Probenahme und chemische Charakterisierung von ultrafeinen Partikeln

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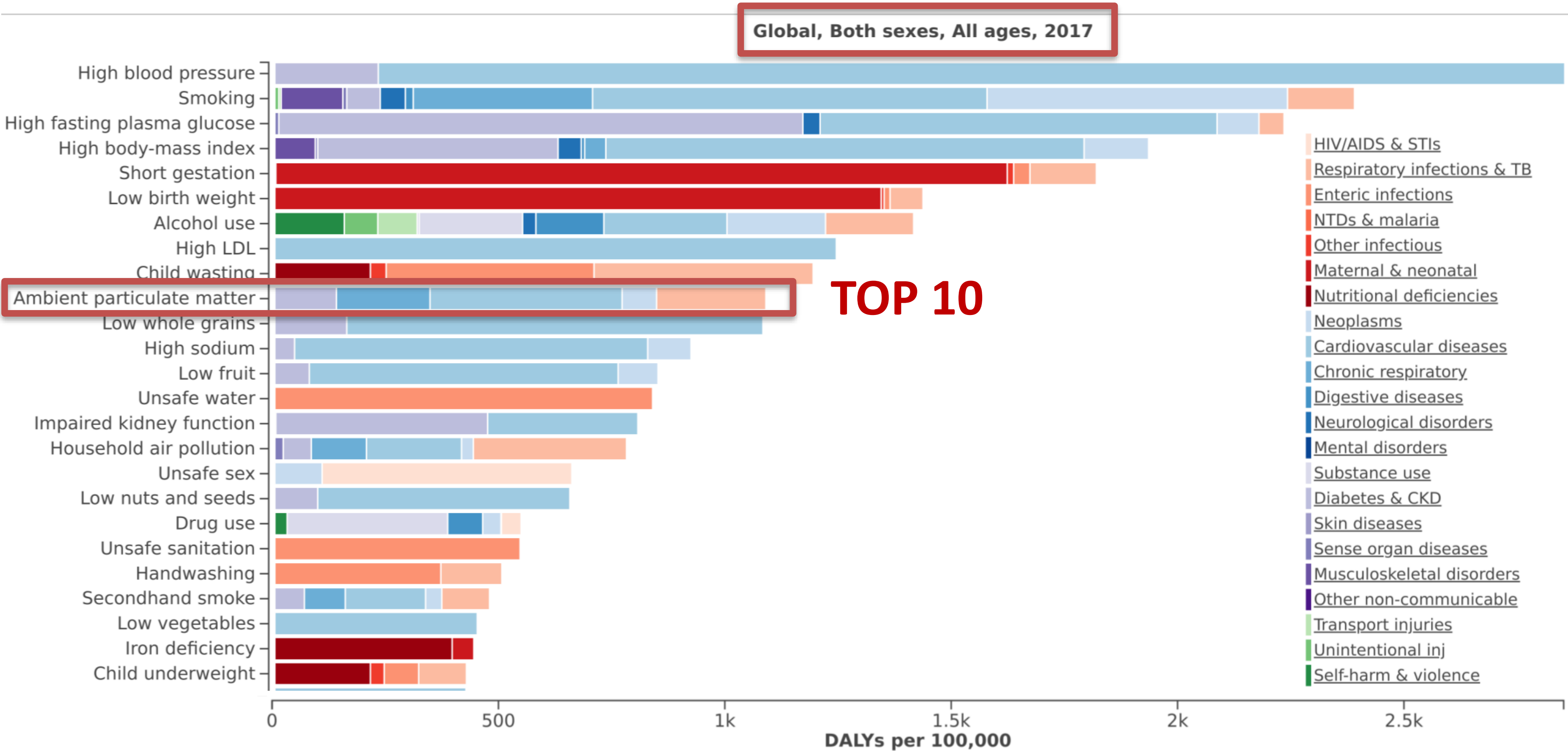
Motivation

PM as a health risk: Global burden of disease study



www.healthdata.org/gbd

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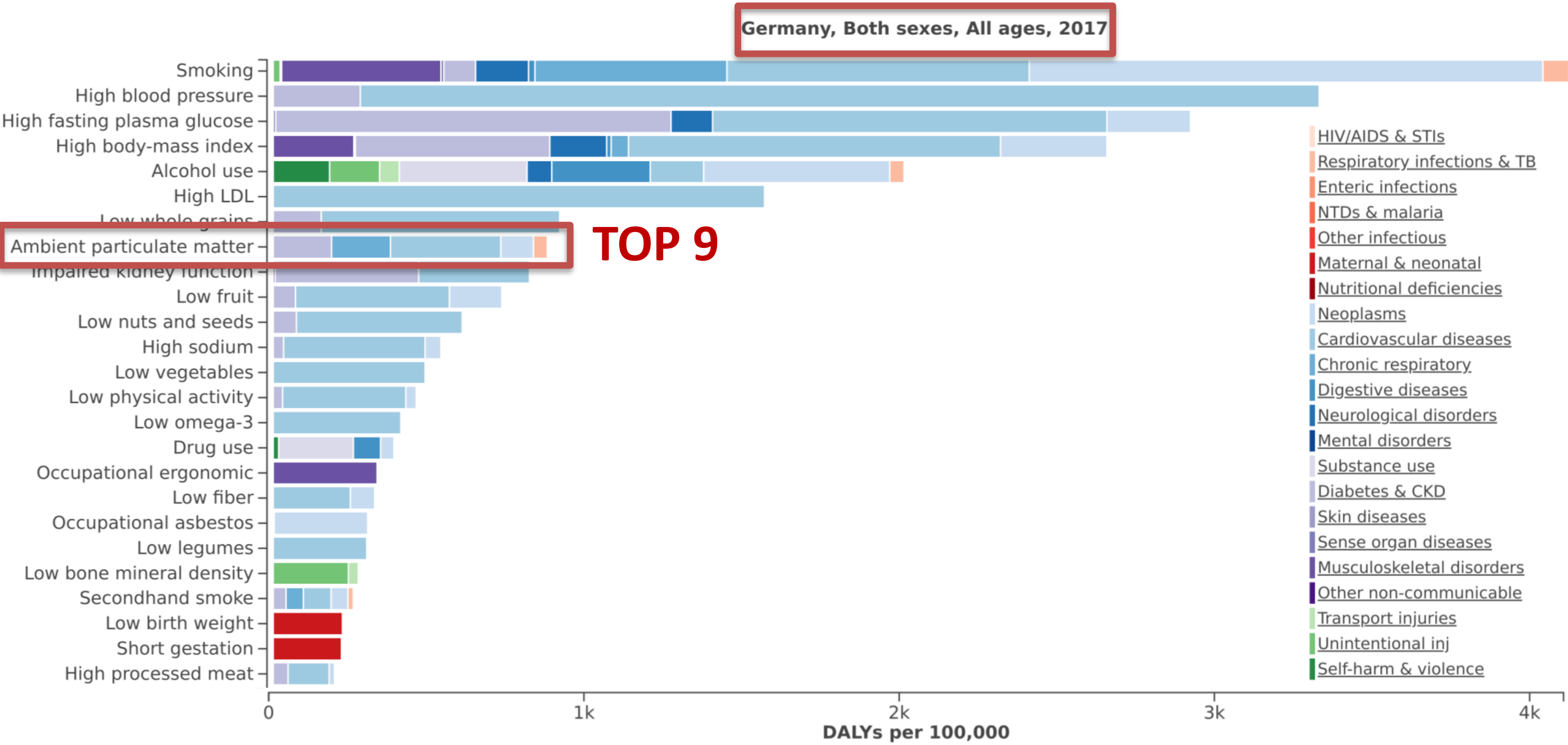
PM as a health risk: Global burden of disease study



→ **Fine and ultrafine particles pose a significant health risk even in highly developed countries**

