Research on Petrol Engine Particle Emissions

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17.03.2017

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Vehicles

GDI

Data of investigated cars

Diesel

Vehicles ①②③	Volvo V60 T4F ①	Opel Insignia 1.6 EcoFlex ②	Mitsubishi Carisma 1.8 GDI ③
Number and arrangement of cylinders	4 / in line	4 / in line	4 / in line
Displacement cm^3	1596	1598	1834
Power kW	132 @ 5700 rpm	125 @ 6000 rpm	90 @ 5500 rpm
Torque Nm	240 @ 1600 rpm	260 @1650-3200 rpm	174 @ 3750 rpm
Injection type	DI	DI	DI
Curb weight kg	1554	1701	1315
Gross vehicle weight kg	2110	2120	1750
Drive wheel	Front-wheel drive	Front-wheel drive	Front-wheel drive
Gearbox	a6	m6	m5
First registration	27.01.2012	2014	05.2001
Exhaust	EURO 5a	EURO 5b+	EURO 3
Aftertreatment	TWC	TWC	TWC/Ox.Cat

Vehicles ④⑤⑥	Opel Zafira Tourer ④	VW Golf Plus ⑤	Peugeot 4008 1.6HDi STT ⑥
Number and arrangement of cylinders	4 / in line	4 / in line	4 / in line
Displacement cm^3	1598	1390	1560
Power kW	125 @ 6000 rpm	118 @ 5800 rpm	84 @ 3600 rpm
Torque Nm	260 @ 1650 - 3200 rpm	240 @ 1500 rpm	270 @ 1750 rpm
Injection type	DI	DI	DI
Curb weight kg	1678	1348 - 1362	1462
Gross vehicle weight kg	2360	1960 - 1980	2060
Drive wheel	Front-wheel drive	Front-wheel drive	Front-wheel drive
Gearbox	m6	m6	m6
First registration	22.07.2014	01.02.2010	12.04.2013
Exhaust	EURO 5b+	EURO 4	EURO 5b
Aftertreatment	TWC	TWC	DPF

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MPI
Data of investigated MPI vehicles

Vehicles ⑦⑧⑨⑩	Opel Adam ⑦	Fiat Panda 4x4 Twin Air ⑧	Ford KA 1.2i ⑨	Suzuki Baleno 1.2 Hybrid⑩
Number and arrange-ment of cylinders	4 / in line	2 / in line	4 / in line	4 / in line
Displace-ment cm^3	1398	875	1242	1242
Power kW	64 @ 6000 min^{-1}	62.5 @ 5500 min^{-1}	85 @ 5500 min^{-1}	66 @ 6000 min^{-1}
Torque Nm	130 @ 4000 min^{-1}	145 @ 1900 min^{-1}	102 @ 3000 min^{-1}	120 @ 4400 min^{-1}
Injection type	MPI	MPI	MPI	MPI
Curb weight kg	1195	1170	989	1010
Gross vehicle weight kg	1465	1550	1320	1405
Drive wheel	Front-wheel drive	4x4	Front-wheel drive	Front-wheel drive
Gearbox	m5	m6	m5	m5
First registra-tion	5.3.13	2.12.15	30.5.16	29.4.16
Exhaust	EURO 5b	EURO 6b	EURO 6b	EURO 6b
After-treatment	TWC	TWC	TWC	TWC + EGR

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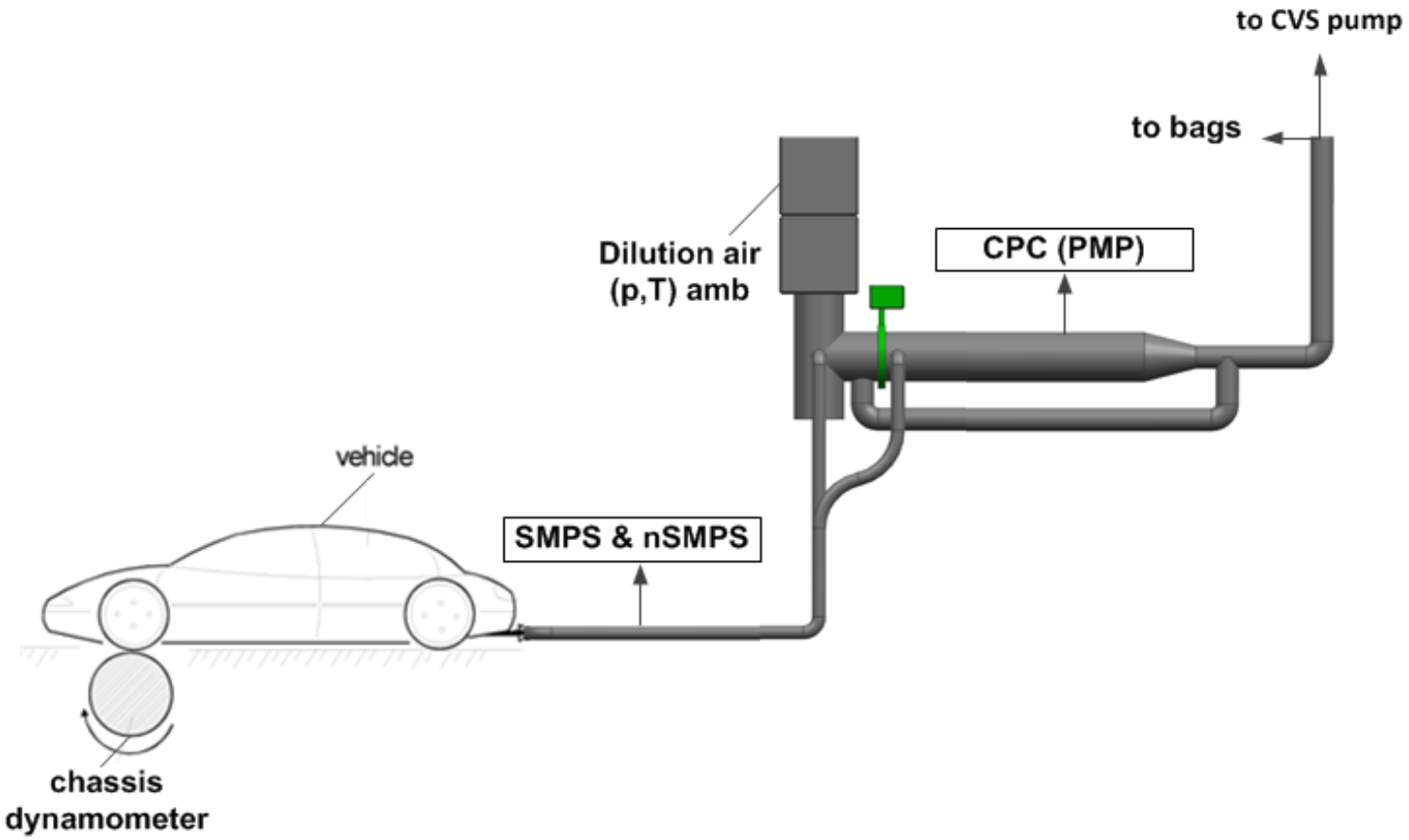
Test Methods and Instrumentation

