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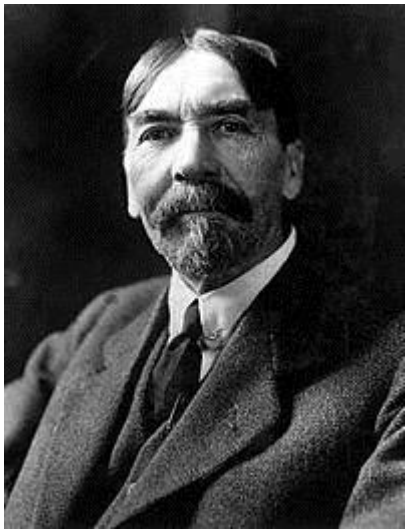
# Assessment of personal exposure to airborne nanomaterials - Lessons learned during the project

*Institut für Energie- und Umwelttechnik e.V.*

*Air Quality & Filtration*

Fifth nanoSafeConference
Grenoble, November 8th, 2016

*"The outcome of any serious research can only be to make two questions grow where only one question grew before"*



Thorstein Veblen (1857–1929)

# Assessment of Individual Exposure to manufactured nanomaterials by means of personal monitors and samplers

Funded in the framework of the SIINN Era-Net program in EU-FP7

Duration: June 2013 – May 2016

7 partners + 1 subcontractor from 5 countries

# Personal monitors

http://www.nanoindex.eu/wp-content/uploads/2016/06/Nano_Brosch%C3%BCre.pdf

| INSTRUMENT ► | MINIDISC DISCMINI | NANOTRACER | | PARTECTOR | PUFP C100 | PUFP C200 | MICROAETH AE51 |
|---|---|---|---|---|---|---|---|
| |  |  | |  |  |  |  |
| SIZE (H x W x D) (cm x cm x cm) | 18 x 9 x 4.5 | 16.5 x 9.5 x 3 | | 13.4 x 7.8 x 2.9 | 19 x 11 x 7 | 13 x 10 x 7 | 11.7 x 6.6 x 3.8 |
| WEIGHT (g) | 670 | 750 | | 400 | 1,000 | 750 | 280 |
| PARTICLE SIZE RANGE (nm) | 10–300 | Fast mode 20–120 | Advanced mode 10–300 | 10–10,000 | ≥ 4.5 | | – |
| CONCENTRATION RANGE | $10^3$–$10^6$ #/cm³ | 0–$10^6$ #/cm³ | | 0–2*$10^4$ µm²/cm³ | 0–2*$10^5$ #/cm³ | | 0–1 mg BC/m³ |
| METRIC | NC/$d_p$/LDSA | NC | NC/$d_p$/LDSA | LDSA | NC | | Black Carbon concentration |
| ACCURACY | ± 30% | ± 1,500 cm$^{-3}$ | | ± 20% | ± 10% | | ±1 µg BC/m³ |
| SAMPLE FLOW (lpm) | 1 | 0.3–0.4 | | 0.5 | 0.3 | | 0.05/0.1/0.15/0.2 |
| TIME RESOLUTION (s) | 1 | 3 | 16 | 1 | 1 | | 1/10/30/60/300 |
| BATTERY LIFE TIME (h) | 6–8 | 7 | | 15 | 3.3– 6 | | 6–24 |

# Personal samplers

http://www.nanoindex.eu/wp-content/uploads/2016/06/Nano_Brasch%C3%BCre.pdf

| INSTRUMENT | PGP | NANOBADGE | | NRD | TEM PARTECTOR | ESPNANO 100 | TPS |
|---|---|---|---|---|---|---|---|
| |  |  | |  |  |  |  |
| | | 2013 | 2015 | | | | |
| RANGE (nm) | | | | | | range | |
| SAMPLE FLOW (lpm) | 2 | 0.6 | 1 | 2.5 | 0.45 | 0.1 | 0.001–0.01 |
| SUBSTRATE | gold-coated track-etch membrane filter | polycarbonate track-etched membrane filter quartz filter | | nylon mesh screens | TEM grid | TEM grid metallic/silicon substrate | nickel TEM grid |
| BATTERY LIFE TIME (h) | depends on the pump | > 8 | | depends on the pump | 15 | 6–24 | 8 |

(1) Depends on model (E, A or FAP)

Plenary presentation by Rapahël de Thoury on Thursday morning at 8 am

# Lesson 1:

# Size matters

# Size matters

FMPS

Personal Samplers/Monitors


**Miniaturization**

What do we need to compromise?

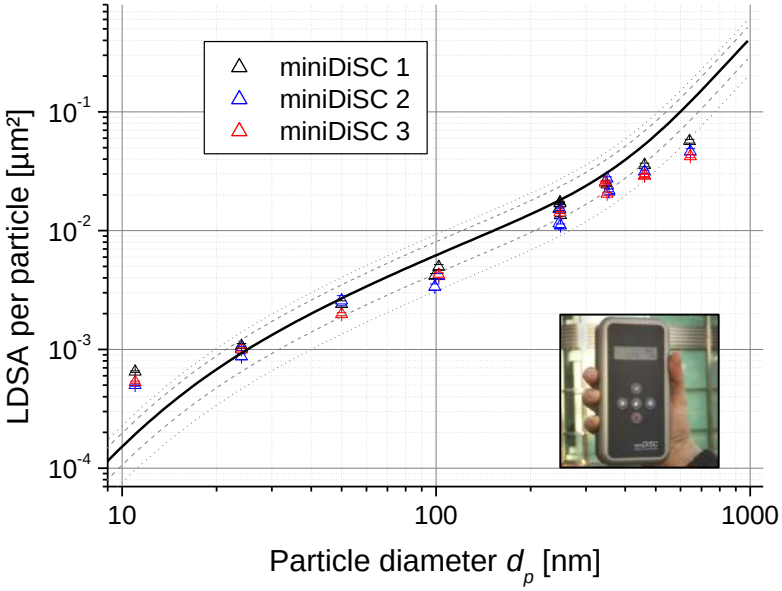
# Compromise

| Instrument | Metric(s) | Size range [nm] | Time resolution | Size resolution |
|---|---|---|---|---|
| **SMPS** | Size distribution | 2.5 – 1,000 nm | 30 s to several minutes | Up to 128 ch. per decade |
| **FMPS** | Size distribution | 5.6 – 560 nm | 1 s | 16 ch. per decade |
| **Personal monitors** | Number, LDSA and/or mean size | 20 -400 nm | 1 – 16 s | None |
| **Personal samplers** | Mass conc., chemical comp. | $< d_{50}$ | Typ. several hours (full shift) | None |

