PMP 33RD MEETING

Institute for Energy and Transport
Joint Research Centre

B. Giechaskiel, G. Martini

30 Sept 2014

Outlook

- *Regeneration*
- *Sub23nm*
  - Status / Need of change?
  - Vehicles
  - PN systems
- *Catalytic Stripper (CS)*
- *Calibration*
  - Status / Need of change?
  - PNC
  - VPR

Regeneration

Objectives

- *Confirm robustness of PMP protocol*
- *Check (absolute) emission levels*
- *Investigate <23nm*

Regeneration: Test plan

- *Pre-conditioning of system (ideally with gasoline vehicle at high speed) and monitoring of emissions + regeneration of vehicle*
- *Only if OEM data are available: Continuously NEDCs until regeneration to compare with OEMS data. 4 – 5 tests per day (only 1 cold)*
- *Continuously WLTCs until regeneration. 4 – 5 tests per day (only 1 cold)*
- *Estimation of regeneration distance and repeat with loading at low temperature mode. Then WLTC cycles until regeneration.*

Regeneration: Info missing

- *How to ensure that the regeneration will not happen during the loading phase (e.g. a switch/procedure to prevent active regeneration (e.g. to deactivate post injection)) → It must be cold cycle (LD)*
- *Indicators of regeneration or parameters that should be monitored to confirm the start of regeneration (HC and/or CO engine out emissions, EGR rate, state of post injection (on/off) etc.)*
- *Any available info on regeneration frequency (in km, based on x type of loading)*

European Commission

Regeneration: Next steps

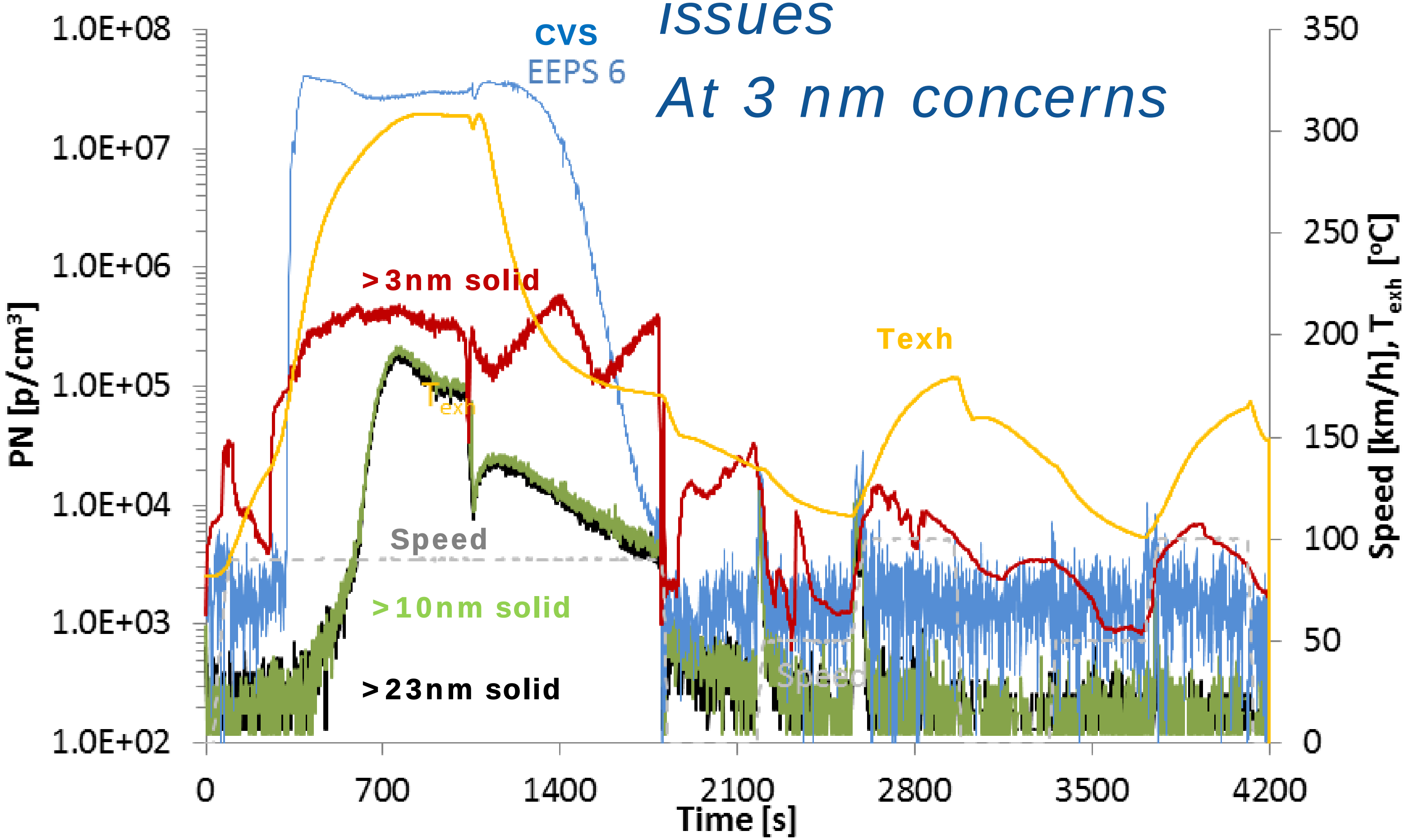
- *Need for Euro 6 vehicles (with info of previous slide)*
  - OEMs to provide?
- *Possibility to test a Euro 6 beginning of 2015*
- *→Important to know the aftertreament technology*
- *→Check different aftertreament technologies*