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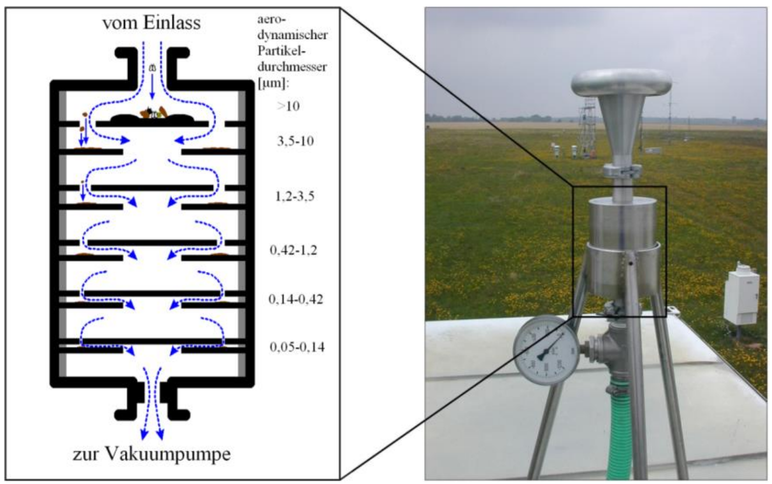
Sampling methods

Sampling approaches for fine and ultrafine particles

Offline approach:

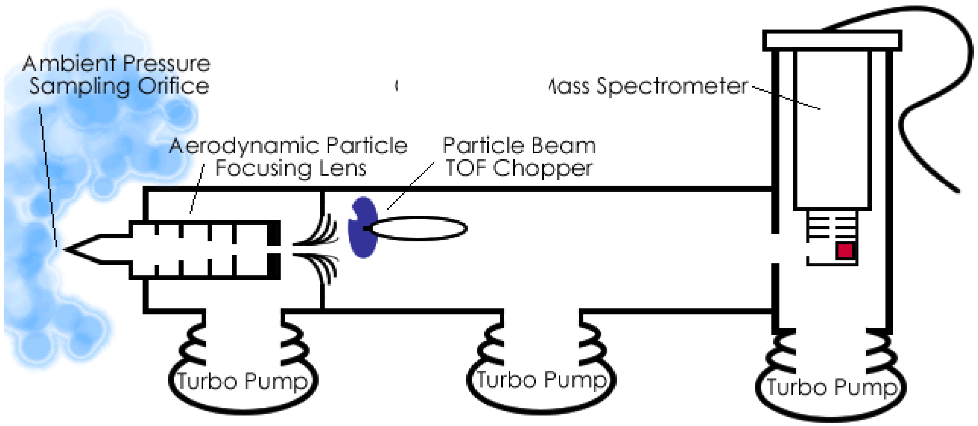
1. Sample particles on substrate
2. Analyse composition in lab



Pro: comprehensive composition
Con: long sampling times (hours – days)

Online approach:

Sample and analyse particles in one instrument



Pro: short sampling times (sec – mins)
Con: limited compositional information

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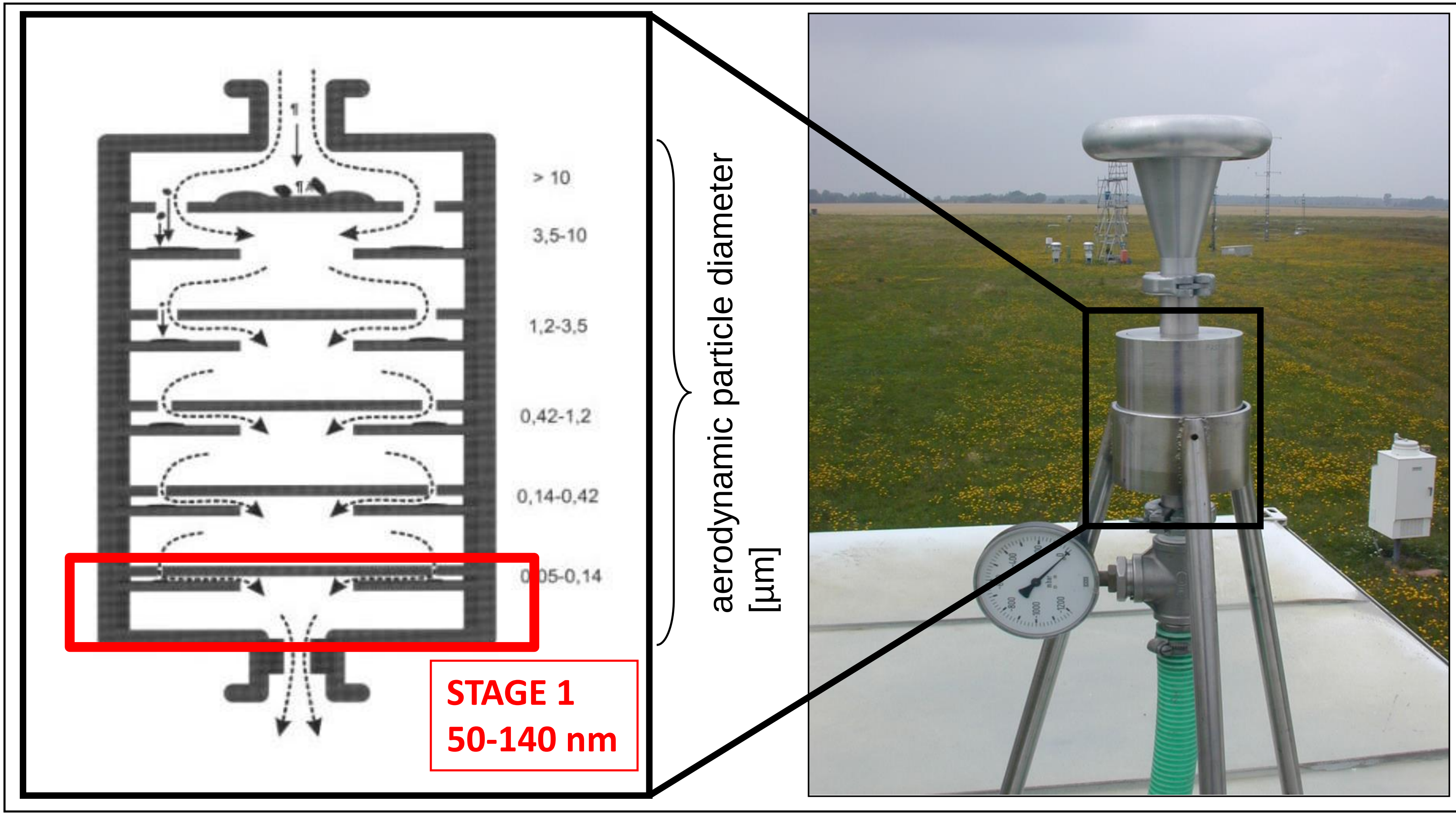
Low pressure five-stage BERNER-impactor