**Compromise: Information wealth and size resolution**

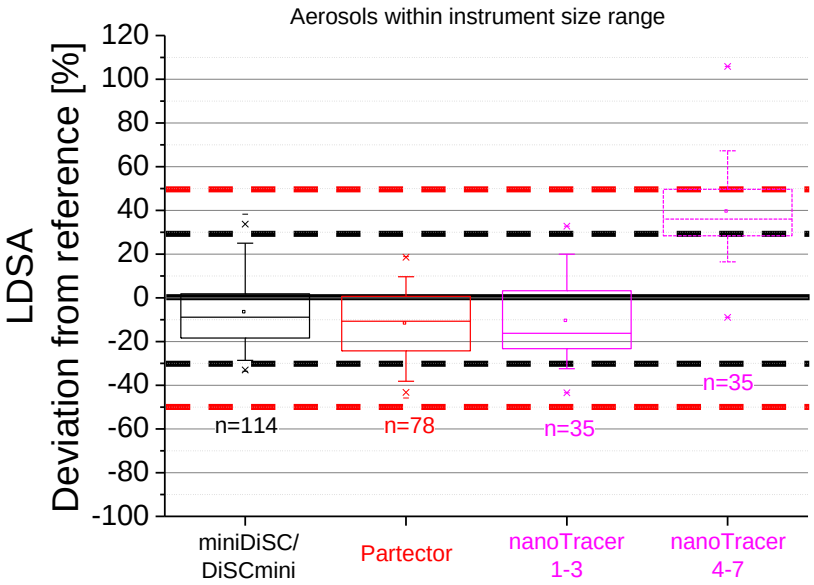
# Accuracy and comparability

## Accuracy




Todea et al., *J. Aerosol Sci.* **89:** 96-109, 2015

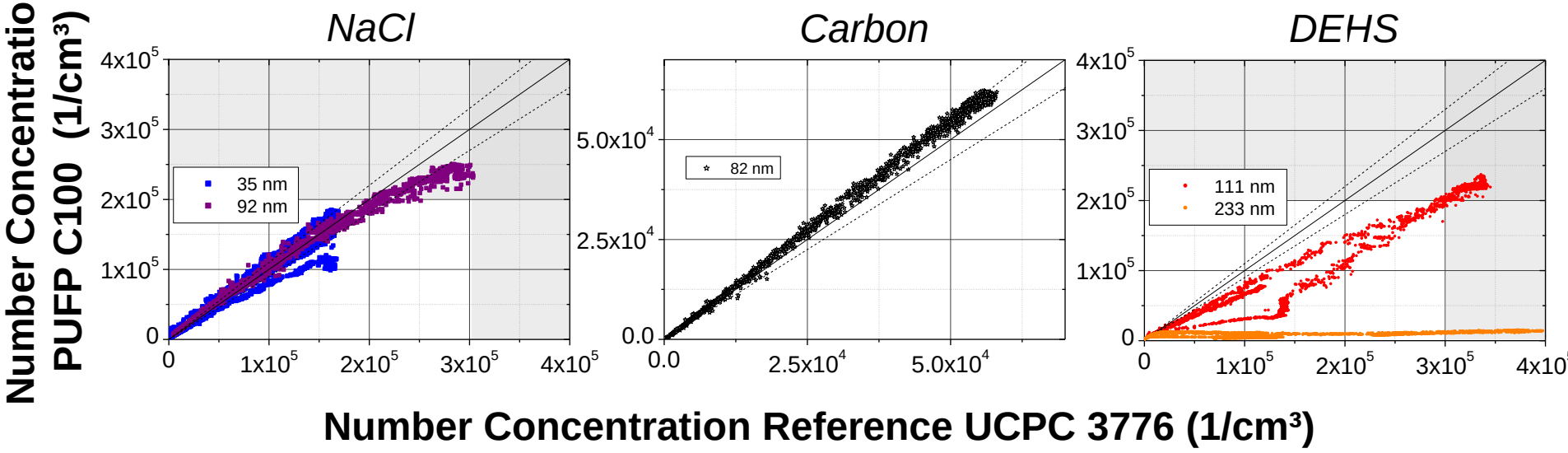
## Comparability




Todea et al., *Sci. Total Environ. (close to submission)*

**Compromise: Accuracy and comparability of personal diffusion charging instruments for particles and agglomerates around ± 30% for 20 nm ≤ $d_p$ ≤ 400 nm**

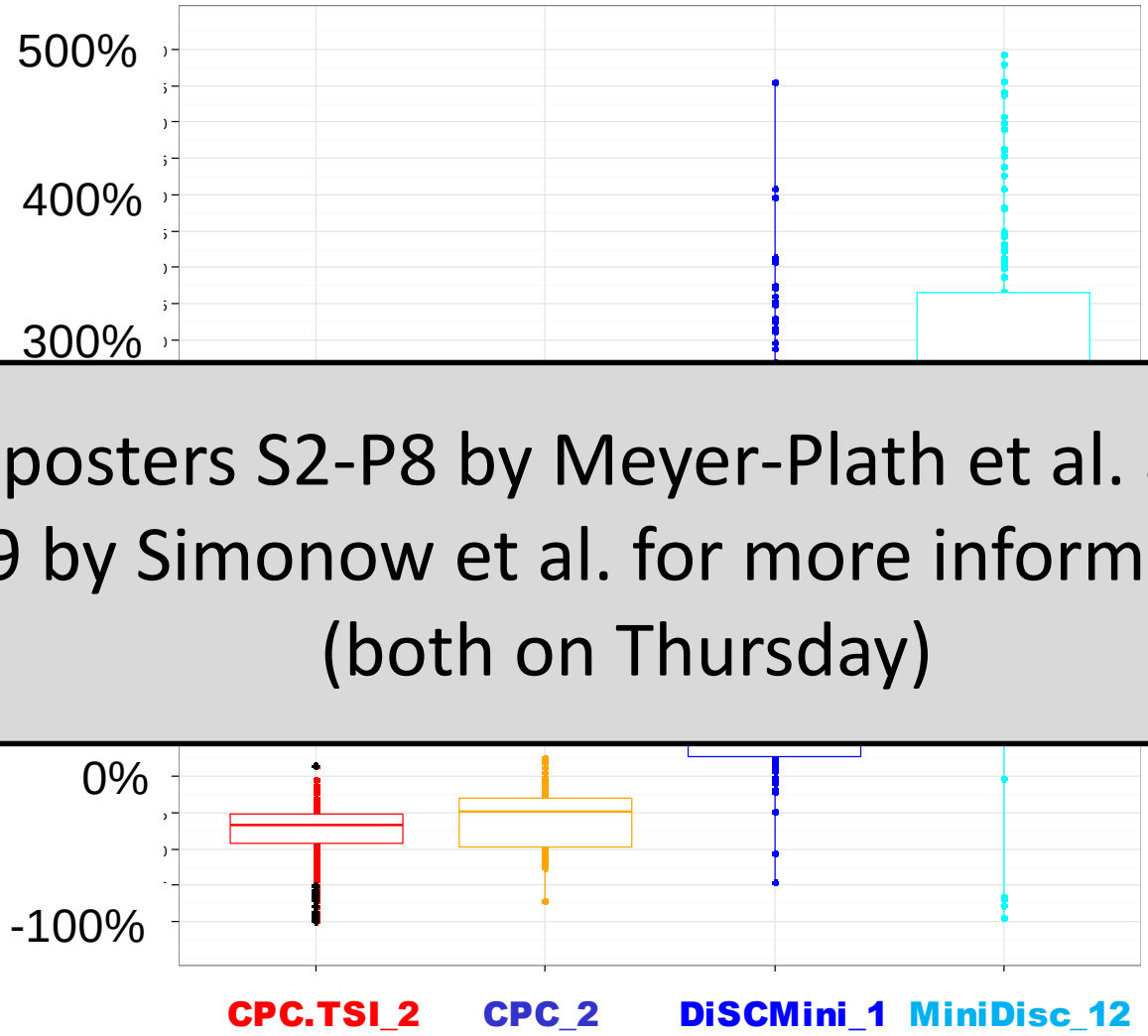
# Comparability of a personal CPC




Asbach et al., *Aerosol Air Qual. Res. (submitted)*

**Personal CPC ± 10% accurate, except for highly hydrophobic particles**

# Relative error for fibres




See posters S2-P8 by Meyer-Plath et al. and S2-P9 by Simonow et al. for more information (both on Thursday)