- *Experience/Tests from others (sub23nm)*
- *Input from WLTP group regarding regeneration procedure open points → November (?)*
- *JRC can try eg manual recording PN after end cycle*
- *HD hot cycle continuous*

Regeneration

Down to 10 nm no issues

At 3 nm concerns



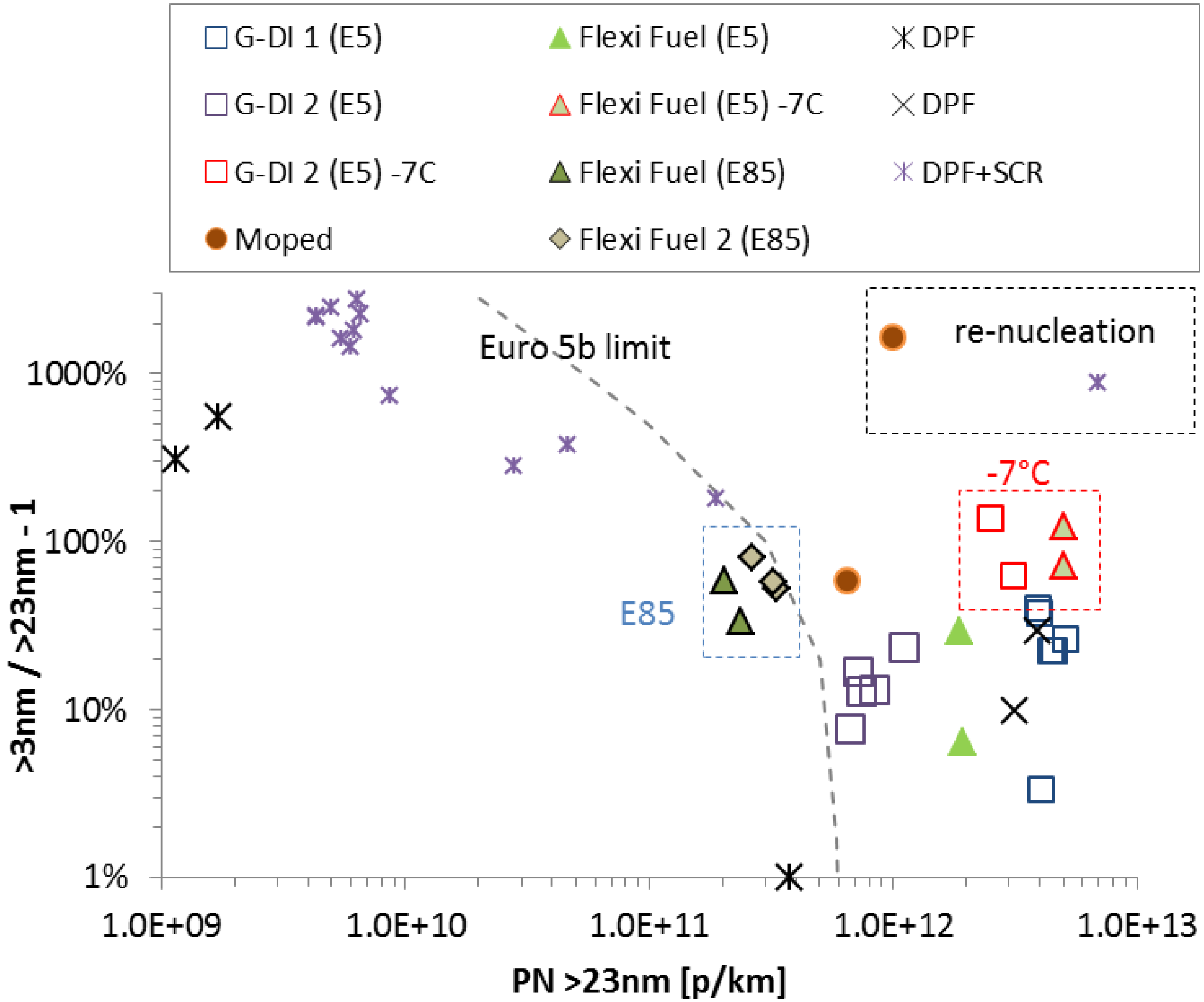
Sub23nm

Sub23 nm

- *G-DI vehicles: 30-40% particles are below 23 nm over a cycle (slightly higher compared to diesels)*
- *Higher percentages can be measured with different fuels or ambient temperatures*
- *The percentage could be even higher when losses in the VPR are taken into account*

Concerns for high percentages:

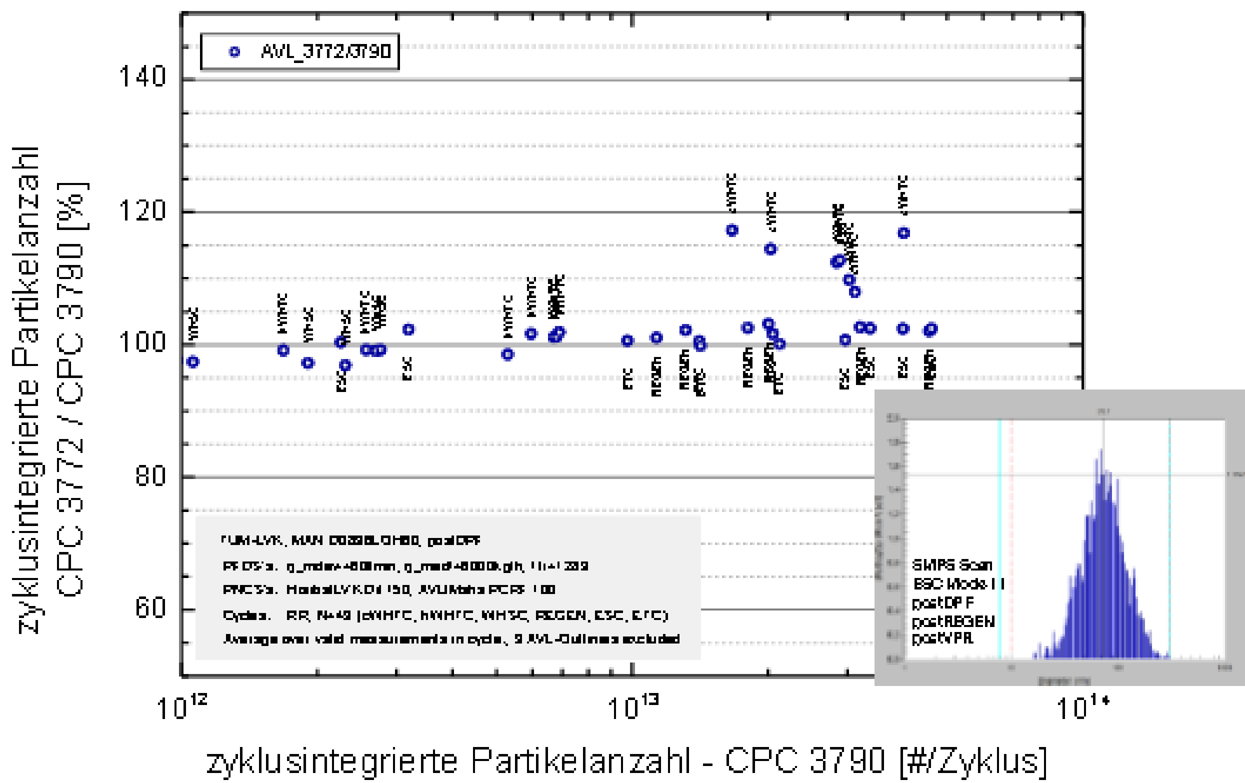
Might be PN system artifact



Sub23nm: FVV study

Regenerated DPF:

Sub23nm 20%



Sub23nm PN systems feasibility

- *Theoretical evaluation showed that >23nm measurements are robust*
- *Critical issue is re-nucleation of sulfuric acid after the VPR, even for modern vehicles. Nucleis can grow (with HCs)*
- *Particle losses could affect reproducibility*
- *Other methods (e.g. CS) could be better*
- *Measurements above 7-10nm seem feasible for the near future without big investment (eg optimized PNCs or VPRs*

Sub23 nm: Objectives

- *Future technologies should be monitored (>10nm)*
- *PN systems should be prepared for sub23nm measurements (>10nm)*
    - CS needs investigation

Sub23nm: New results

- *10-23nm ratio around 25%,*
- *slightly higher for PFI*
- *Regeneration slightly increased the ratio*
- *Mopeds need special attention*
- *23nm PNCs had differences of up to 20%*

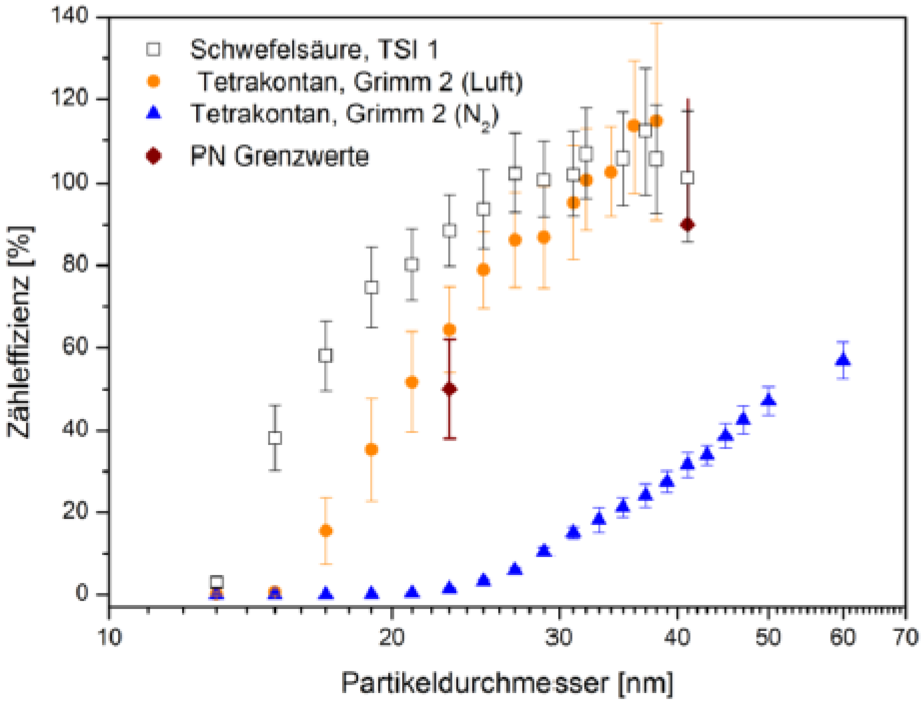
Moped	WMTC col	1.03E+12	102%	up to 50% less
Moto #1	WMTC	4.91E+12	21%	up to 15% less
Moto #1 (LPG)	WMTC	3.67E+12	19%	up to 15% less
Moto #2	WMTC	5.71E+12	17%	
DPF #1	Steady		1%	
DPF #1	Regen		16%	
DPF #2	NEDC	2.41E+10	45%	up to 20% less
GDI	WMTC	2.37E+12	23%	
PFI #1	WLTC	1.36E+11	55%	
PFI #2	WLTC	1.00E+12	35%	
PFI #3	WLTC	4.25E+11	45%	
PFI #4	WLTC	4.50E+12	35%	up to 20% less