To the vacuum pump

Sampling volume: 108 m³ in 24h

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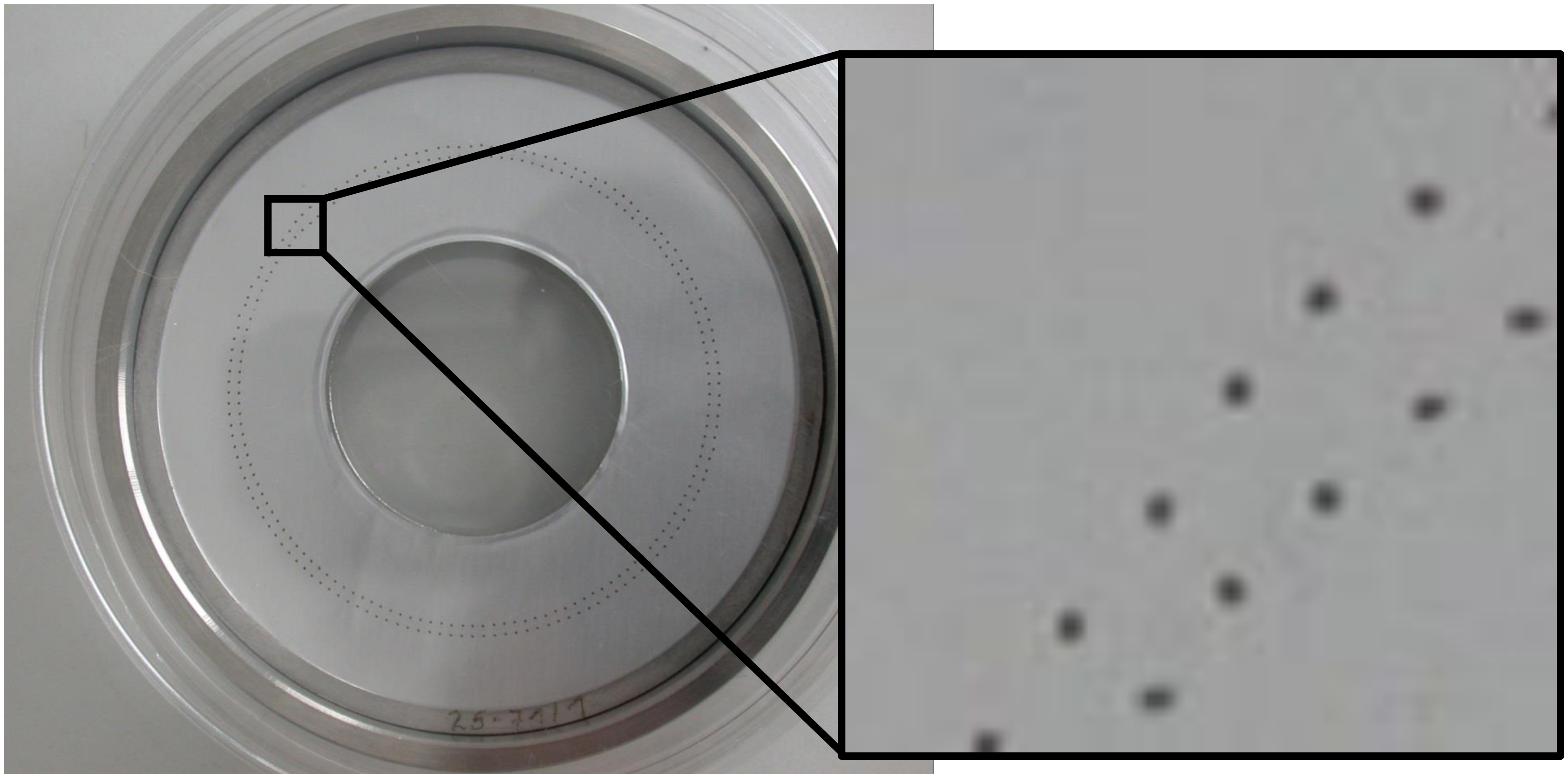
Sample collection: 5-stage Berner impactor

Sample collection on aluminum foils:



… which are chemically analysed.

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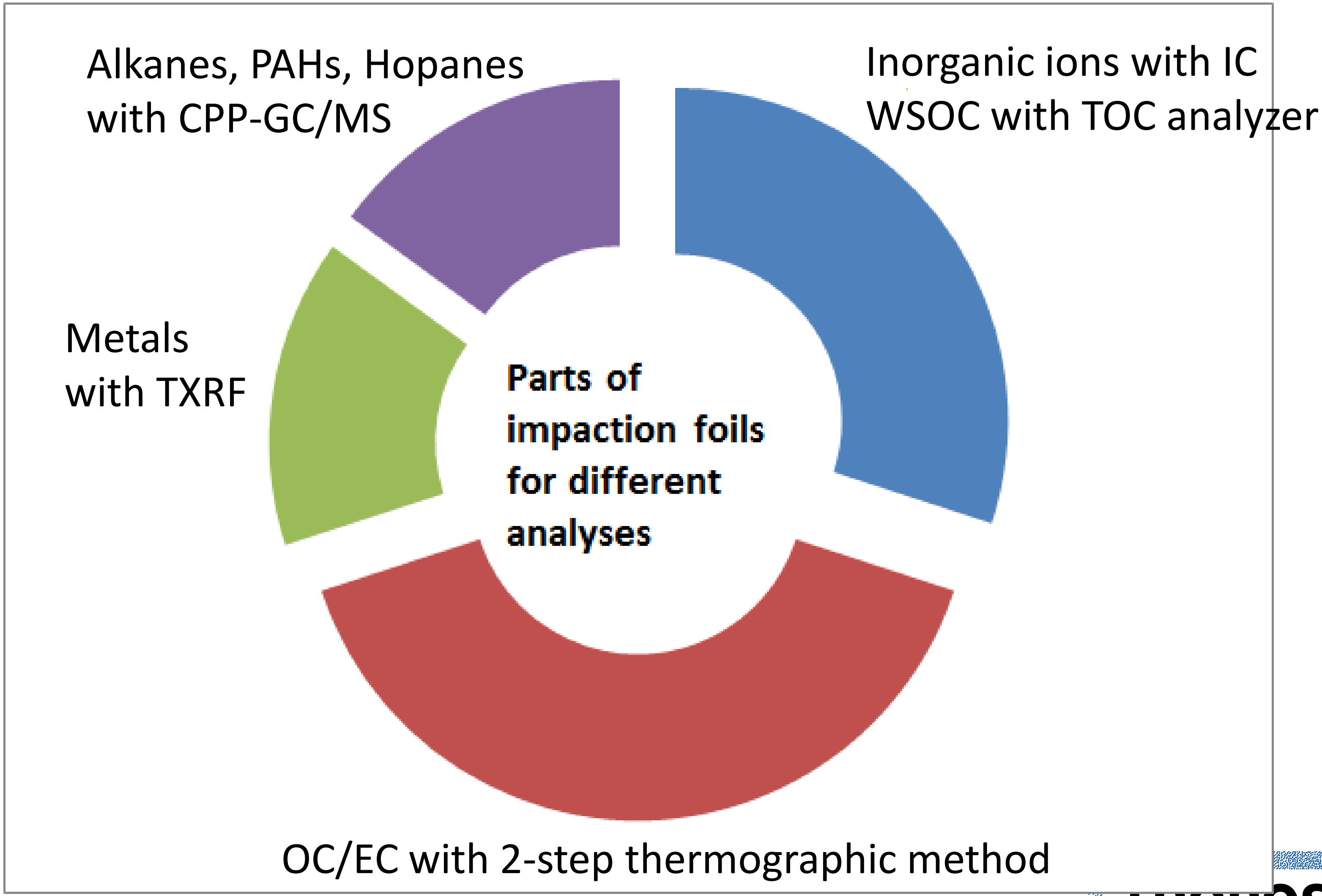
Chemical analyses from impactor foils



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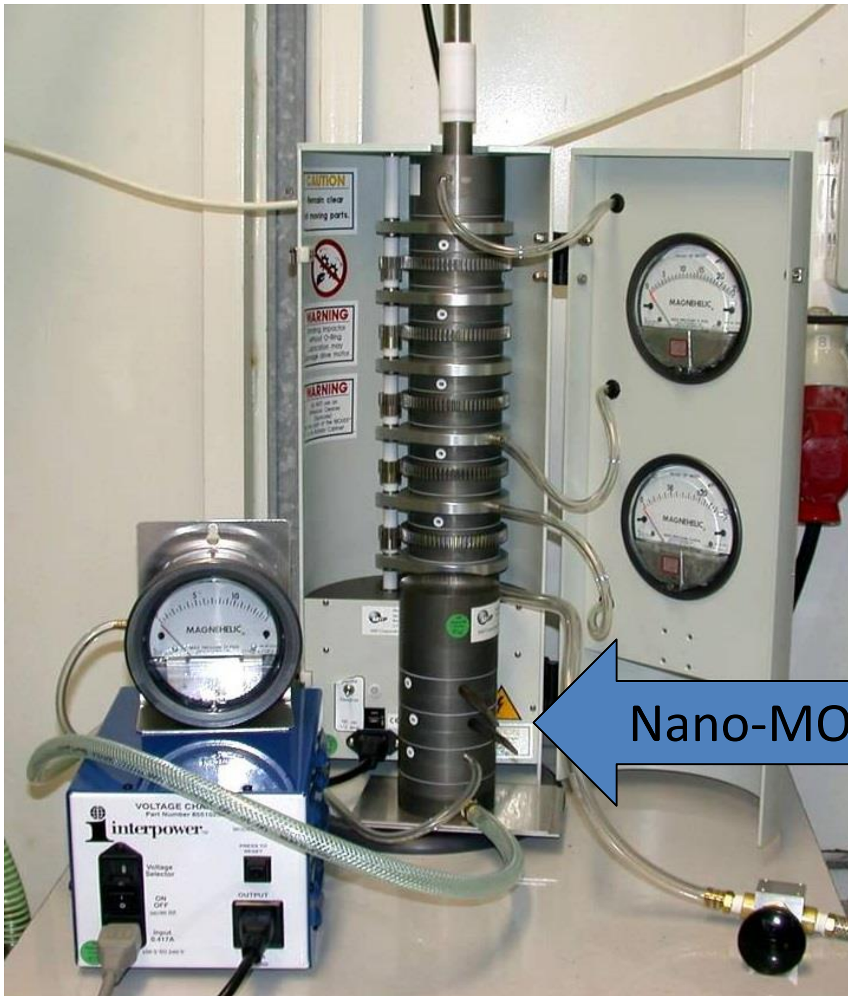
Size-resolved sampling of UFP