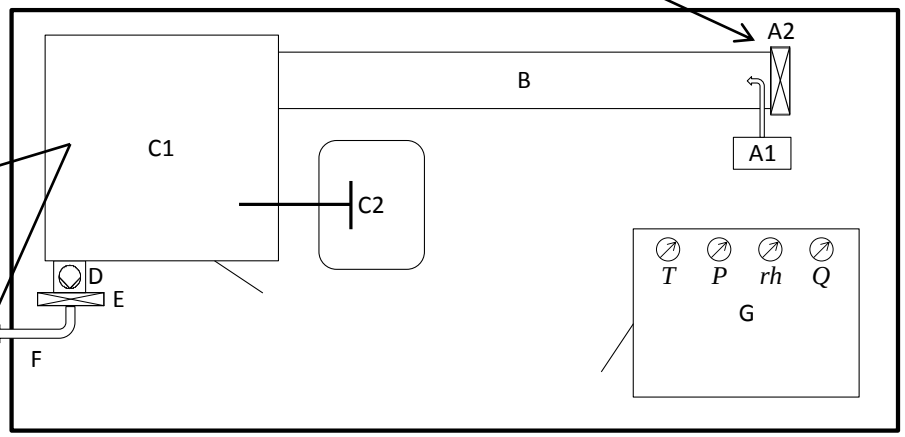
Data courtesy of A. Meyer-Plath, BAuA

# Lesson 2:

# Wearing of the instruments

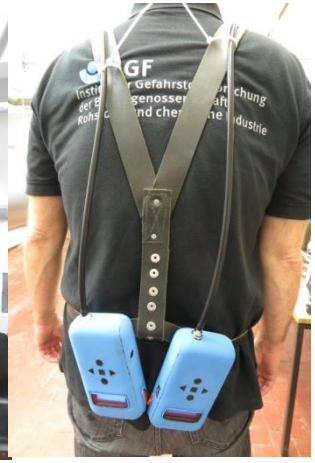
# Comparability of the monitors at field-like conditions

NaCl Test Aerosols (30 & 80 nm)

