WEBINAR

T-AERO - *A Complete Solution for Sampling Airborne Particulate Matter*

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Outline

01 T-AERO Introduction

BRUKER ELECTRON MICROSCOPE ANALYZERS

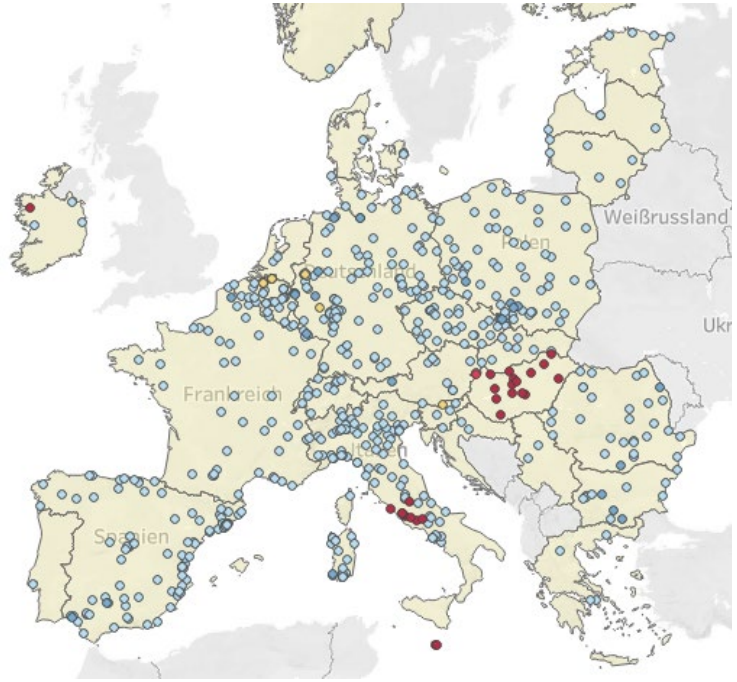
Current Situation and Opportunities

Current Situation

Situation in the EU

- About 300.000 premature deaths resulted from exposure to fine particle matter (PM). 96% of the EU's urban population is exposed to unsafe concentrations of fine particulate matter (PM2.5)
- Regulatory: New measurement techniques are needed for enforcing new air quality regulations for toxic elements in the air (Ni, As, Pb, Cd, Hg)
- ICP and AAS are recommended techniques in old norms (EN 14902:2005, EN 15841:2010, EPA IO-3.2 (AAS) and IO-3.5 (ICP))

Element	Limit value EU	WHO guideline
Pb	0.5 µg/m³	0.5 µg/m³ (AQG)
As	6 ng/m³	6.6 ng/m³ (RL)
Cd	5 ng/m³	5 ng/m³ (AQG)
Ni	20 ng/m³	25 ng/m³ (RL)
AQG: air quality guideline, RL: reference levels		



Pb in PM, 2023, ● >1 µg/m³

Sources

- Europe's air quality status 2024
- EU air quality standards
- WHO air AQG/RL

Current Situation

Situation in the USA

- Protection and improving air quality is described in the Clean Air Act from 1990.
- Since 2008, the only regulated toxic element is Pb (0.15 µg/m³)
- Accepted techniques are AAS, ICP and EDXRF (about 100 monitoring sites)

Situation in Asia

- Campaign on Atmospheric Aerosol Research Network of China (CARE-China, 2015)
- 36 field stations, PM 2.5, carbon, gas and salt measurements, no elemental analysis
- Legal limit for Pb is 0.5 µg/m³ (China, South Korea)
  no elemental limit in Japan

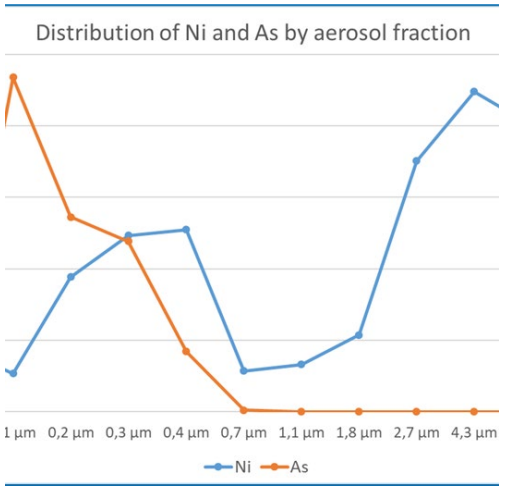
Sources

- US clean air act
- CARE China
- Air quality standard China

Current Situation

Recent activities and upcoming projects

- Participation at AEROMET I and II
  EU funded program for atmospheric science and air quality driven by national metrology institutes.
  www.aerometproject.com
- Successful in-field application of TXRF during 1st pilot program
- Project proposal for „Non-exhaust emissions“
  - focus on emmissions from brakes, tires (incl. EV)
  - inhouse testing at industrial manufacturers
  - start in 2026 (?)
- MI-TRAP
  - MItigating TRansport-related Air Pollution in Europe
    https://mitrap-project.eu/



Literature

Quantification of Element Mass Concentrations in Ambient Aerosols by Combination of Cascade Impactor Sampling and Mobile Total Reflection X-ray Fluorescence Spectroscopy
Seeger, S., et al., Atmosphere 2021 (12), 309

Projects and Collaborations

Field tests

- Leibniz Institute for Tropospheric Research, Leipzig, Germany
  - Air quality projects in Europe and Africa
  - Has been started in September
- Institute for Environment, Energy, Technology and Analytics (IUTA), Duisburg, Germany
  - Qualified 3 stages (cut-off values)
  - Non-exhaust emissions (brakes, tires)

EU funded project MI-TRAP

- MItigating TRansport-related Air Pollution in Europe
  - 22 beneficiary and 4 associated partner organisations
  - Duration: 01.01.2024 – 31.12.2027 start workshop 06./07.02.2024, Athens
  - WP 1: Innovative air quality monitoring technologies for transport emission sources, campaign in december 2024
  - WP 2: Provide NRT (Near Real Time) datasets and maps for monitoring pollutants, campaigns from march 2025