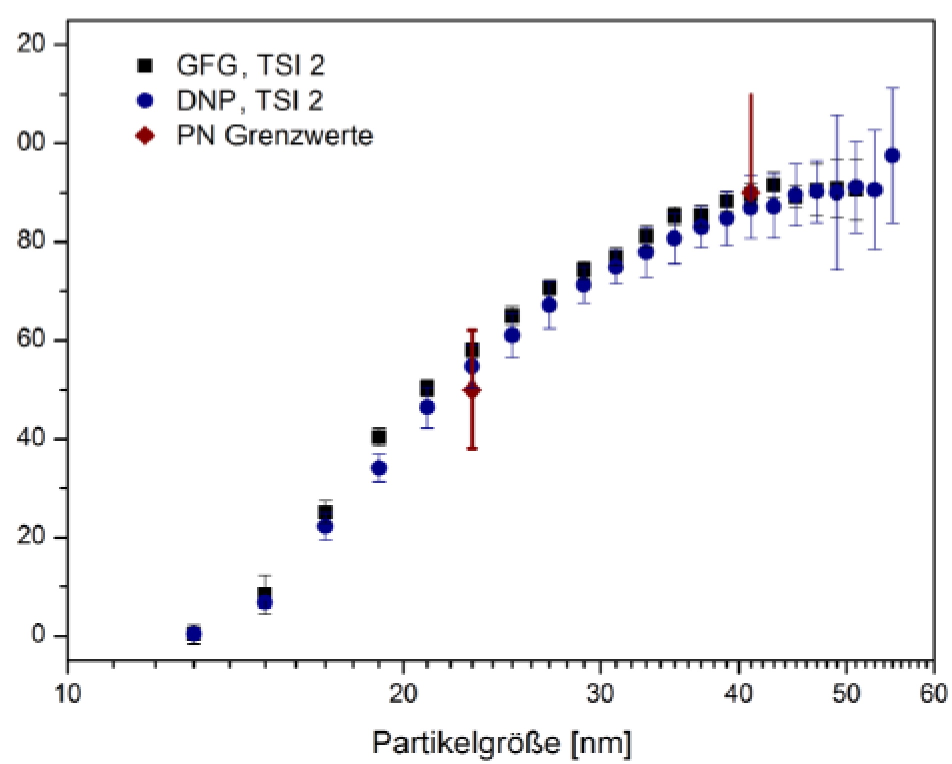
Sub23nm: Evaluation

- *Approaches*
  - PCRF(30+50+100) and PCRF(15)
  - Low losses VPR
  - Detailed penetration curve and measured (or assumed) size distributions