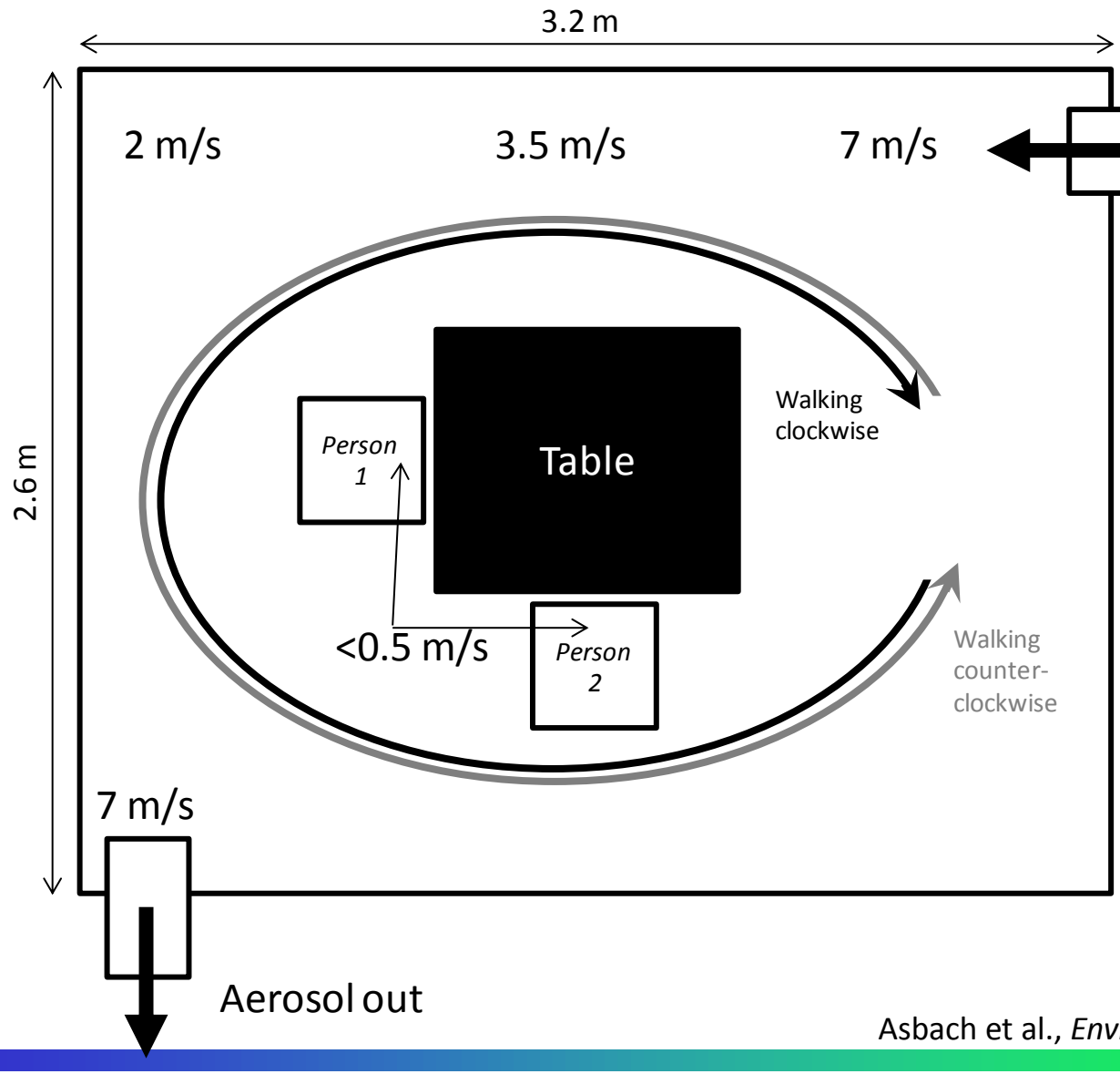



Partector

miniDiSC/DiSCmini



# Test sequence




**Sequence:**

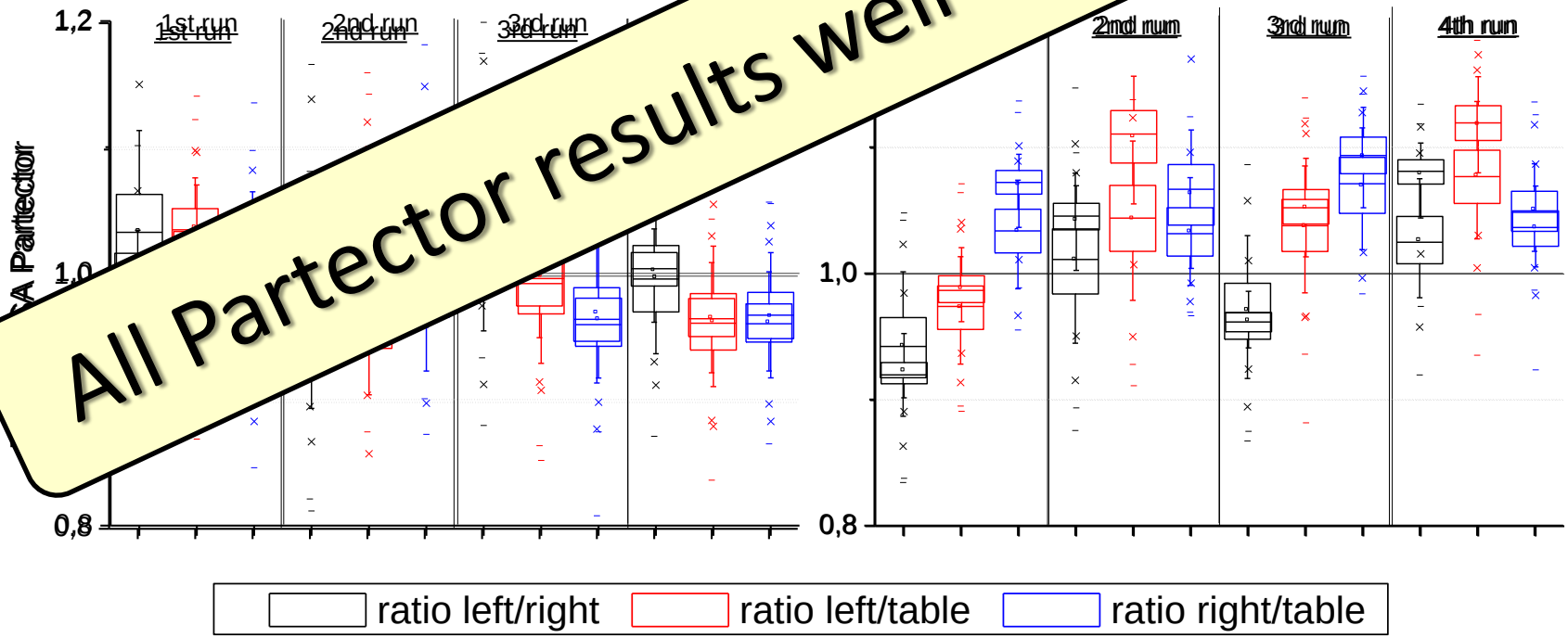
- 5 min sitting
- 5 min walking clockwise
- 2 min sitting
- 5 min walking counter clockwise
- 2 min sitting
- 5 min assembly & disassembly of MPG II dust sampler

