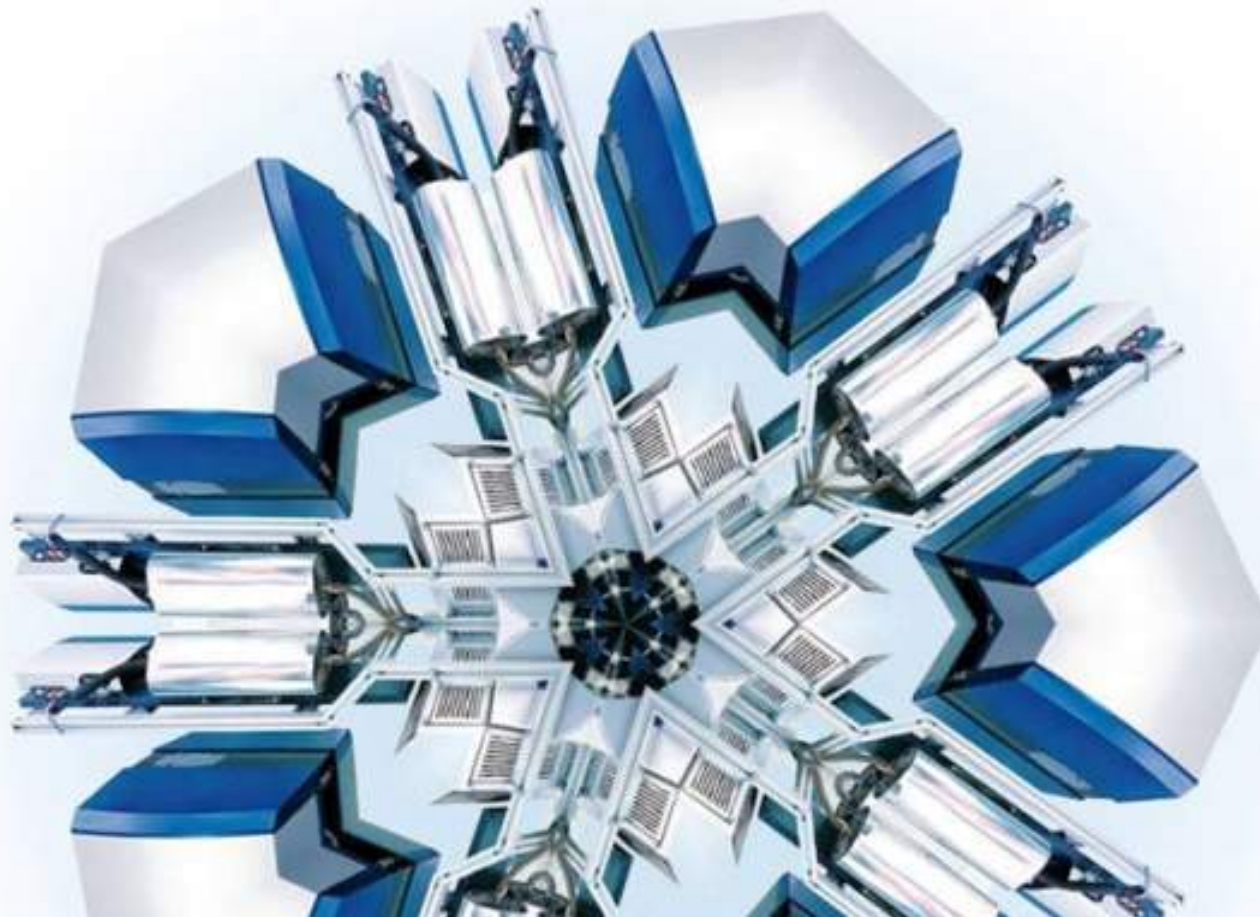


PARTICLE NUMBER MEASUREMENT – FROM ECE-R83 TO ECE-R49

Herwig JÖRGL



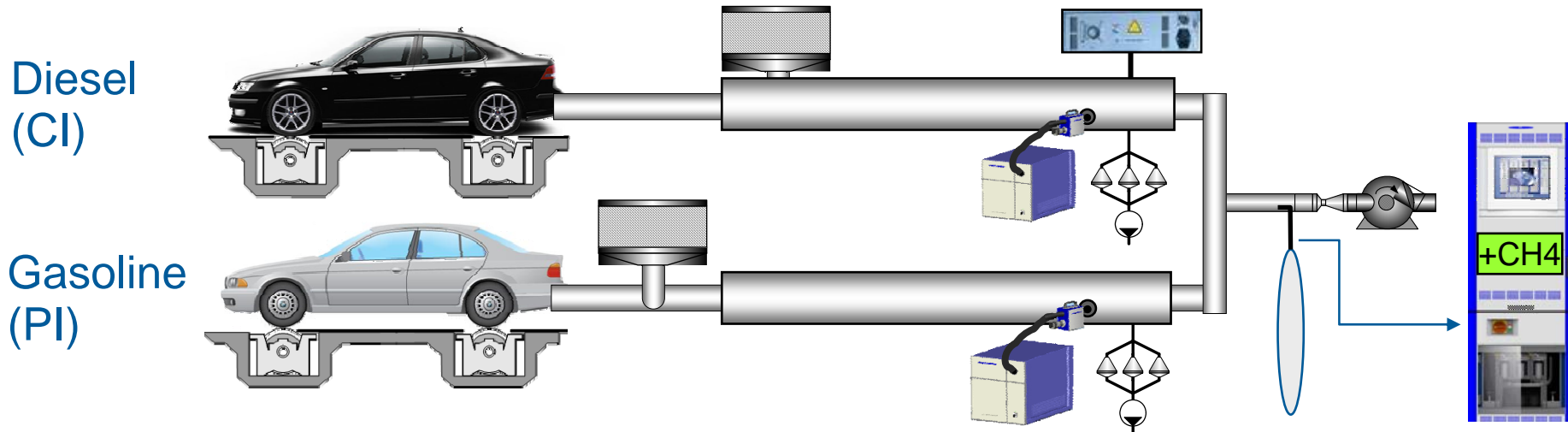
AGENDA




- Overview Light Duty Emission Regulations
- Overview Heavy Duty Emission Regulations
- Recommended System Setup
- The AVL Particle Counter
- Applications and Measurement Results

LIGHT DUTY

Continuously adding new test requirements



 Emission	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 5+	Euro 6
	1992	1996	2000	2005	2009	2011	2014
CO, THC, NO _x , CO ₂	✓						
Diluted Hot THC – CI only („Diesel“)	✓						
Particulate Mass – CI only („Diesel“)	✓						
NMHC					✓		
Particulate Mass – PI-GDI only					✓		
Particle Number – CI only („Diesel“)						✓	
CO ₂ Limit						✓	
Particle Number – all PI („Gasoline“)							(✓)

LIGHT DUTY

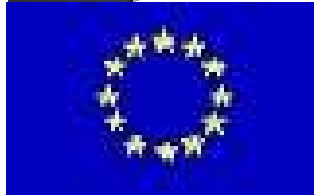
Euro 4 to 6 – Limits PM/PN



		2009	2011		2014 (proposal)	
	Motor	Euro 5	Euro 5 +		Euro 6	
		mg/km	mg/km	#/km	mg/km	#/km
Particulate mass	GDI	5	4,5		4,5	
	Diesel	5	4,5		4,5	
Particle number	Gasoline			no		TBD
	Diesel			6*10 ¹¹		6*10 ¹¹

- Decrease of PM limit from Euro 5 to Euro 6
- Introduction of new PN limit within 2011
- PN limit for gasoline vehicles to be defined

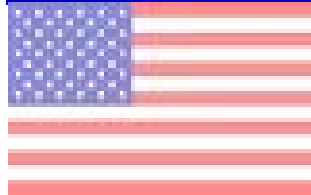
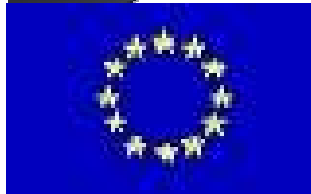
HEAVY DUTY EU-VI Approach



- **Particle Number-Limit (PN)**
 - Likely implementation of new particle number limit with EU-VI