FVV: PNC response to volatiles

- *The removal efficiency of the VPR is important*





FVV: PNC response to volatiles

- *The removal efficiency of the VPR is important*

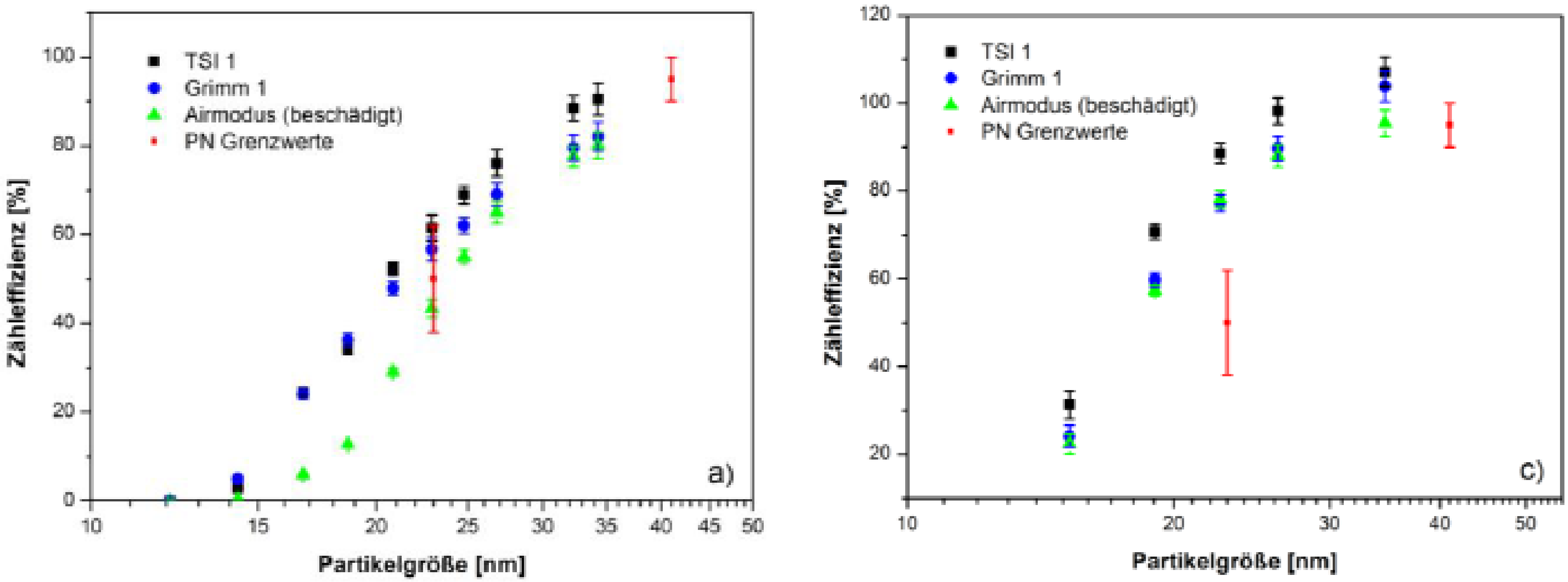
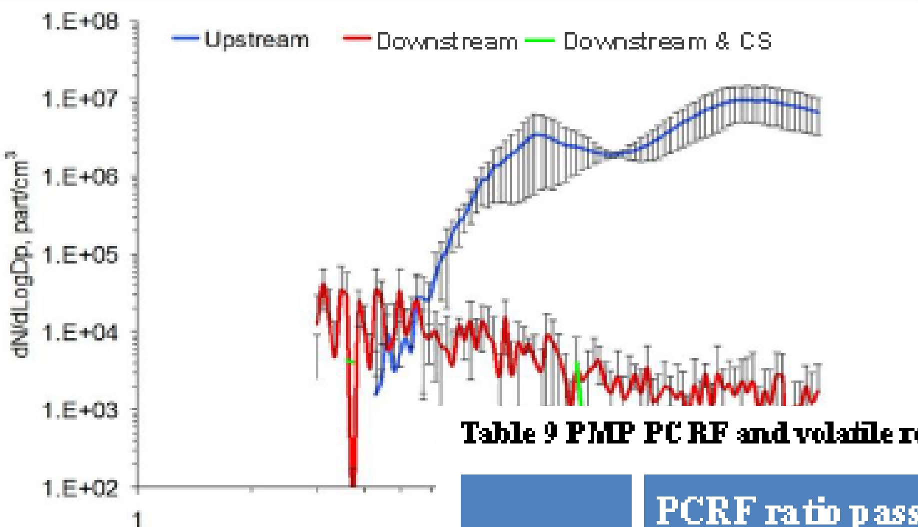


Abbildung 18: Zähleffizienzen für Rußkerne mit unterschiedlichen Mengen n-Hexadekan beschichtet: a) ohne Beschichtung, b) Sub-Monolage C_{16}, c) 1-nm-Schicht C_{16}.

Catalytic Stripper (CS)

CS: Sample III a



CS was investigated for aircraft gas turbines in 2011

Table 9 PMP PCRF and volatile removal efficiency pass Criteria summary for various VPR

VPR	PCRF ratio pass between x > y			Volatile removal efficiency pass >99%			
	15/100 Not PMP	30/100 1.3>0.95	50/100 1.2>0.95	15nm Not PMP	30nm	50nm	100nm
AVL	1.25	1.11	1.06	96.813	99.267	99.084	99.389
Dekati	1.17	1.12	1.03	98.490	99.960	99.903	99.044
Grimm	1.4	1.19	1.18	97.143	98.933	83.299	74.500
Bespoke	1.24	1.09	1.06	99.899	99.990	99.996	99.900
CS	1.73	-	1.08	100.00	100.00	100.00	100.00

CS: Sample III b

Confirmation of high oxidation efficiency of HCs

(400 ug/m3)