Asbach et al., *Environ. Sci. Nano (revision submitted)*

# Partector results

During 2 min sitting clockwise

All Partector results well within ±20%

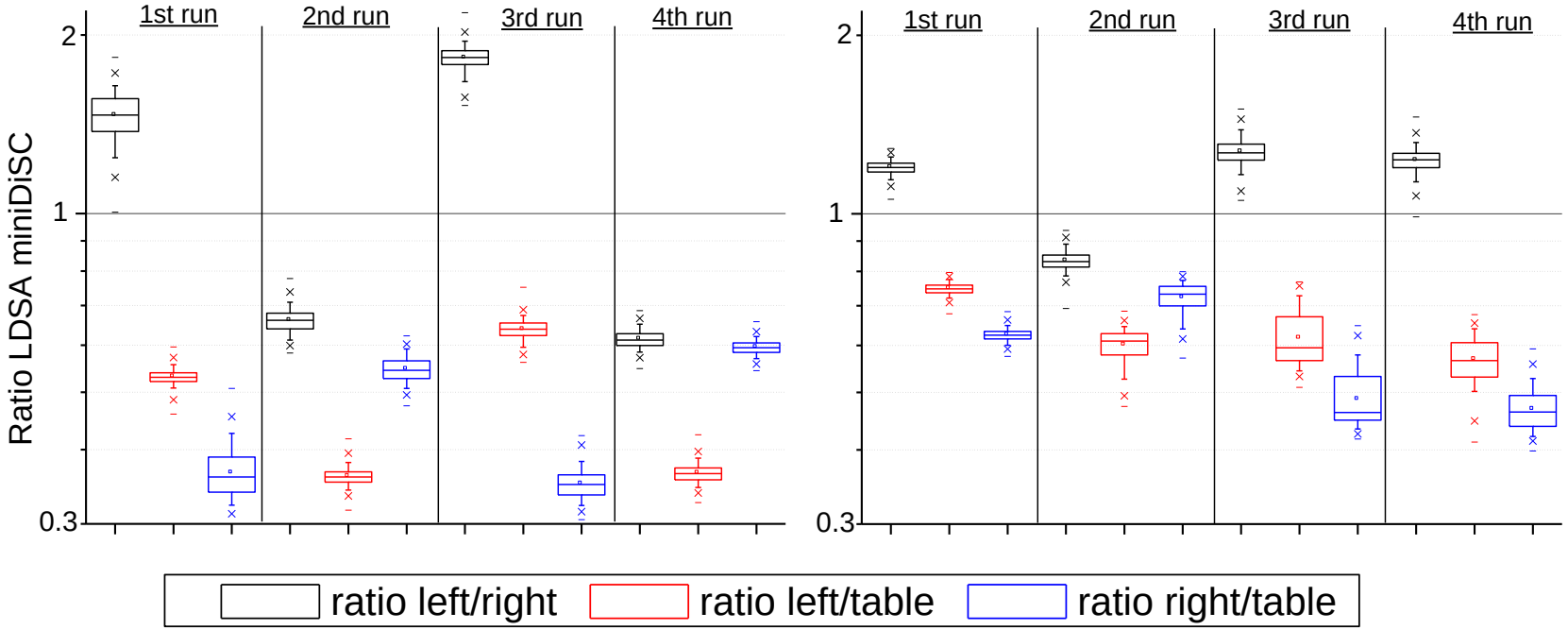



Asbach et al., *Environ. Sci. Nano (revision submitted)*

# During sitting

## NaCl 28 nm

## NaCl 82 nm

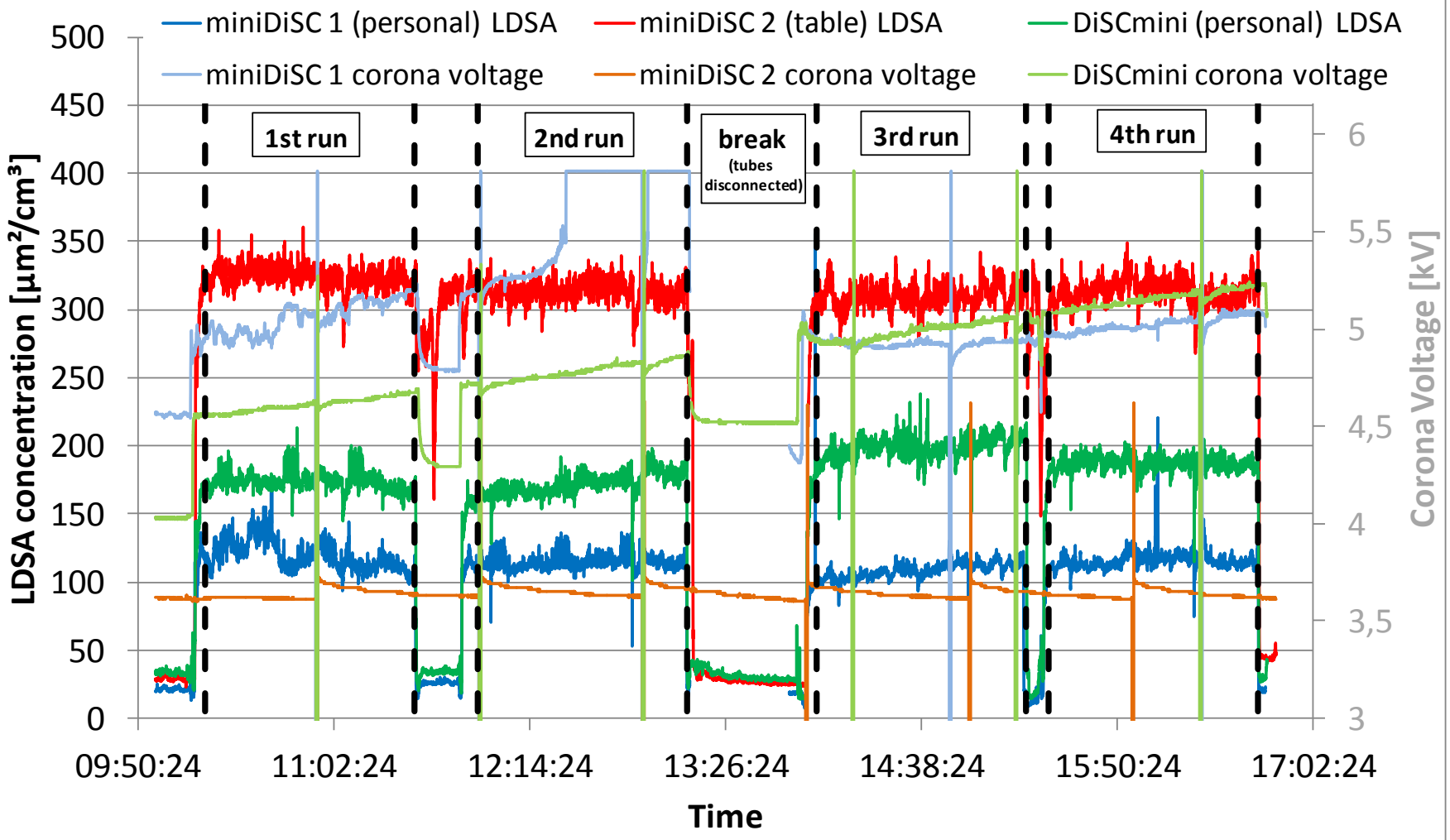



Asbach et al., *Environ. Sci. Nano (revision submitted)*

# Lesson 3:

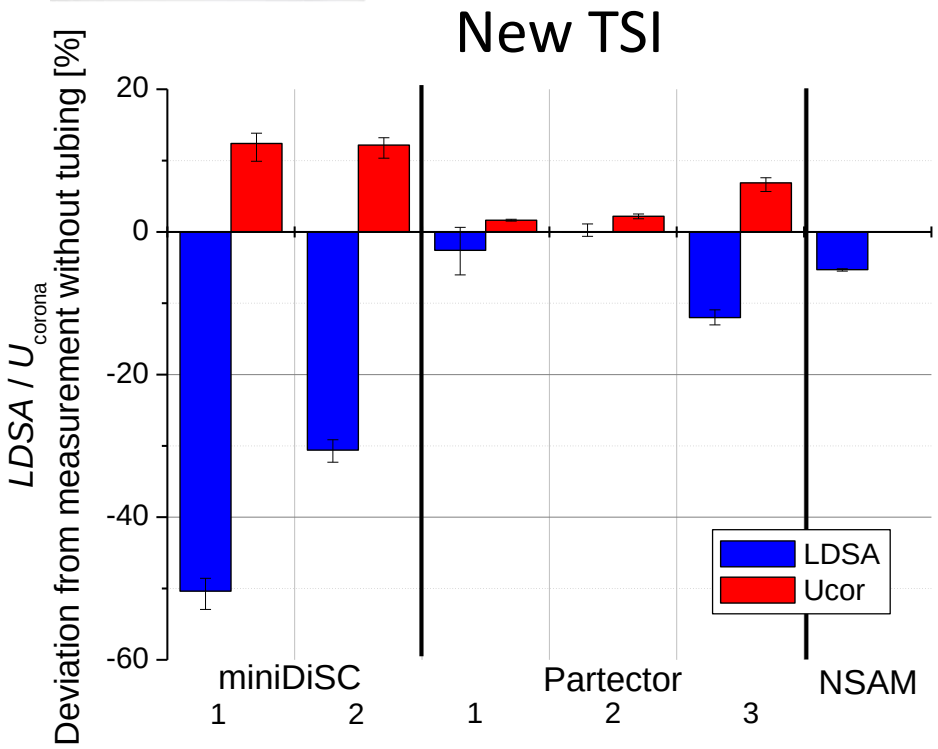
# Unexpected artefacts

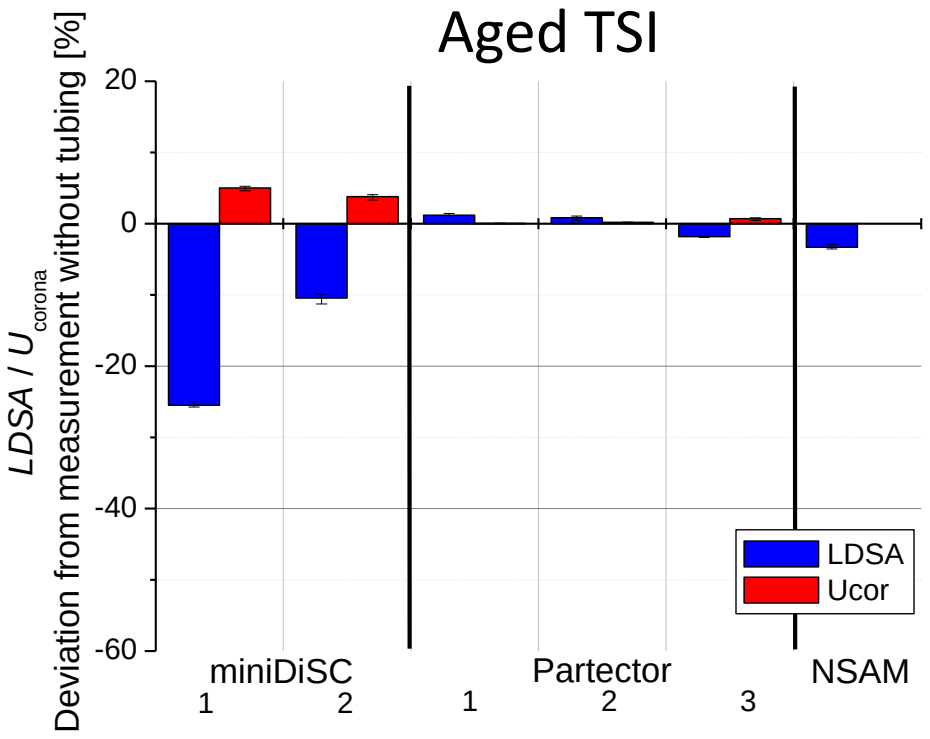
# Observed artefacts during personal measurements



