PMP Comparison Study of Particle Measurement Systems

Martin Mohr & Urs Lehmann

EMPA
Swiss Federal Laboratories for Materials Research and Testing
Laboratory for Internal Combustion Engines and Furnaces

Dübendorf, Switzerland

www.empa.ch

contact: martin.mohr@empa.ch

Abstract

The international programme PMP under the auspices of the UNECE WP29/GRPE is focused on a new approach to the measurement of particles in vehicle exhaust emissions, which may be used to complement or to replace the existing regulated mass based measuring system. This abstract deals with a comparative study of particle instruments within the collaborative programme PMP. The objective was to gain comparable information about repeatability, linearity, detection limit, response time and correlation of about 20 particle measurement instruments.
Simultaneous measurements with all instruments were carried out on a real diesel exhaust of a modern heavy-duty engine. The tests were performed on two different emission levels: downstream of a particle trap representing the technical lowest available level and a level about two third of the future emission limit (Euro 4). In a second phase an aerosol generator (CAST) was applied as an emission source to obtain engine independent results of the performance of the instruments.
The group of investigated measurement systems comprises a wide range of measurement principles that apply optical, electrical and filter methods and combination of these. The instruments to quantify the particle concentration use different metrics (number, length, surface, mass).

Martin Mohr, Particle Emissions Group

MOTIVATION

Demands on a future measurement method:

Quantification of particle emissions on *sub Euro 4* and *post-trap level* in a reliable way taking into account the present knowledge of health impact

CONTENTS

- Investigated instruments
- Experimental set-up
- Results
  - > Repeatability
  - > Sensitivity
  - > Detection limit
  - > Time response
  - > Size measurement
  - > Absolute values
  - > Correlations
  - > Linearity
- Conclusions

MEASUREMENT TECHNIQUES

Instrument	No	Manufacturer	Dilution	Principle
Diffusion Charger	2	Matter, TSI	hot dil	El. Charging
DMS	1	Cambustion	CVS	El. Charging
SMPS/CPC	3	Grimm, TSI	hot dil	El. Charging
ELPI	1	Dekati	hot dil	El. Charging / Impactor
MASMO	1	Dekati	hot dil	El. Charging / Impactor
El. Diffusion Battery	1	Matter	hot dil	El. Charging
Photoelectric Sensor	1	Matter	hot dil	El. Charging
TEOM	1	R&P	CVS	Filter
PM gas analysis	1	Horiba	CVS	Filter
Coulometry	1		PFD	Filter
Grav. Filter Method	1		CVS	Filter
Photoacoustic Sensor	1	TU Munich	CVS	
LII	1	Esytec	CVS	Opti-cal det.
Light Scattering	2	Grimm, Sensors	hot dil	Opti-cal det.
Light Extinction	3	Hartridge, Wizard, AVL	hot dil	Opti-cal det.

EMISSION SOURCES

HD Engine

7 l, 6 Cyl., TC, IC, EURO 3, (provided by Volvo)
equipped with particle filter (CRT-System)
Diesel fuel, <10 ppm sulphur

Emission levels

- post-trap
- partial bypass of particle trap ⇒ 40% below Euro 4

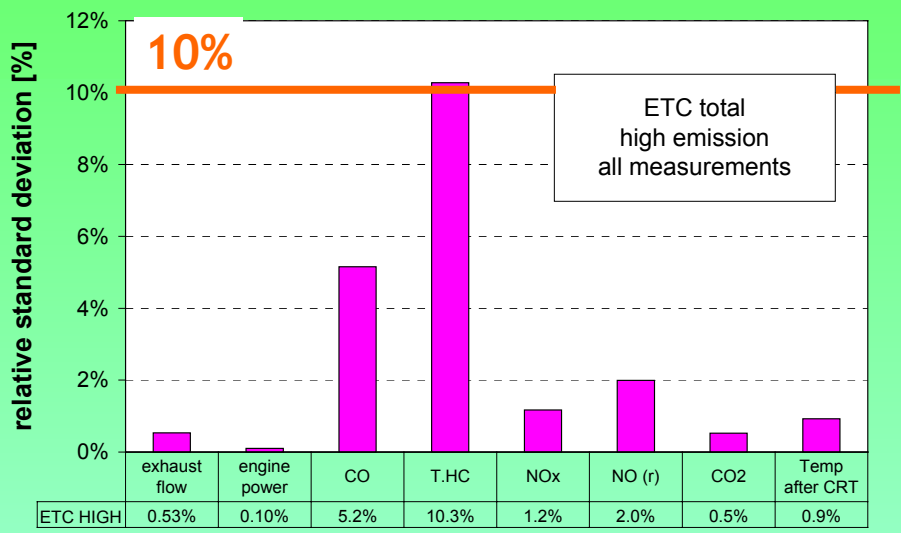
Combustion aerosol generator (CAST)