 - Specifications based on the Particle Measurement Program (PMP)
 - Limits established on “Best available technology” or “Correlation with PM limit (10mg/kWh)”
 - Proposal: $8 \cdot 10^{11} \#/\text{kWh}$ for the stationary and $6 \cdot 10^{11} \#/\text{kWh}$ for the transient cycle
 - Implementation of these limits expected in 2010 (maybe not before 2011).

- **PMP Heavy Duty Evaluation**
 - Evaluation Program still in progress
 - Measurements showed good correlation, except low concentration levels (background).
 - Background level might be included in the upcoming regulation
 - “Draft Heavy Duty Validation Exercise Report” in progress

HEAVY DUTY European & US Approach



- **Implementation of particle numbers (PN) in ECE-R49**
Draft for the enhancement of the R-49 in progress
Current highlights:
 - Compensation of the extracted sample flow in partial flow dilution applications
 - Time Alignment (Proposal: „system transformation time“ t50)
 - Cold start weighting factor of 14% instead of 10% (depending on WHDC)?
 - Regeneration?

- **Implementation of particle numbers (PN) in LEV III (Californian emission legislation)**

Proposal for the future amendments:

- Mandatory standard not being considered at this time, but
- an optional PM number standard of about 10¹² particles/mi is being considered (which could be chosen by manufacturers instead of the PM mass standard).

