University of Stuttgart
Institute of Combustion and Power Plant Technology (IFK)

28th ETH-Nanoparticles Conference (NPC-25)

Abstract

Characterization of UFP emissions at a railway brake test bench

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19.06.2025

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Rail transport and its emissions

- According to the Federal ministry for digital and transport, the railway is “the most efficient, climate and environmentally friendly means of motorized land transport” (BMDV, 2018)
- ~190 years and more than 33 500 km operating length rails in Germany (DB, 2024) have an impact on the environment

Means of transport	Parameter [Gram / Person or Tons / km]		
	*$CO_{2\ eq}$	*NO_X	*PM10
Passenger car	194.41	0.53	0.070
Bus line	88.63	0.40	0.025
Regional train	73.69	0.23	0.022
Long-distance train	46.32	0.06	0.018
Medium truck	126.30	0.34	0.035
Inland shipping	42.55	0.43	0.024
Freight train	32.61	0.06	0.016

(UBA, 2021)

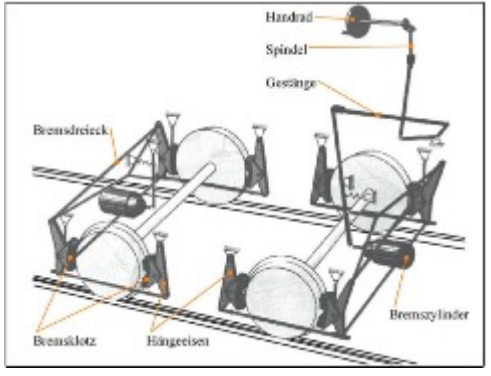
* Usage, energy provision, vehicle provision and infrastructure considered.
Without abrasion and resuspension emissions

- The emissions can be divided in two categories:
  - Engine-related emissions (Diesel)
  - Non engine related emissions

Contact wire abrasion

(Stemmann-Technik GmbH, 2012)

Brake abrasion

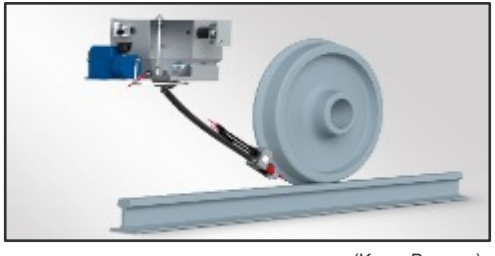


(Ihme, 2019)

Wheel/rail abrasion

Photo by Dr. Ulrich Vogt

Sanding



(Knorr-Bremse)

Project Emides

- Project “Emissions and Immissions from Rail Traffic – Air pollut
- Proje den

Photos by Dr.Ulrich Vogt and Daniel Obando

Identification and chemical characterization of specific pollutant parameters through emission and immission (ambient air quality) measurements

- Open track
- Marshaling yard (Freight transport station)
- Underground train station
- Tunnel
- (Aboveground) Train station
- ✓ Brake test bench

Measurement location and concept

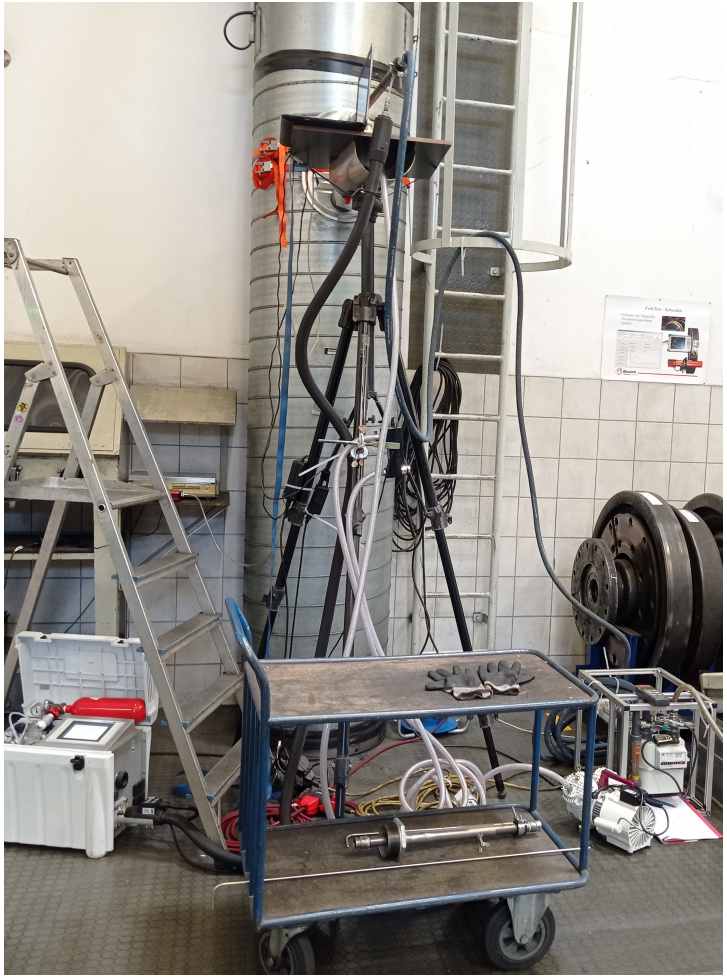
- Test bench from Faiveley, BECORIT GmbH Wabtec Company in Recklinhausen, Germany
- Brake dynamometer test program for freight trains based on DIN EN 16452:2019 Appendix R (DIN, 2019)
- Brake pads: C810 (UIC, 2020)
- Wheel: Ö 874 Lucchini
- Conditioning of brake pads through pre-wear and cleaning of the wheel with a cleaning brake pad before test program
- 7 cycles for stop braking from different initial speeds to 0 km/h, different contact forces for empty and loaded train
- 3 cycles for regulation braking from 75 to 45 km/h with different contact forces for loaded train **(unfortunately for these ones no UFP measurement)**