02 T-AERO Introduction

BRUKER ELECTRON MICROSCOPE ANALYZERS

The T-AERO Package

The Aerosol Package Content

T-AERO

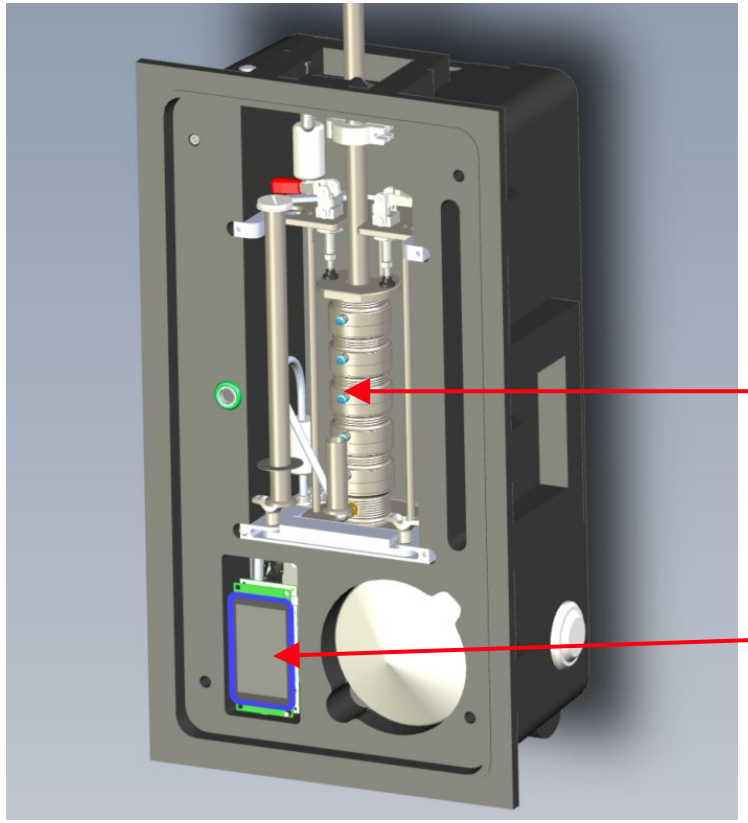
Aerosol Sampling Package

The Aerosol Package Content

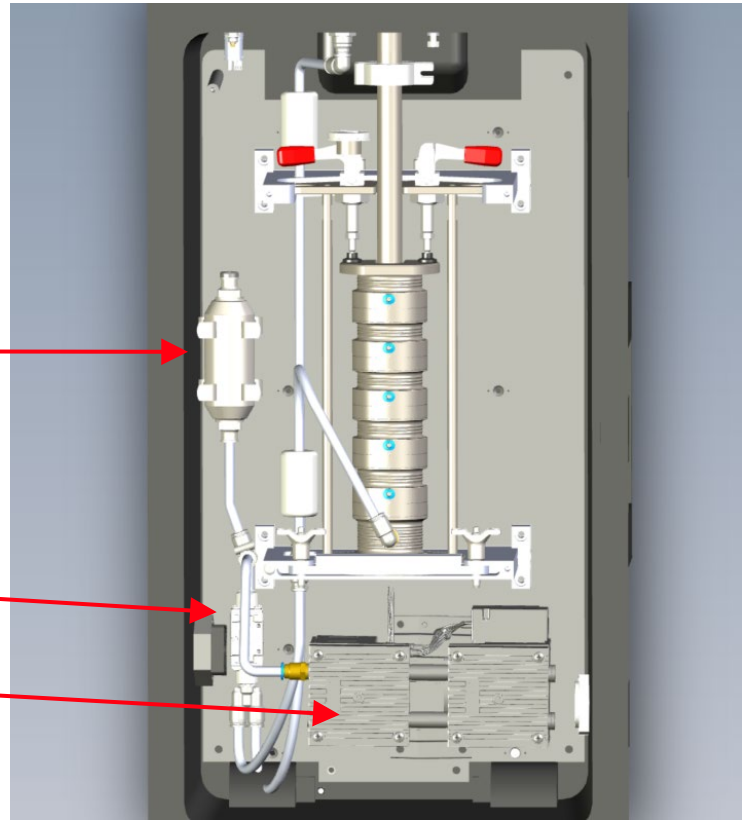
Instrument	S4 T-STAR 400 S2 PICOFOX 400
	Package w/o instrument
Impactor	Bruker 4-stage
Impactor accessories	Pump + flowmeter Micro controller Filter, fittings, tubings
Method	AeroQuant
Standard samples	Cr, Ni, Cd in PM deposition pattern
Transport box impactor	Pelicase
1st delivery	Q1/2026

Transport case with omni-directional air inlet

The Aerosol Package
The Case



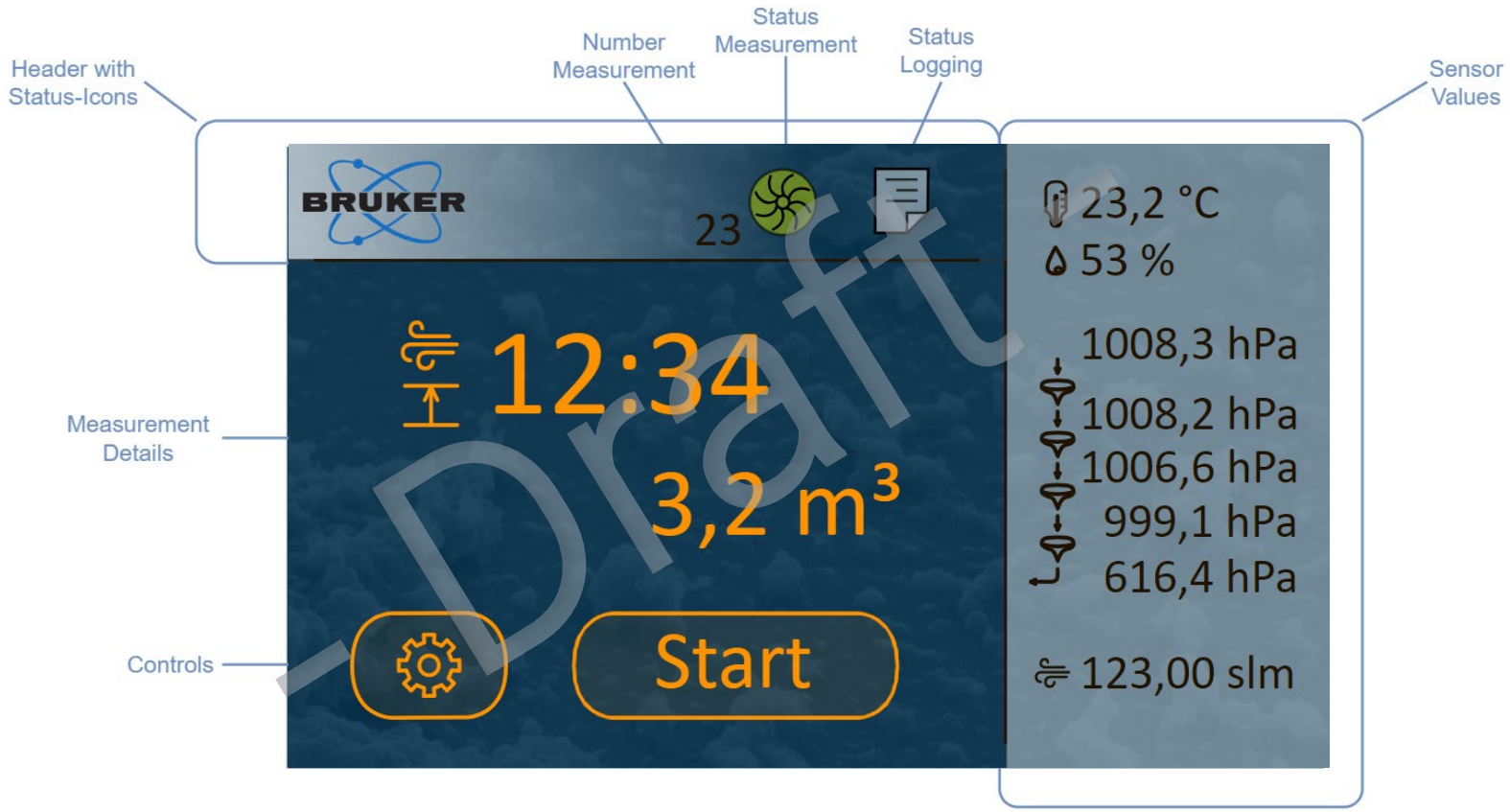
Transport case – upper level



Transport case – lower level

The Aerosol Package
The Controller

- Setting of pump parameters
- Status display
  - Measurement, logging
- Sensor values (planned)
  - Temperature, humidity
  - Pressure



Snapshots of the Installation Video

Key Benefits for the User

T-AERO – Fast, Easy and Accurate Airborne Particle Analysis with TXRF	
Direct sampling on TXRF carriers	Avoids digestion of filters minimizes time effort and risk of contamination
Rapid results	Total sampling and analysis time under one hour
High sensitivity	Detection limits for toxic elements in the pg/m³ range
Compact and robust design	Complete sampling package, easy to install, ready for immediate on-site use
User-friendly operation	Touchscreen control with automated volume display
Versatile applications	From industrial emission monitoring to urban air quality studies