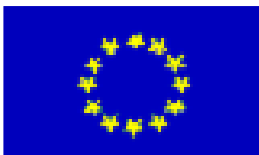
HEAVY DUTY Limits



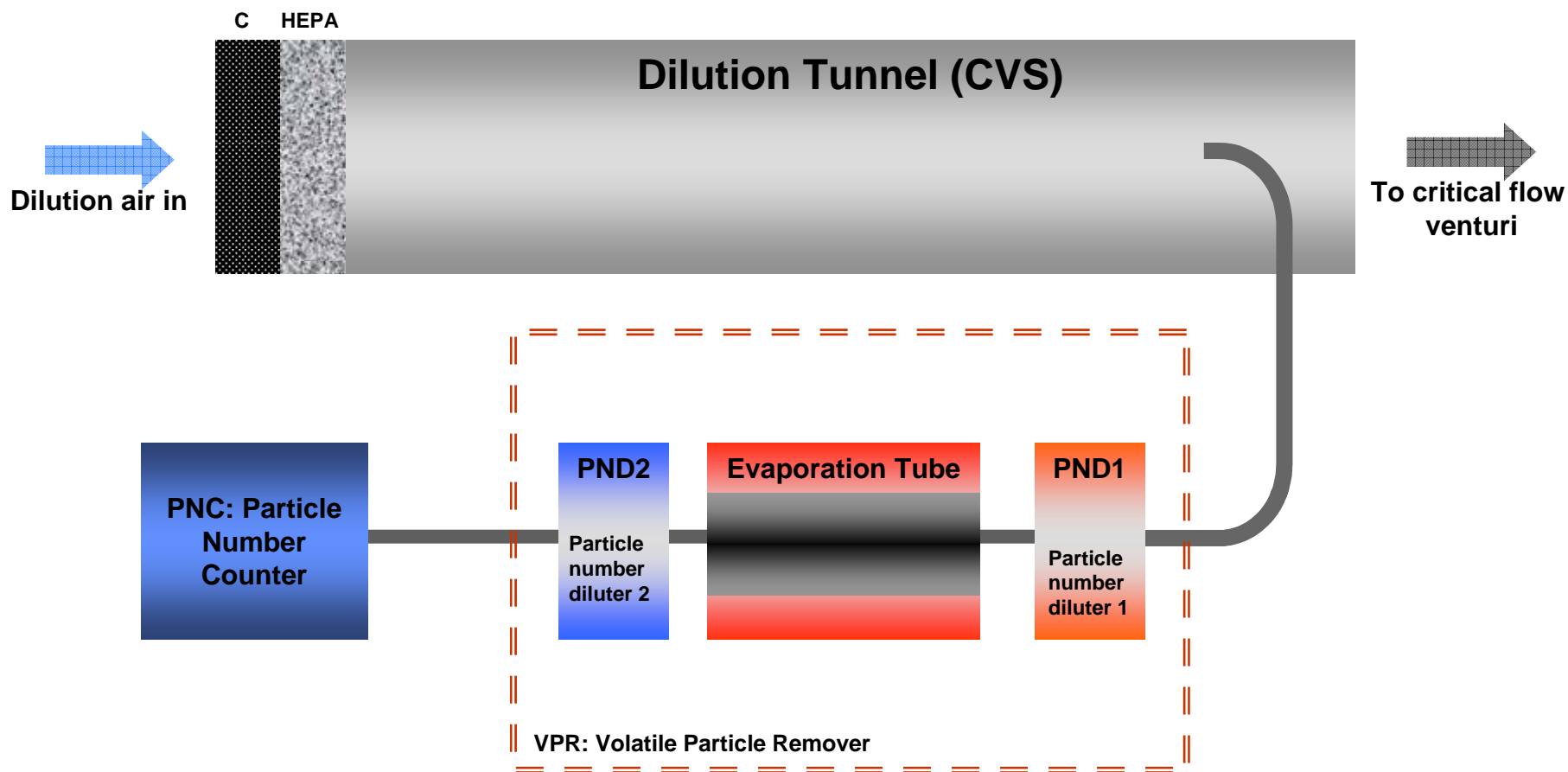
Test / Emission			EU-I	EU-II	EU-III	EU-IV	EU-V	EU-VI
			1992	1996	2000	2005	2008	2013
ESC (WHSC) Test cycle	CO	g/kW-h	4,50	4,00	2,10	1,50	1,50	1,50
	THC	g/kW-h	1,10	1,10	0,66	0,46	0,46	0,13
	NMHC	g/kW-h						
	CH4	g/kW-h						
	NOx	g/kW-h	8,00	7,00	5,00	3,50	2,00	0,40
	PM	g/kW-h	3,60	0,15	0,10	0,02	0,02	0,01
	NH3	ppm				25	25	10
	PN	#/kWh						"8*10 ¹¹ "
	CO2, FC	g/kW-h						?
	unregulated	g/kW-h						?
ETC (WHTC) Test cycle	CO	g/kW-h			5,40	4,00	4,00	4,00
	THC	g/kW-h						0,16
	NMHC	g/kW-h			0,78	0,55	0,55	
	CH4	g/kW-h			1,60	1,10	1,10	
	NOx	g/kW-h			5,00	3,50	2,00	0,40
	PM	g/kW-h			0,16	0,03	0,03	0,01
	NH3	ppm				25	25	10
	PN	#/kWh						"6*10 ¹¹ "
	CO2, FC	g/kW-h						?
	unregulated	g/kW-h						?

