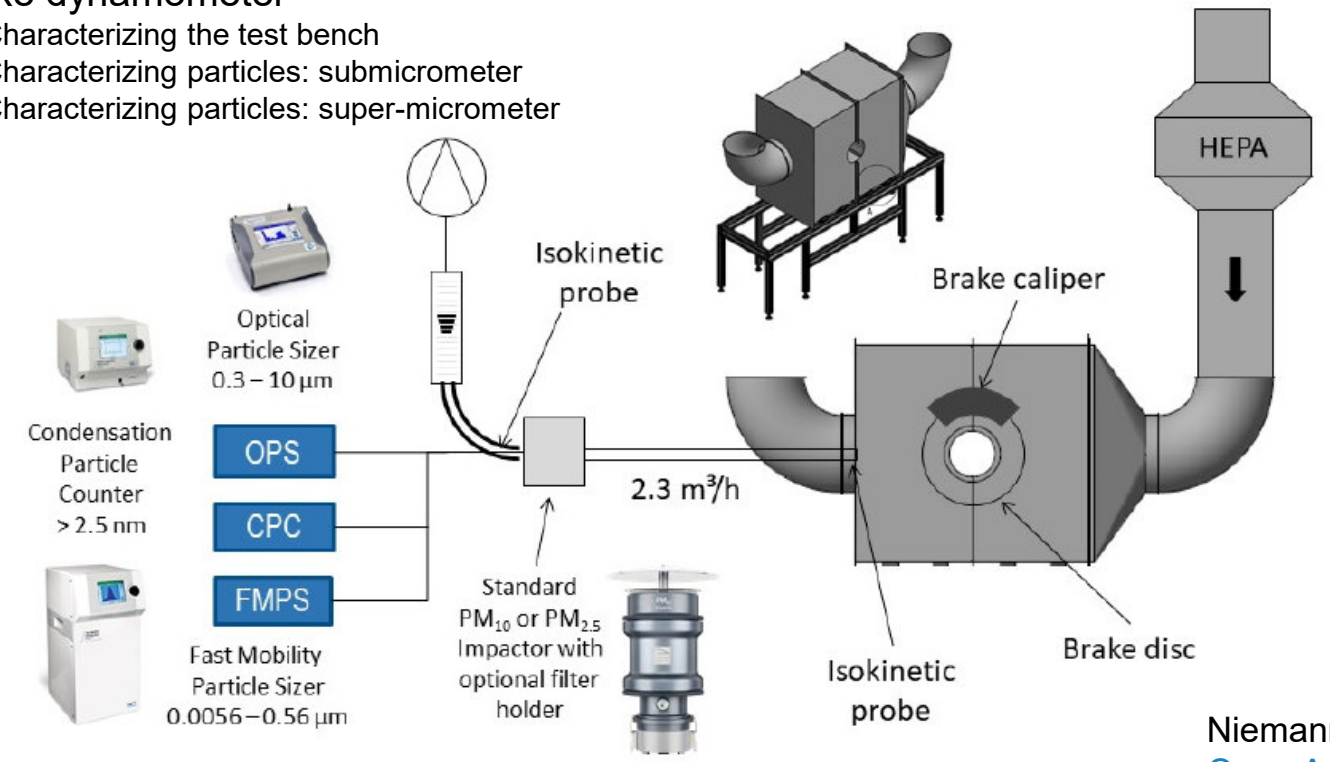
Airborne Particle Measurements - Brake Wear Emission Research, Occupational Exposure Assessments and Ambient Monitoring

Jürgen Spielvogel, Andrea Tiwari, Carsten Kykal, Stephane Percot

Brake wear measurement

Brake dynamometer

- Characterizing the test bench
- Characterizing particles: submicrometer
- Characterizing particles: super-micrometer