Nano-MOUDI

5-Stage Berner Impactor:

Stage 1: 50 – 140 nm Dp_{aer}
Stage 2: 140 – 420 nm Dp_{aer}
Stage 3: 0.42 – 1.2 µm Dp_{aer}
Stage 4: 1.4 – 3.5 µm Dp_{aer}
Stage 5: 3.5 – 10 µm Dp_{aer}

Micro Orifice Uniform Deposit Impactor (MOUDI):

Stage 1: 10 – 18 nm Dp_{aer}
Stage 2: 18 – 32 nm Dp_{aer}
Stage 3: 32 – 56 nm Dp_{aer}
Stage 4: 56 – 100 nm Dp_{aer}

Stages 5-13: 0.18 – 18 µm Dp_{aer}

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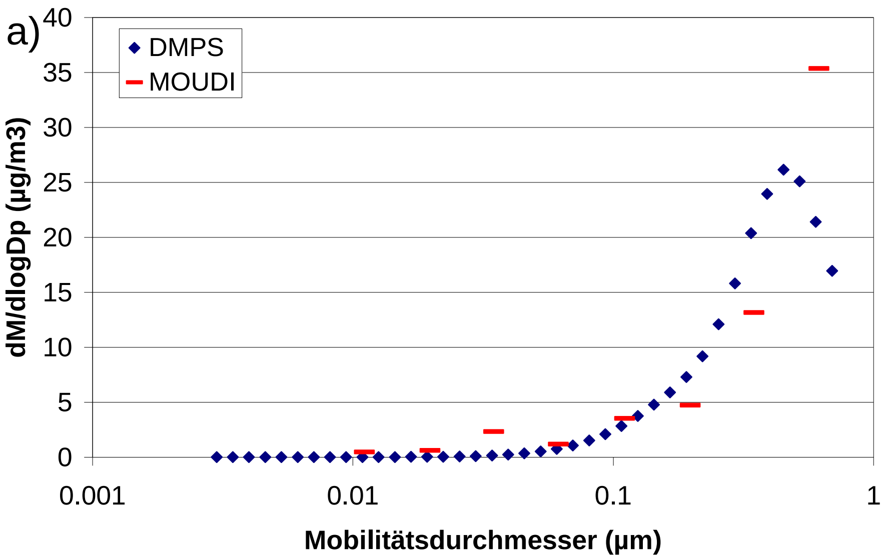
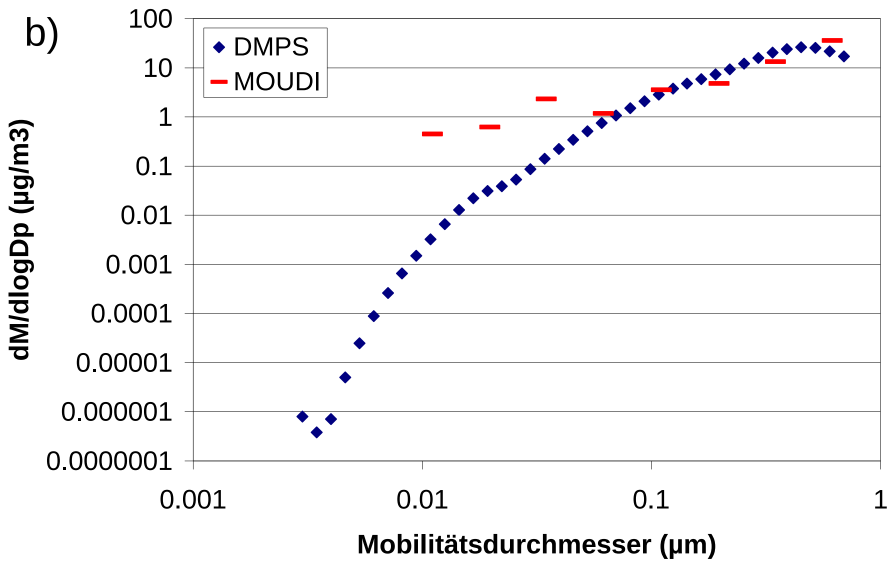
Impactor Sampling: Challenges

Challenges in size-resolved sampling of UFP

nanoMOUDI gravimetric mass compared to expected mass based on number concentration measurement





→ OK at first glance...

...but it‘s not!

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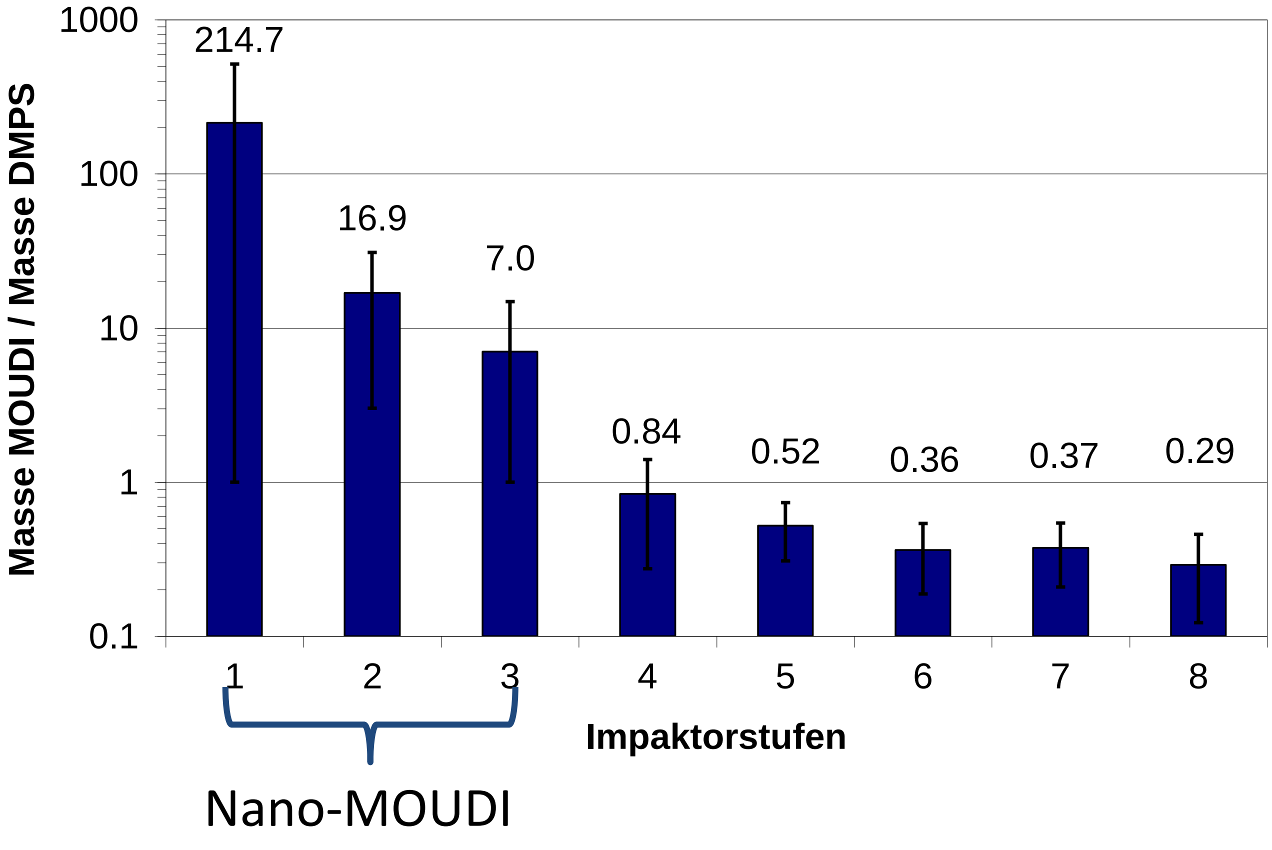
Challenges in size-resolved sampling of UFP