# Effect of sampling tube

- Instruments sampling through 75 cm conductive silicone tubing
- Strong effect on both measured concentration and corona voltage

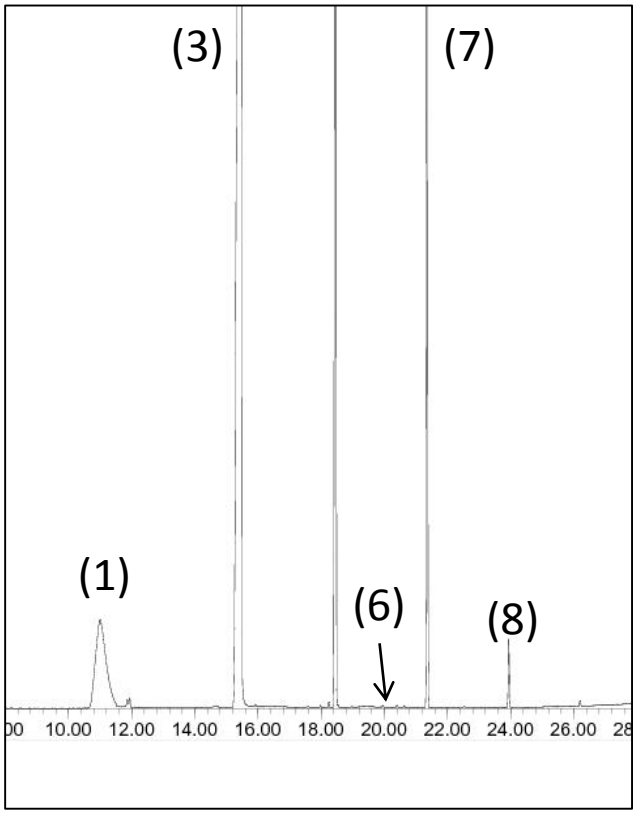



Asbach et al., *Aerosol Sci. Technol.* (accepted)
http://dx.doi.org/10.1080/02786826.2016.1241858

# Siloxanes from new TSI tube

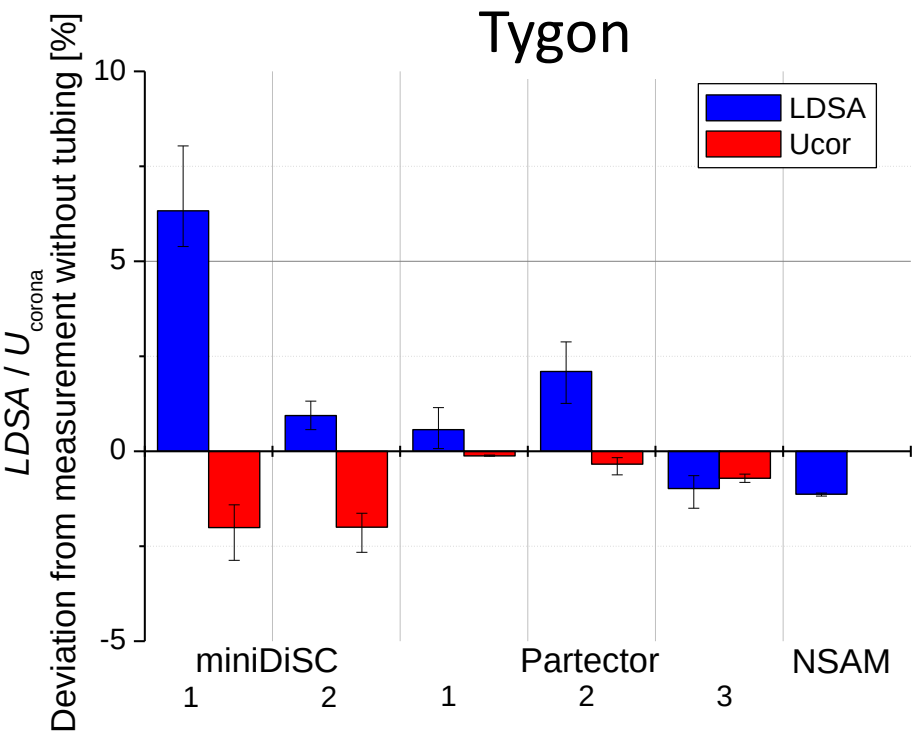
NEU




| | |
|---|---|
| 1) Hexamethyldisiloxane (222,46 g/mol) | > 1mg/ml |
| 3) Octamethylcyclotetrasiloxan e(236,53 g/mol) | > 1 mg/ml |
| 6) Dodecamethylcyclopentasiloxane (296,62 g/mol) | < 0,1 mg/ml |
| 7) Dodecamethylcyclohexasiloxane (444,92 g/mol) | not calibr. |
| 8) Tetradecamethylhexasiloxane (458,99 g/mol) | not calibr. |

Asbach et al., *Aerosol Sci. Technol.* (accepted)
http://dx.doi.org/10.1080/02786826.2016.1241858

# Effect of sampling tube




**The choice of sampling tube material can have a drastic (unexpected) effect on the measurement with personal monitors!**

Asbach et al., *Aerosol Sci. Technol.* (accepted)
http://dx.doi.org/10.1080/02786826.2016.1241858

# Lesson 4:

# Issues related to personal sampling

# Correct sampling time

Gravimetric Analysis:

Must be long enough to collect enough material (depends on sensitivity of the scale)

Chemical Speciation

Must be long enough to collect enough material (depends on LOD of analyzer)

Electron Microscopic Analysis

Must be within a certain time window:

- Short enough to avoid agglomeration on substrate
- Long enough to keep analysis effort reasonable