Sampling of Exhaust Gas for Analysis of Particles



PN-Analysis

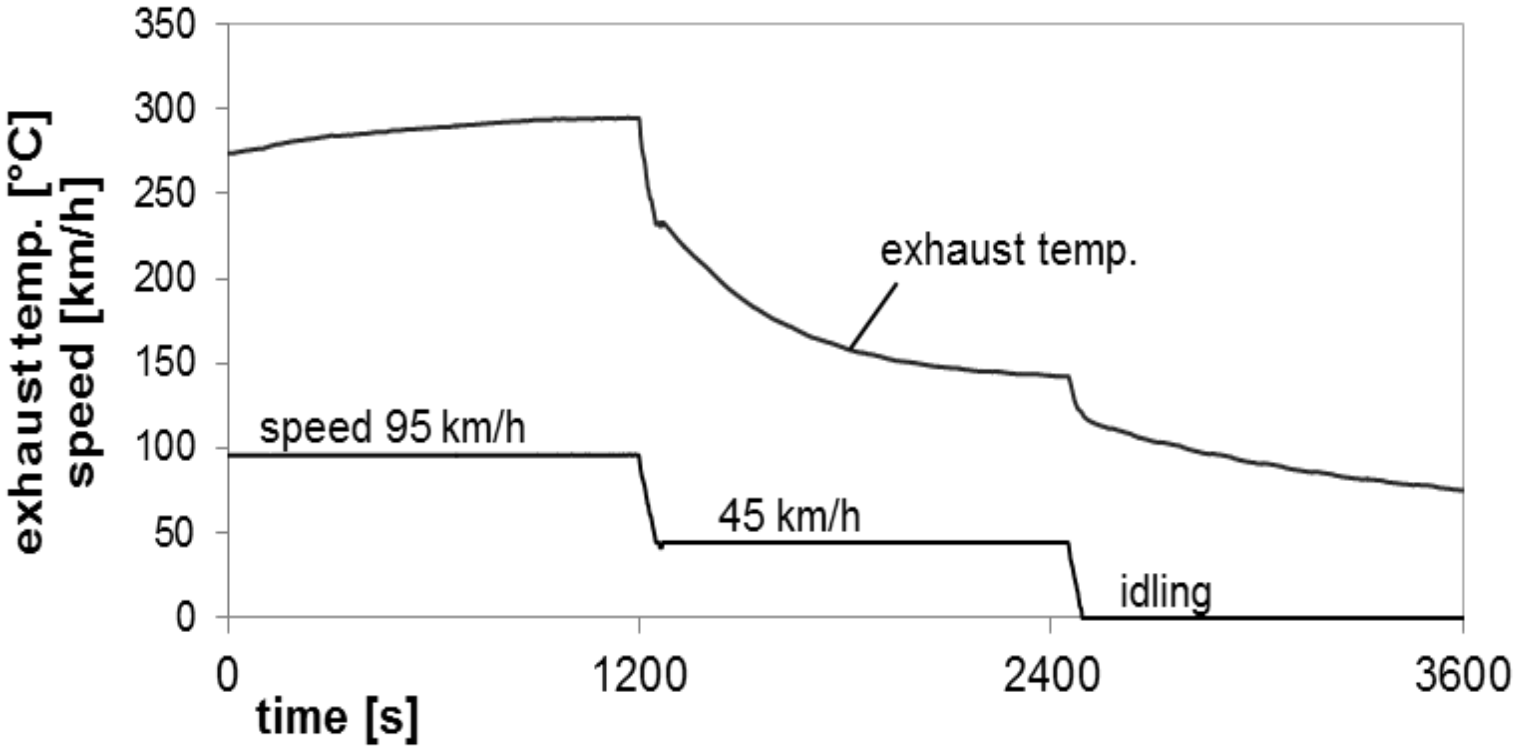
- **At steady state operation:**

  SMPS: DMA TSI 3081 & CPC TSI 3772 (10 - 429 nm)
  nSMPS: nDMA TSI 3085 & CPC TSI 3776 (2 - 64 nm)

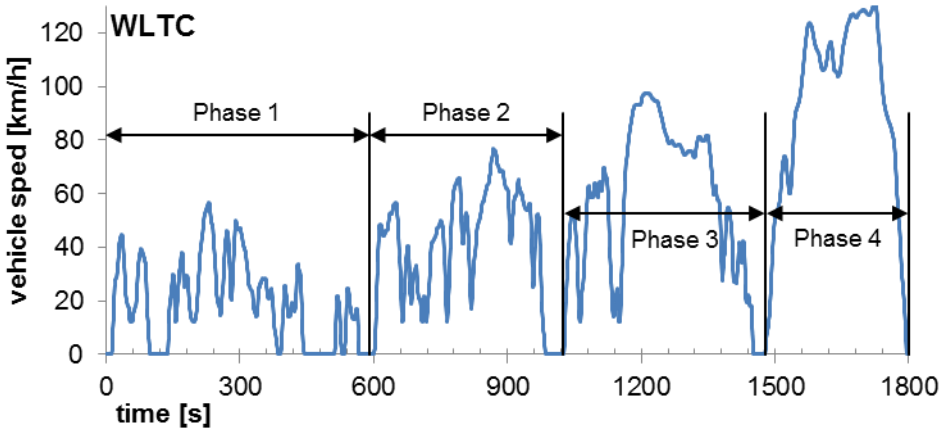
- **At transient operation:**

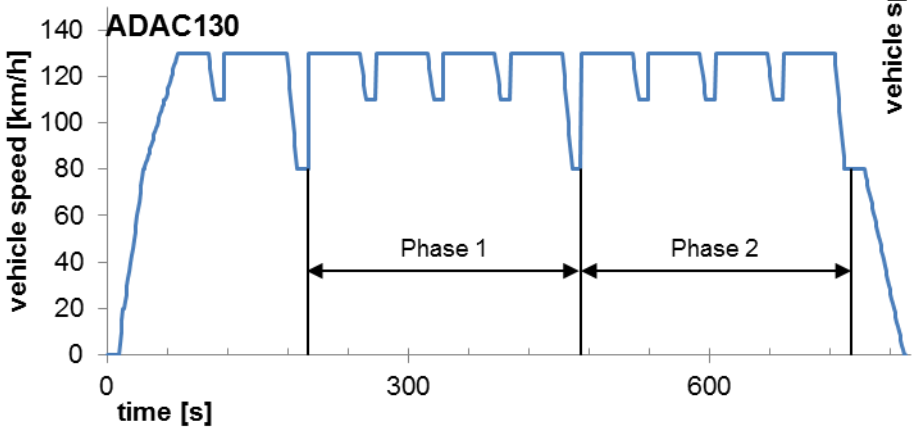
  CPC TSI 3790 (PMP conform)