**WHTC:
0,40
or
0,46**

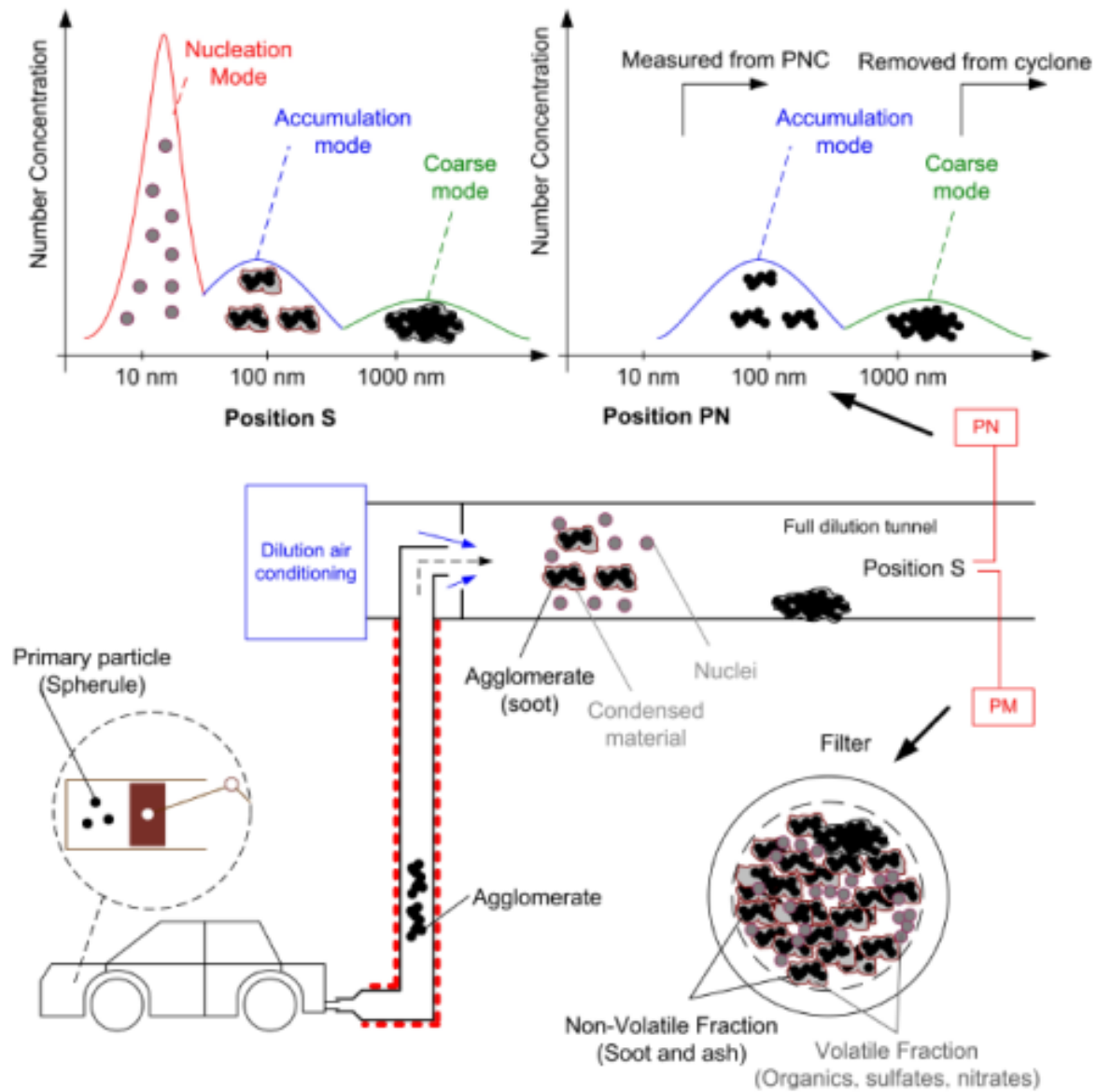
Moderate Reduction (<30%)
 Large Reduction (>30%)