03 T-AERO Introduction

BRUKER ELECTRON MICROSCOPE ANALYZERS

Application Studies

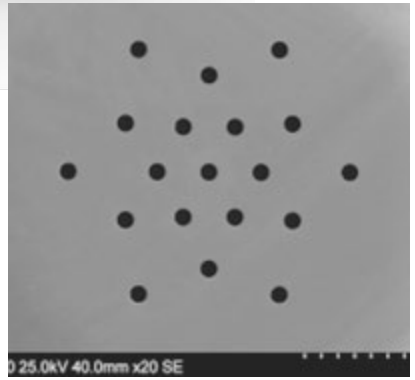
Design of an Optimized TXRF Impactor

Current work

- Design of an impactor optimized for TXRF measurements
  - minimized area of deposited material with a diameter of 3 mm only
- Assembly of a manual 4-stage impactor
  - variation of nozzle plates, nozzle area

Deposition pattern of stage 3, cut-off 1 µm

SEM of stage 4, cut-off 0.15 µm, 19 nozzles

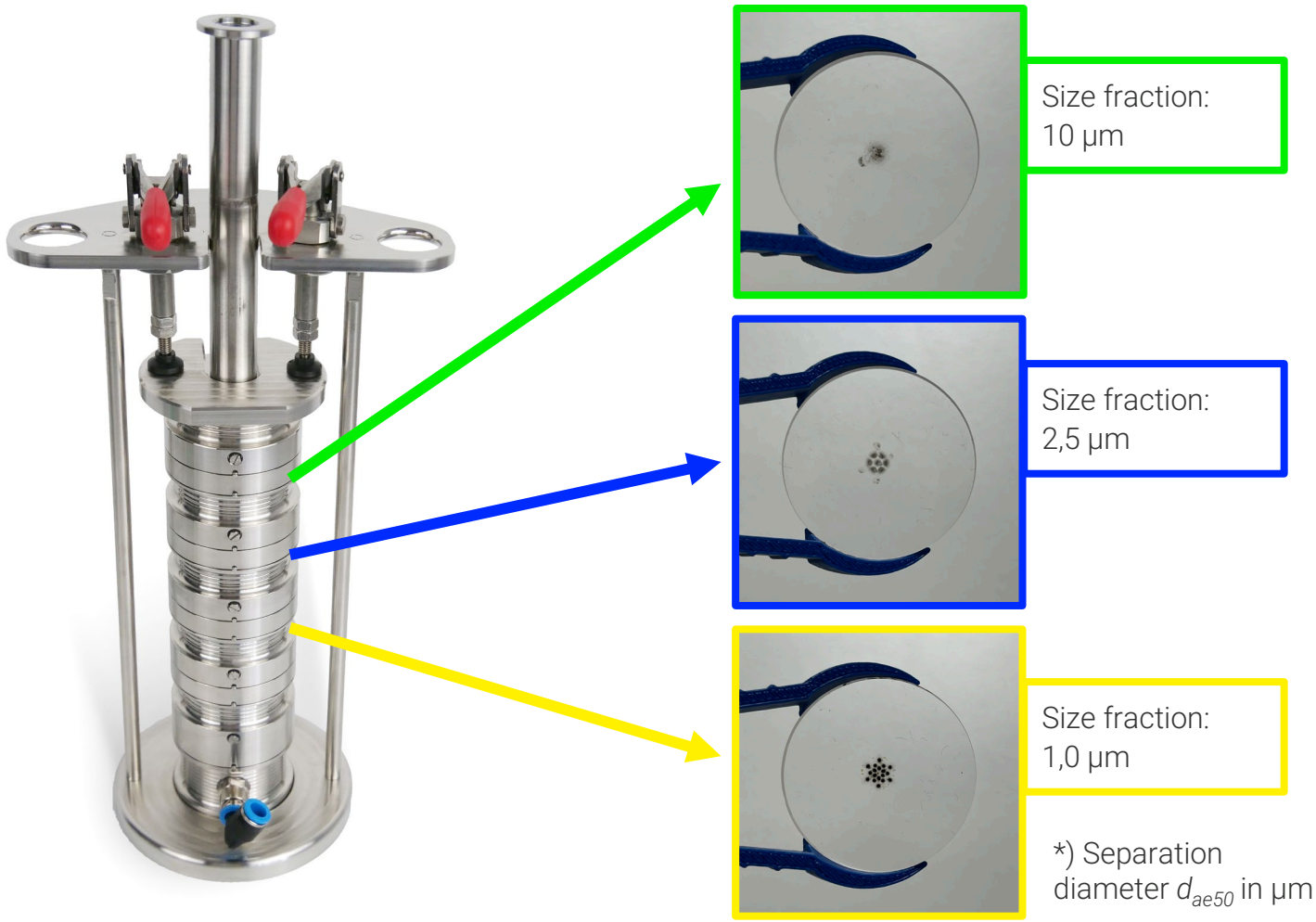


Design of an Optimized TXRF Impactor

Aerosol sampling

1st live test of a 3-stage impactor prototype

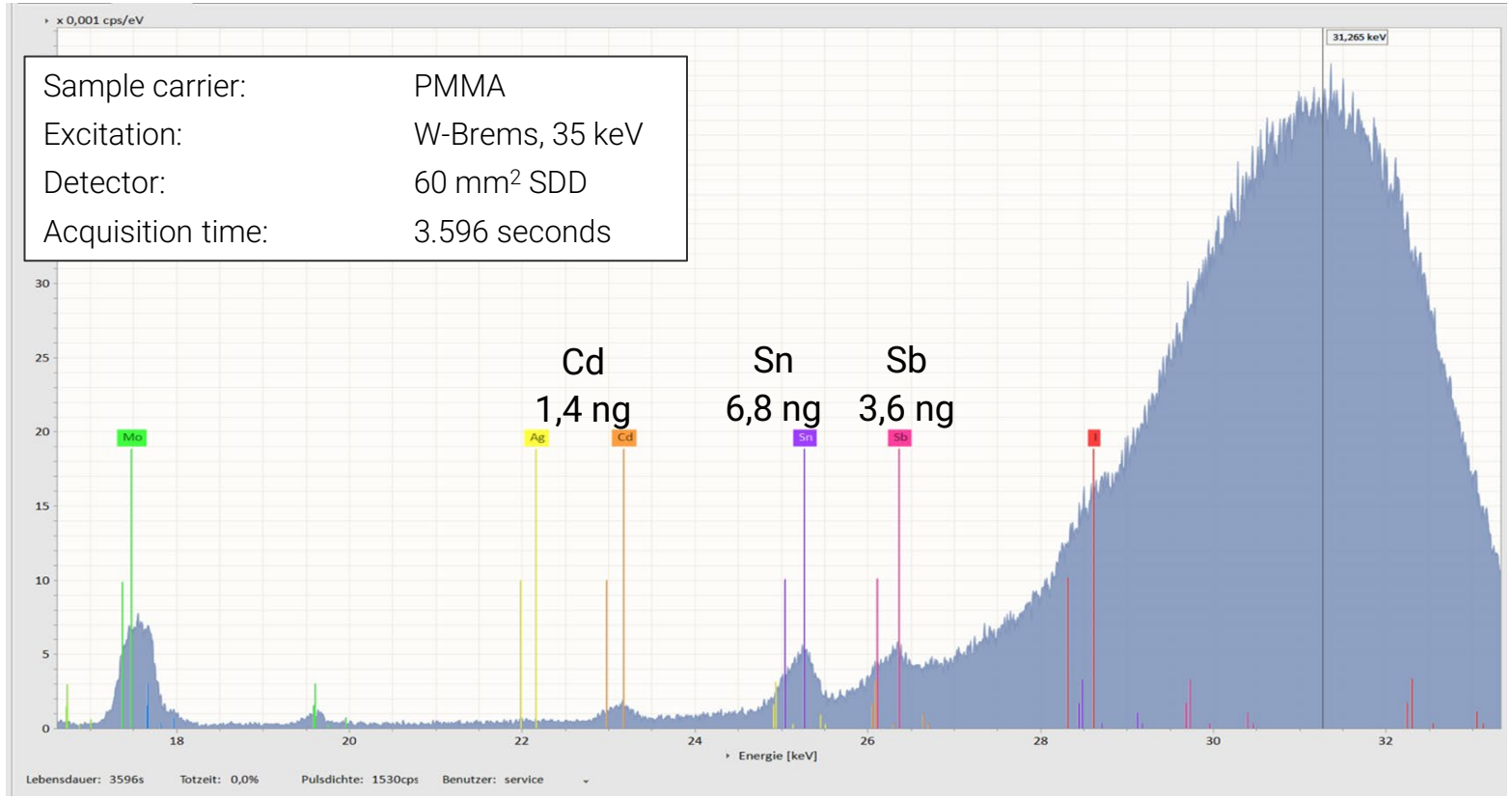
- Flow rate (vol.): 5 slm
- Sampling times: 1 - 72 h
- Sample volume: ≤ 21,6 m^3
- Sample carrier: PMMA
- Location: Bruker building roof terrace