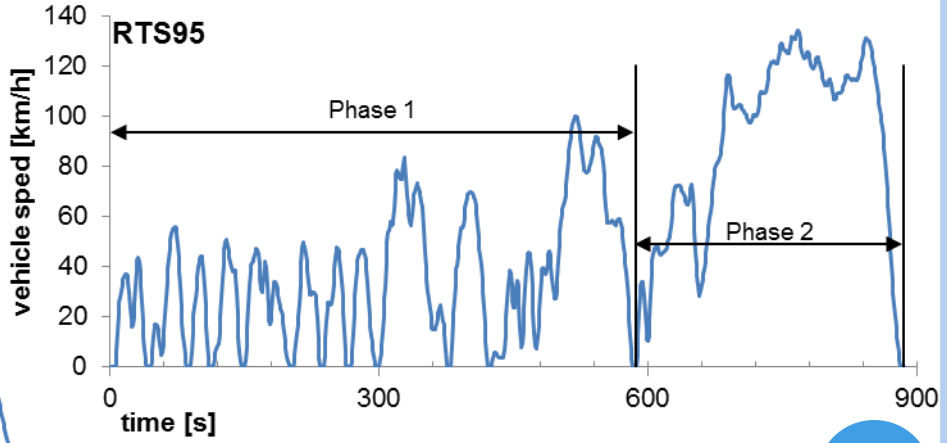
Steady State Cycle (SSC) and tailpipe temperature of vehicle 7 (MPI)



TRANSIENT DRIVING CYCLES WLTC, RTS 95 AND ADAC 130







Results GDI

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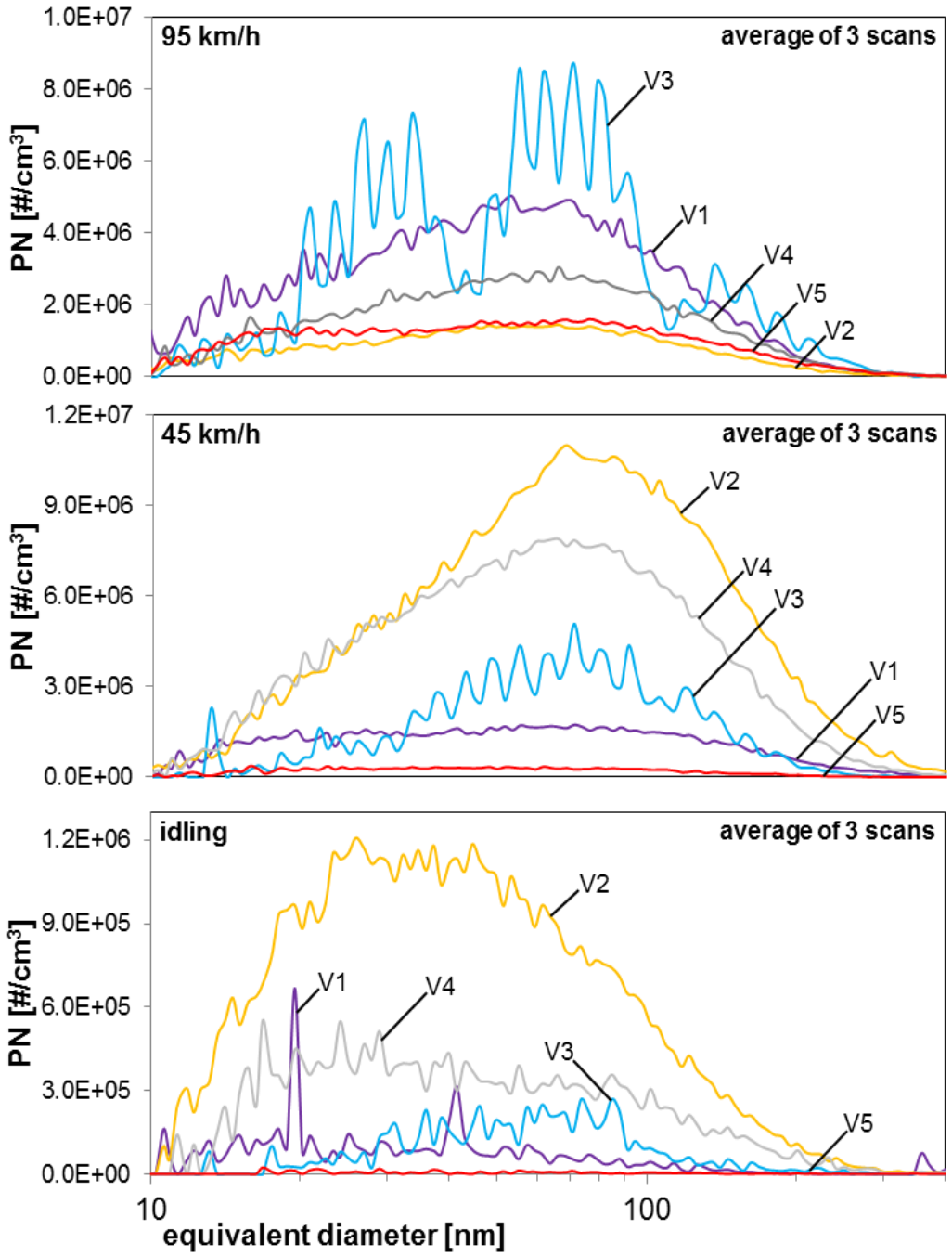
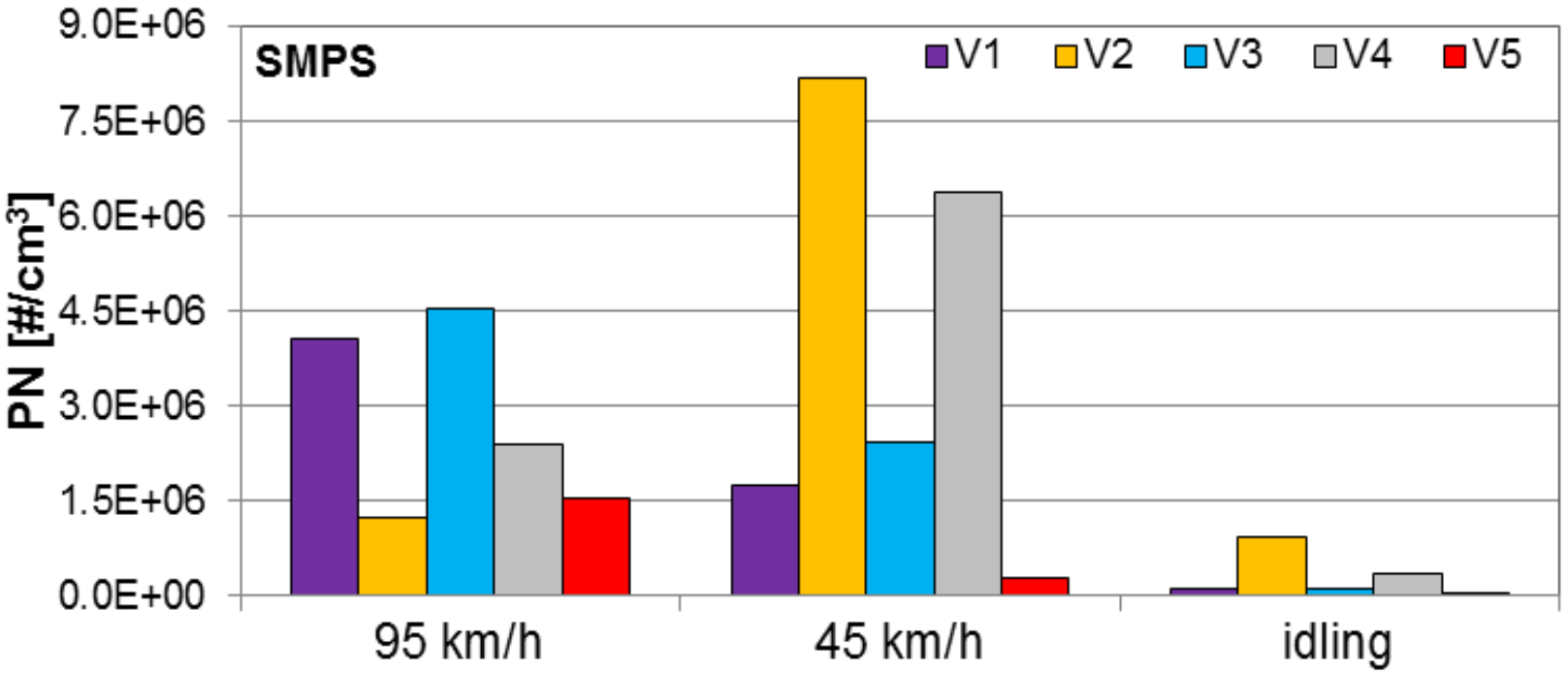
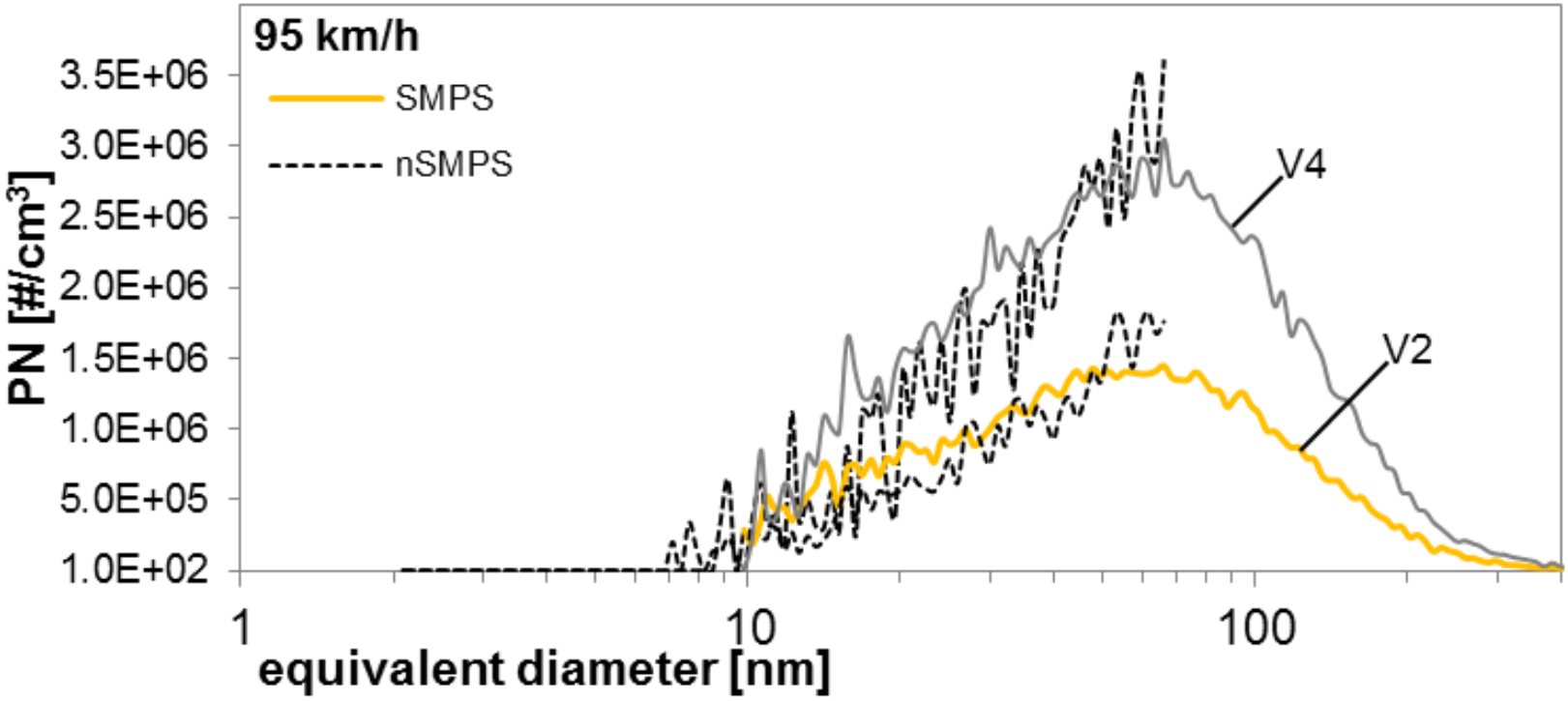