Measurement program

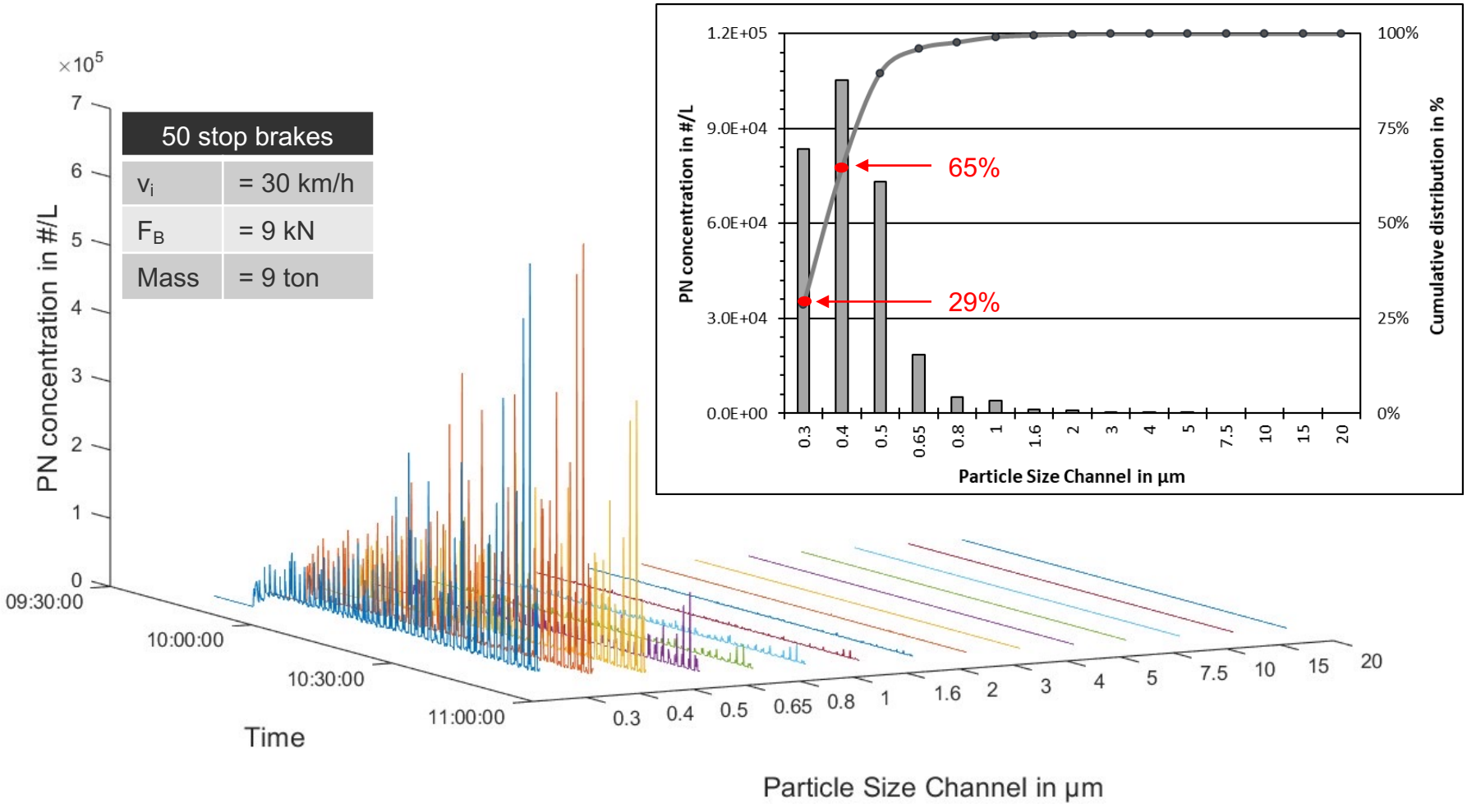
Brake number and type			Initial speed	End speed	Contact force F_B per wheel	Initial temperature	Mass to be braked per wheel	Observation
Nr.	Amount	Type	v	v_3	F_B	Θ_0	m	
			km/h	km/h	kN	°C	tons	
1	50	Stop	30	0	9	90	9	Loaded train
2	50	Stop	30	0	38	90	9	Loaded train
3	50	Stop	60	0	38	90	9	Loaded train
4	50	Stop	100	0	38	90	9	Loaded train
5	50	Stop	30	0	9	90	2.5	Empty train
6	50	Stop	60	0	9	90	2.5	Empty train
7	50	Stop	100	0	9	90	2.5	Empty train
8	5 times: 14 Regulation braking + 1 stop braking, at regular intervals of 180 s („Sawtooth"- Simulation)							
	14	Regulation	75	45	5	60	9	Loaded train
	1	Stop	75	0	5	60	9	Loaded train
9	3 times: 16 Regulation braking + 1 stop braking, at regular intervals of 180 s („Sawtooth"- Simulation)							
	16	Regulation	75	45	9	60	9	Loaded train
	1	Stop	75	0	9	60	9	Loaded train
10	1 times: 11 Regulation braking + 1 stop braking, at regular intervals of 180 s („Sawtooth"- Simulation)							
	11	Regulation	75	45	1.5	60	9	Loaded train
	1	Stop	75	0	1.5	60	9	Loaded train