SUPPLEMENT 07 OF AMENDMENTS TO REGULATION No.83



PARTICLE GENERATION IN GENERAL



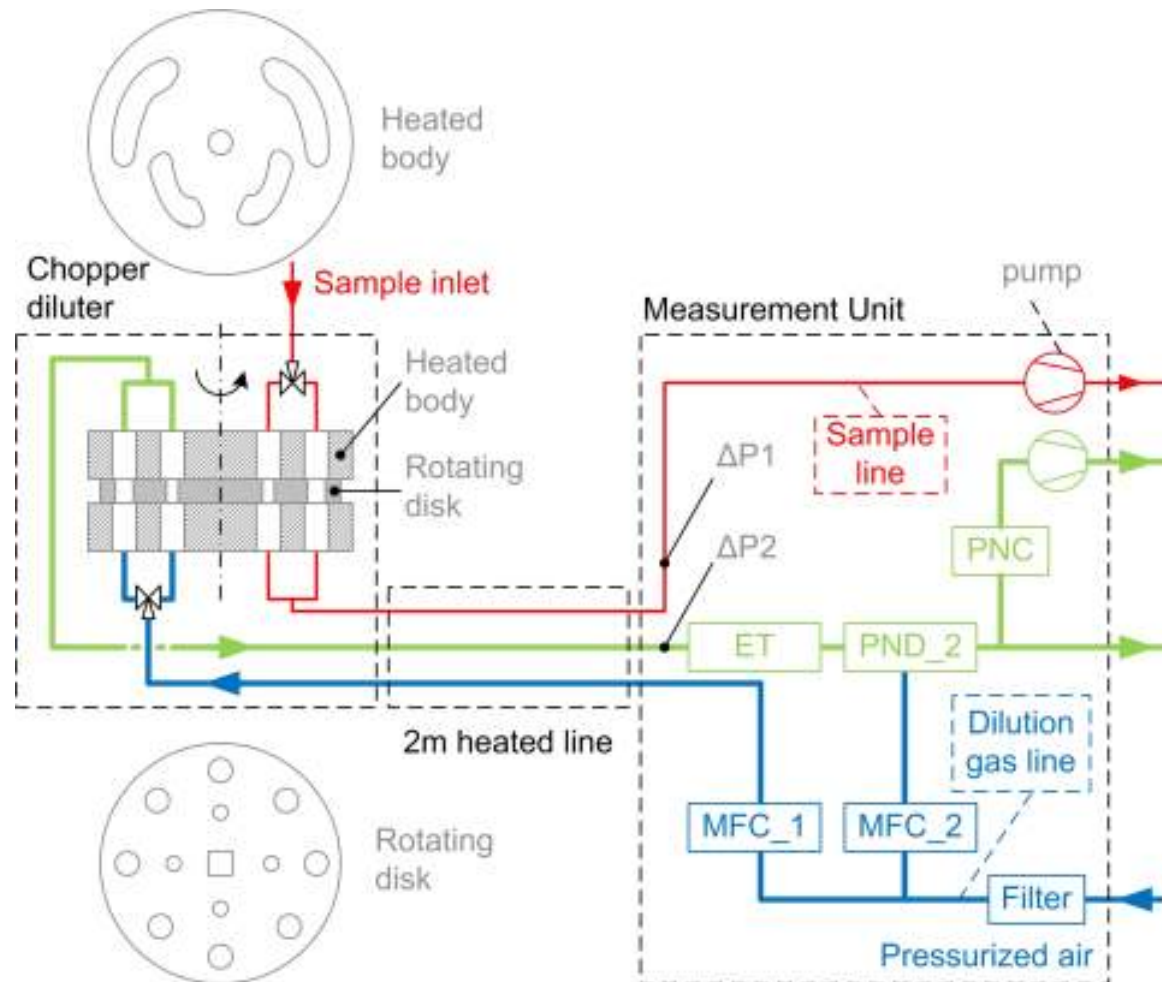
THE AVL PARTICLE COUNTER: APC 489



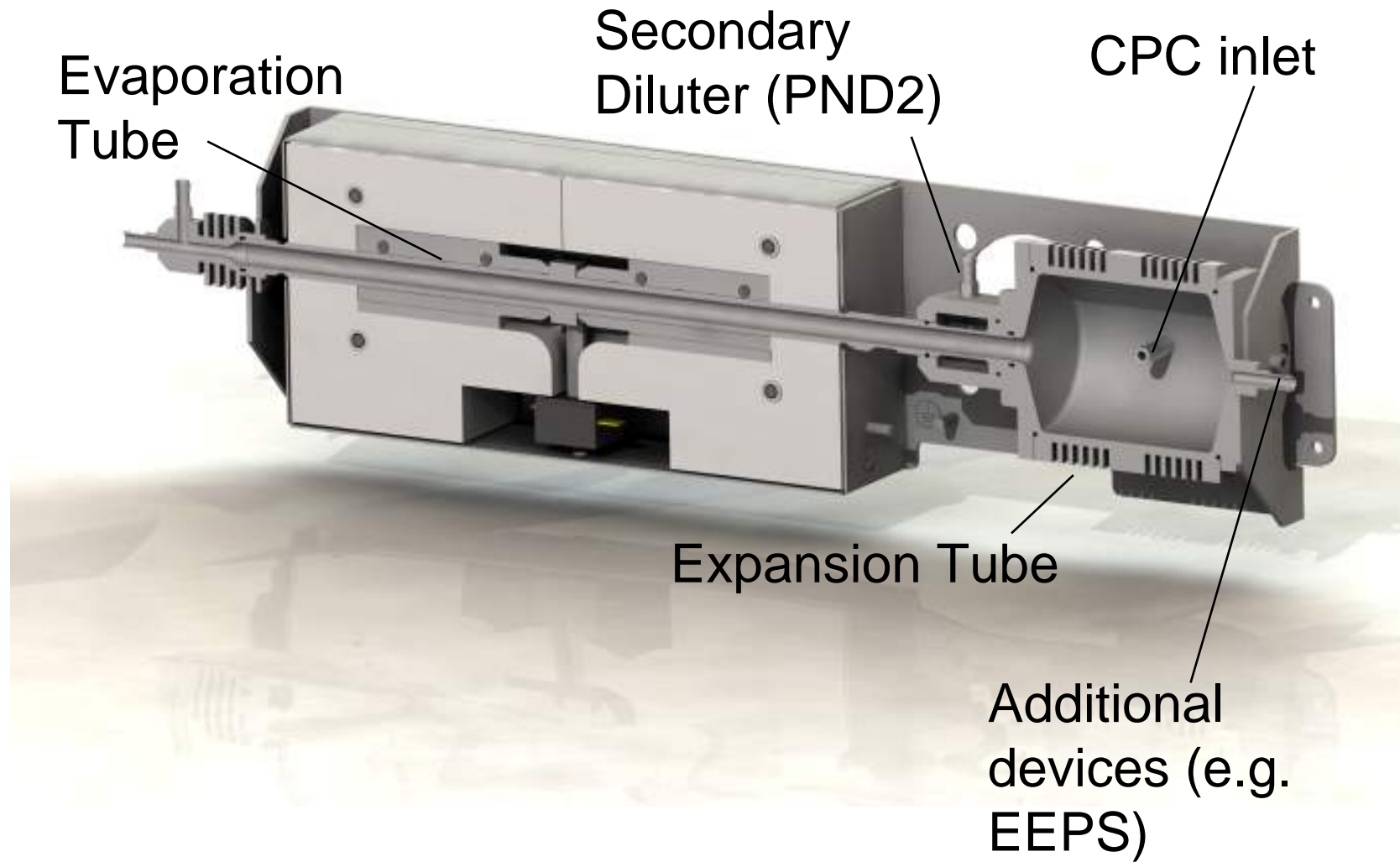
APC 489 – SYSTEM STRUCTURE

AVL solution provides:

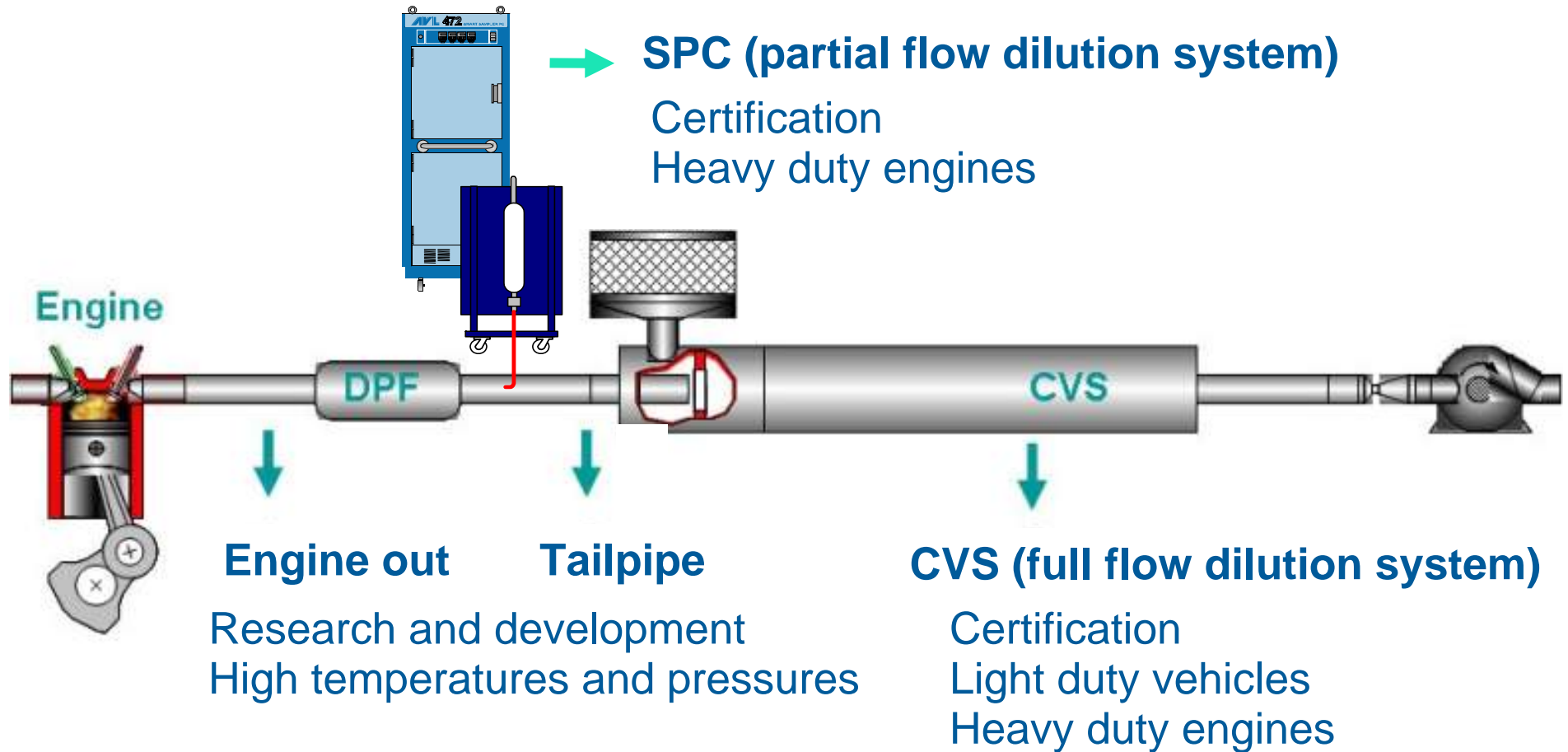
- highest linearity independent from particle size
- very low maintenance
- Switch between high and low dilution without changing the rotating disk