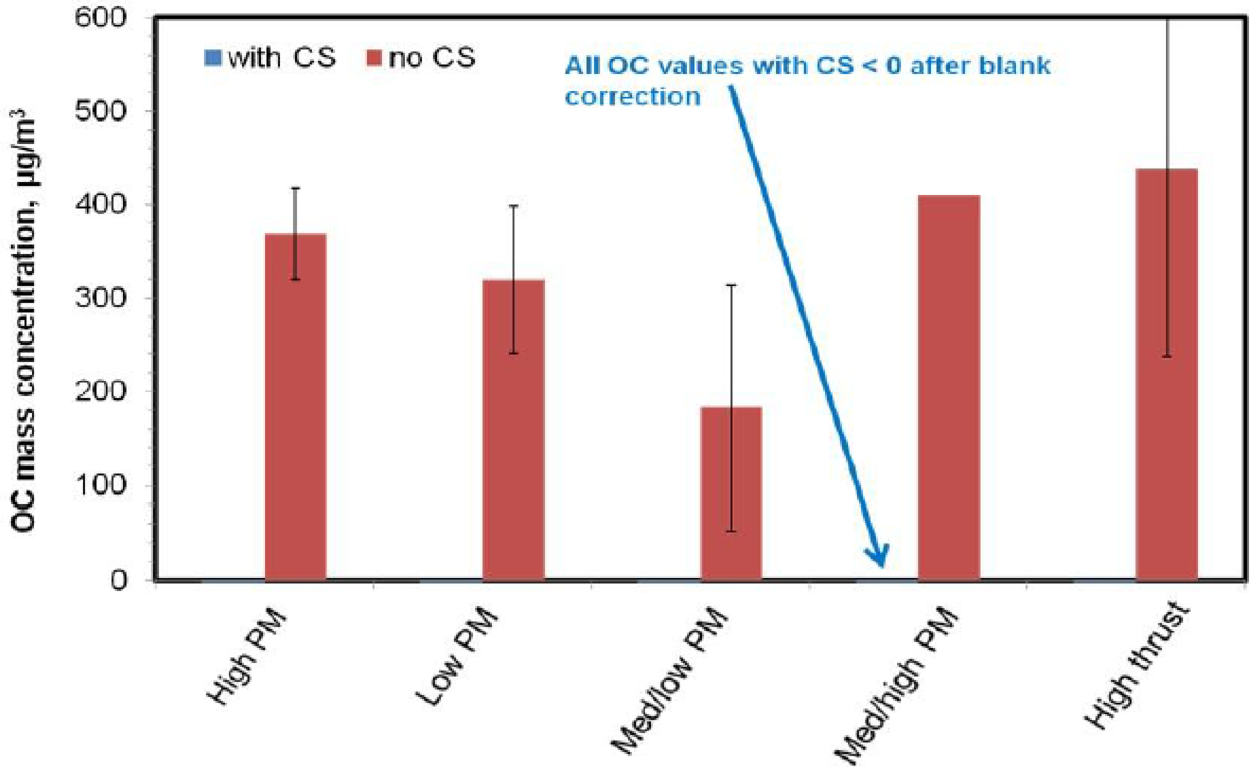


Figure 91 Organic Carbon (OC) mass concentrations obtained simultaneously up and downstream of a catalytic stripper (CS). The error bars represent 1 standard deviation in relation to the 3 filters obtained at a single power condition

CS: FVV study

- *CS from MAN Truck und Bus AG*
- *L: 13 cm (DOC 6.5cm + S-trap 6.5cm), Din: 2.4 cm.*
- *DOC: 600 cpsi, 3 mil with Platin (40 g / ft3).*
- *S-trap: 400 cpsi, 6 mil, Barium, Cerium.*
- *For 1,5 L/min residence time 0,88 s.*

Heizbandtemperatur [°C]	**200**	**350**
DOC [°C]	106 - 159	152 - 262
S-Trap [°C]	159 - 200	262 - 349

European Commission

CS: FVV study

H_2SO_4

	Catalytic Stripper	Evaporation Tube
Abtrennungseffizienz (C40)	> 99, 99 %	99,8 %
PCRF, 30 nm	1,98 **1.29**	40,9 **1.24**
PCRF, 50 nm	1,64 **1.07**	35,7 **1.08**
PCRF, 100 nm	1,53	33,0

Tabelle 5: Bestimmung der Abtrennungseffizienz des VPR mit Schwefelsäure.

Partikelanzahl-konzentration	CS (besch. Substrat)	CS (unbeschich. Substrat) **No washcoat**	ET
VPR Eingang[cm^{-3}]	$3{,}9 \cdot 10^7$	$2{,}8 \cdot 10^6$	$4{,}0 \cdot 10^7$
VPR Ausgang [cm^{-3}]	$8{,}9 \cdot 10^3$	$4{,}5 \cdot 10^5$	$3{,}4 \cdot 10^5$
Abtrennungseffizienz [%]	99,9	90,6	99,2