Mean (± 1σ) deviations of nanoMOUDI vs. DMPS mass for 29 samples



→ **Severe overestimation of UFP mass, possibly due to „bounce-off"**

→ **Reasonable agreement from approx. 60 nm upwards**

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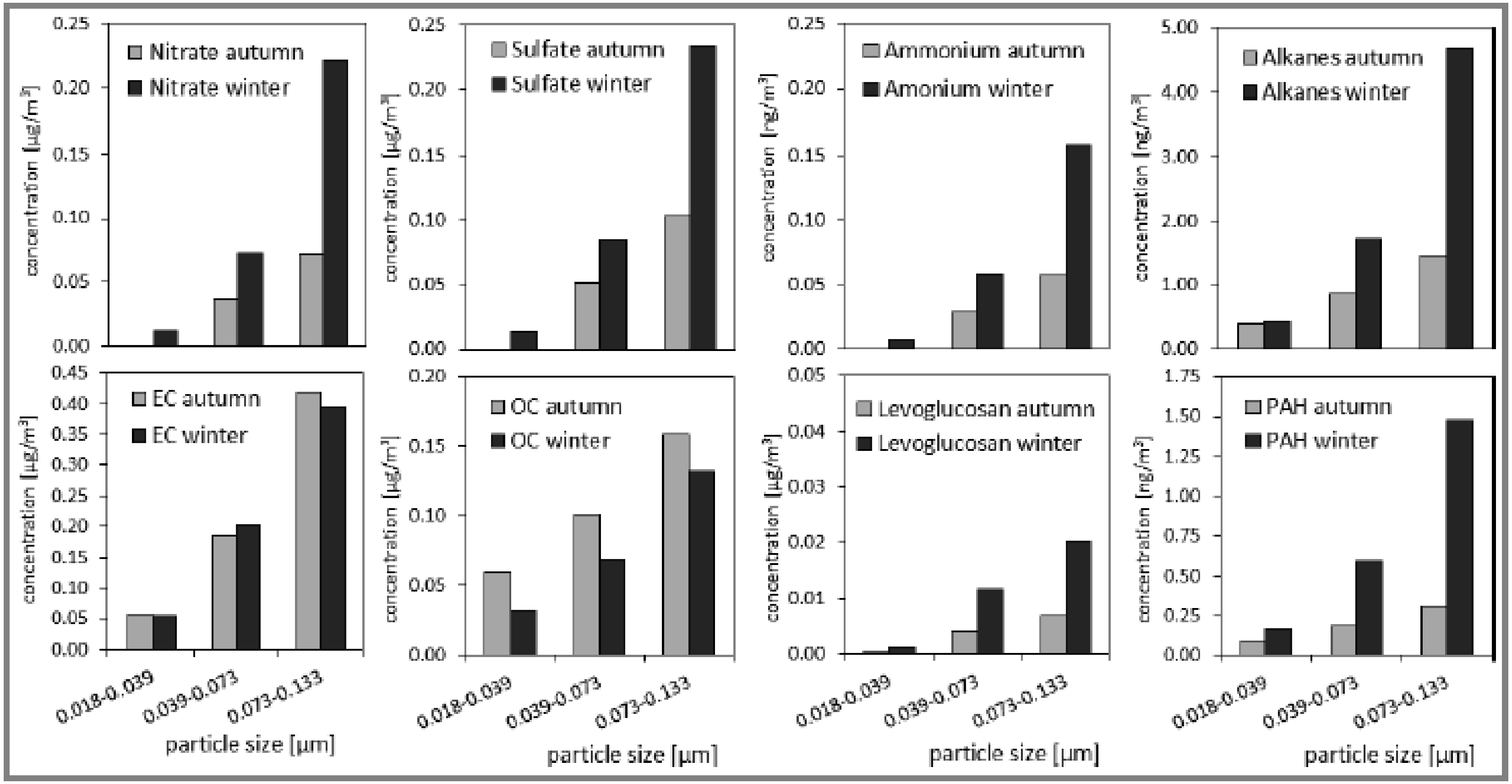
Size-resolved UFP chemical composition

Street canyon samples comparison autumn vs. winter

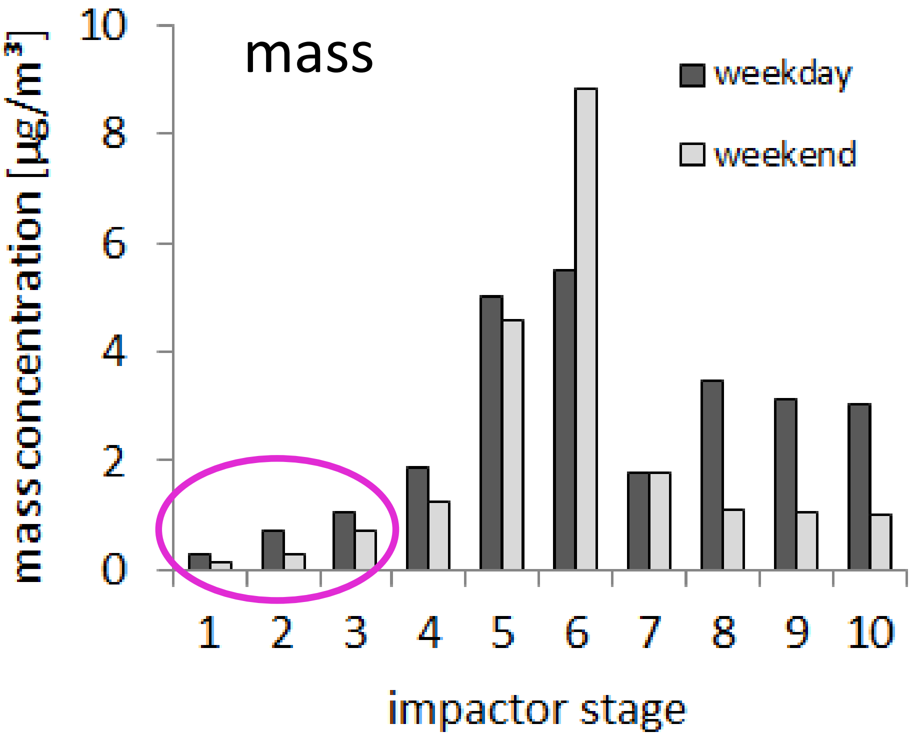
Leipzig, Eisenbahnstrasse, street canyon, 10-stage Berner impactor

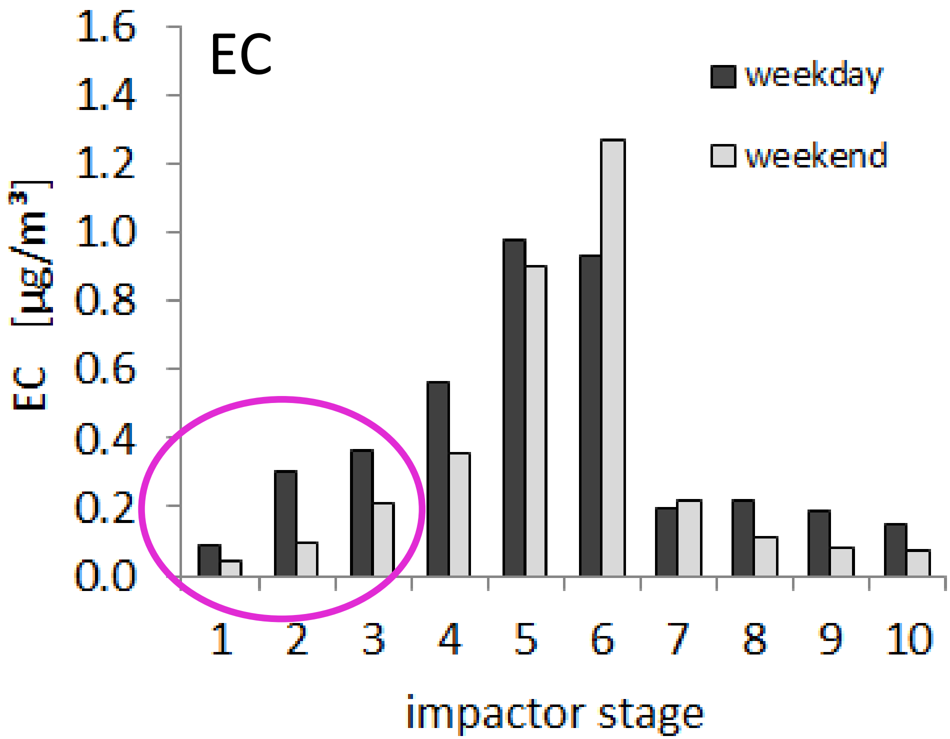


Müller et al., 2012, doi: 10.1002/cite.201100208

→ low, but measureable concentrations of ions, OC/EC + organics

Street canyon samples comparison weekday vs. weekend





→ Reasonable trends
→ Absolute mass concentrations overestimated
→ Absolute constituents concentrations might be correct

