

Performance evaluation and calibrations of two commercial exhaust particle counters during a long operation window

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Background

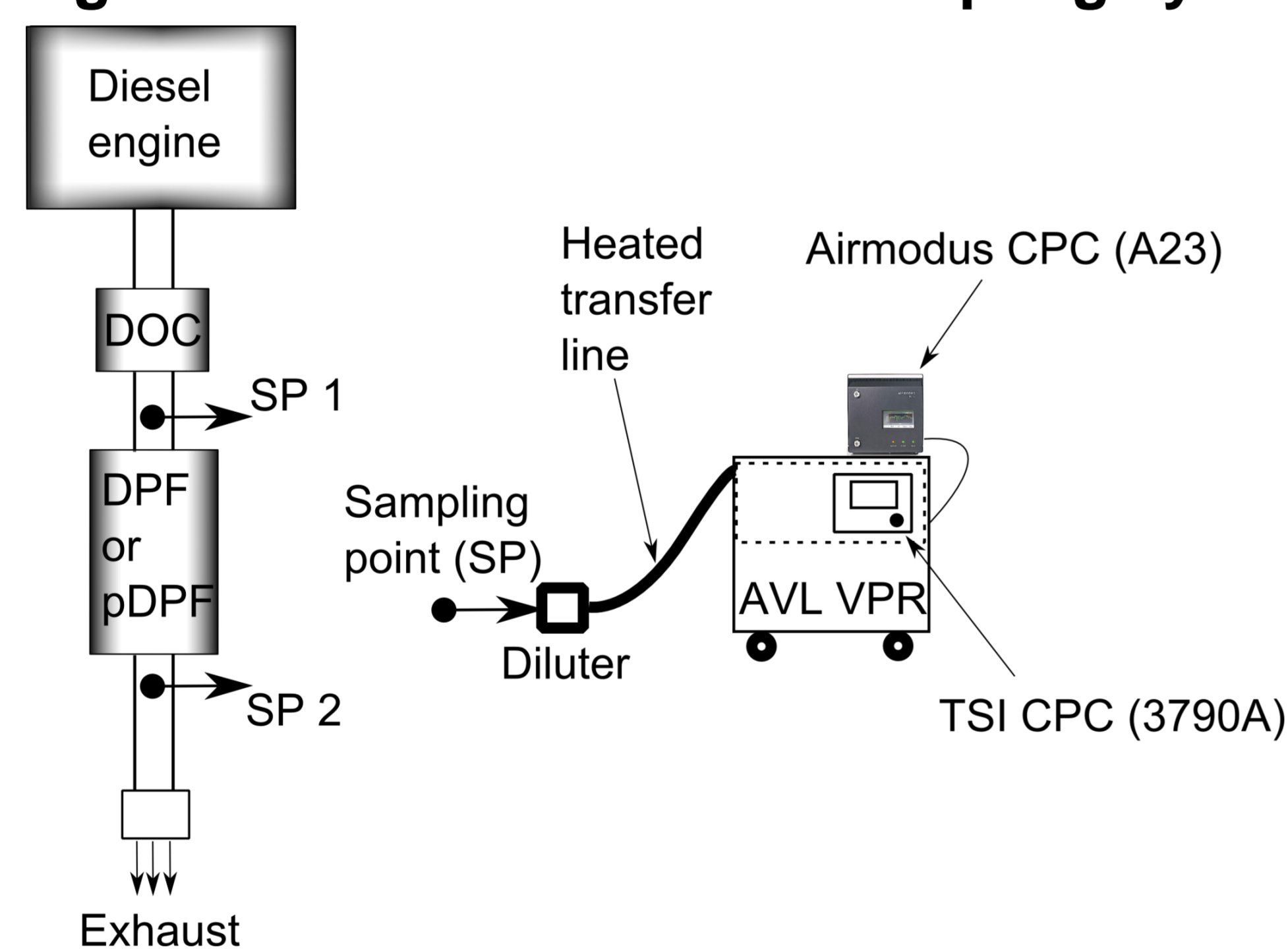
The current regulations in Europe for diesel passenger cars (EURO 5/6) and trucks (EURO VI) involve limitation for particulate number (PN). The measurement system includes two diluters where the first one is heated together with an evaporation tube where semivolatile particle fraction is evaporated. After the conditioning, remaining particles are counted with a condensation particle counter (CPC) where the 50% detection efficiency limit is set to 23 nm. These instruments are used in the development of engines and exhaust aftertreatment systems, and in the validations of vehicles. The CPCs are calibrated occasionally; usually the interval is 1 year. Problems may arise if the functioning of the CPC changes during the use due to e.g. deposition of particles or gases, which can bias the results.