CS: Horiba study

- *Concentration 10^7 p/cm3*
- *ET: residual at 10 nm*
- *CS: no residual*

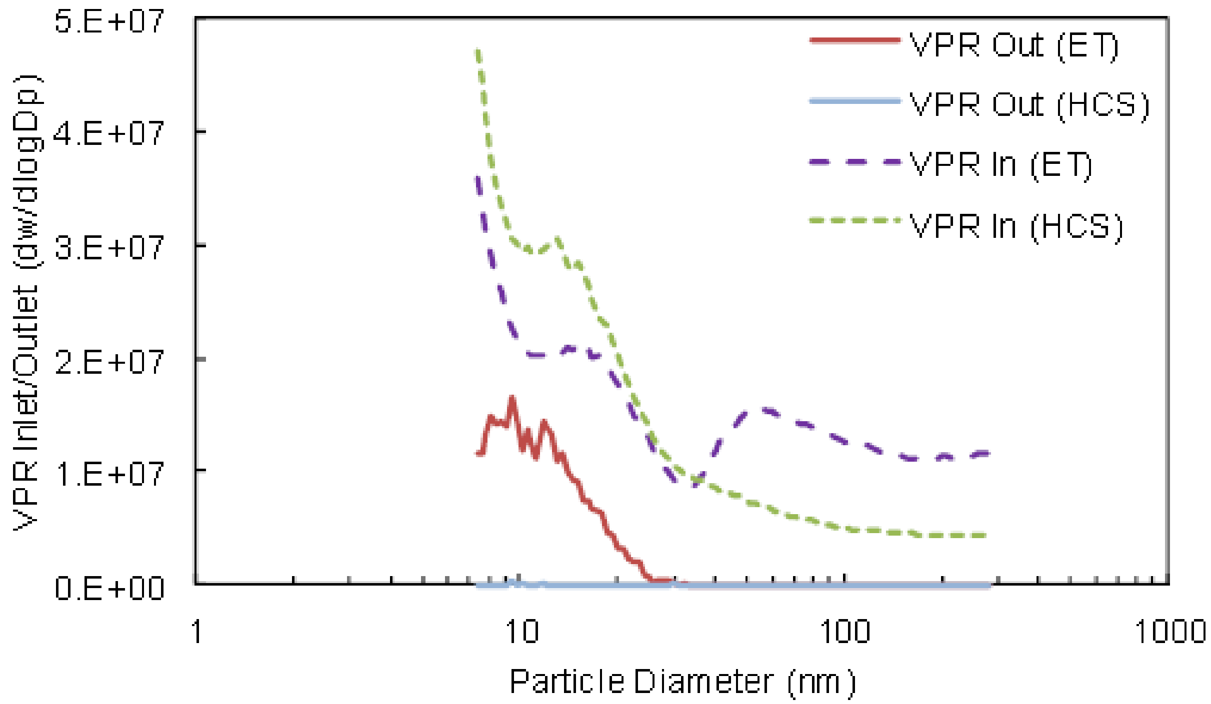


Figure 15. Size distributions of sulfuric acid mists

CS: FVV study

- *Sulfur storage capacity*
- *2 mg with no penetration*

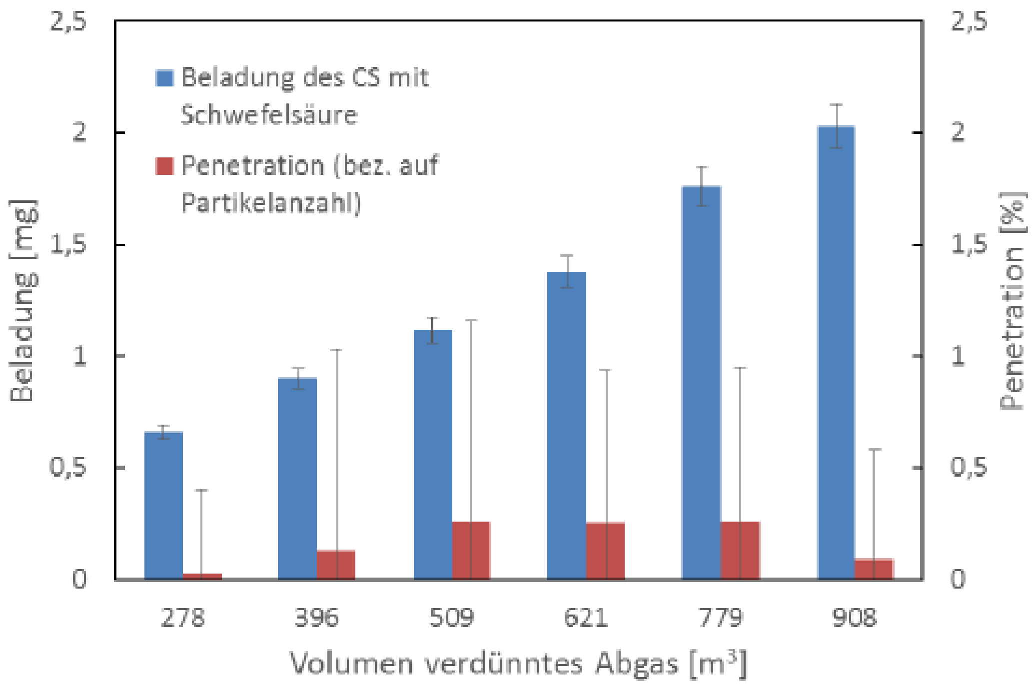


Abbildung 23: Penetration polydisperser Schwefelsäurepartikel bei verschiedenen Beladungen des CS mit H_2SO_4.