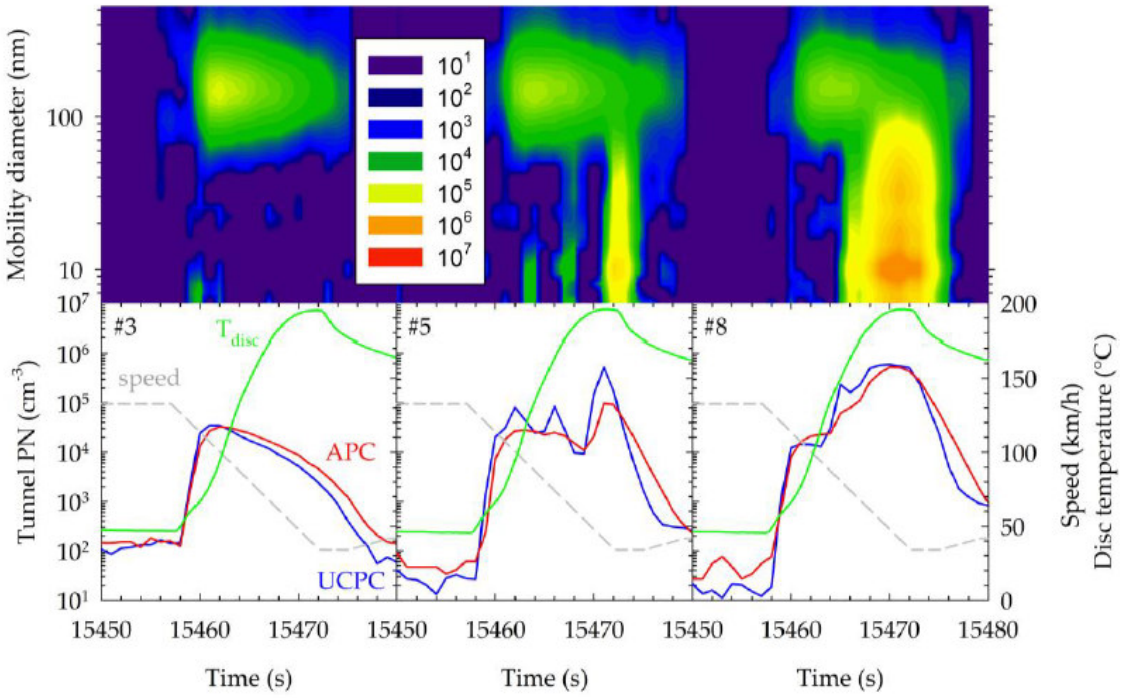


Niemann *et al* 2020 *Atmosphere*, Fig 2, Open Access license

EEPS for dynamic particle behavior

- Size of emitted particles changes with time….
- …number data alone doesn't reveal this