Design of an Optimized TXRF Impactor

Spectrum

- W-Brems excitation
- 72 h sampling time
- 1st detection of Cd, Sn, Sb

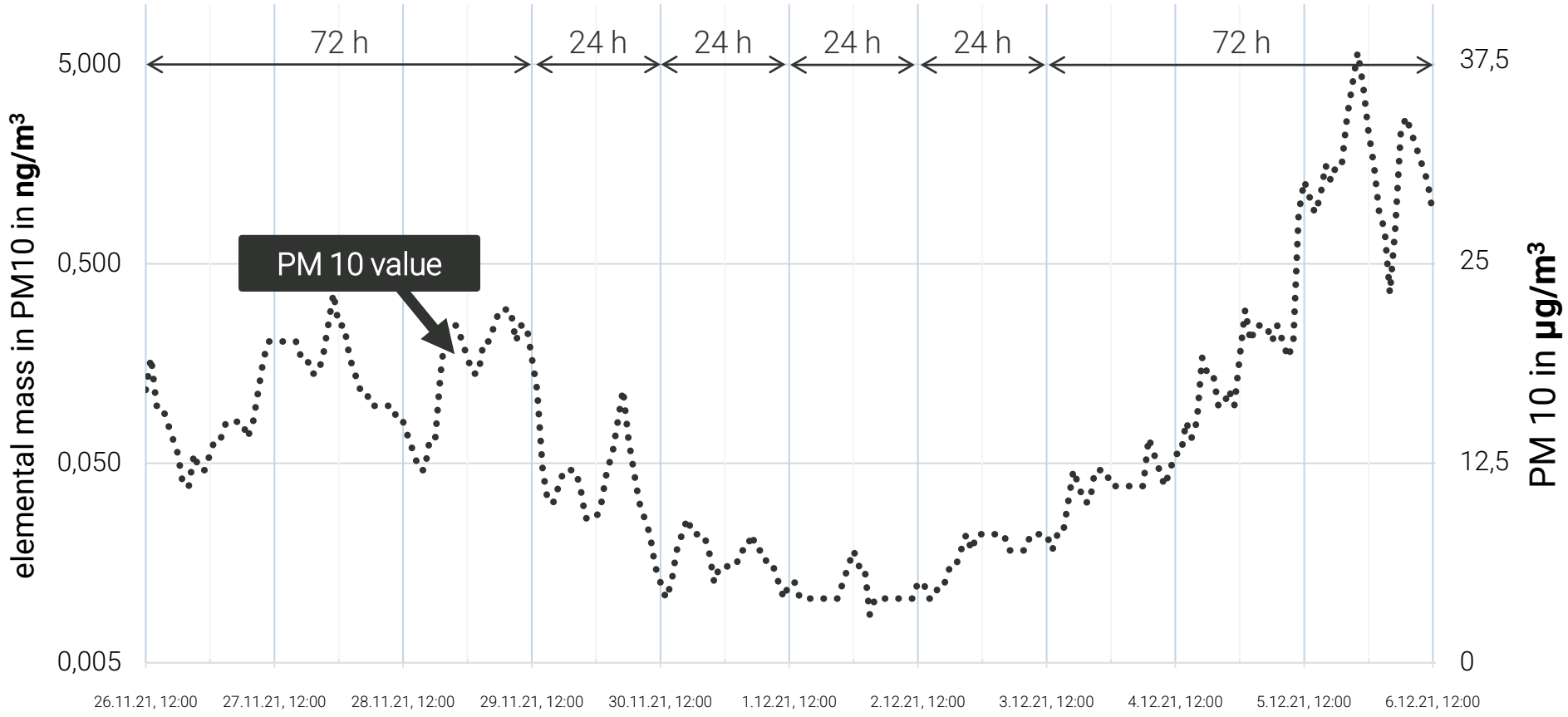


Crazzolara, C. and Held, A. B.: Development of a cascade impactor optimized for size-fractionated analysis of aerosol metal content by total reflection X-ray fluorescence spectroscopy (TXRF), Atmos. Meas. Tech., 17, 2183-2194, 2024

Design of an Optimized TXRF Impactor

First results

- Mo-K and W-Brems excitation
- 24 h - 72 h sampling time
- Similar trend for all elements