→ In the following: Berner impactor stage 1 (50-140 nm) as proxy for UFPs

Leipzig ‚Aerosol 2013 - 2015‘ study: Source apportionment of UFPs

Experimental approach

- 2 Campaigns
  (summer+winter 2013-2015)
- 4 Sampling sites in parallel
- 24h samples with 5-stage Berner impactor during 21 sampling days per season
- Comprehensive chemical characterisation
- Different source apportionment approaches

LANDESAMT FÜR UMWELT, LANDWIRTSCHAFT UND GEOLOGIE | Freistaat SACHSEN

van Pinxteren et al., Schriftenreihe LfULG, Heft 7/2016
van Pinxteren et al., 2016, doi: 10.1039/c5fd00228a

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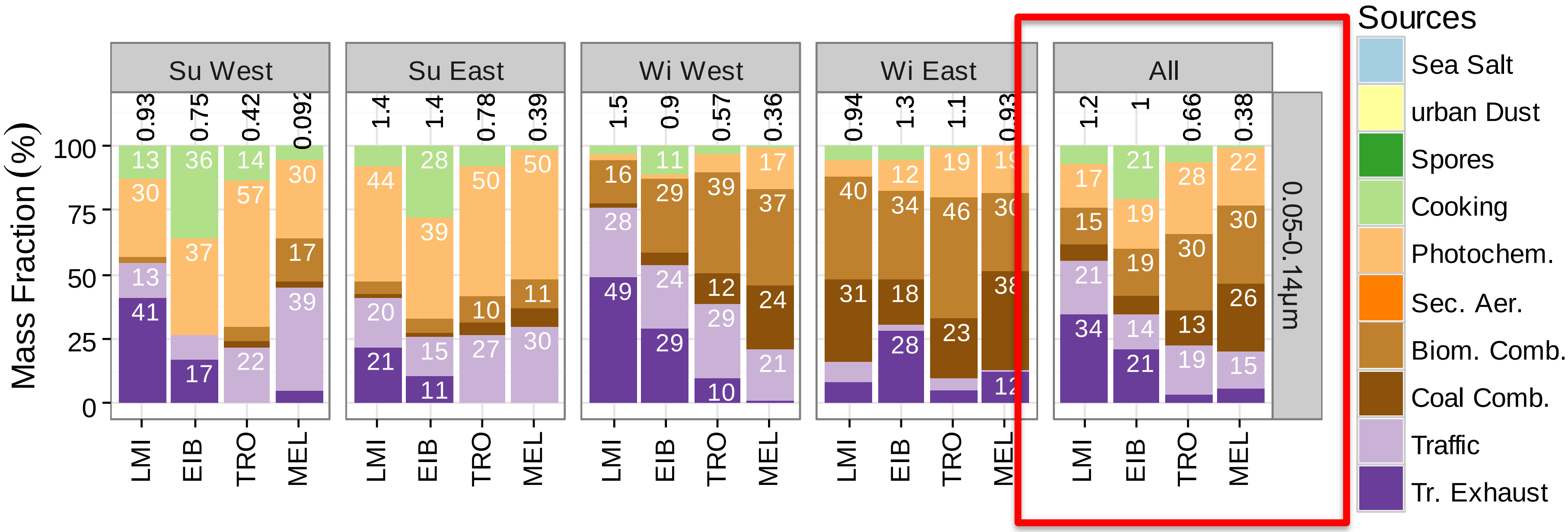
PMF: Identified sources in all particle size ranges

Sources in UFPs

Source	Size range	Main constituents	Marker compounds
Traffic exhaust	ultrafine coarse	WISC	Hopanes, <C25 n-Alkanes
Traffic (non-exhaust)	ultrafine fine coarse	WISC, (Fe)	Copper, Barium
Coal Combustion	ultrafine fine (coarse)	WISC, Sulfate	PAHs, Arsenic, (Hopanes)
Biomass Combustion	ultrafine fine coarse	WISC,WSOC	Levoglucosan, Potassium
Photochemistry	ultrafine fine	Sulfate, WSOC	Oxalate
Secondary (inorganic) aerosol	fine (coarse)	Nitrate, Ammonium, Sulfate	WSOC
Cooking	ultrafine fine	WISC	odd n-Alkanes
Crust material (urban)	coarse	Nitrate, WSOC	odd n-Alkanes, Magnesium, Calcium, Oxalate
Fungal spores	coarse	WISC, WSOC	Arabitol
Fresh sea salt and road salt	coarse	Chloride, Sodium	Magnesium
Aged sea salt	coarse	Nitrate	Sodium, Magnesium

Sources in ultrafine particles (0.05 – 0.14 µm)

Impactor Stage 1



→ Traffic at traffic sites: ca. 0.2 – 1 µg m^{-3}, 20 – 70 % of stage 1 mass (means)

→ Photochem. at urban sites in summer: ca. 0.2 – 0.6 µg m^{-3}, 20 – 50

→ Solid fuel combustion in winter: ca. 0.2 – 0.9 µg m^{-3}, 20 – 70 %

Approx. mean contributions to UFP mass at Leipzig-Mitte:

50 % traffic

20 % combustion

20 % photochemistry

10 % cooking

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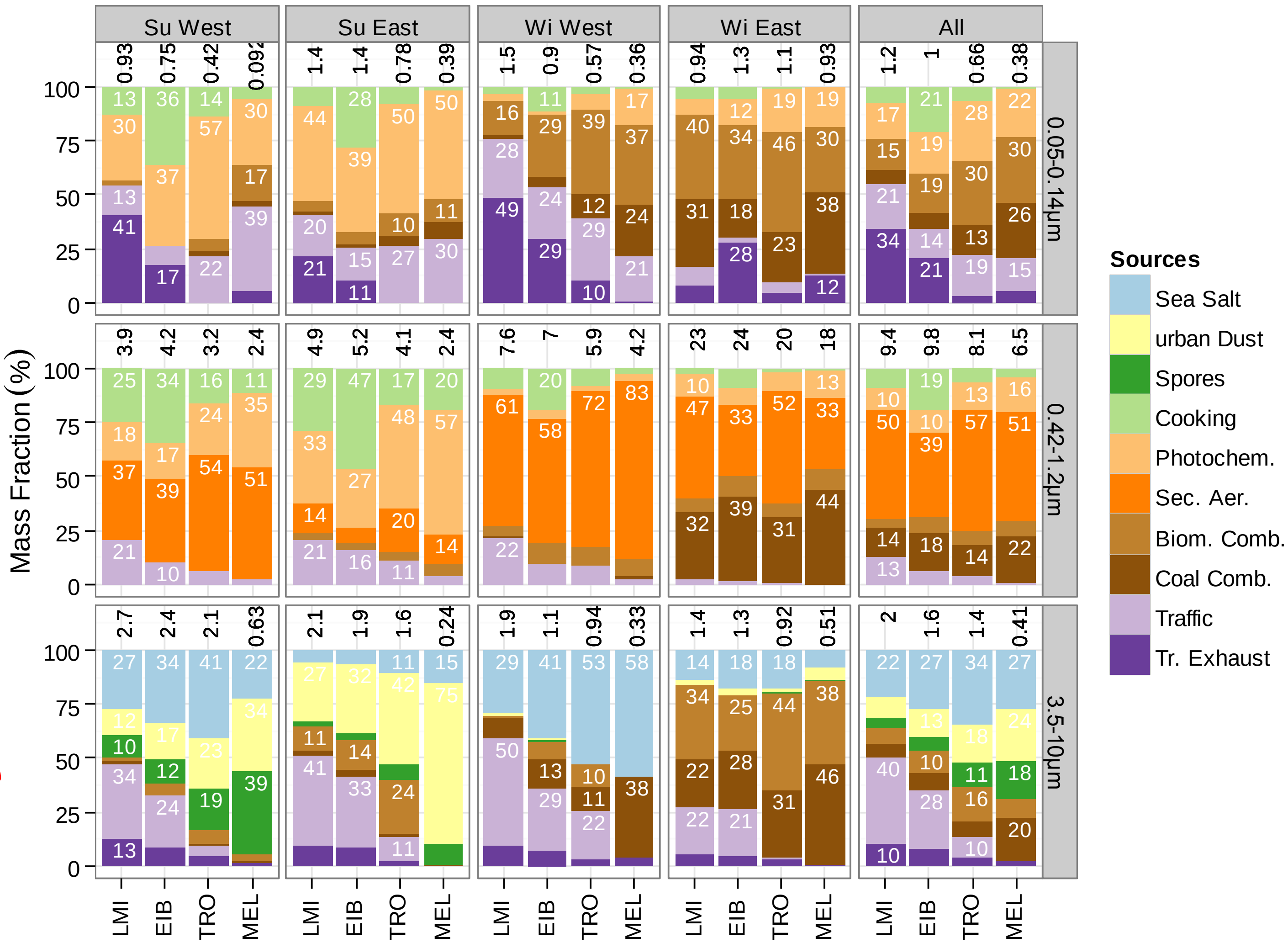
Source contributions in ultrafine, fine and coarse particles