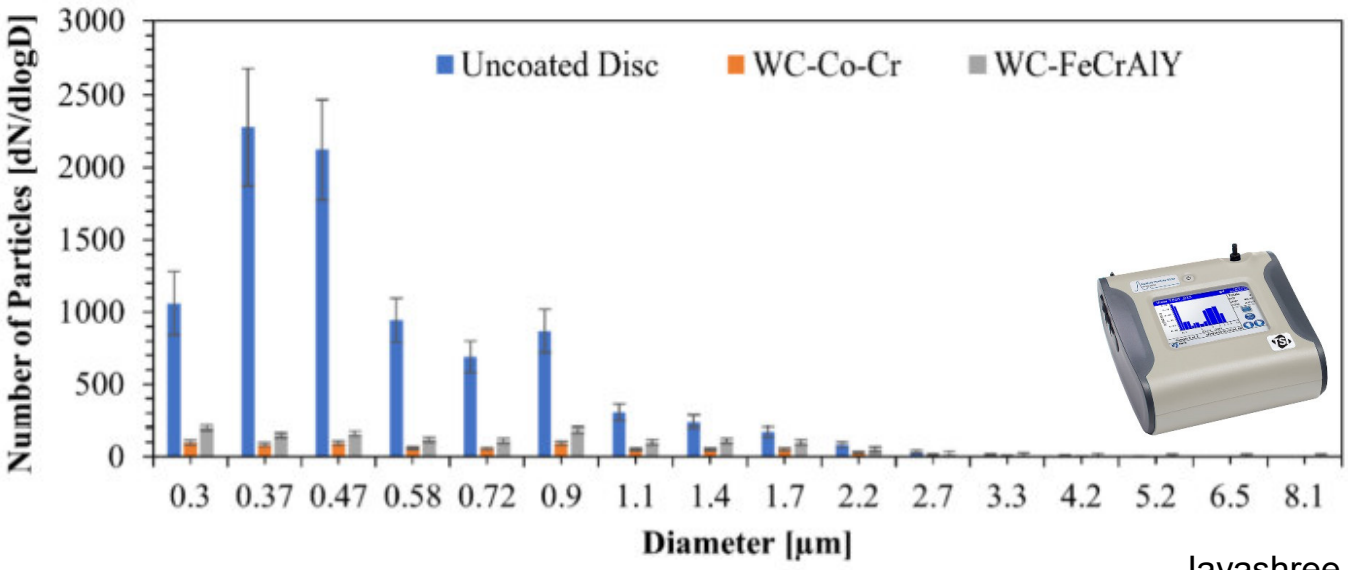
EEPS



Mamakos *et al* 2021 *Atmosphere,* Fig 6, Open Access license

Measurement of larger particles - OPS

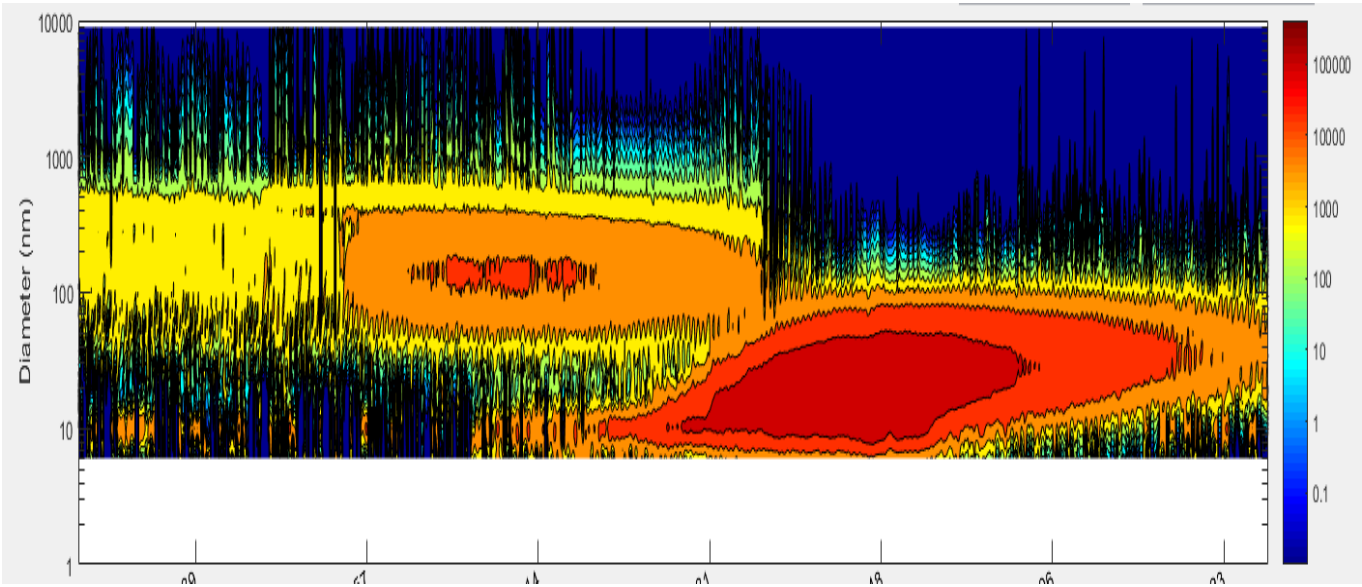
- Emissions vary by disc type
  - Overall concentration
  - Size distribution (i.e. peaked vs. ~flat)



Jayashree *et al* 2022 *Atmosphere,* Fig 7, Open Access license

Combining data: 6 nm – 10 µm

- EEPS + OPS in Multi-instrument-manager (MIM) software
- Size distribution of particles generated upon brake application, and upon release