SMPS PARTICLE SIZE DISTRIBUTIONS AT CONSTANT SPEEDS WITH DIFFERENT GDI VEHICLES (W/O GPF)

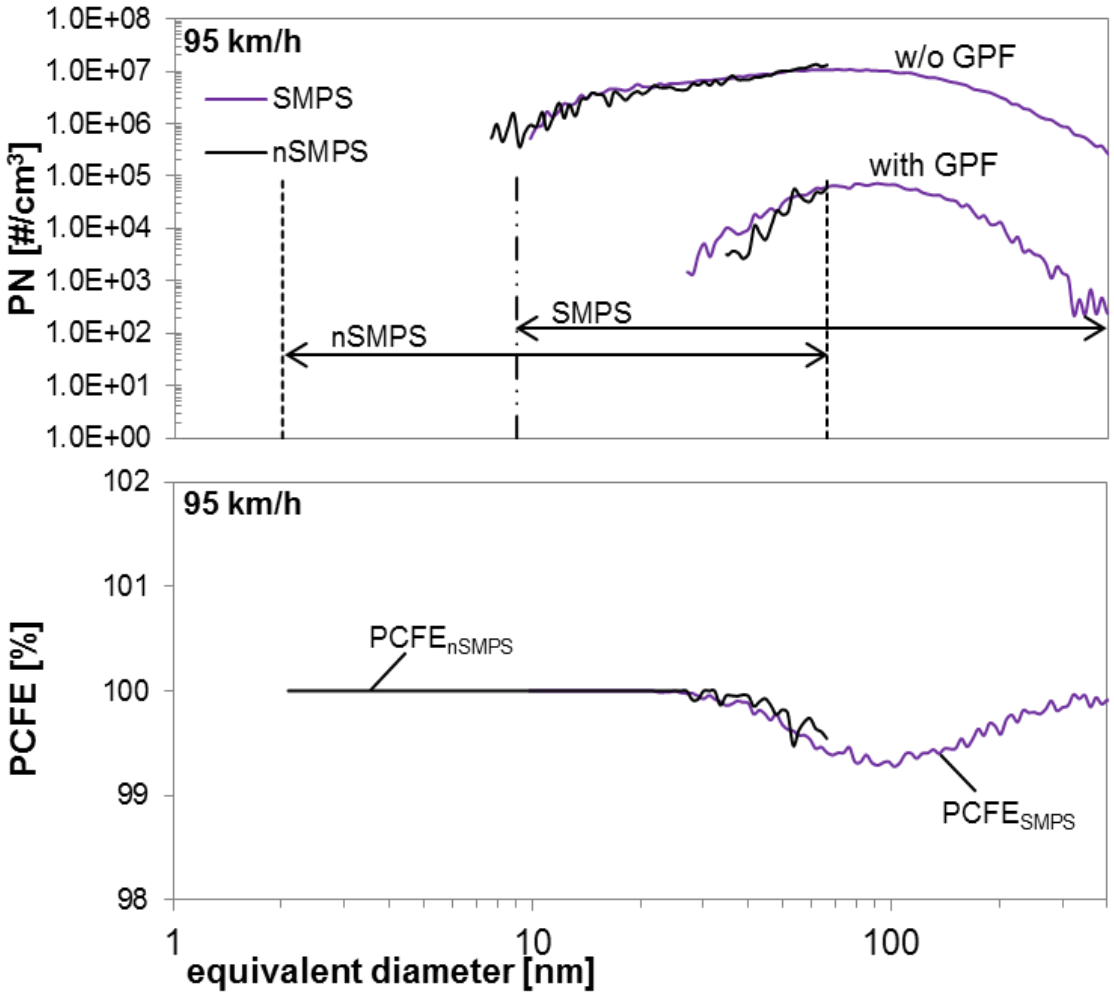
Integral PN emissions at constant speeds with different GDI vehicles (w/o GPF)