Settings (as determined by SMPS, TSI)

- 4 concentrations: 5000 - 150000 cm^{-3} (total number)
- 2 sizes: 40 nm and 140 nm (mode)

EMPA

REPEATABILITY OF ENGINE PARAMETERS



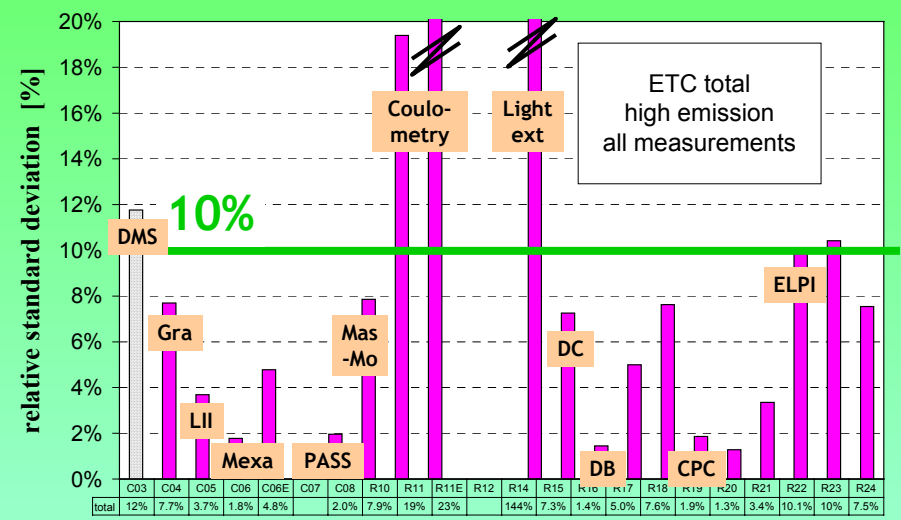
	exhaust flow	engine power	CO	T.HC	NOx	NO (r)	CO2	Temp after CRT
ETC HIGH	0.53%	0.10%	5.2%	10.3%	1.2%	2.0%	0.5%	0.9%

Martin Mohr, Particle Emissions Group

EMPA

REPEATABILITY

High emission level



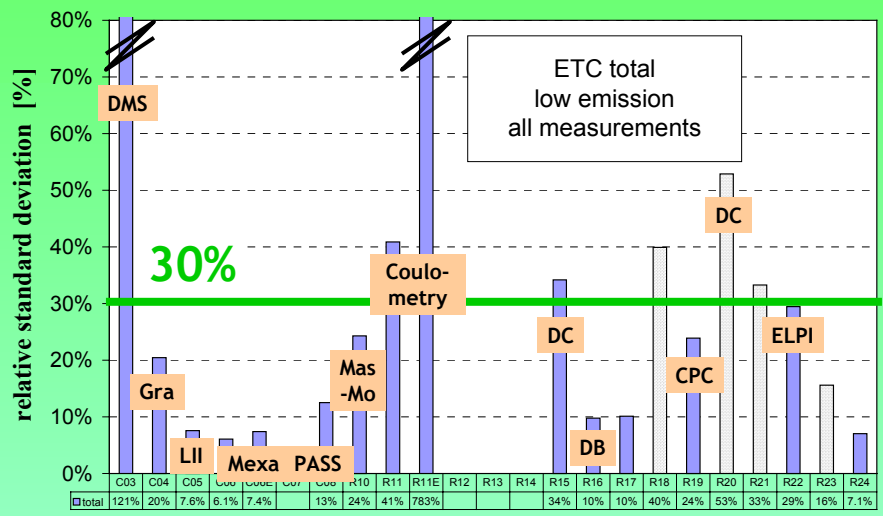
	C03	C04	C05	C06	C06E	C07	C08	R10	R11	R11E	R12	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24
total	12%	7.7%	3.7%	1.8%	4.8%		2.0%	7.9%	19%	23%		144%	7.3%	1.4%	5.0%	7.6%	1.9%	1.3%	3.4%	10.1%	10%	7.5%