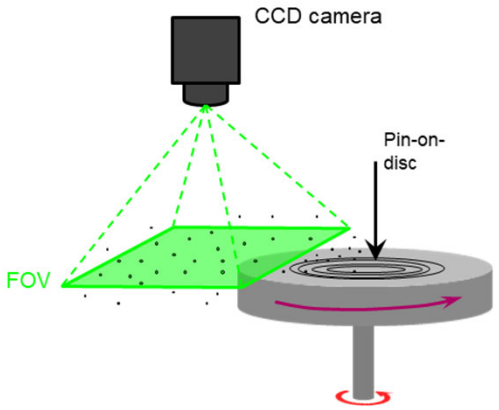


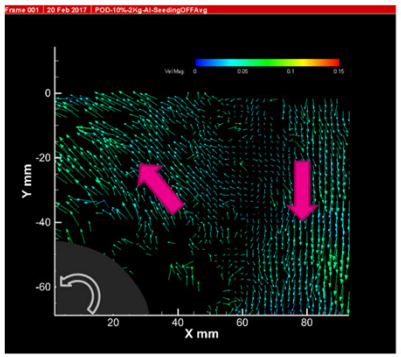
Fluid dynamics observations

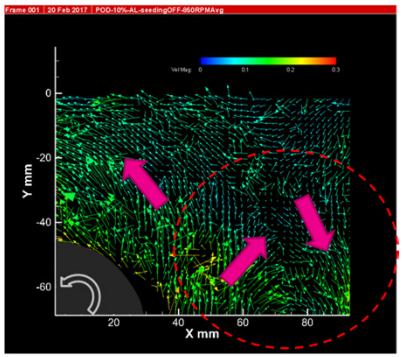
- **Particle Image velocimetry (PIV) system:**
  - Camera CCD 8MP (4Hz)
  - Laser Nd-YAG with 200mJ/pulse (wavelength 532nm)
  - Synchronizer
  - Software : Insight4G®
  - Size of the FOV : 70×70mm² Duration of acquisitions: 15 seconds

- **Two tests performed:**

- 1) Seeding the flow in the chamber and measure the velocity fields around the disk
- 2_ Solid particles ejected used as seeding particles (no seeding is added in the chamber)





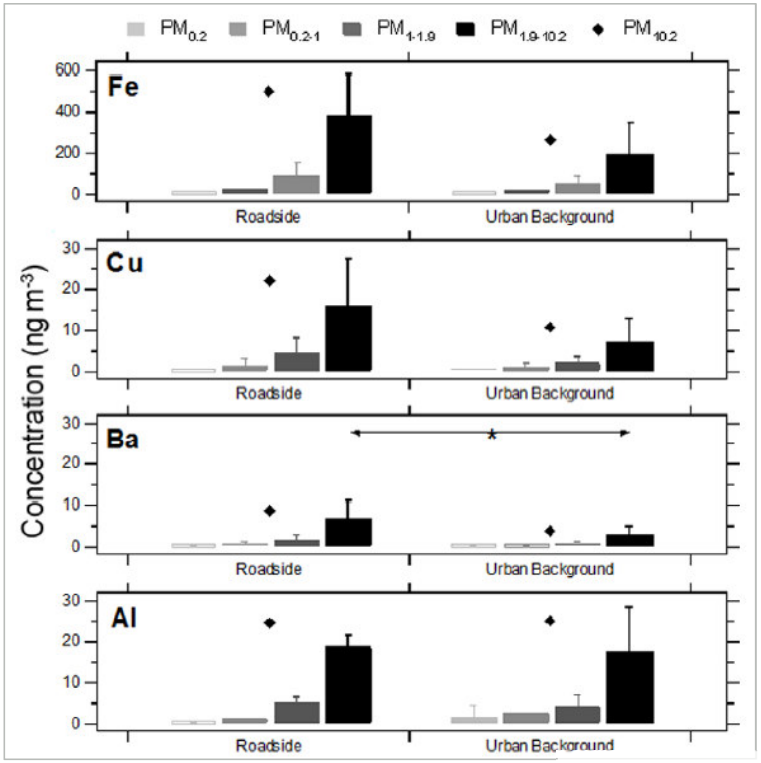


Higher rotation speed (850RPM)