Experiments

Two commercial CPCs:
Airmodus A23 and TSI 3790A

Engine tests

- Test period was 7 months long
- Tests were run with a heavy-duty diesel engine at a test bench
- Various aftertreatment configurations of oxidation catalysts and particle filters were applied during the tests
- Suitable particle levels (< 10000 p/cc) were achieved by controlling the dilution ratio of the sampling system (AVL)



CPC calibrations

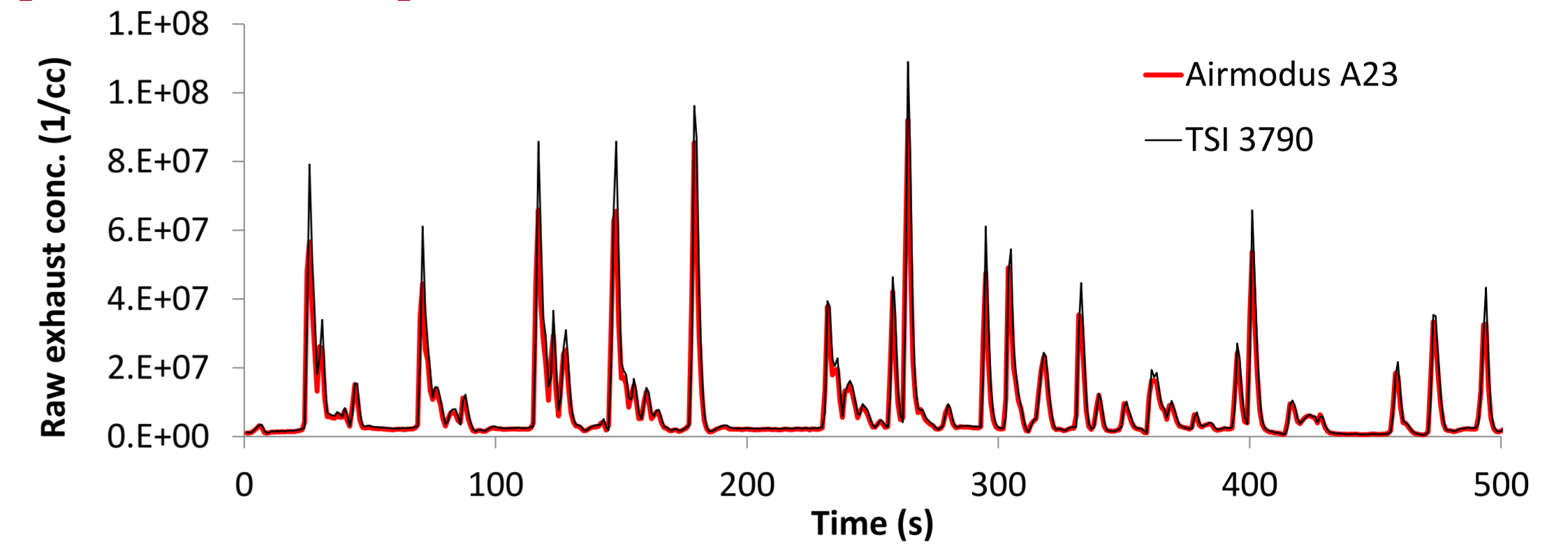
- Soot particles
 - Generated with a MiniCAST burner
 - Before, in the middle of and after the engine tests
- Singly charged particles (dioctyl sebacate (DOS) + NaCl)
 - Generated with a SCAR device [1]
 - Before and after the engine tests
- Silver nanoparticles (only A23)
 - Generated with evaporation-condensation method
 - Before and after the engine tests