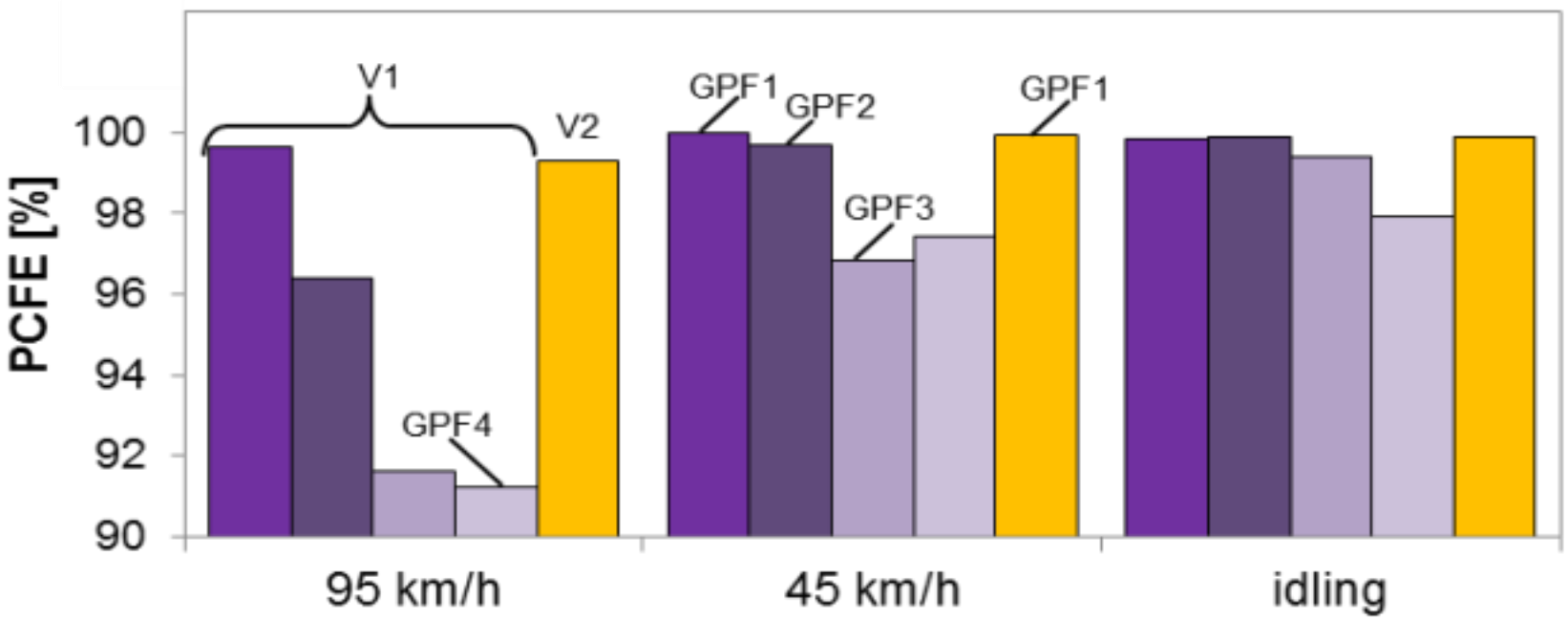
SMPS & nSMPS PARTICLE SIZE DISTRIBUTIONS AT 95 KM/H WITH GDI V2 & V4 (W/O GPF)



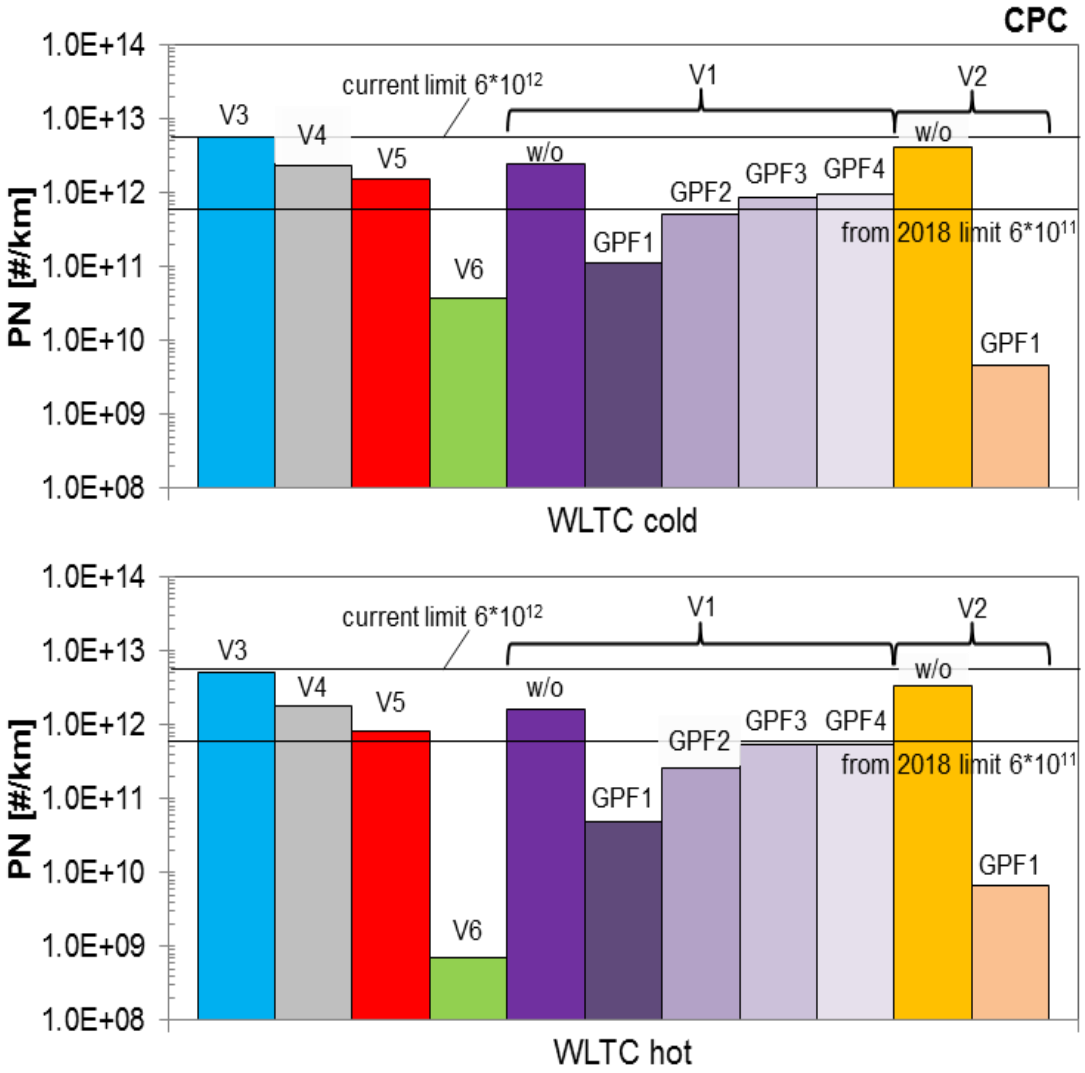
EXAMPLE OF PSD'S WITH SMPS & NSMPS AND PARTICLE COUNTS FILTRATION EFFICIENCY (PCFE) WITH V1, GPF 1 AT 95 KM/H