Measured parameters

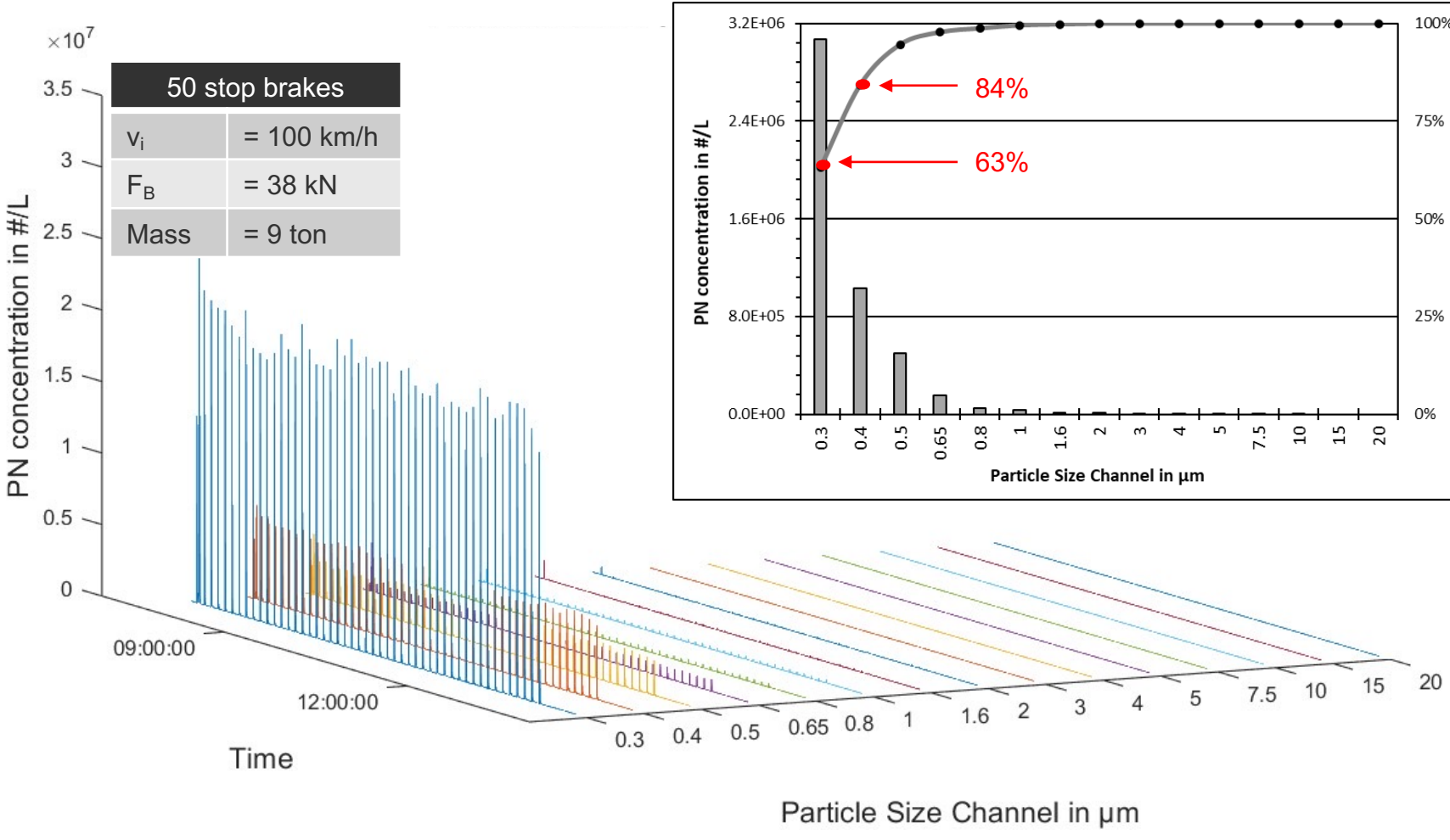
Parameter	Measurement principle
Total PM	Gravimetry
PM Distribution	Impactor (Dekati) Gravimetry
	Optical Particle Counter (GRIMM 1108)
Special measurements	
Black Carbon	Optical attenuation (MA200, Aethlabs)
Ultra fine particles	Diffusion charging (Disc Mini, Testo)
Flow Parameters	
Temperature	Thermoelement NiCr/Ni
Relative humidity	Capacitive humidity measurement
Flow rate	Prandl pipe
Brake parameters	
Braking time and distance	Dynamometer
Wheel temperature	Thermocouple