Design of an Optimized TXRF Impactor

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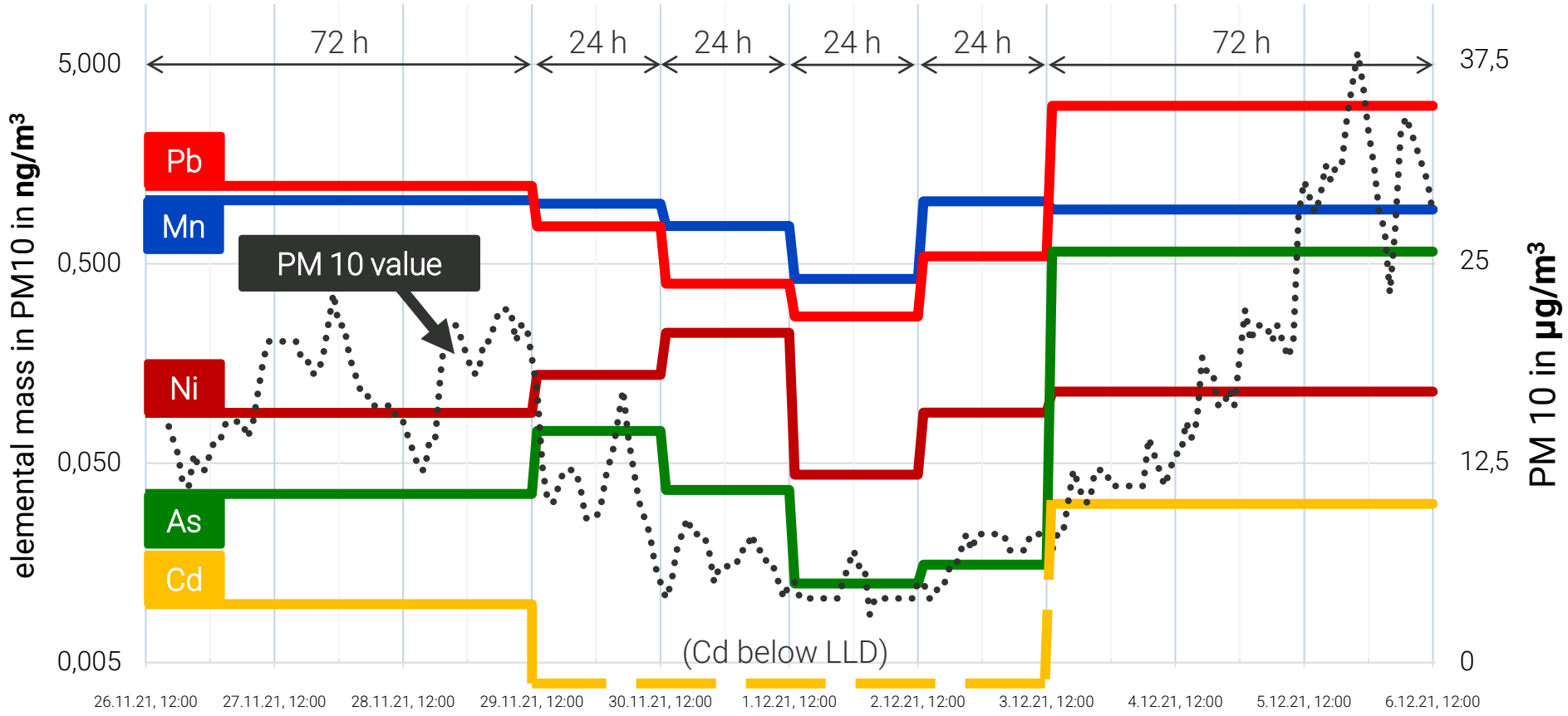
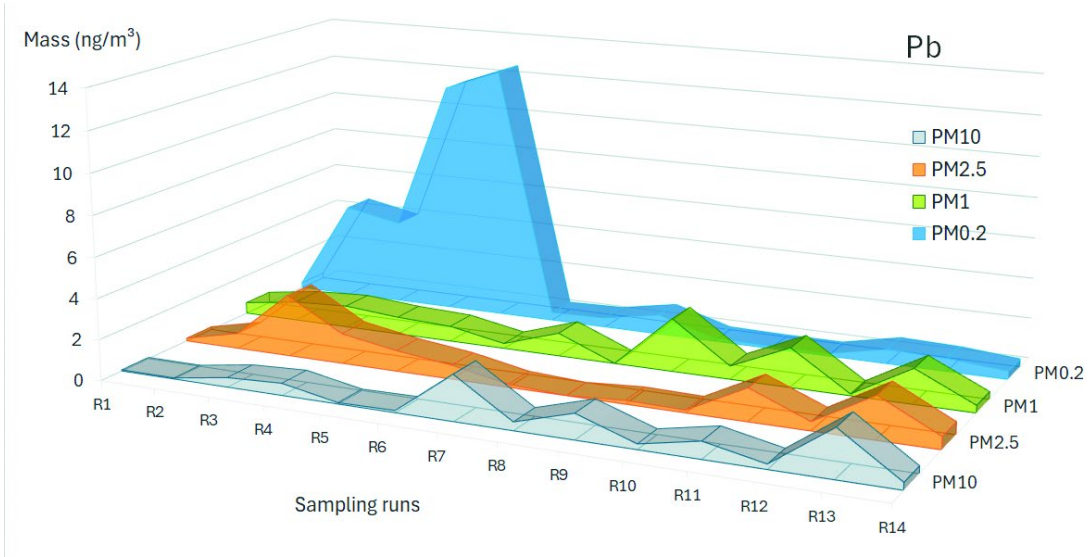


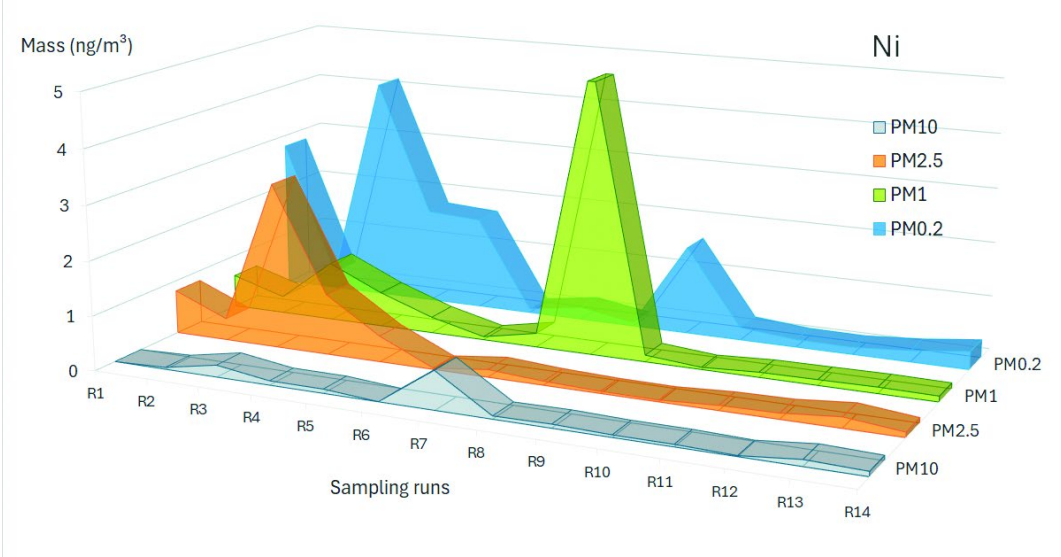
1st Onsite campaigns

Florence, Italy, December 2024

- 4-day campaign with 14 sampling runs (1 – 16 h)
- On-site TXRF measurements with S2 PICOFOX enabled the detection of elements such as Cr, Cu, Ni, As and Pb

- The figures show the development of the mass content of the elements Ni and Pb in the different size fractions
- Detection limits in the pg/m³ range could be achieved at short sampling time of 1 hour





Mass content of Ni and Pb in PM fractions during a 4-day measurement campaign

1st Onsite campaigns

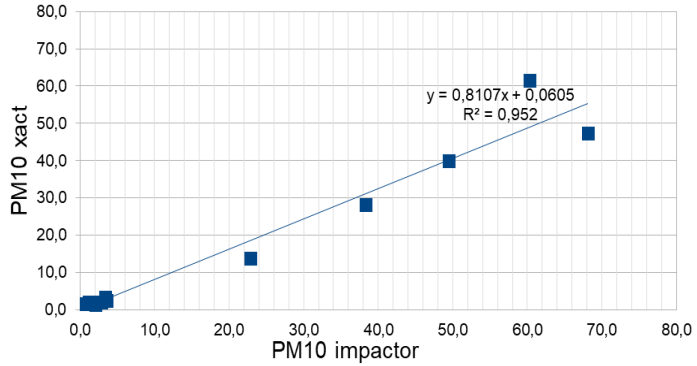
Comparison with online monitor XAct 625

- Online monitoring of metals with XRF based system

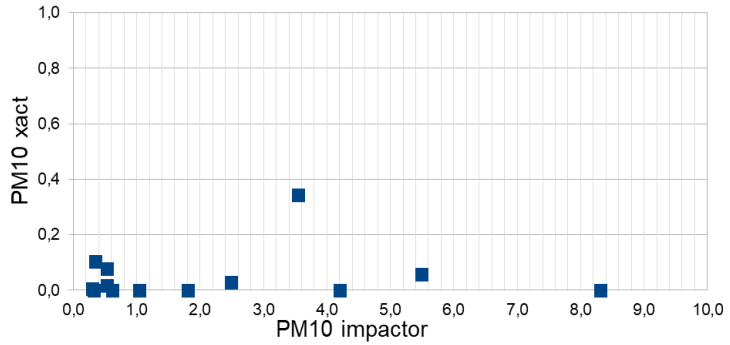
(SailBri Cooper Inc., Tigard, OR, USA, model Xact 625)