Martin Mohr, Particle Emissions Group

EMPA

REPEATABILITY

Post-trap emission level



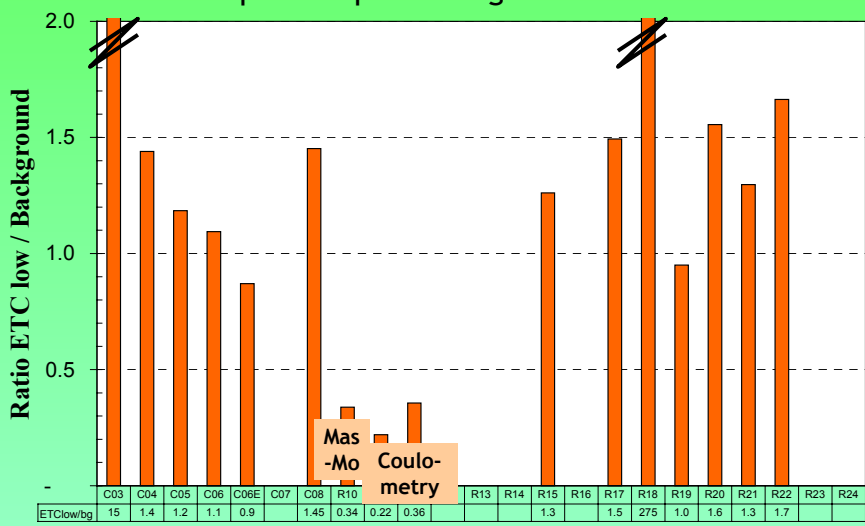
	C03	C04	C05	C06	C06E	C07	C08	R10	R11	R11E	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24
total	121%	20%	7.6%	6.1%	7.4%		13%	24%	41%	783%				34%	10%	10%	40%	24%	53%	33%	29%	16%	7.1%

Martin Mohr, Particle Emissions Group

EMPA

POST-TRAP EMISSIONS

Ratio post-trap to background concentration



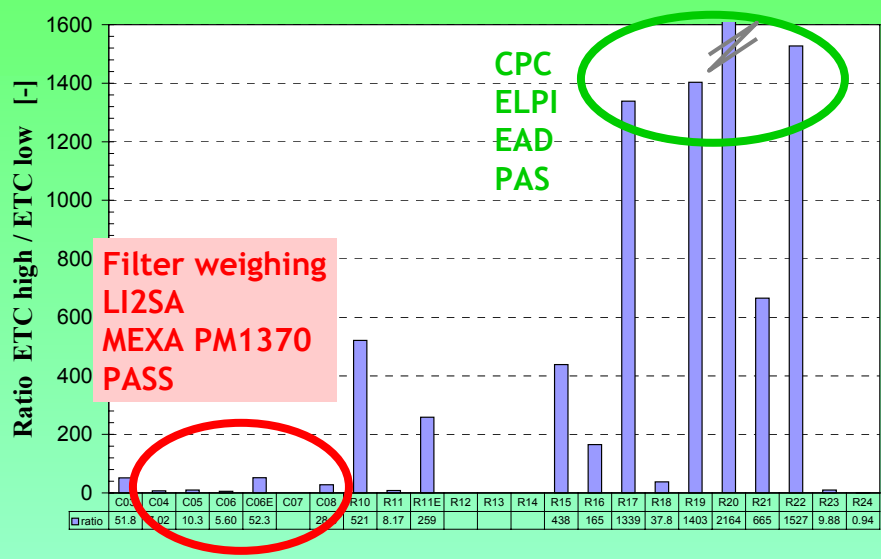
	C03	C04	C05	C06	C06E	C07	C08	R10			R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24
ETClow/bg	15	1.4	1.2	1.1	0.9		1.45	0.34	0.22	0.36			1.3		1.5	275	1.0	1.6	1.3	1.7		