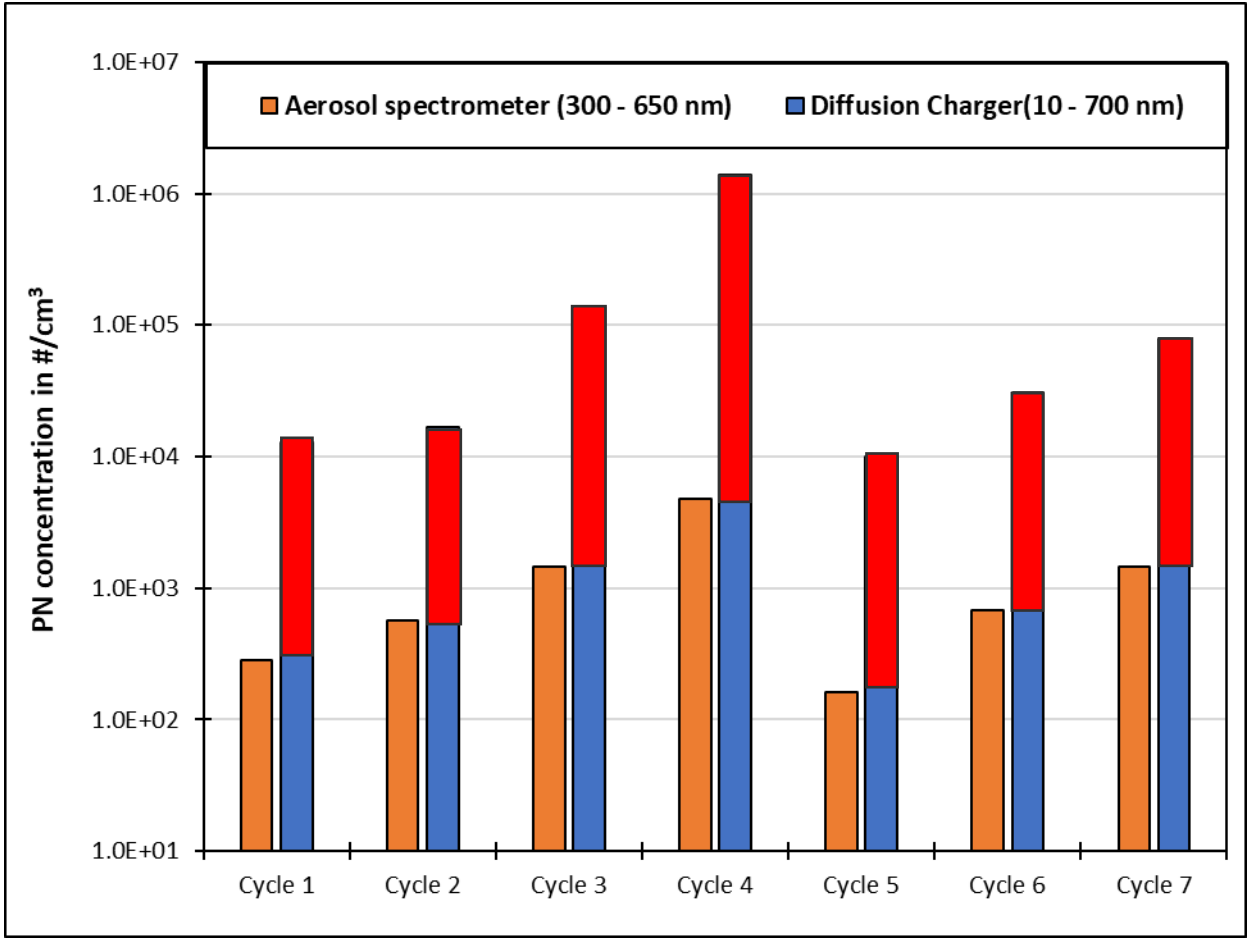
Cycle 1, Particle size distribution – coarse and fine range