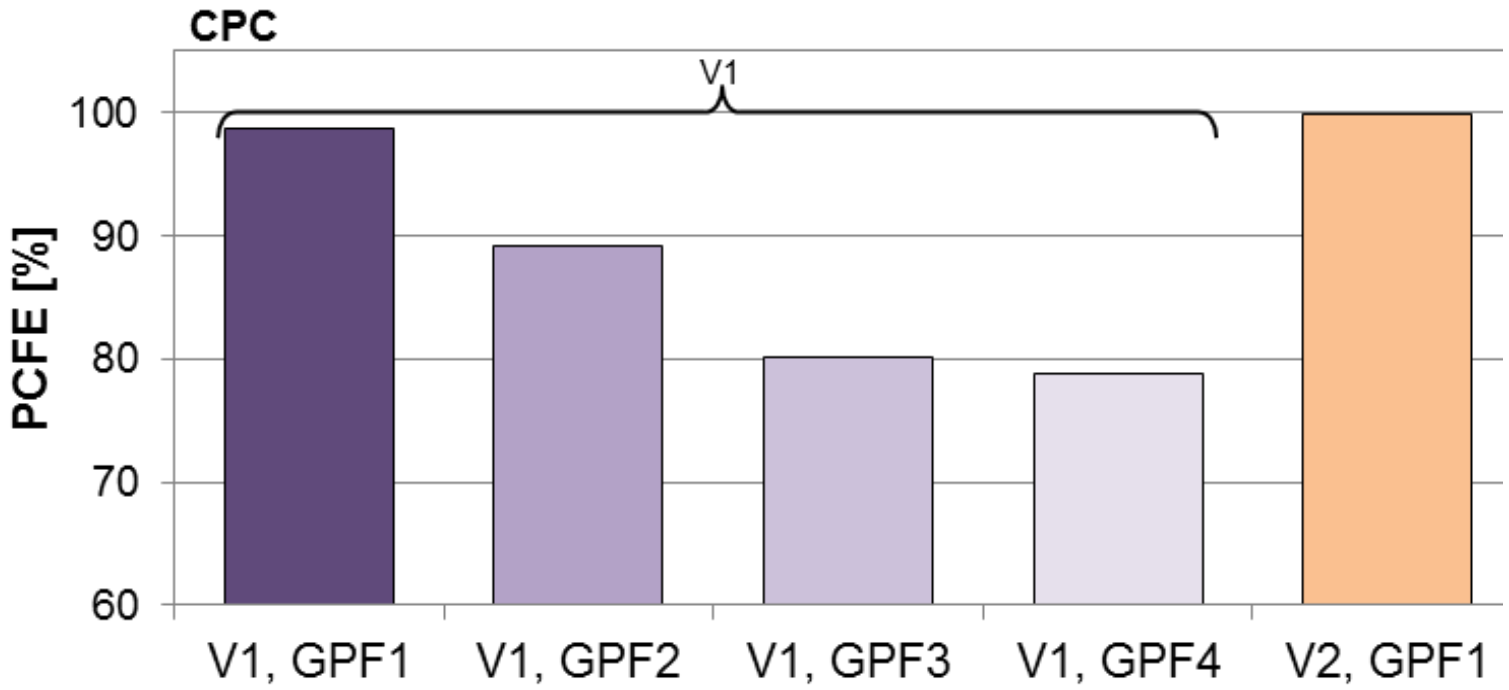
Filtration efficiencies PCFE at constant speeds with different GPF's (SMPS data)