→ Difficult, as sampling time depends on size and concentration

# Pressure drop of „nano-samplers“

*Thongyen et al., Aerosol and Air Quality Research*, 15: 180–187, 2015

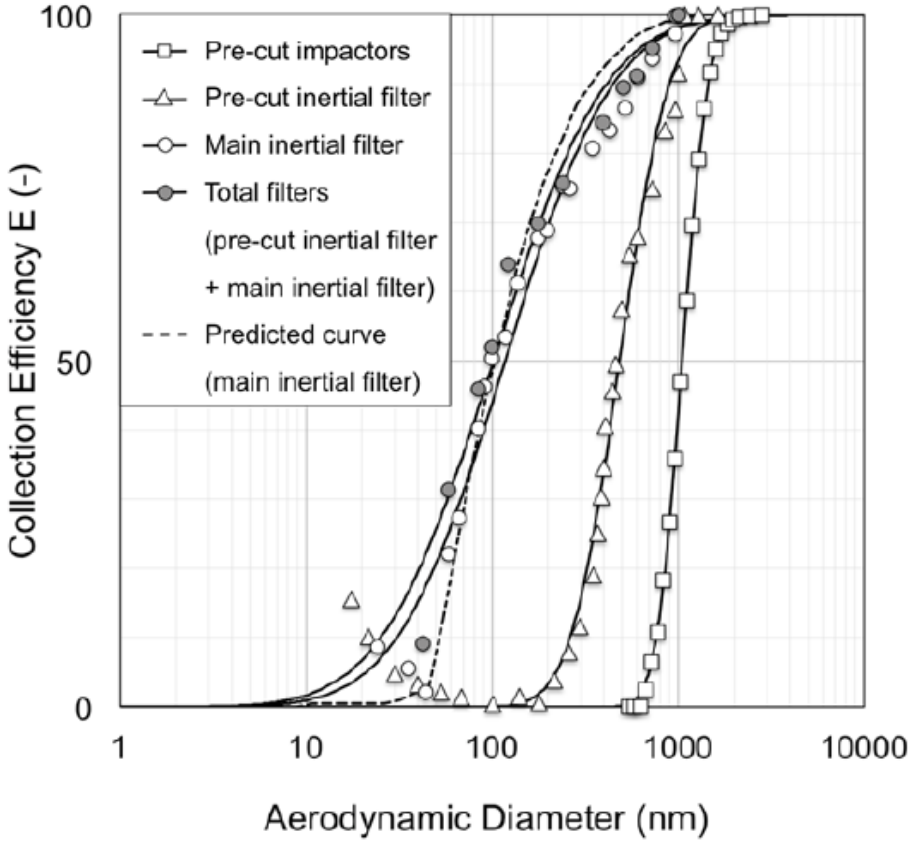



**Fig. 5.** Collection efficiency curves for the pre-cut impactors, the pre-cut inertial filter and the main inertial filter and the combination of the pre-cut and main inertial filters.

*Furuuchi et al., Aerosol and Air Quality Research*, 10: 30–37, 2010

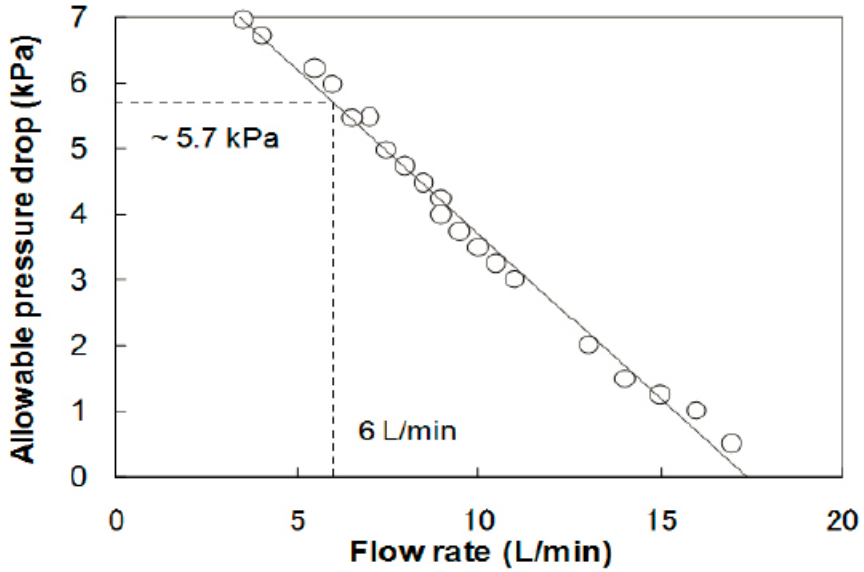



**Fig. 5.** Allowable pressure drop a portable pump used in relation to flow rate.

$\Delta p$ can be overcome by personal pumps

**<u>BUT</u>**: battery time is reduced, full shift measurement may not be possible

# Sampling or monitoring?

**There is no clear answer!**

Sampling….

- …if chemical composition shall be determined
- …if particle morphology (e.g. fibre) is of interest
- …if (

See poster S2-P2 by Simon Clavaguera et al for more information (on Thursday)

Mo

- 
- 

No single instrument can do it all!
A combination of sampler and monitor may be the best compromise in given situations

# Lesson 5:

# Field studies

# Field measurements at IUTA pilot plant

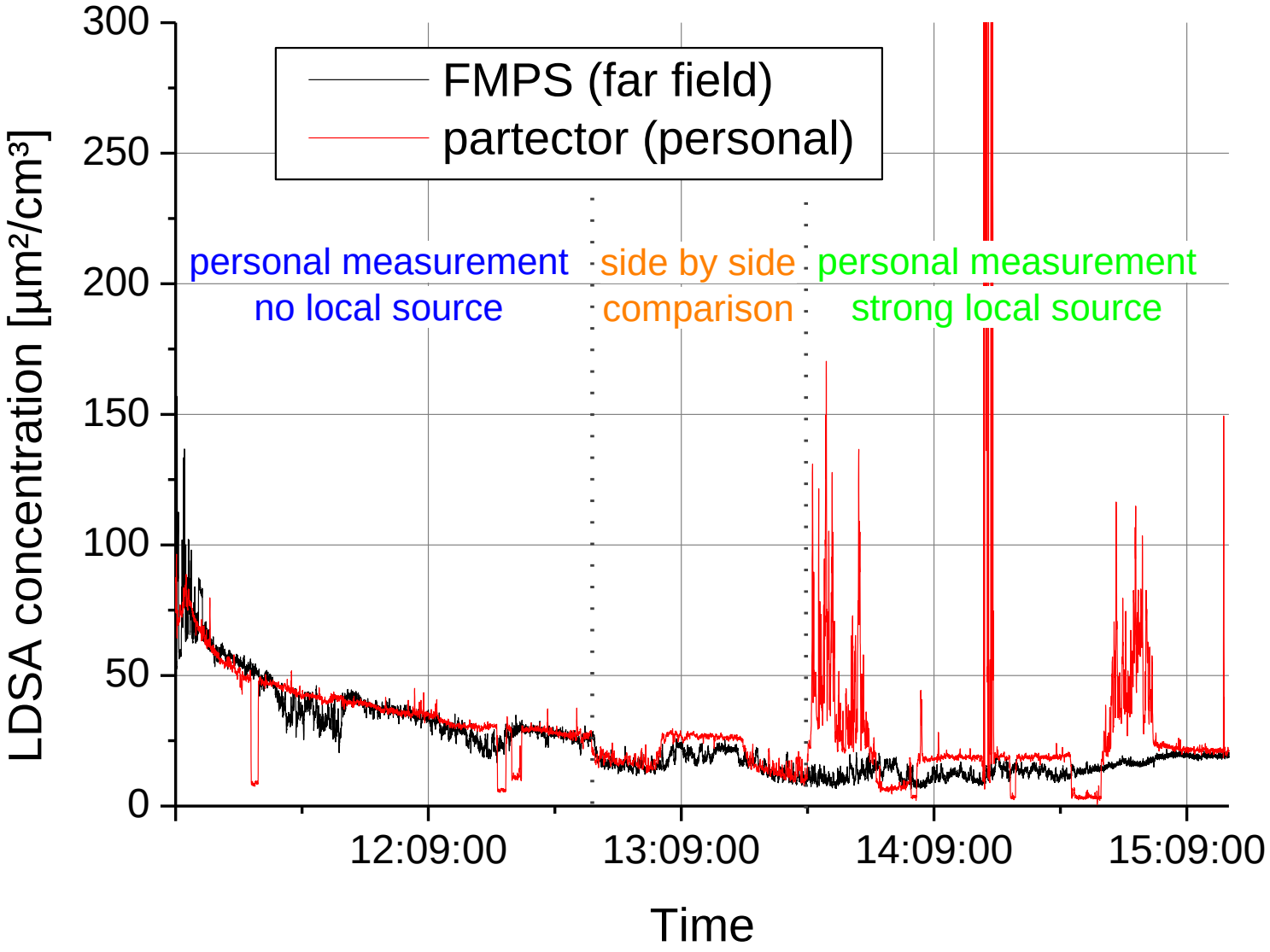
- Pilot plant for the production of up to several kg/day
- Here: production of Fe doped $SiO_2$
- Measurement during synthesis, bagging and cleaning