Cycle 4, Particle size distribution – coarse and fine range

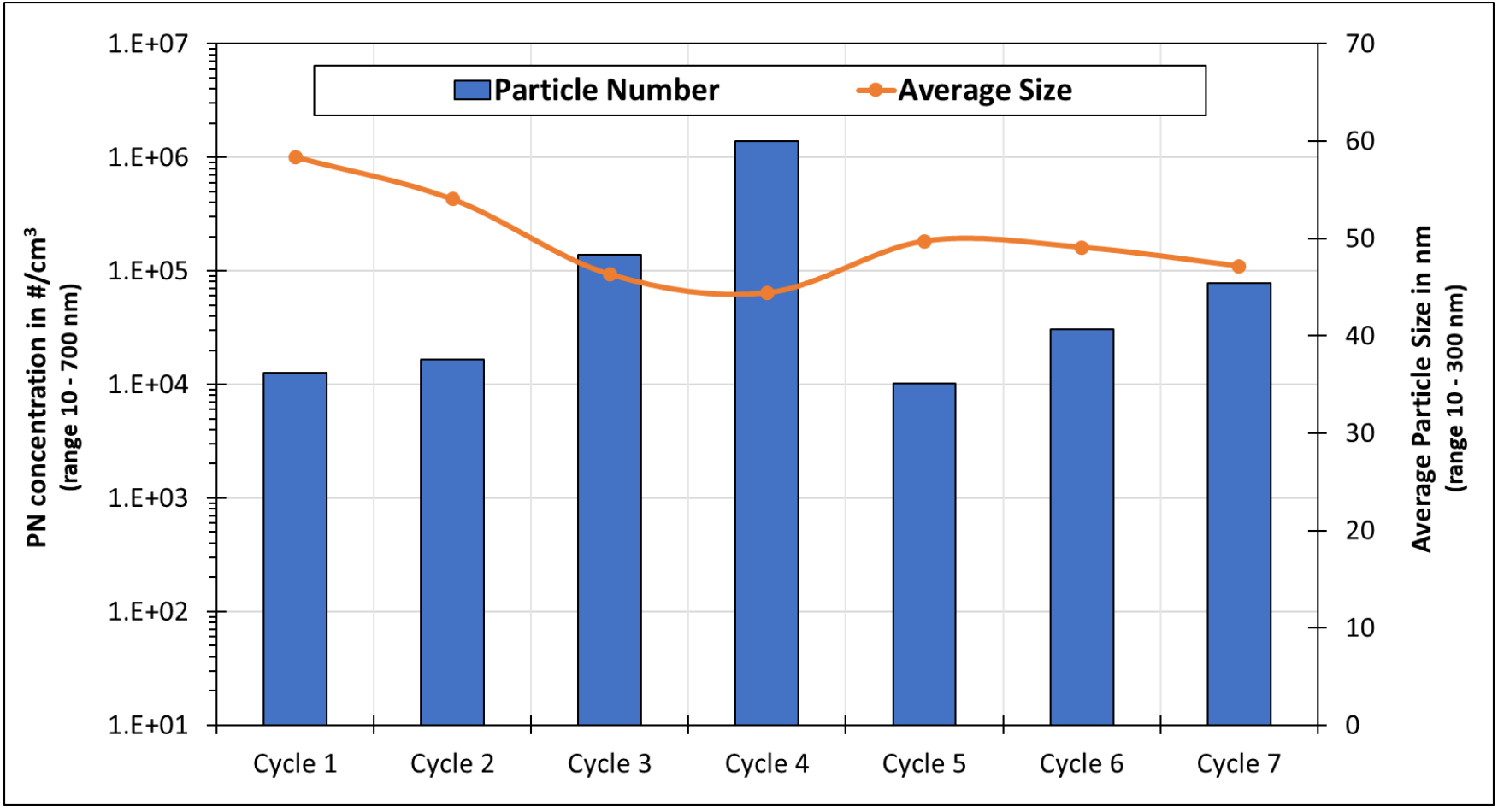


Cycles 1 to 7, PN emissions – Fine and ultrafine range