➔ Different path for the solid particles

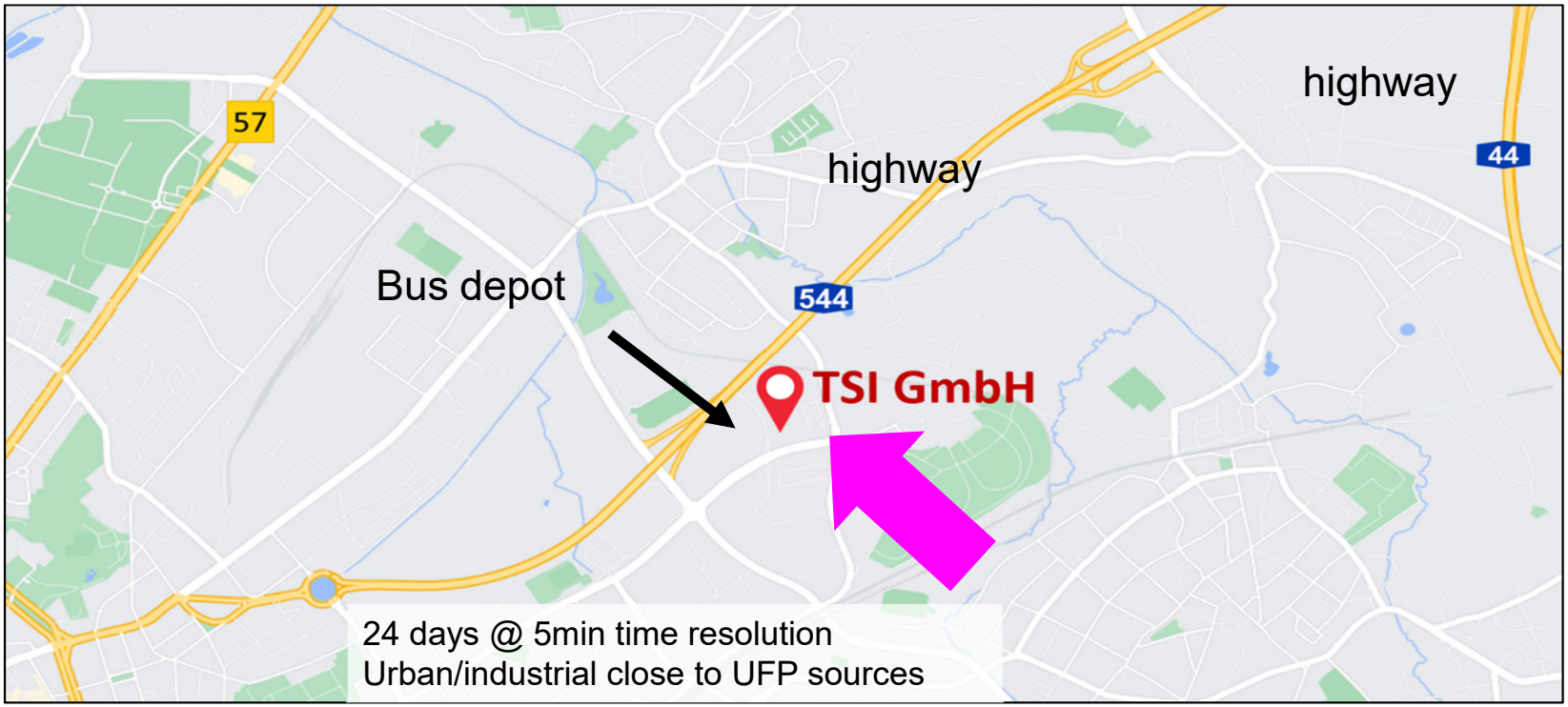
Aerosol composition: cascade impactors

- Sampling ambient air
  - MOUDI used to collect airborne PM samples at schools (roadside vs. background)
  - Barium elevated at roadside sites relative to urban background sites
    - Ba is a marker for brake wear



Godri *et al* 2011 *PLoS ONE,* Fig 2, Open Access license

CEN-compliant Ambient Monitoring – SMPS & CPC



Schmitt et al. (EAC 2021)