Comparison of PN-emissions in WLTC cold and hot for different vehicles



PCFE'S OF THE INVESTIGATED GPF'S IN WLTC HOT



Results MPI

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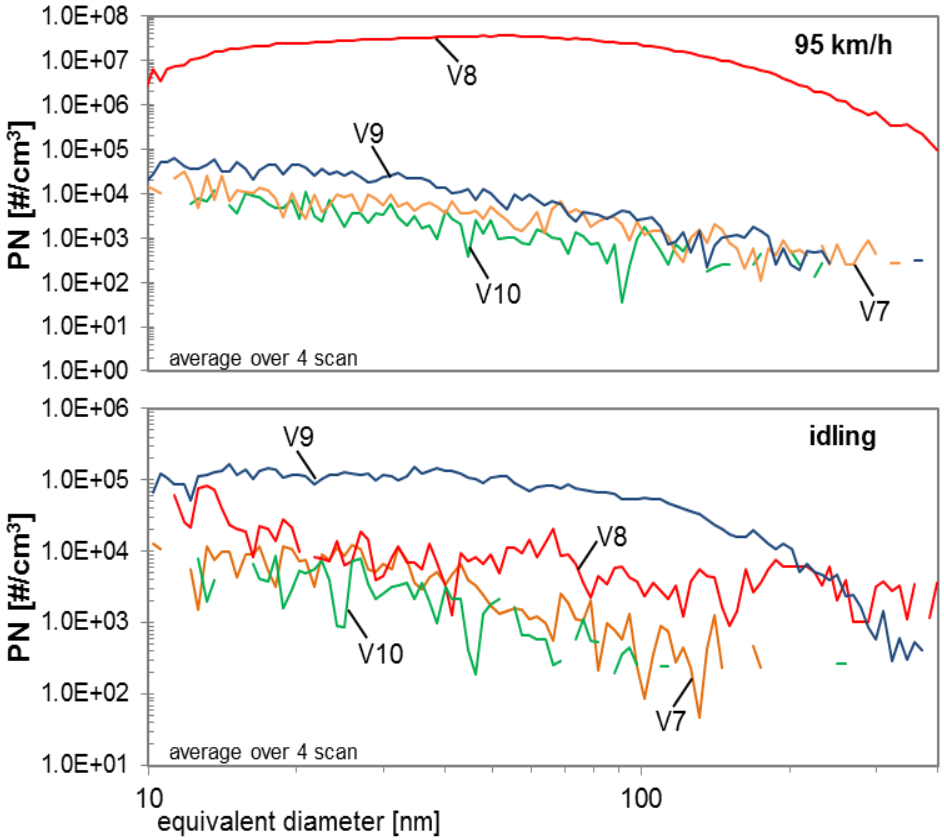
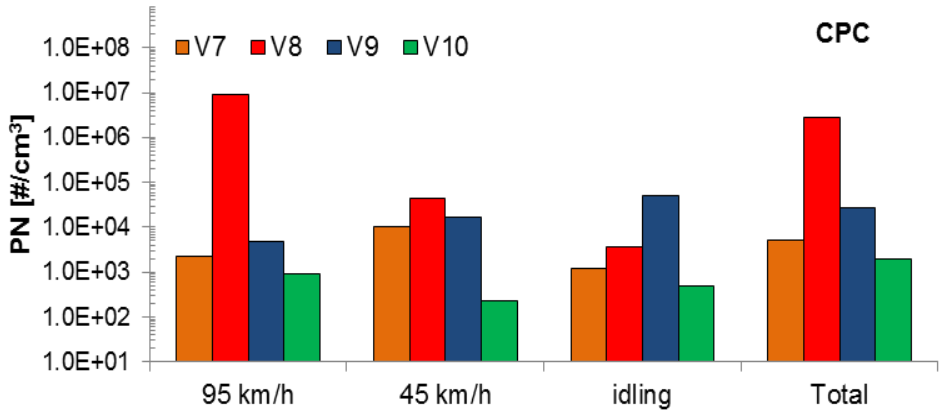
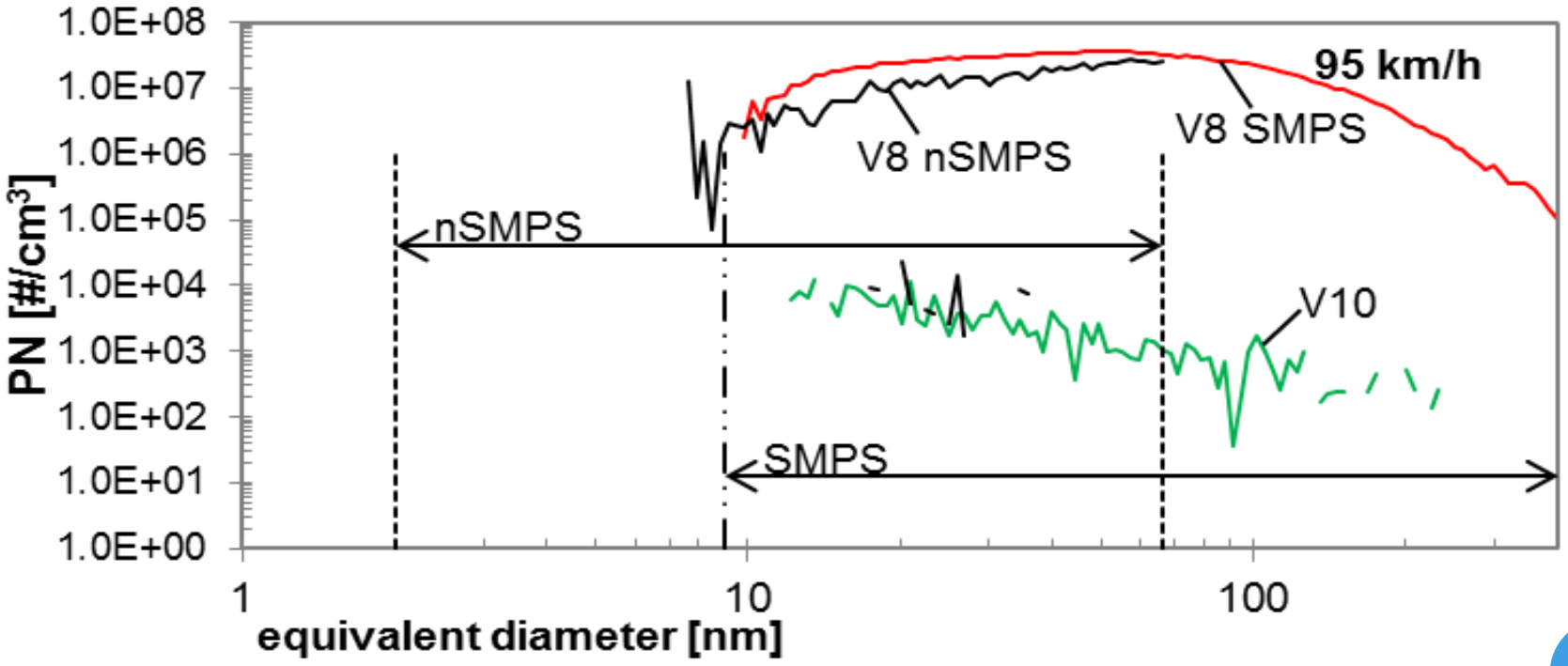