Real exhaust tests

No differences for diesel vehicles

Differences for a GDI at <10 nm

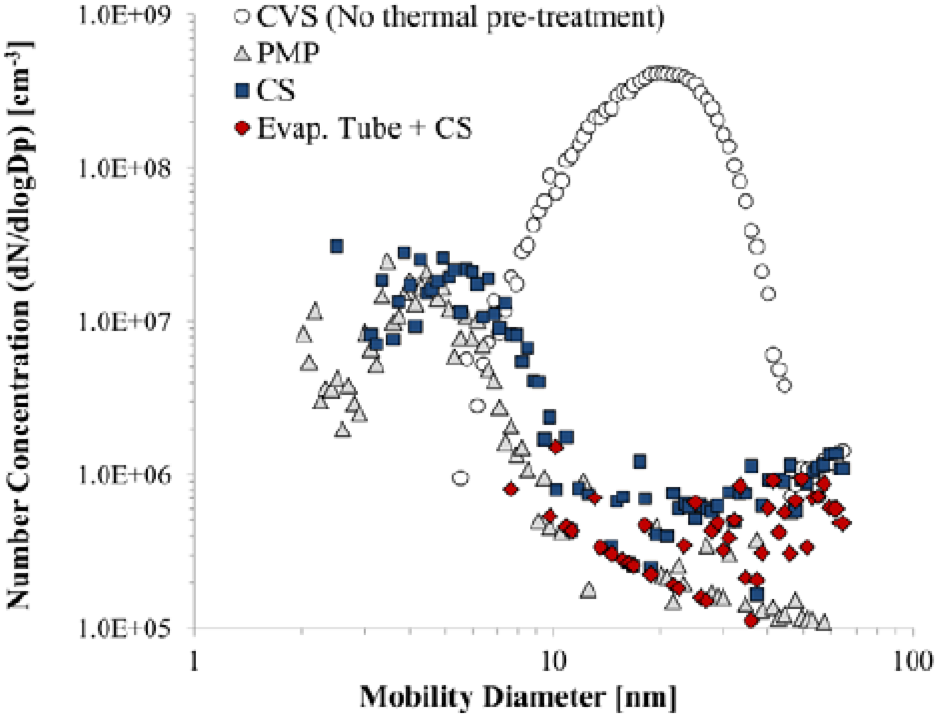


Figure 10. Performance of the CS in eliminating volatile particles from the DISI vehicle during a steady speed test, in comparison to a PMP compliant system.

CS: Typical characteristics

- *HC (particles): 200 ug/m3*
- *HC (gas): >4% HCs (=700 mg/m3)*
- *Sulfur removal: 5 ug/m3 (no S-trap), 10 mg/m3 (with S-trap)*
- *Sulfur storage: 2 mg (SO2 or H2SO4)*
- *Ammonium sulfate: 850 ug/m3*
- *Losses: 50% at 10 nm*
- *Vehicle exhaust: limited comparisons*

Input from CS manufacturers needed!

CS: Manufacturers specifications

AVL

Specifications of the Catalytic Stripper

Oxidation efficiency: >99% for decane inlet concentration of 4%

Sulphur Storage Capacity: > 6mg

Catalytic Instruments

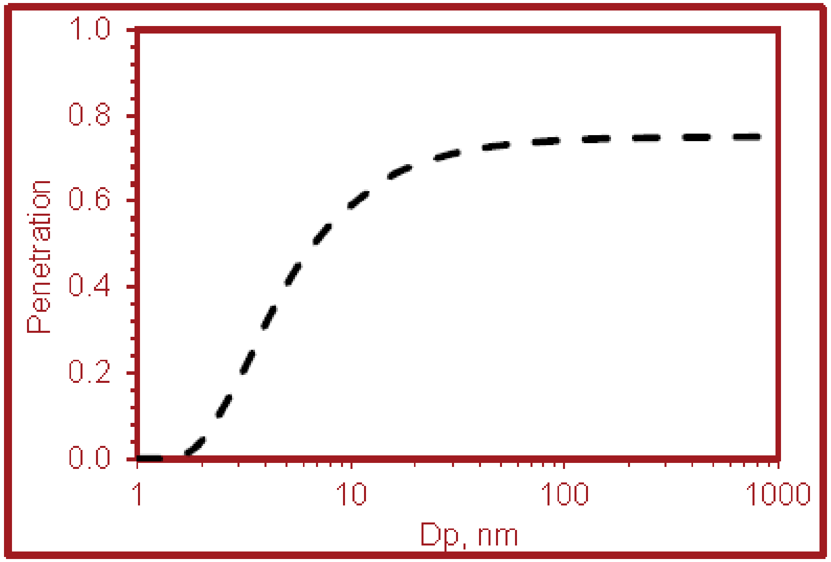
Inlet flowrate
1.5 L/min

Oxidation efficiency
> 99% of propane

Solid particle loss
< 40% at 100 nm

Operating gas temperature
350°C

Outlet temperature
ambient



Typical solid particle penetration curve

CS: JRC next steps

- *Prototype AVL CS (with S-trap) (only for research, not a product)*
- *Catalytic Instruments CS*
- *No other CS manufacturers were identified or made an offer*
- *Tender for a PMP system with CS and both 23nm and 10 nm PNCs*
- *Focus on vehicle exhaust, but not on the characterization of the CS (for now)*

Conclusions

- *Regeneration*
  - PMP robust
  - >10nm measurements with ET ok (needs confirmation)
  - New technologies need investigation
- *Sub23*
  - There is a sub23nm fraction 30-40% (no losses corr)
  - Maybe technology dependent
  - No CS studies so far to confirm the fraction
- *CS*
  - Losses are higher
  - Specifications are lacking / Long term investigation