Occupational exposure assessment

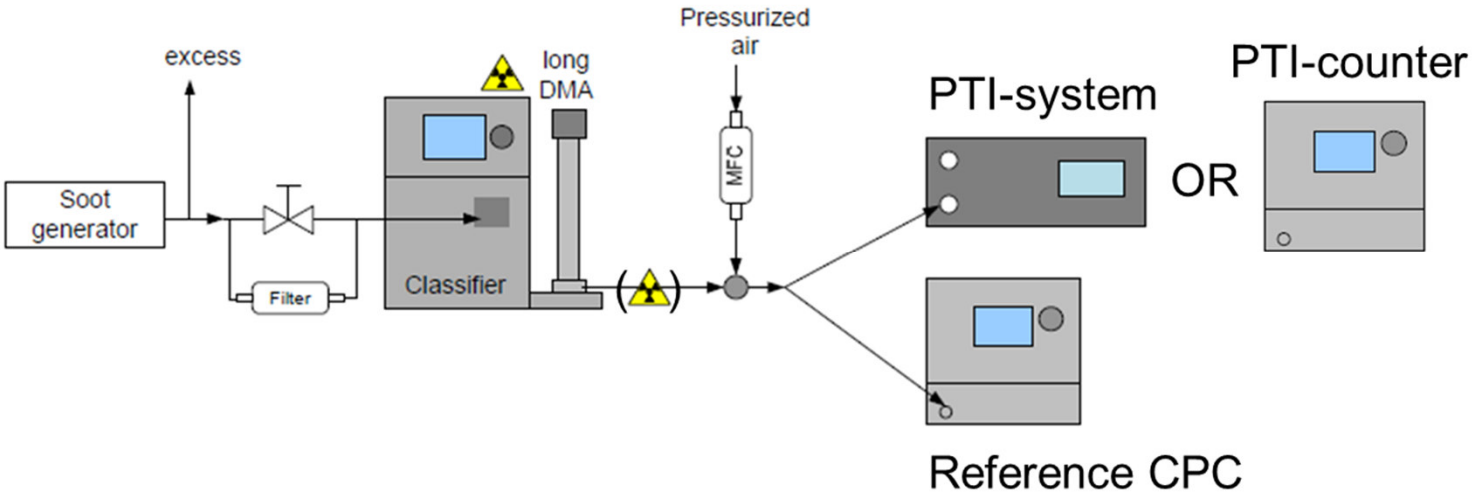
- Mini-MOUDI Impactor
  - Personal or industrial hygiene sampling
  - 2 L/min sample flow
  - 10 mm to 56 nm
  - 6, 8 and 10 impaction stages

- Personal Environmental Monitor™ (PEM™), Model 200
  - Lightweight, personal sampler with single stage impactor and final filter
  - Impactor cut-point of 2.5 or 10 µm
  - Can be operated with a personal sampling pump

- DustTrak
  - PM-10, respirable, PM-2.5, PM-1
  - Collects sample for gravimetric analysis

Calibration – e.g. PTI counters

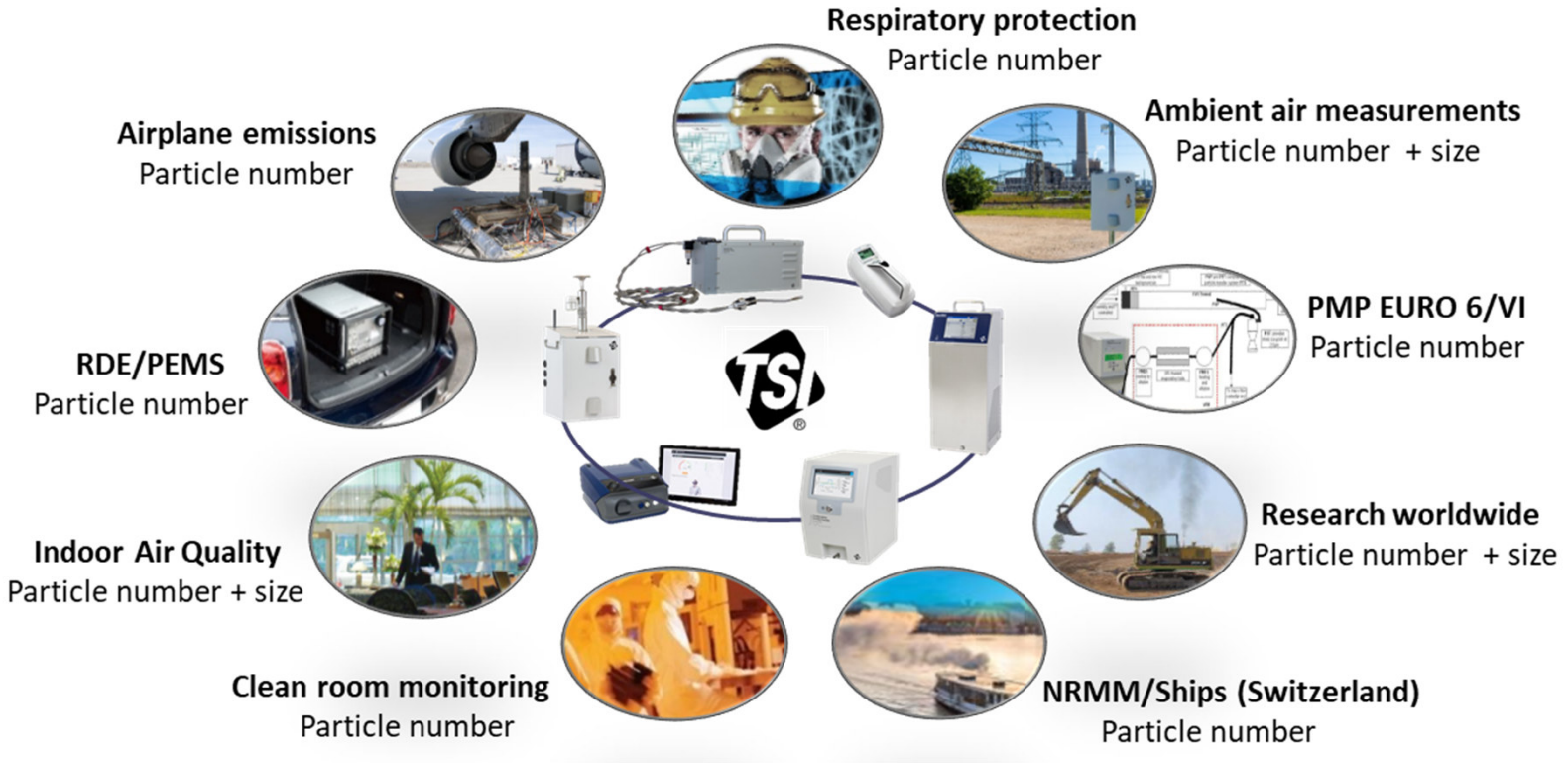
- Setup – adapted from JRC Technical Report 2018, Real Driving Emissions (RDE) B. Giechaskiel