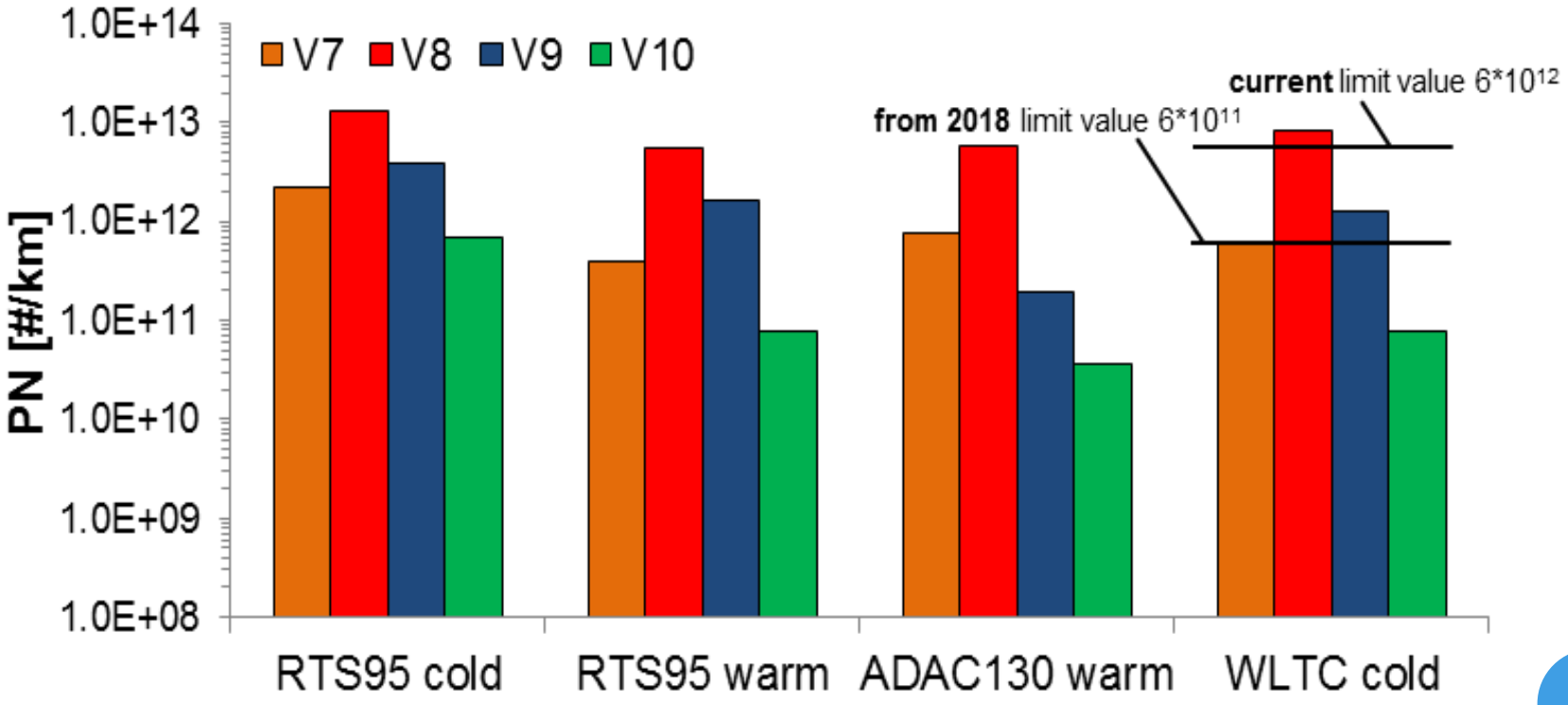


SMPS PARTICLE SIZE DISTRIBUTION AT CONSTANT SPEEDS WITH DIFFERENT MPI VEHICLES

Particle size distribution of MPI vehicles (min/max emissions) at 95 km/h.



PN RESULTS IN ALL DRIVING CYCLES.



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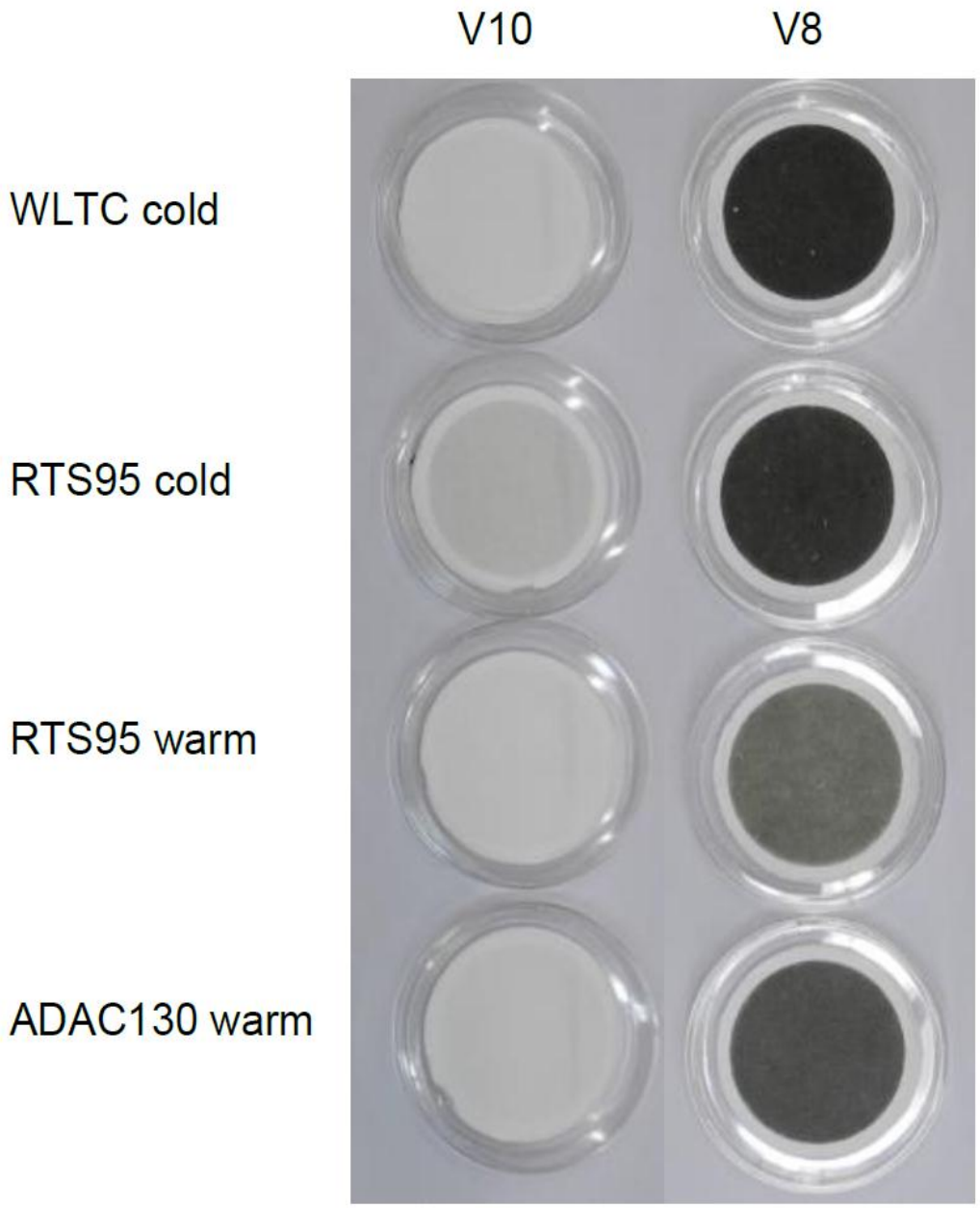

PM-RESULTS OF THE LOWEST & HIGHEST EMITTING VEHICLES IN DIFFERENT TRANSIENT CYCLES.

Conclusion (1)

- **The PN-emission level of the investigated GDI cars in WLTC without GPF is in the same range of magnitude and very near to the actual limit value of 6.0 x 10^{12} #/km.**
- **The present work demonstrated that the modern SI-vehicles with MPI also emit a considerable amount of PN and PM. In an extreme case the PN-emission was in the range of Diesel car (without DPF).**

Conclusion (2)

- **With the GPF's with better filtration quality it is possible to lower the emissions below the future limit value of 6.0 x 10^{11} #/km.**
- **The filtration efficiency of GPF can attain 99% but it can also be optimized to lower values – in this respect the requirement of "best available technology for health protection" should be considered.**

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Support of VERT and AFHB for DPF Retrofit Projects on the Knowledge and Research Level

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DPF Retrofitting, Motivation and Experiences

Poznan University of Technology

Session of PTNSS Congress

27th – 29th June 2017


Thank you
for your
attention !