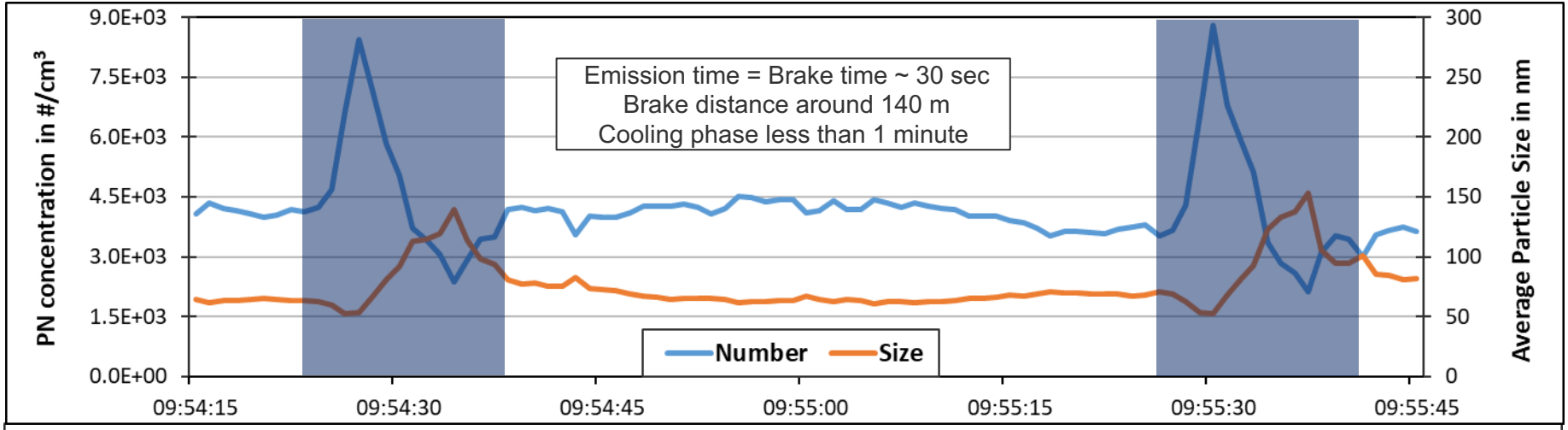


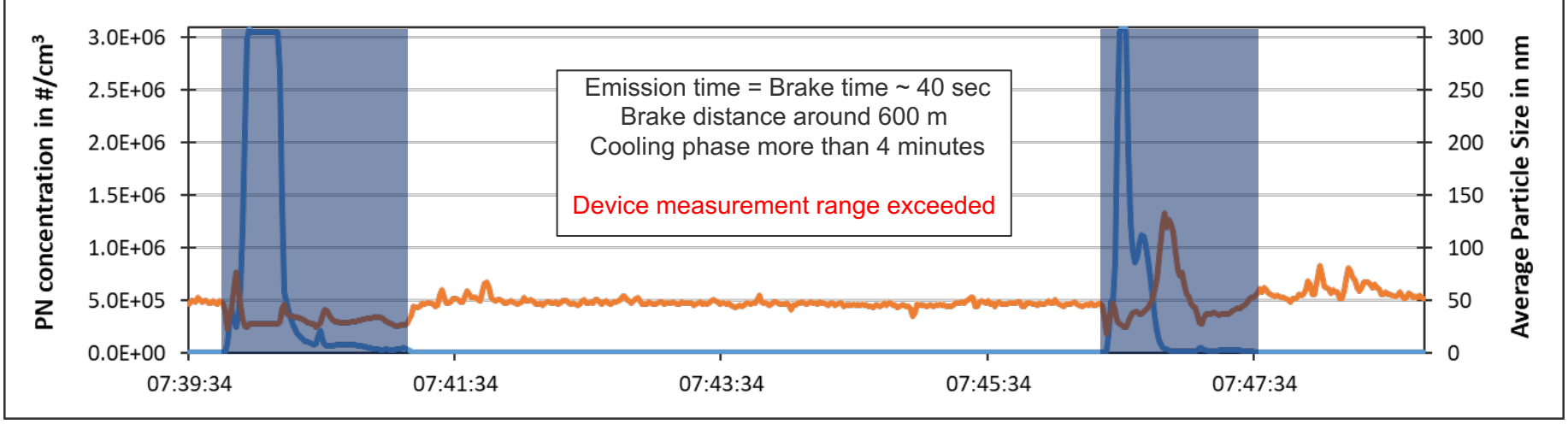
Cycle	Particle # 10 – 300 nm range
1	1.2 E+4