Martin Mohr, Particle Emissions Group

EMPA

SENSITIVITY

Ratio high to low emission level

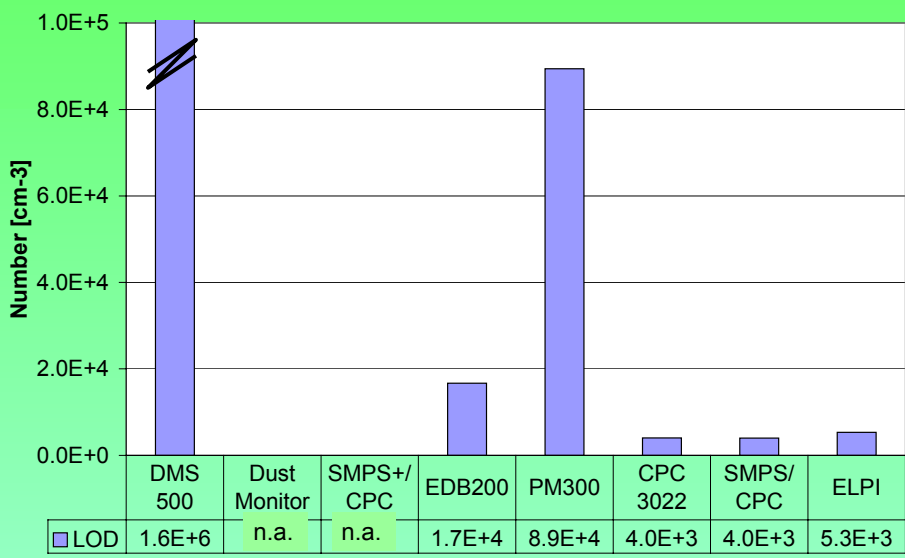


Martin Mohr, Particle Emissions Group

EMPA

DETECTION LIMIT

Number Instruments

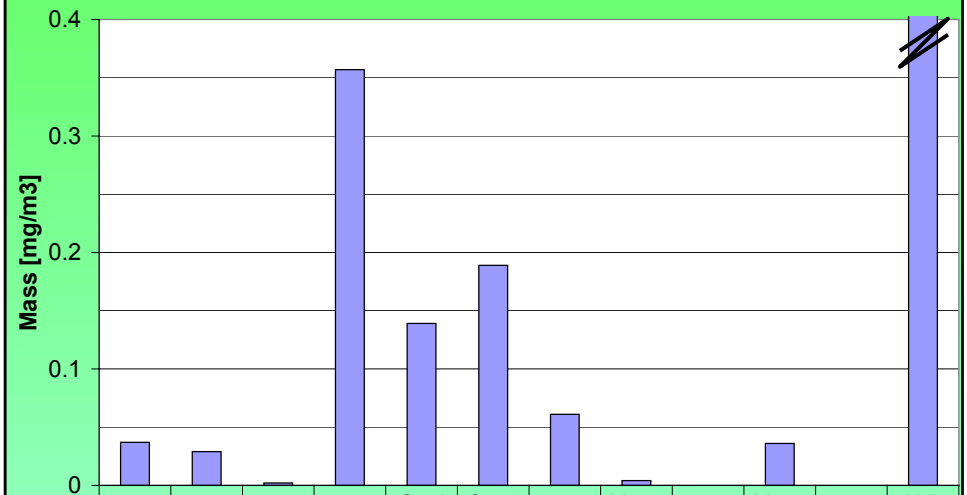


Martin Mohr, Particle Emissions Group

EMPA

DETECTION LIMIT

Mass Instruments

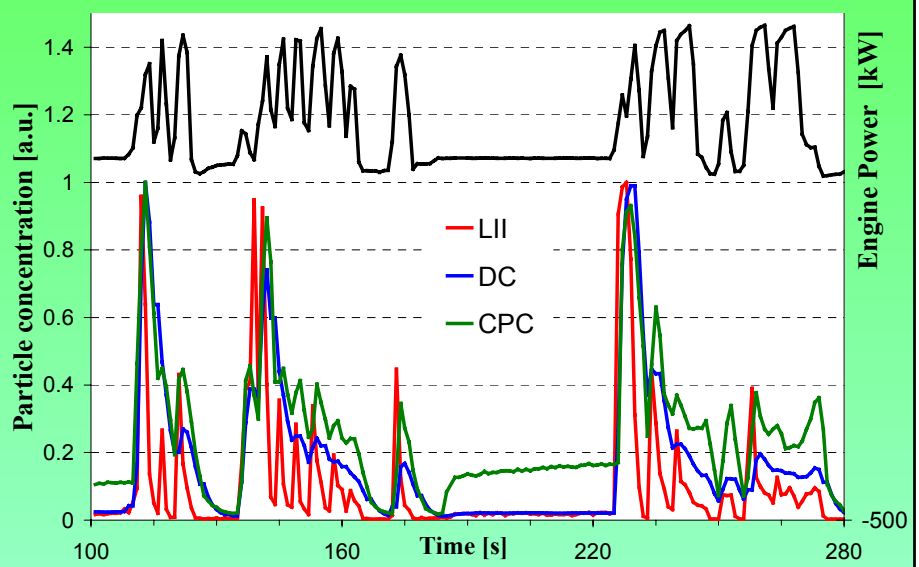


	LI2SA	PASS	PAS	Coul	Coul EC	Gravi metry	Mexa	Mexa EC	TEOM	Mass Mo	DPSO	AVL 439
LOD	0.037	0.029	0.002	0.357	0.139	0.189	0.061	0.004	n.a.	0.036	n.a.	1.22