(traceably calibrated according to ISO 27891)

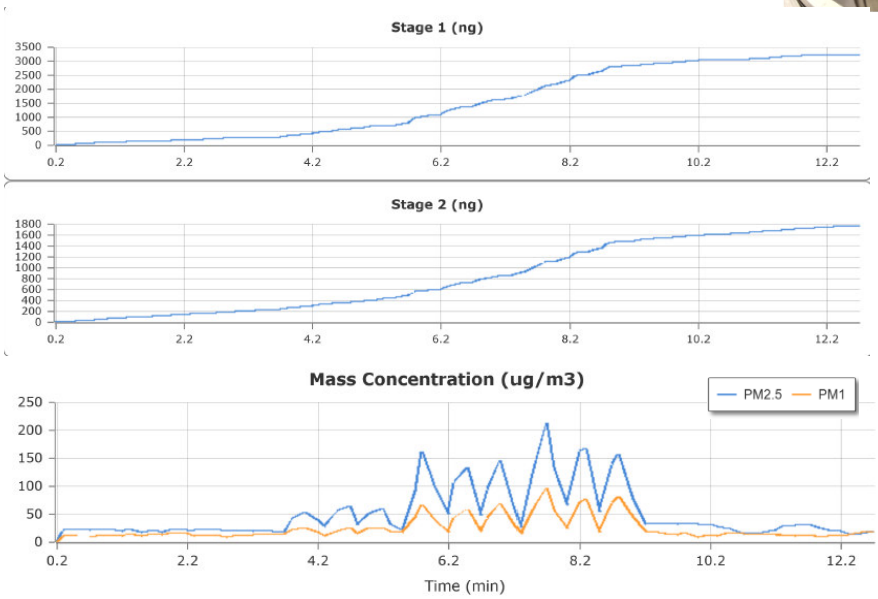
Thank you for your attention!

juergen.spielvogel@tsi.com



Real-time mass measurements

- QCM MOUDI (140)
  - Real-time PM2.5 mass data in six stages
    - Stage cut points (in nm): 960, 510, 305, 156, 74, 45
  - Combines two technologies
    - Cascade impactor (MOUDI)
    - Quartz crystal microbalance (QCM)



- QCM MOUDI captures mass emissions from pin applications
- Mass-based size distribution data can be cumulative or time series