References

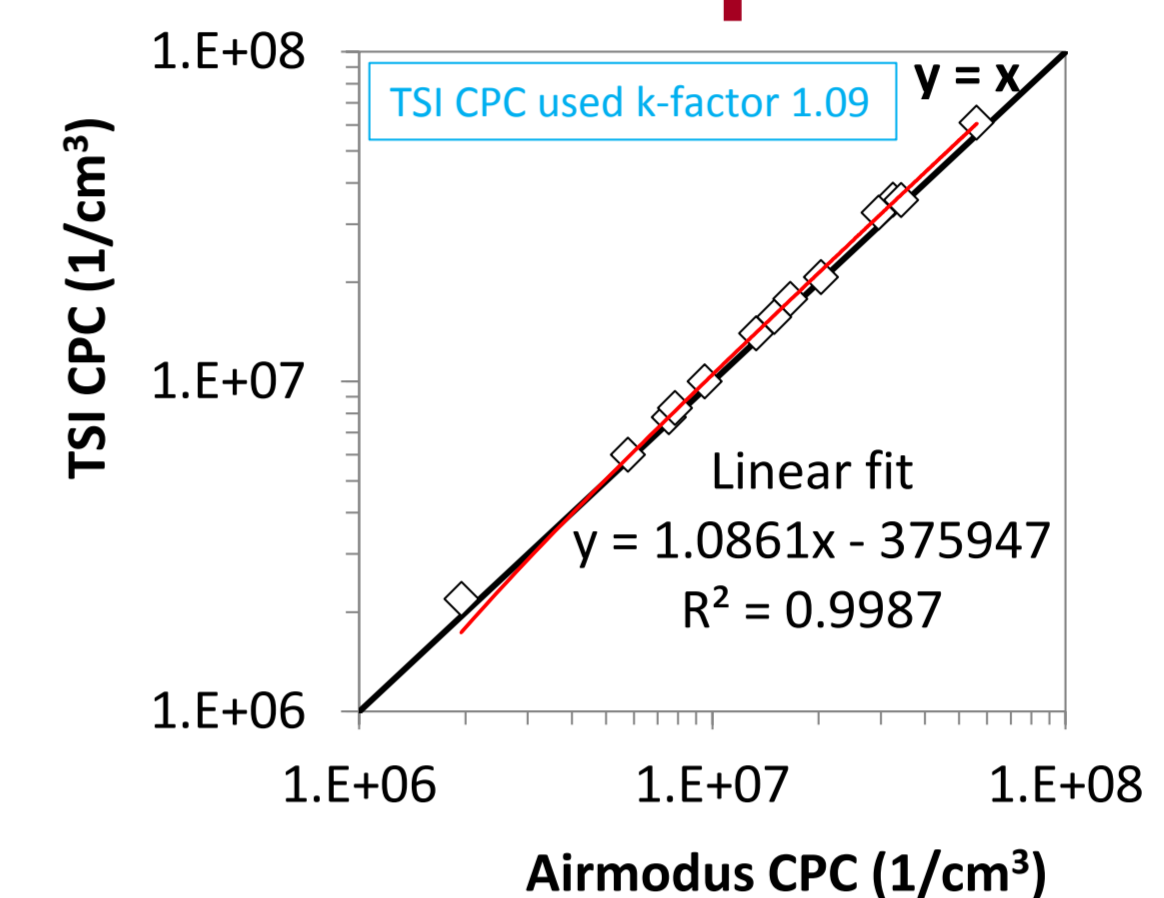
1. Yli-Ojanperä, J., Mäkelä, J.M., Marjamäki, M., Rostedt, A., Keskinen, J. (2010). J. Aerosol Sci., 41, 719-728.
2. Wang, X., Caldow, R., Sem, G. J., Hama, N. and Sakurai, H. (2010). J. Aerosol Sci., 41, 306-318.