Cycles 1 to 7, PN emissions – fine and ultrafine range



Single brake analysis





Key findings

- Braking emissions vary from $1x10^2$ to $1x10^6$ particles/cm^3 depending on factors like initial speed, contact force and train load
- Emissions at low initial speed braking tend to be in the range of fine particles while at higher initial speeds the peaks moves to the ultrafine range
- Complex emission behavior for average size and concentration was observed, especially at high initial speeds
- There is a large unexplored field in the area of emissions from rail transportation, therefore more research is needed

The project “Emides” was supervised by the **German Centre for Rail Traffic Research at the Federal Railway Authority (DZSF)** and funded by the **Federal Ministry for Digital and Transport (BMDV)**

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Thank you!

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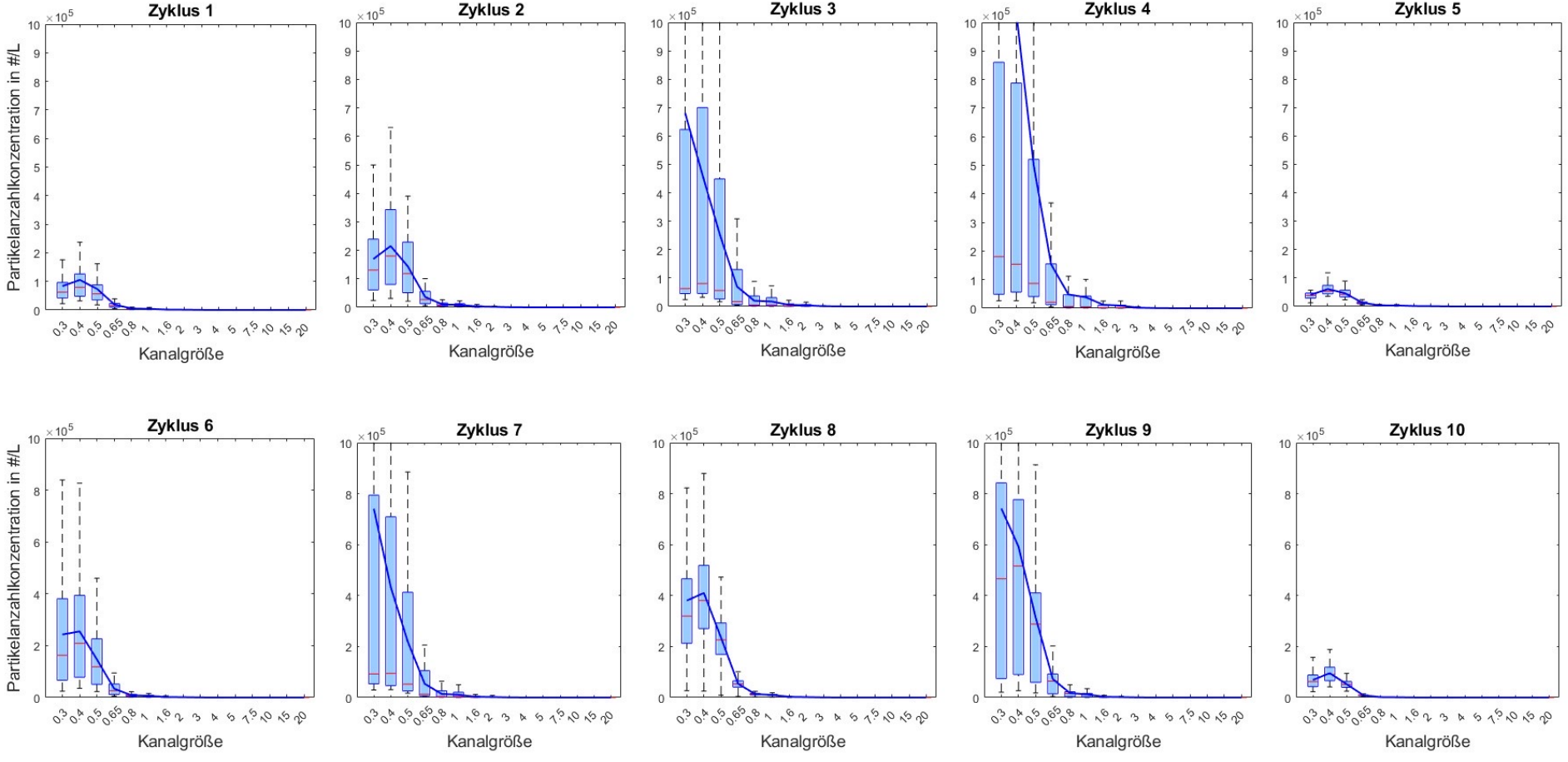
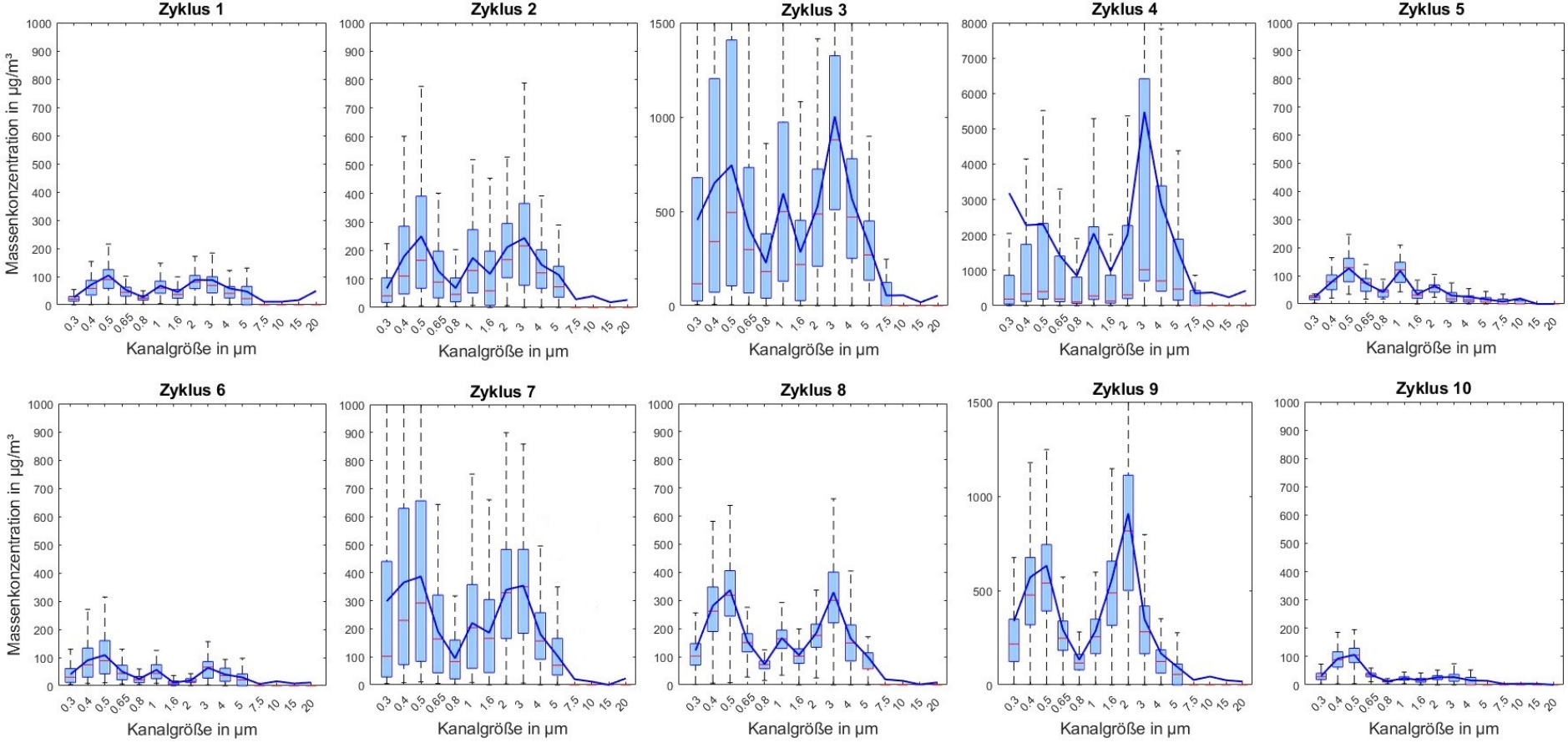
Whole program, Particle size distribution – coarse and fine range



Whole program, Particle size distribution in mass – coarse and fine range



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