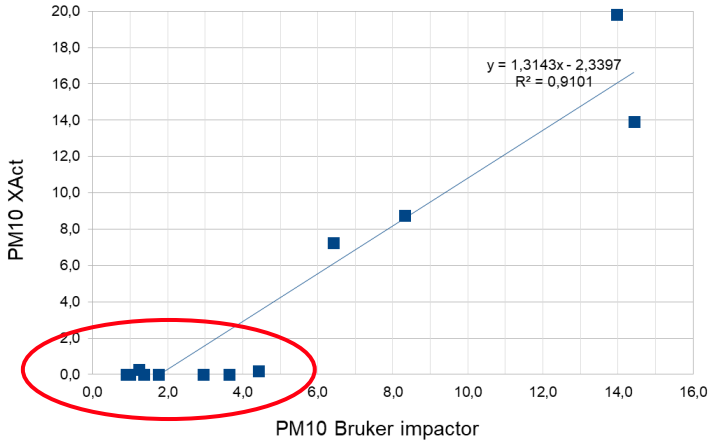
- Published limits are questionable, only apply for full PM fraction

Good concordance for geogenic elements (Ca, Fe)



no XAct values for Ni or low Pb





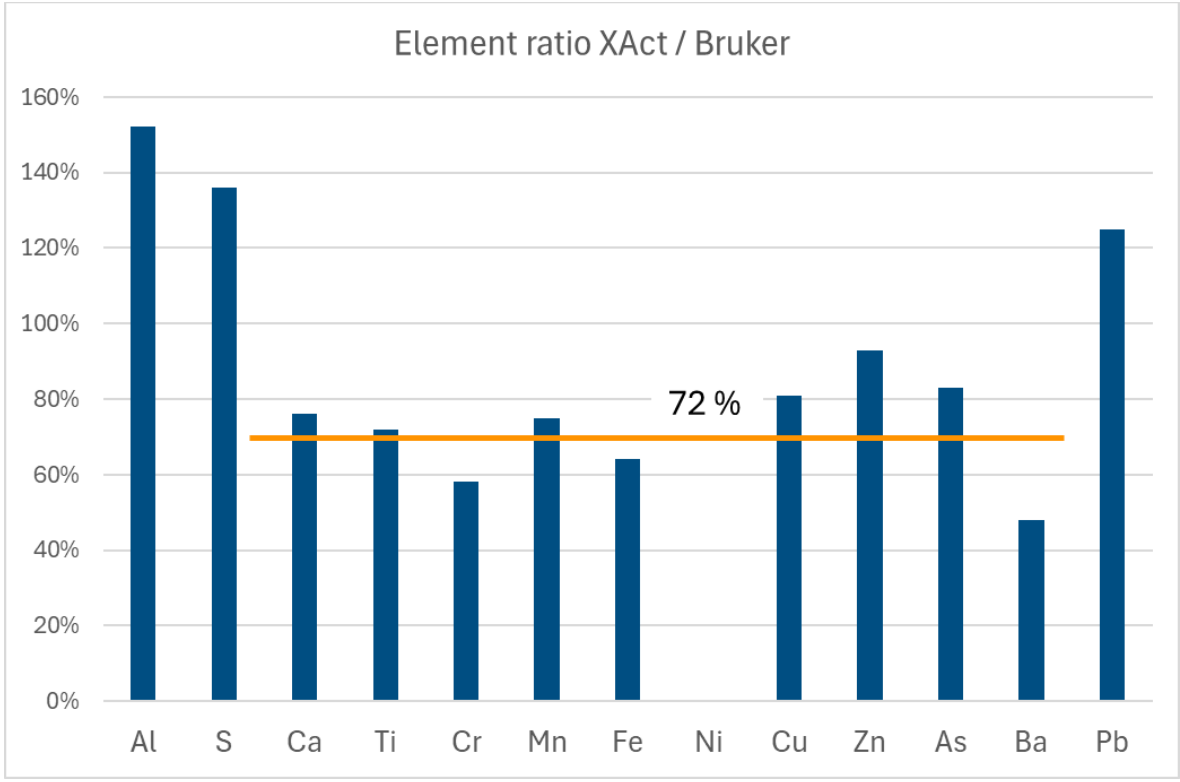
1st Onsite campaigns

Comparison with online monitor XAct 625

- Online monitoring of metals with XRF based system

(SailBri Cooper Inc., Tigard, OR, USA, model Xact 625)

- systematic underestimation of metal composition ?