Martin Mohr, Particle Emissions Group

EMPA

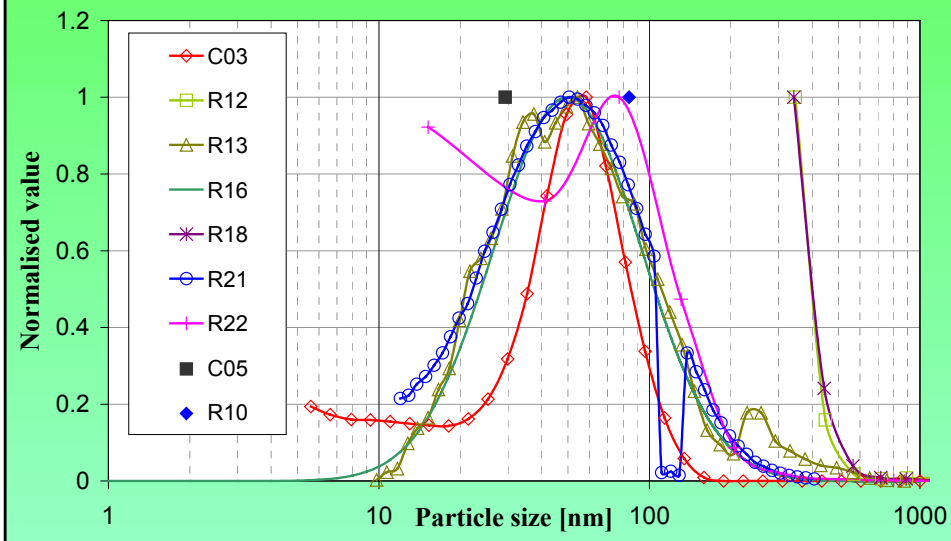
TIME RESPONSE



Martin Mohr, Particle Emissions Group

EMPA

SIZE MEASUREMENTS

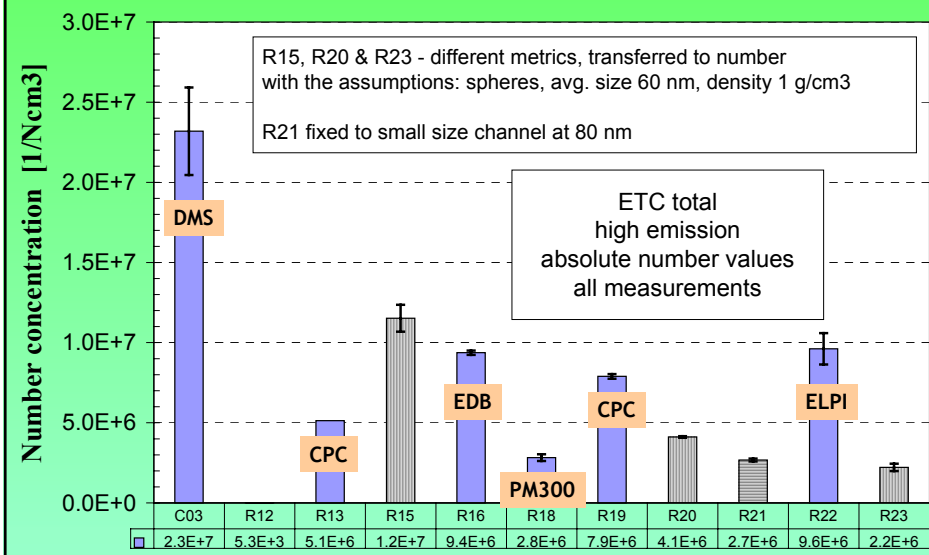


Martin Mohr, Particle Emissions Group

EMPA

ABSOLUTE VALUES

Number - high emission level

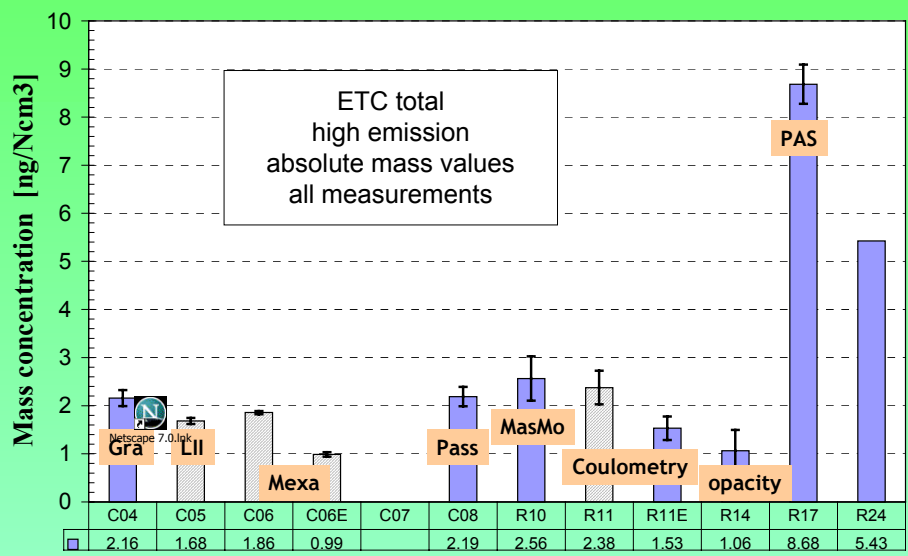


Martin Mohr, Particle Emissions Group

EMPA

ABSOLUTE VALUES

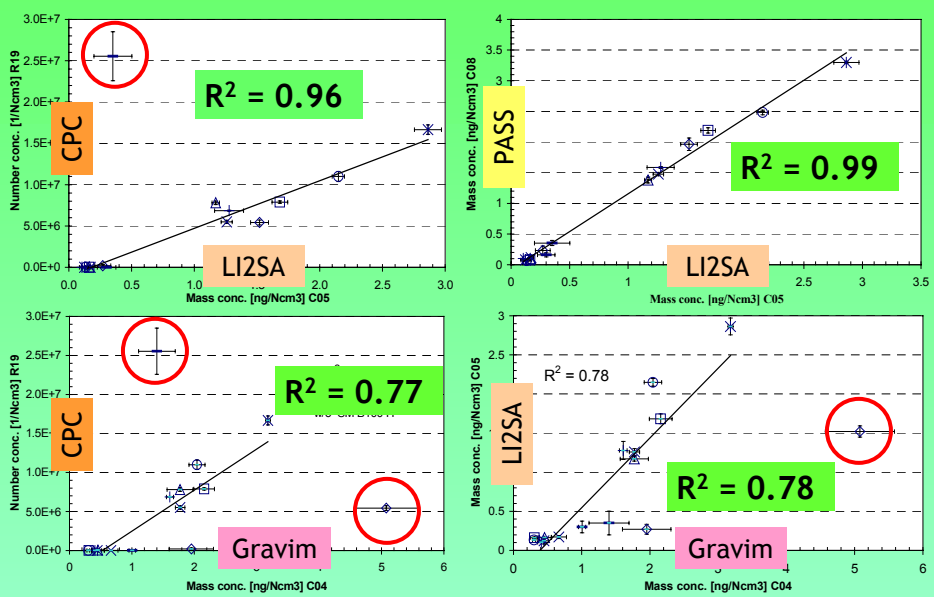
Mass - high emission level