# IUTA colleagues, equipped with personal monitors

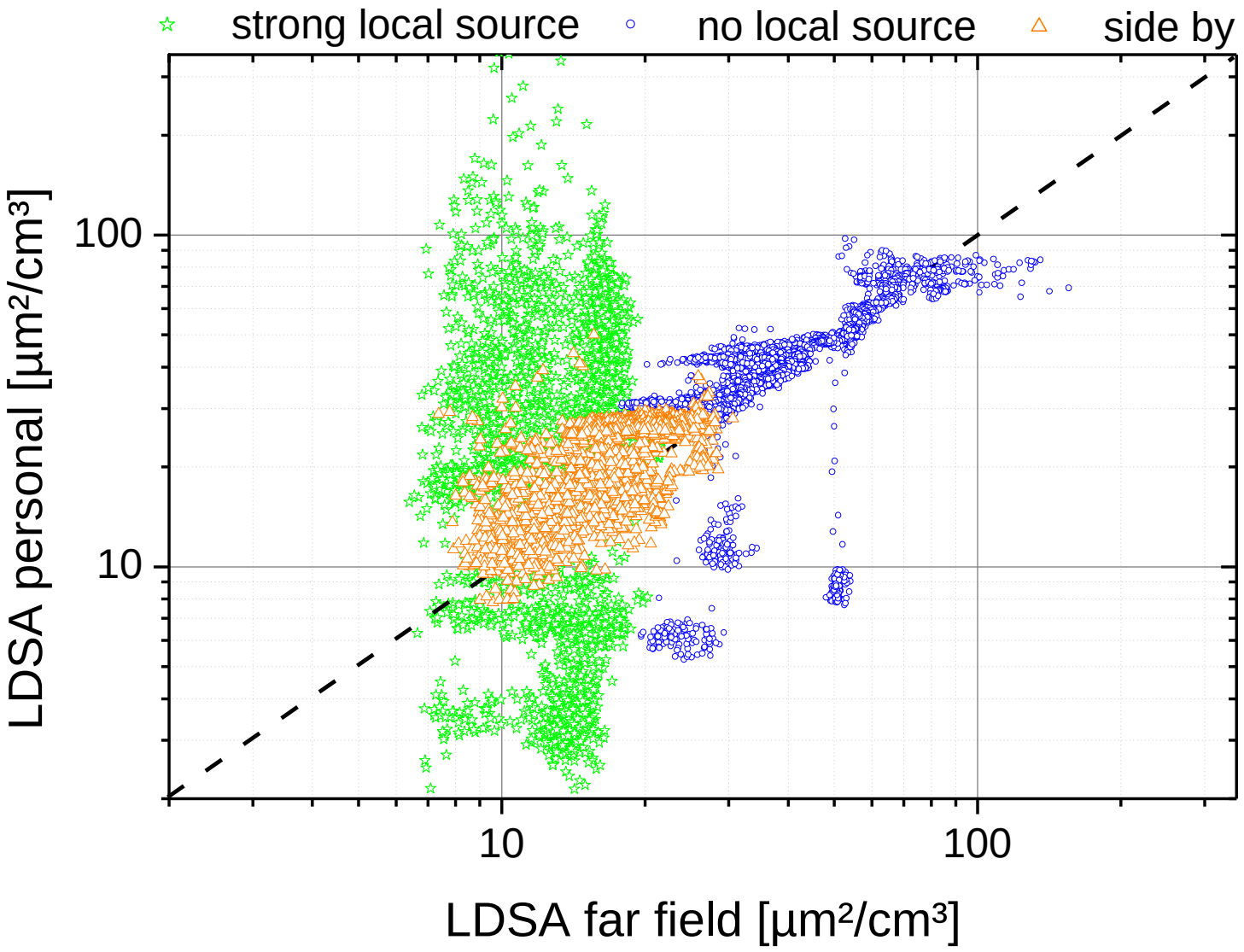



75 cm long sampling tubes

# Time series of LDSA concentration



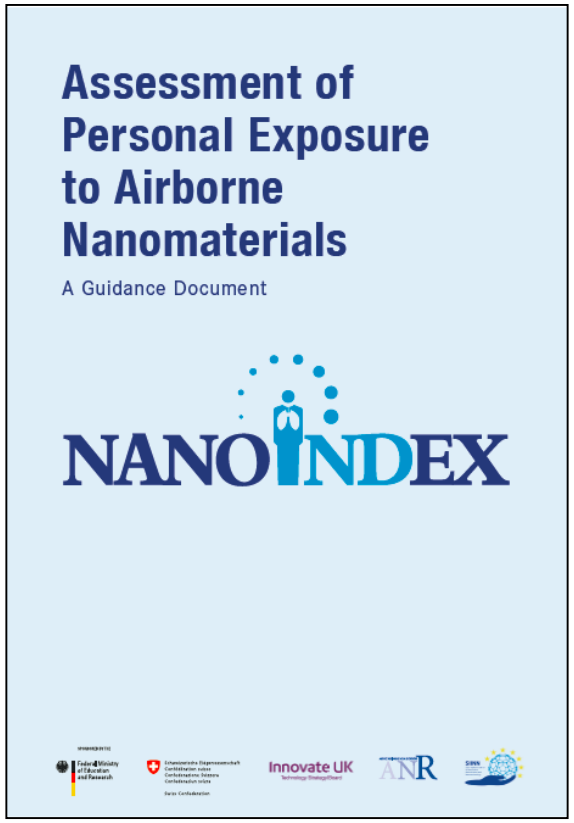
# Correlation personal – far field



# Lessons learned?

*"The outcome of any serious research can only be to make two questions grow where only one question grew before"*

- nanoIndEx taught us several lessons, many of them with direct practical implications
- If we keep them in mind, the new samplers and monitors can be readily applied in field studies
- For more information, please refer to the Guidance Document and our website




http://www.nanoindex.eu

# Thanks for funding these lessons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Lessons learned!

Thank you for your attention