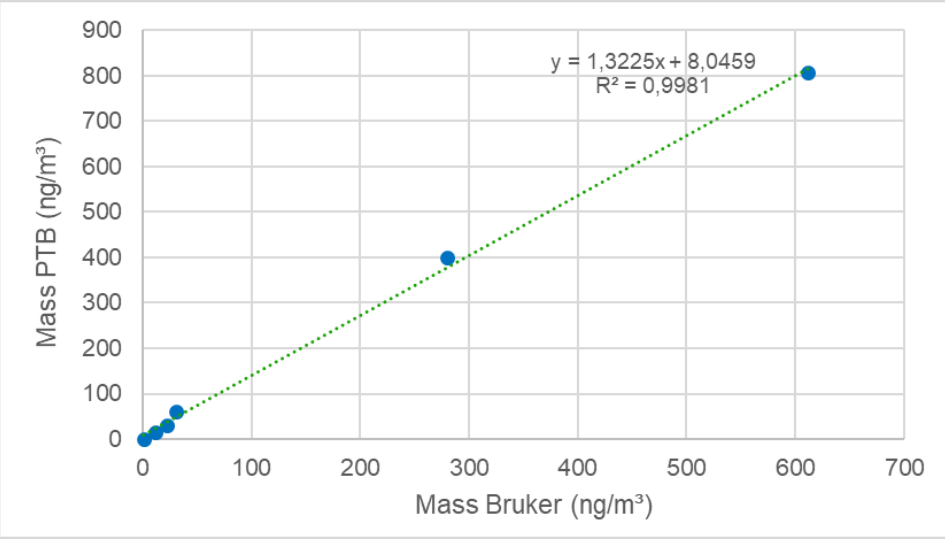


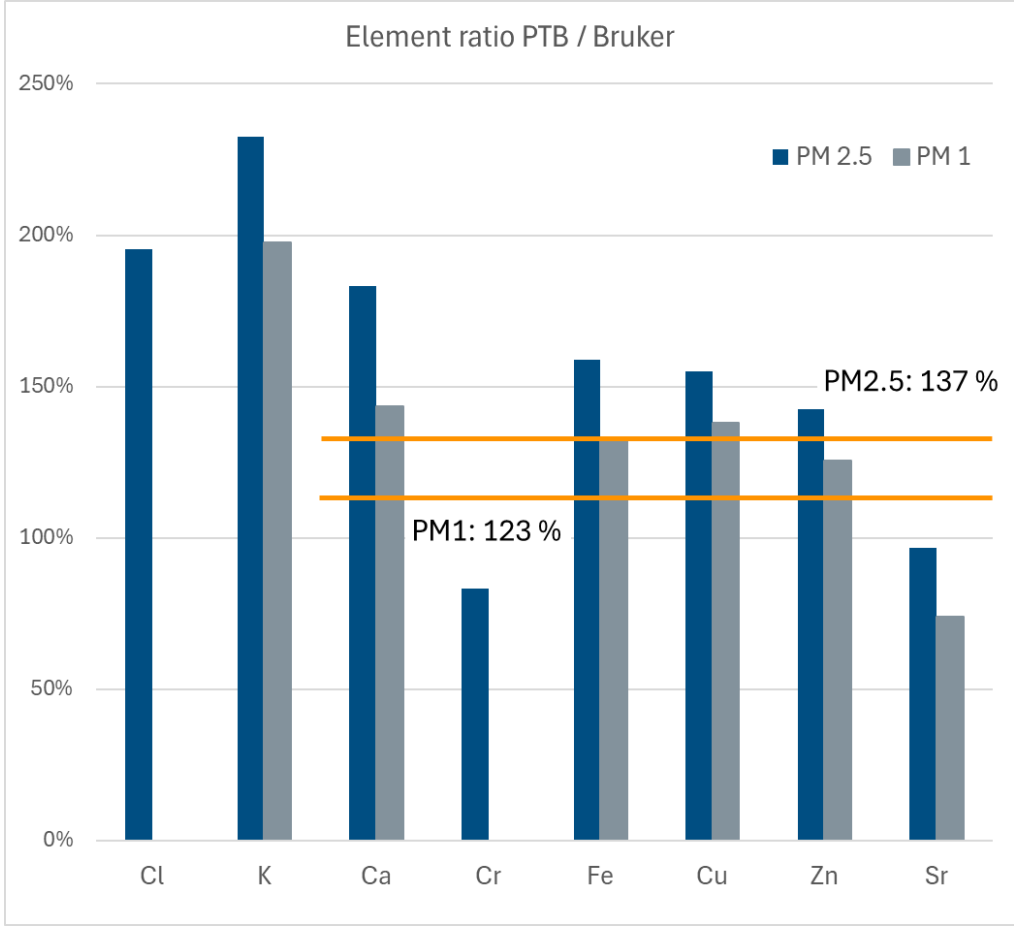
for Al, S, Pb only run 1 and/or 2 to 5 (of 14)

1st Onsite campaigns

Comparison with PTB beamline (Bessy Berlin)

- Two discs from run 3 (PM 1) and run 5 (PM 2.5) were analyzed by SR-XRF





Quantification

Preparation of calibration standards

- Deposition of metals by a picoliter printer (Technical University Clausthal, Germany)
- Target mass 1 ng Ni, 2 ng Cr, 3 ng Cd, complexing agent EDTA
- Discs with all “PM-pattern”, blanks

Absolute quantification method

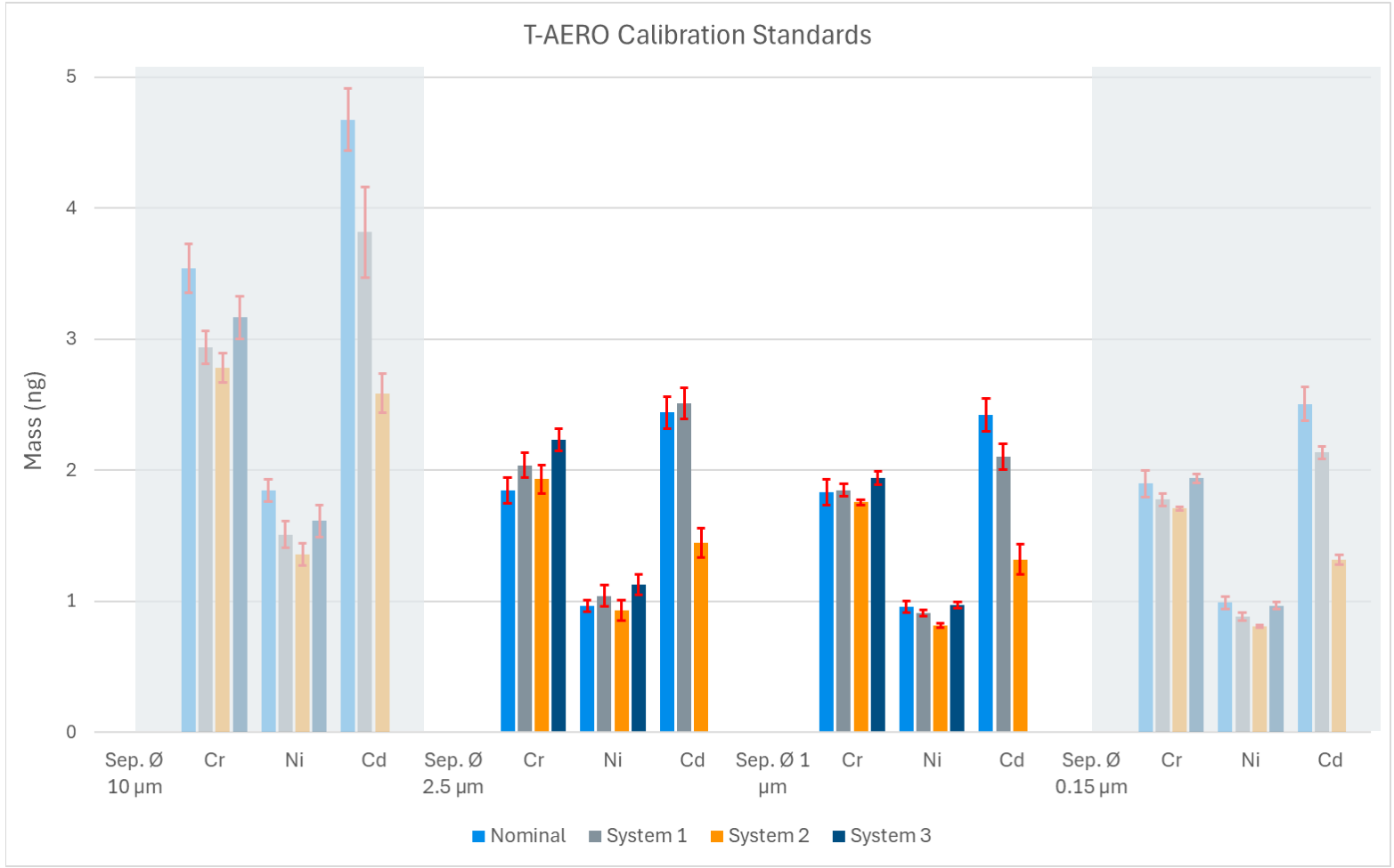
$$m_i = \frac{N_i * S_{Ni}}{S_i * s_{Ni} * t * I}$$

m_i	absolute amount of an analyzed element
N_i	net pulses of the element to be analyzed
S_{Ni}	relative sensitivity of the element Ni
S_i	relative sensitivity of the element i
s_{Ni}	absolute sensitivity of the element Ni (counts*s^{-1}*ng^{-1}*mA^{-1})
t	measurement time
I	tube current in mA