UFP

Fine

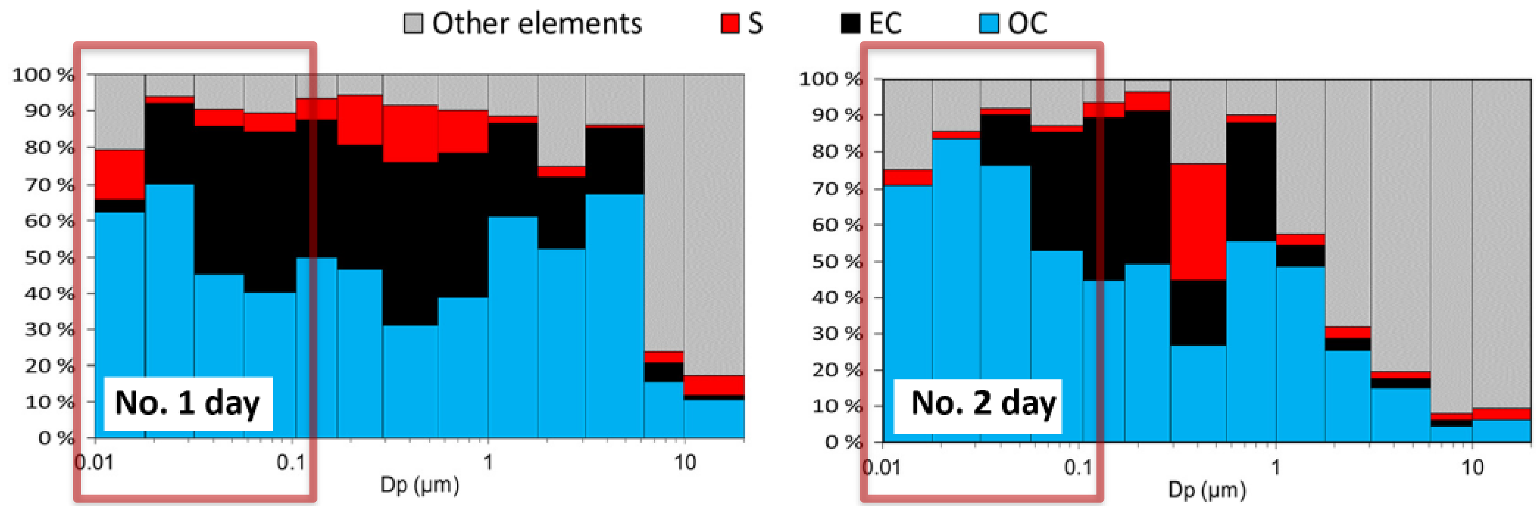
Coarse



→ Very different source contributions in different particle size ranges

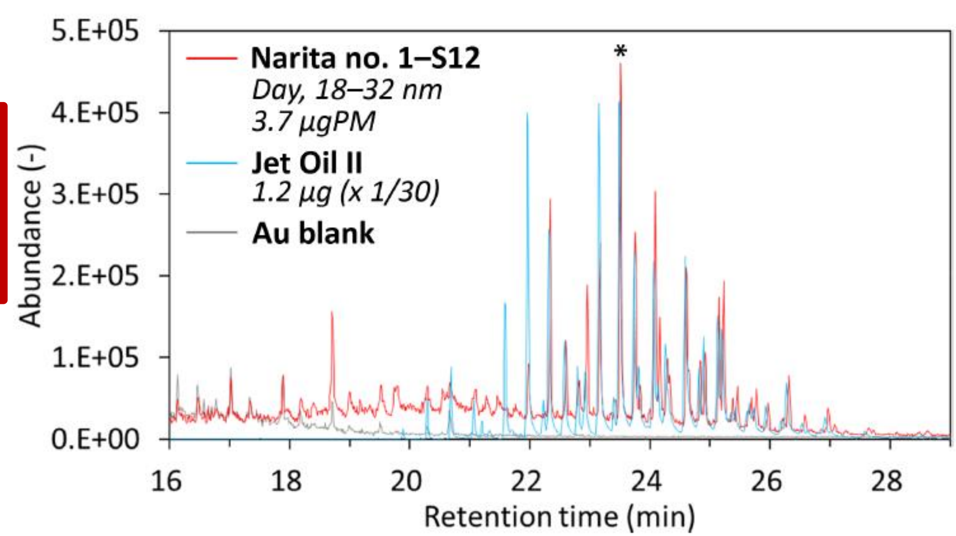
UFP source contributions from airports?

Fushimi et al., 2019: nanoMOUDI sampling @ Narita International, Japan
(doi: 10.5194/acp-19-6389-2019)



UFP size range

Chemical analysis with TD-GC/MS identifies strong contribution of jet lubrication oils to aircraft exhaust UFPs



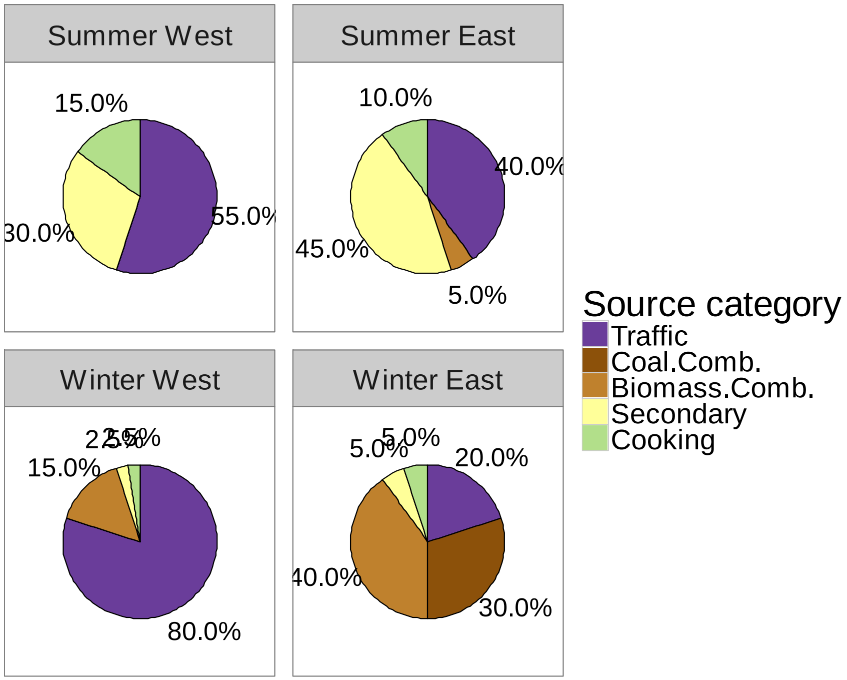
Summary

Zusammenfassung

- UFP Probenahme ist problematisch, v.a. für Partikel < 70 nm
- UFP Gesamtmasse wird von kohlenstoffhaltigem Material dominiert
- Hohe Anteile toxischer Bestandteile wie PAK (polyzyklische aromatische Kohlenwasserstoffe) und Metalle
- Hauptquellen:
  - Verkehr (Abgas und Nicht-Abgas)
  - Feststoffverbrennung (Winter)
  - Photochemie (Sommer)

→ Die chemische Zusammensetzung kann zur Identifizierung von UFP-Quellen verwendet werden

