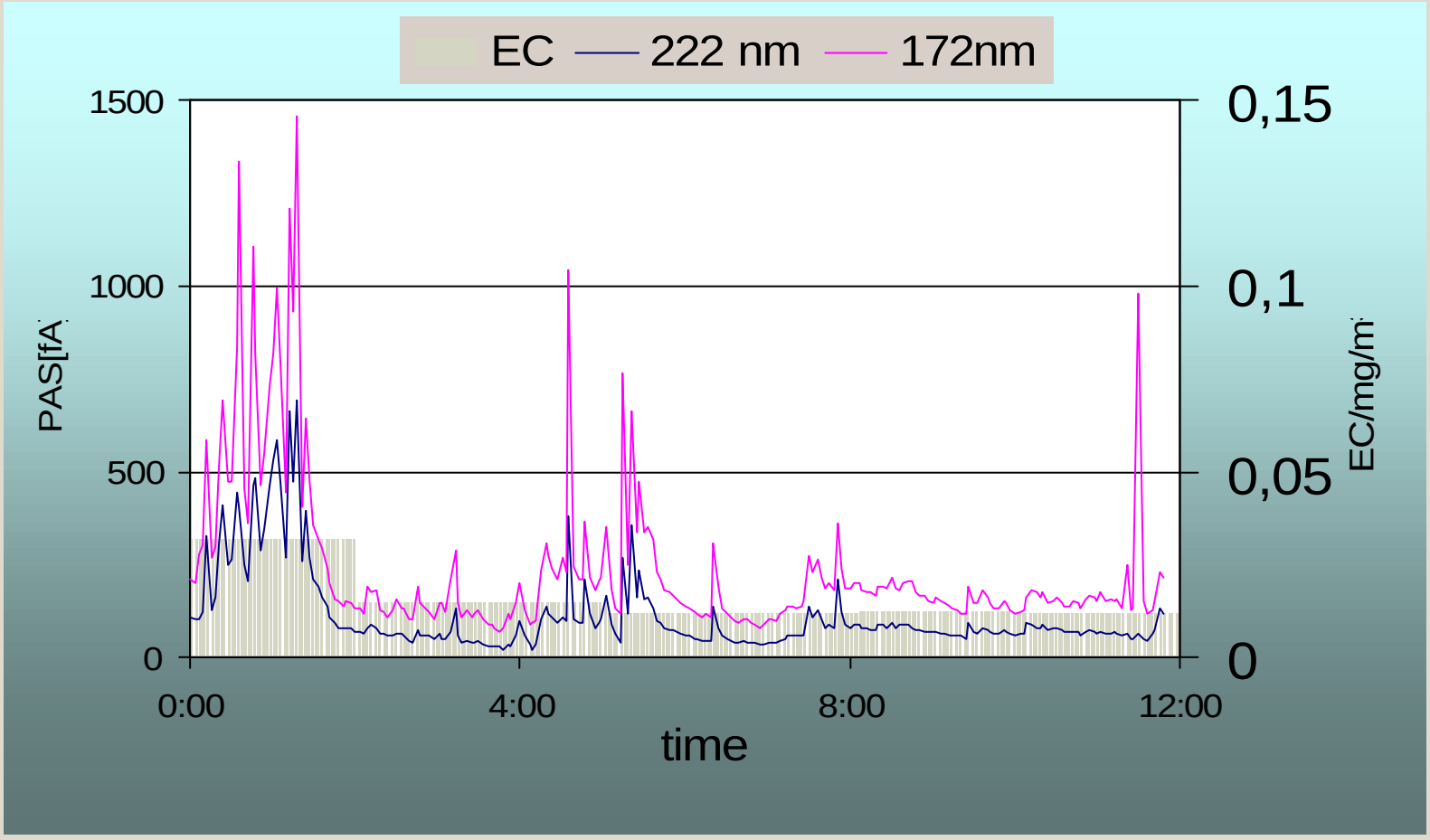
Correlations of two selected PAS sensors - Examples of one measurement series (N=35)



Field measurements

- A 24-h measurement campaign in a major bus repair shop:
  - the whole train of instruments (see above) went to the site
  - respirable dust sampling was performed in longer intervals
  - the sensors were used throughout the whole period

Field measurements - example of a 12 h measuring episode



Conclusions (up to now)

- The test chamber is well suited for the task providing homogenuous and well defined aerosols over extended periods
- The different PAS monitors (UV-lamps) have differing (however constant) calibration factors.
- The PAS sensors provide very valuable informations for workplace measurements
- There seem to be recalculation algorithms for PAS signals with respect to ec-concentrations.

What needs to be done?

- Find out, how differing diesel sources (e.g. engine) change the nature of the PAS signals (and the ec-concentrations).
- Find out, how these effects (if any) will influence field measurements.
- Give recommendations for the application of PAS-sensors in workplace field measurements.

Thank you for your attention!