Quantification

Preparation of calibration standards

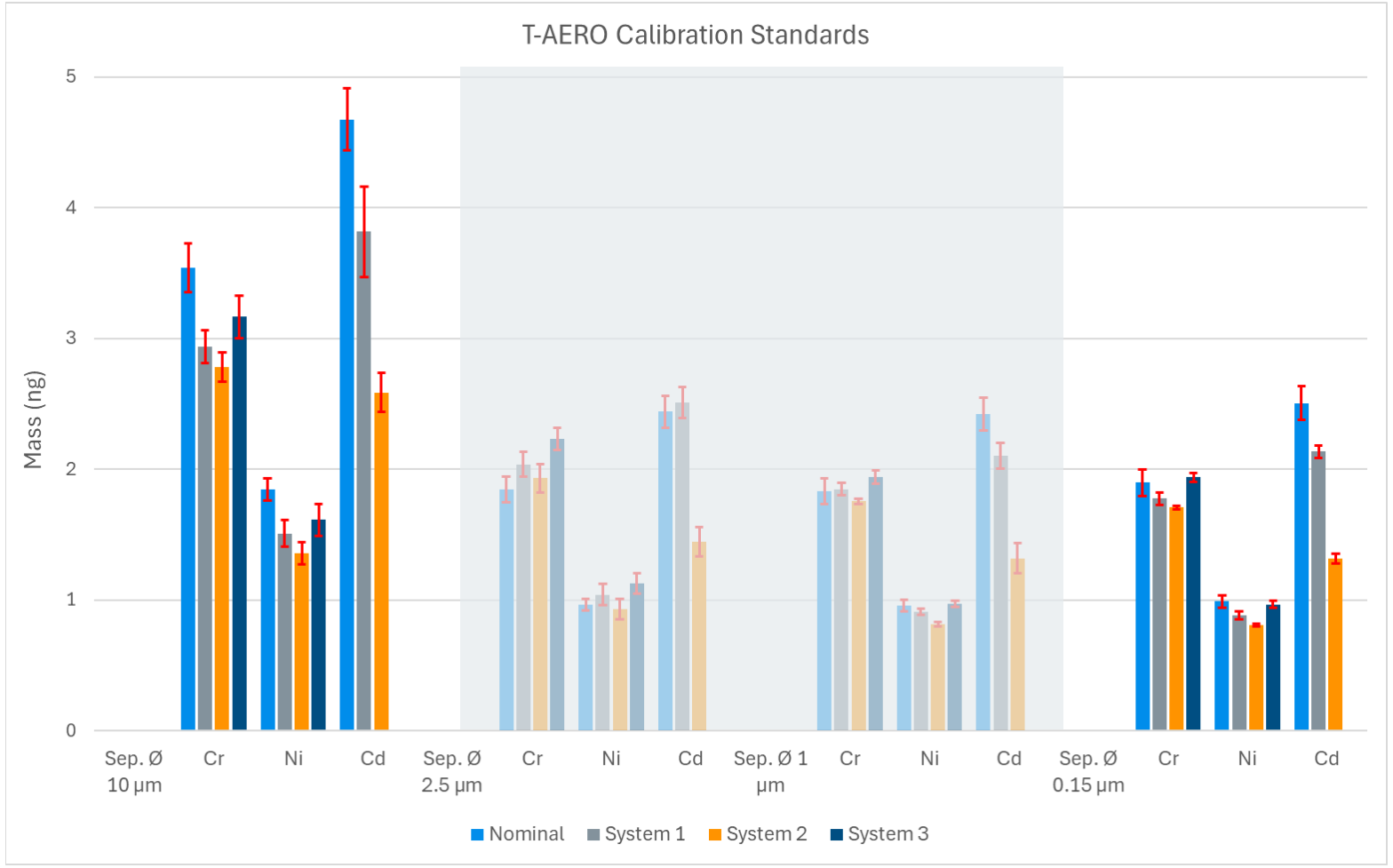
- 3 different instruments provide comparable results
  (2 x S4 T-STAR, 1 S2 PICOFOX)
- PM 2.5 and PM1:
  measured values correspond to nominal values within the error limits



Quantification

Preparation of calibration standards

- 3 different instruments provide comparable results
  (2 x S4 T-STAR, 1 S2 PICOFOX)
- PM 10 and PM0.15:
  measured values are 10-20% lower, correction factor implemented in software



T-AERO content and specifications

Hardware	
Impactor for PM sampling	4 stages (PM 10, 2.5, 1, 0.15)
Inlet assembly group	Inlet pipe, 2 clamping rings, hood
Membrane pump	Fixed flow rate 5 l/min
Control unit	Setting of delayed start, sampling time, incl. pressure sensor
Gas flow sensor	Controls air flow
Set of filters, fitting and connections	Pressure resistant
USB-C charger (100 W)	Power delivery for control unit
Transport case incl. foaming	PelicaseTM (ATA certified): rugged case with wheels and handles for safe transport
Calibration standard	Cr, Ni, Cd on 4 discs, corresponding to PM deposition pattern

04 T-AERO Introduction

BRUKER ELECTRON MICROSCOPE ANALYZERS

Summary and Conclusion

Summary and Conclusion

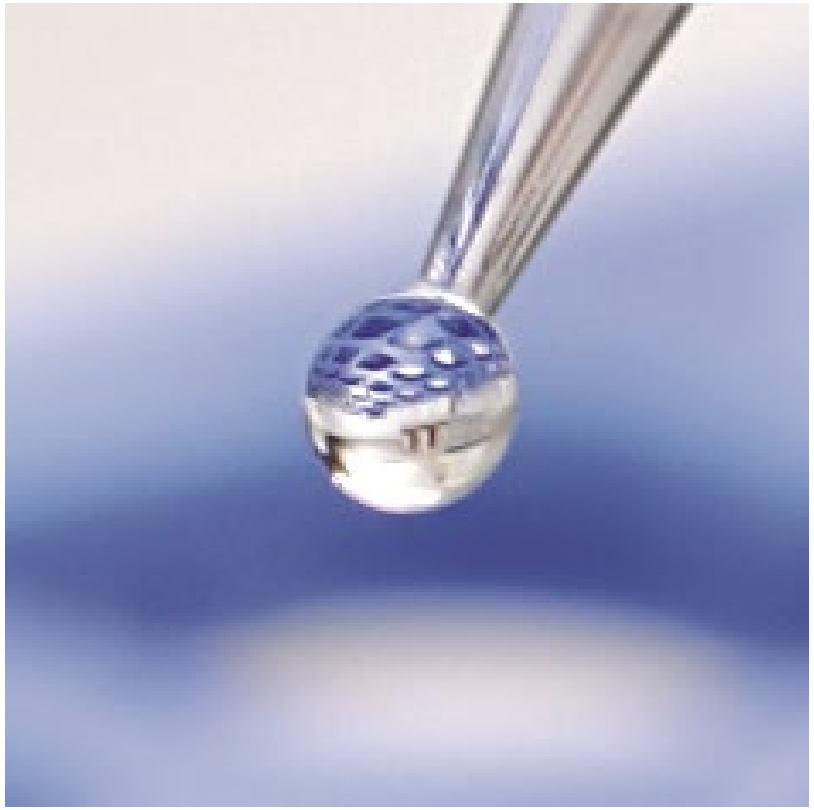
Optimized PM sampling for elemental analysis by TXRF

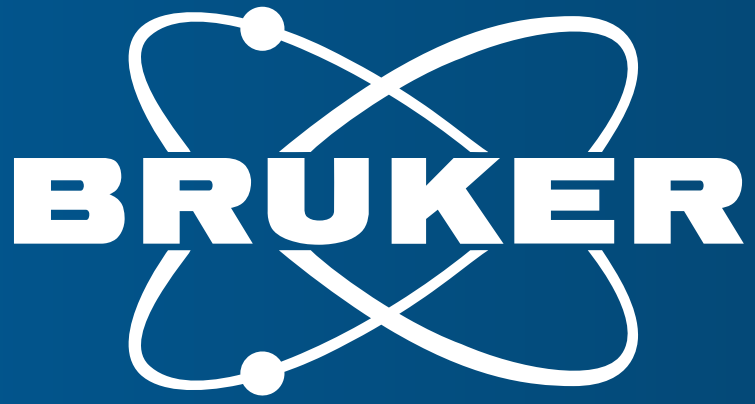
- Newly developed cascade impactor features 4 stages for fractionized PM sampling
- Sampling is performed on TXRF carriers for direct analysis without further preparation
- Time to result down to 1 h
- Achievable detection limits in the pg/m³ range for the detection of toxic elements (Cr, Ni, As, Pb, Cd, Sb etc.)

Q & A

Any Questions?

Please **type in** the questions you may have for our speakers in the **Questions Box** and click **Submit**





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