Martin Mohr, Particle Emissions Group

EMPA

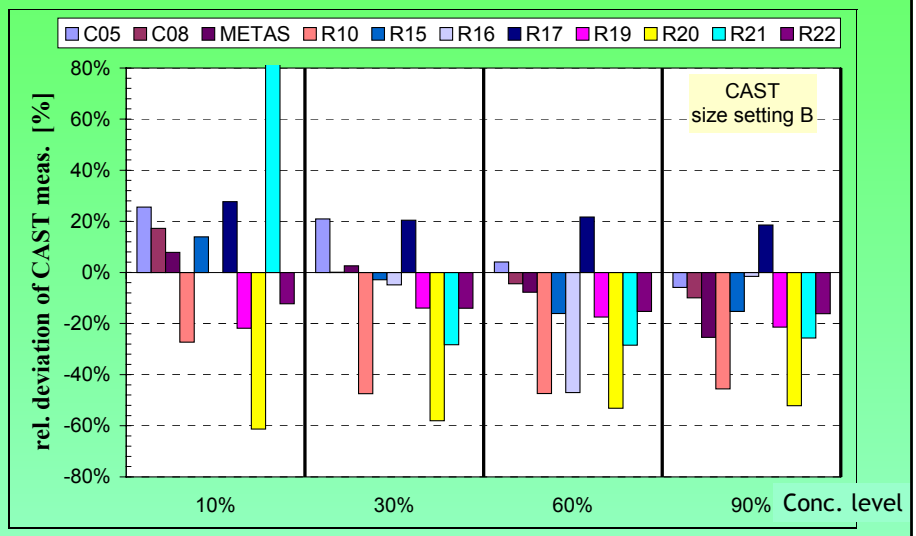
CORRELATION



Martin Mohr, Particle Emissions Group

EMPA

CAST - REPEATABILITY

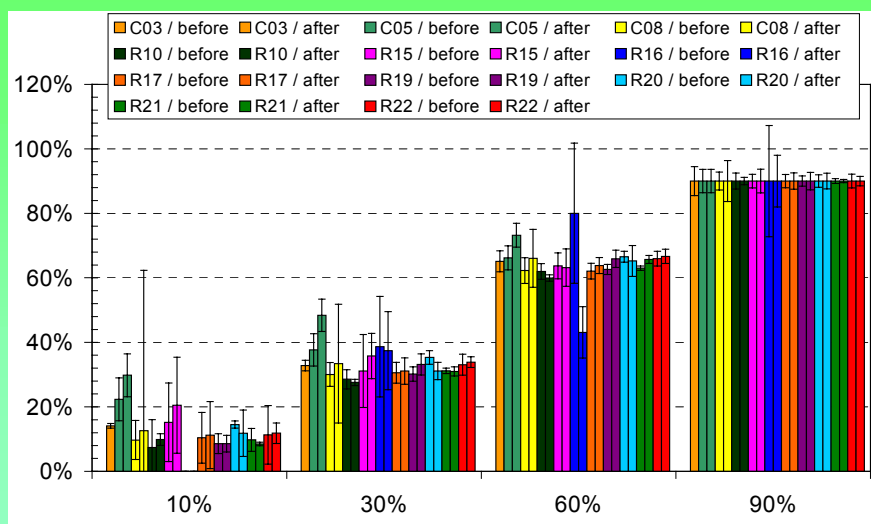


Relative deviation of concentration within two weeks

Martin Mohr, Particle Emissions Group

EMPA

LINEARITY



Martin Mohr, Particle Emissions Group

EMPA

CONCLUSIONS

SENSITIVITY
- Number-based methods higher sensitivity than mass-based methods