Results

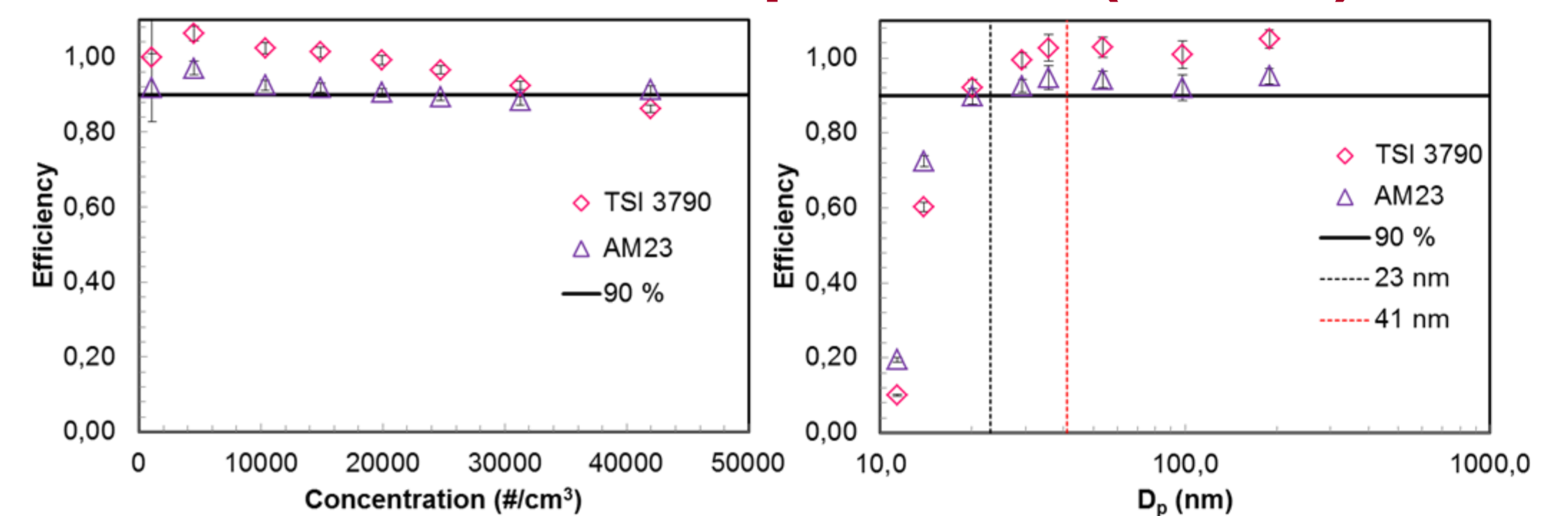
Temporal response



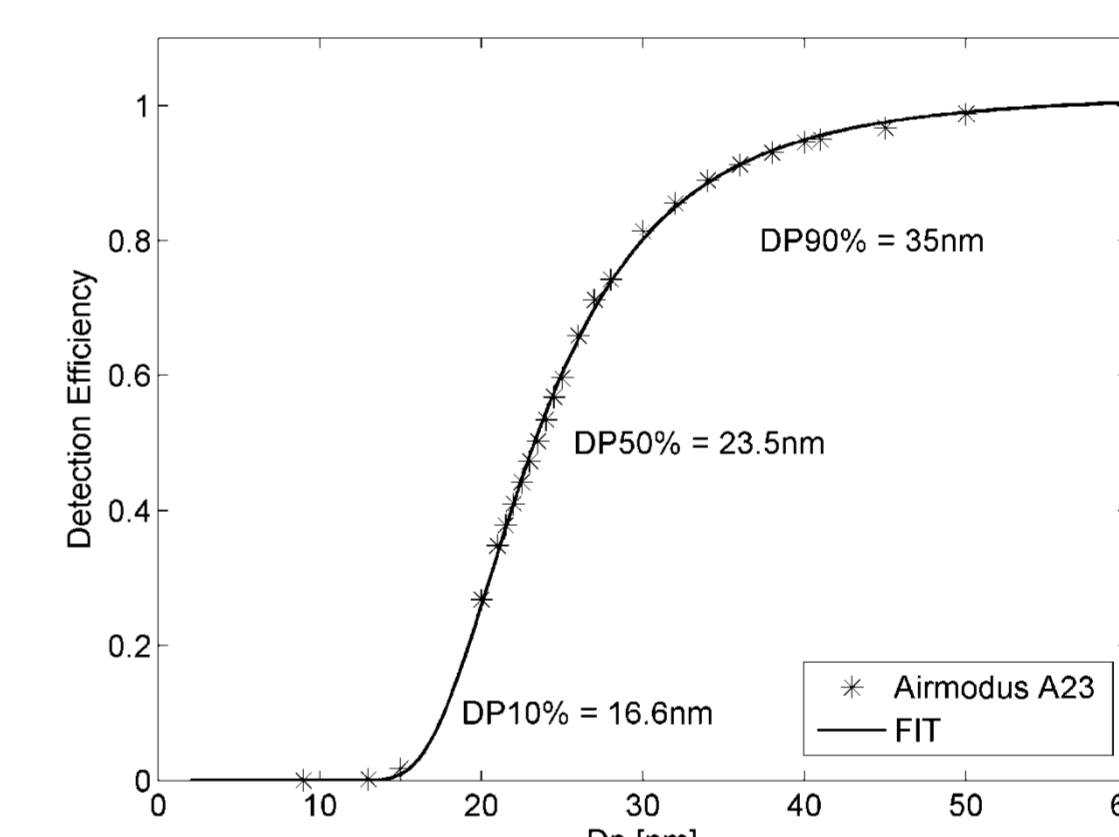
Comparison over 13 step stationary cycle



Calibration with DOS particles (SCAR)



Calibration with silver particles



Calibration with soot particles (MiniCAST)

TSI 3790 (k = 1,09)			Airmodus A23		
Start	After 4 m	After 7 m	Start	After 4 m	After 7 m
Lower Detection & Concentration Linearity Test Results					
56,2%	61,0%	59,0%	63,4%	64,2%	62,8%
87,1%	86,7%	85,7%	85,6%	88,8%	84,5%
99%	98%	103%	89%	92%	95%
1,0000	1,0000	1,0000	0,9999	0,9998	0,9999
Linearity Response: Test CPC vs. Reference CPC 3772					
-1,83	-1,29	2,75	-10,77	-5,02	-3,17
-1,73	-0,92	2,88	-9,10	-5,37	-3,62
-0,81	-1,28	3,63	-9,12	-5,87	-4,06
-1,15	-1,61	2,84	-9,26	-6,71	-5,08
-0,91	-1,87	2,88	-9,35	-8,52	-5,79
					500 p/cc
					1000 p/cc
					3000 p/cc
					7000 p/cc
					10000 p/cc
					Linearity Test
					R ²

Conclusions

- Both CPCs performed well during the entire test period
- No big changes in counting efficiencies during the tests
- The 3790A measured higher concentrations than A23, but this effect was constant throughout the experiments. The 3790A used concentration factor (k-factor) of 1.09
- At small concentration levels the 3790A showed relatively a little bit higher particle concentrations
- Both CPCs had approvable detection efficiency curves as a function of particle size
- The detection curves depended greatly on the particle material. The cut off diameter observed in the SCAR calibration was smaller than the one in the soot particle calibrations. This result is in line with an earlier observation [2].