UFP Zusammensetzung in Leipzig-Mitte



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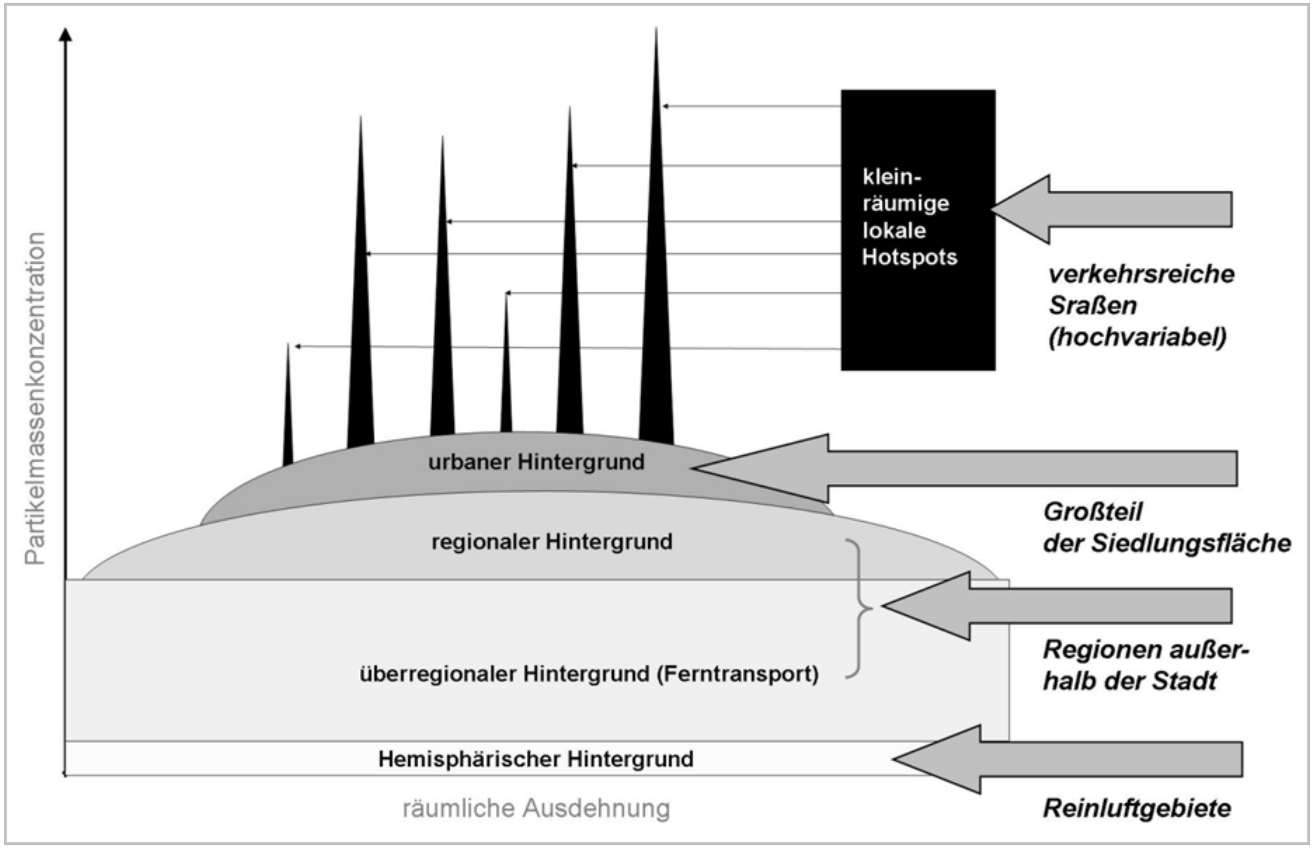
Vielen Dank für ihre Aufmerksamkeit

Annex

Source Apportionment in Leipzig: Lenschow Approach

Source apportionment approaches I: Lenschow

Lenschow et al., 2001: PM as superposition of sources in different regions



LMI, EIB

TRO

MEL

Traffic increment = c(LMI, EIB) - c(TRO)

Urban background increment = c(TRO) - c(MEL)

Regional background = c(MEL)

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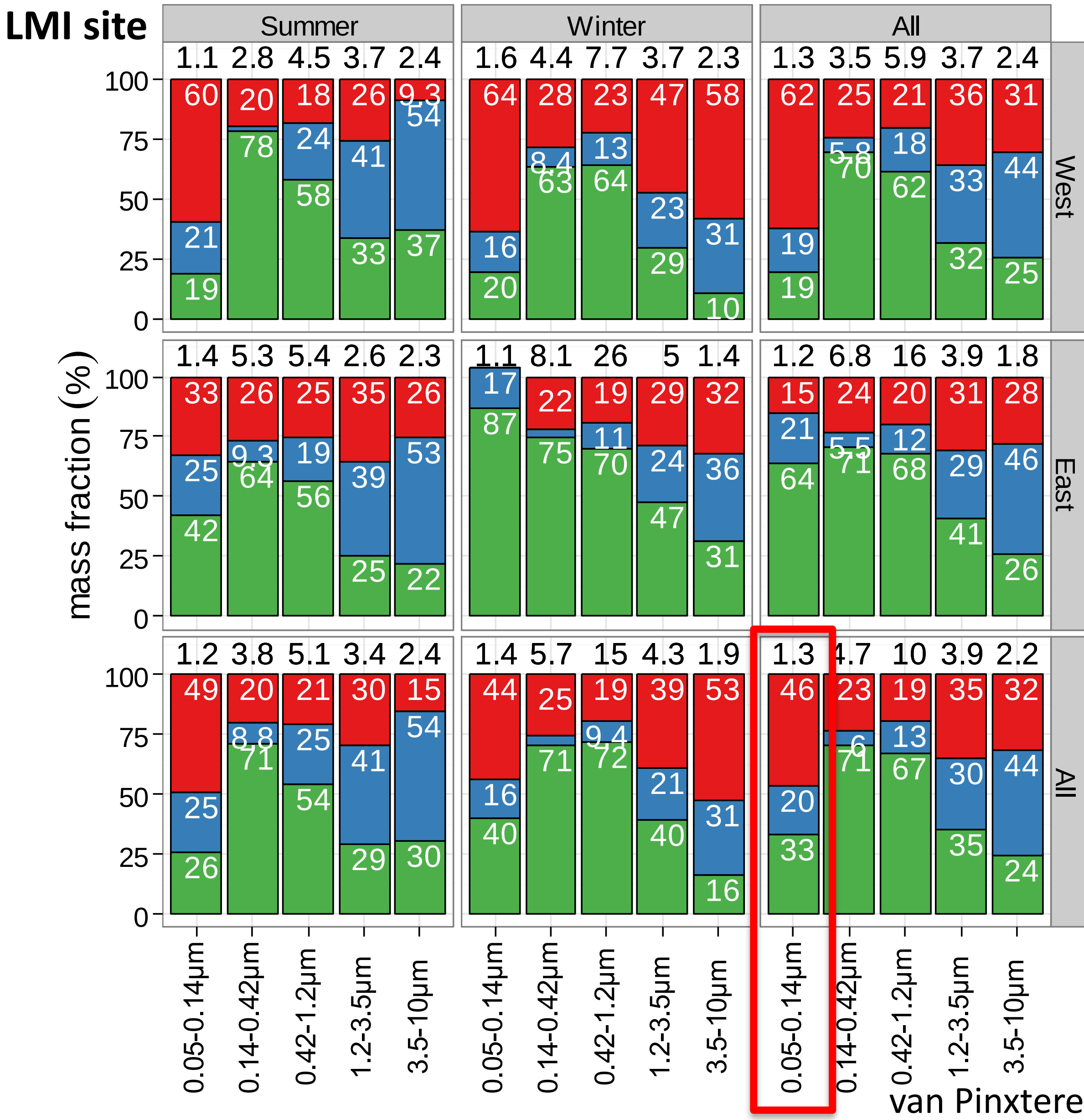
Local vs. regional PM mass contributions at LMI site



Typical regional (transported) contributions:

- 30% for ultrafines
- 70% for accumulation mode particles
- 30% for coarse particles

Mean UFP source contributions:

50 % traffic

20 % urban background

30 % regional background

→ 70 % reduction potential by local mitigation measures

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van Pinxteren et al., 2016, doi: 10.1039/c5fd00228a