➔ better distinction of post-trap & GDI emissions

DETECTION LIMIT
- Advanced mass-based methods lower detection limit than regulated filter method

REPEATABILITY
- Several instruments similar or better repeatability than regulated filter method

➔ Key position: volatile material

➔ Data on Reproducibility needed

CORRELATION
- Regulated filter method poor correlation to most other instruments

CALIBRATION
- In contrast to mass-based methods a traceable standard does not yet exist for particle number, length or surface.

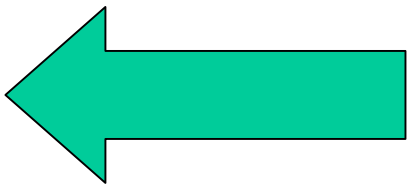
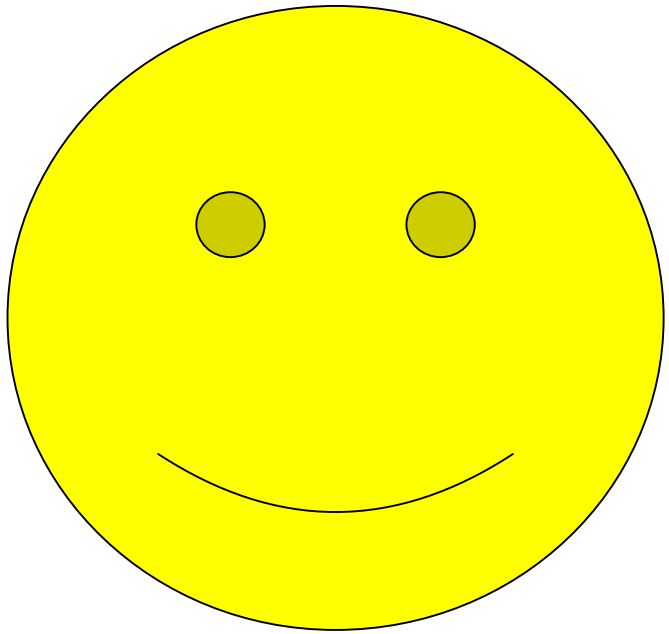
Report ➔ www.empa.ch/pmp

EMPA

Thanks to my EMPA colleagues

- Sepp Rütter
- Roland Graf
- Rolf Ziegler
- Urs Lehmann
- Daniel Schreiber
- Hans-Christian Opstad
- Uzi Saghi

Funded by

- ASTRA
- EMPA
- BUWAL
- Manufacturers (instruments operation)
- METAS (CAST operation)
- R&P (cyclones & filter holders)
- SUVA (coulometry)
- VOLVO (engine)

back to index