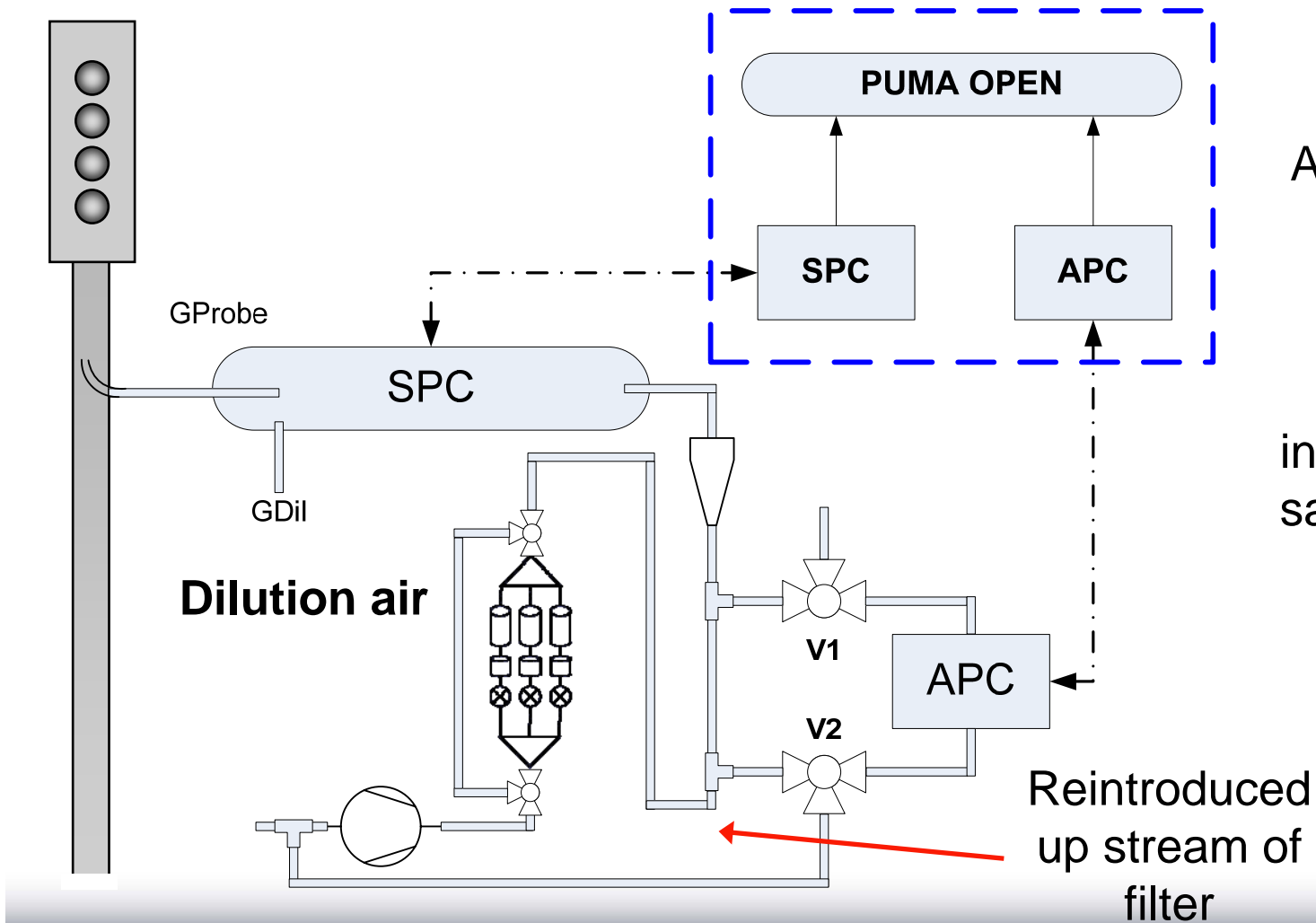
EVAPORATION TUBE AND SECONDARY DILUTION



ONE SYSTEM FOR DIFFERENT APPLICATIONS

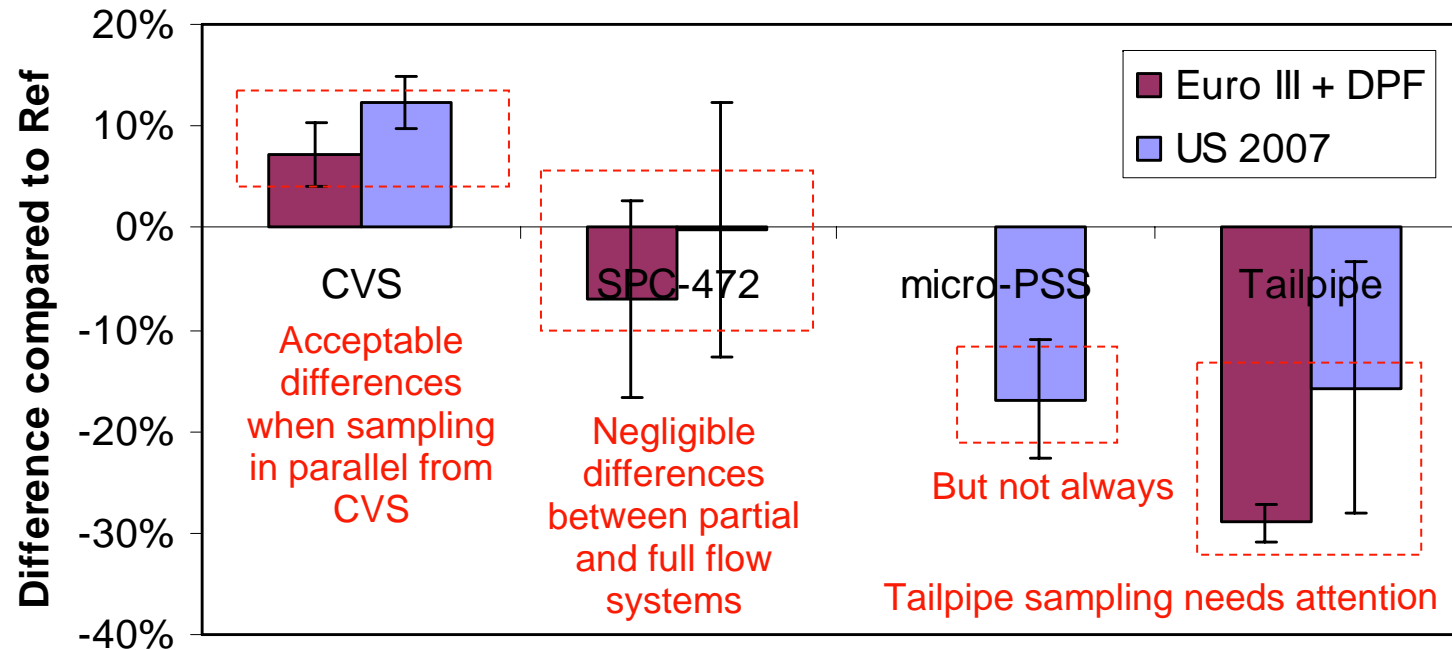


ADD ON SAMPLING – OPERATION PRINCIPLE



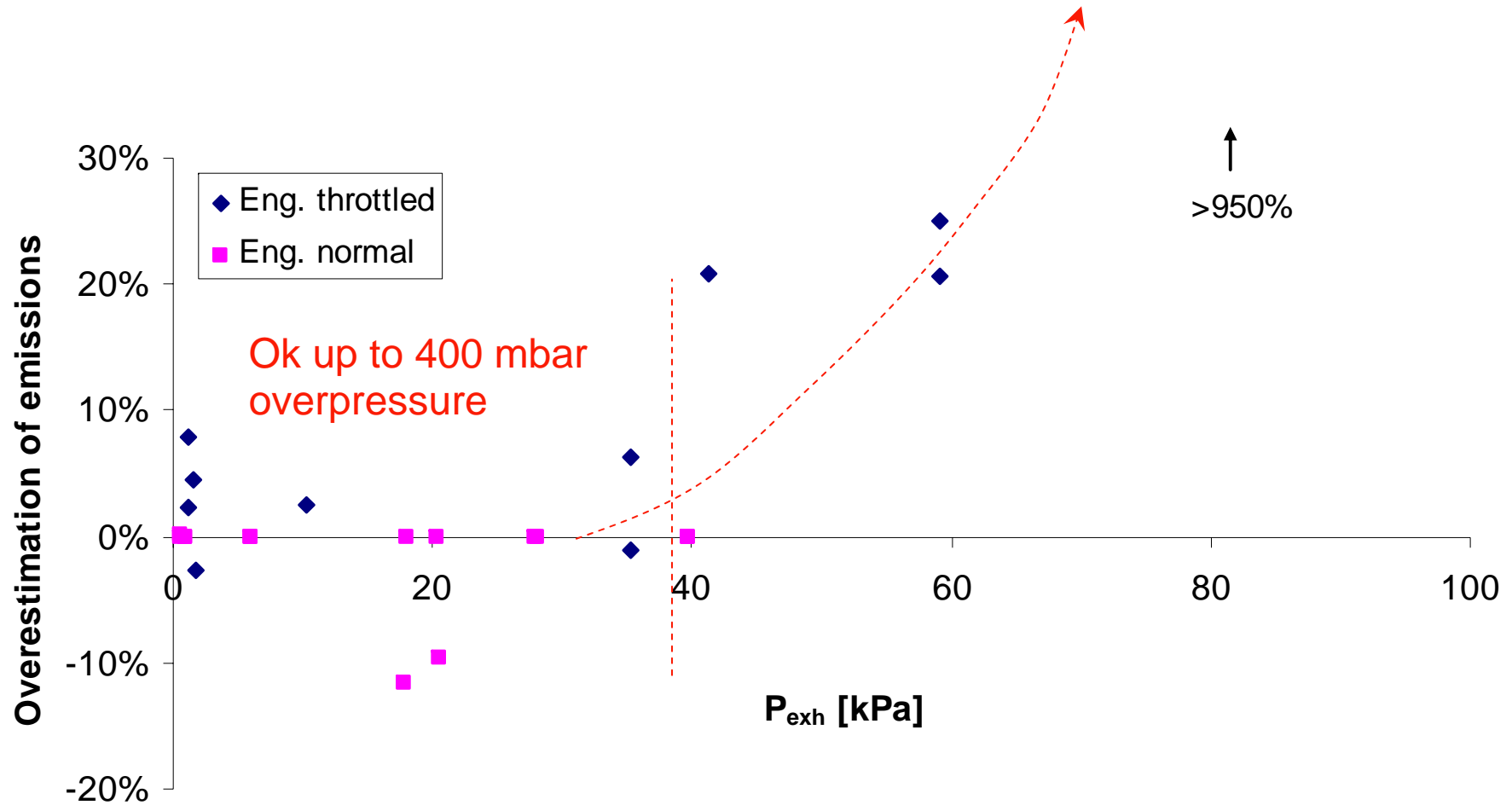
Add on sampling is a totally flexible method that lets user interchange measurement instruments with the same dilution tunnel

DIFFERENT SAMPLING POSITIONS



APC relative differences to the “reference” system (always connected to the CVS) when used at different sampling positions. Error bars show one stdev of >3 repetitions for each case. The reference system was an in house built dual Dekati ejector system.

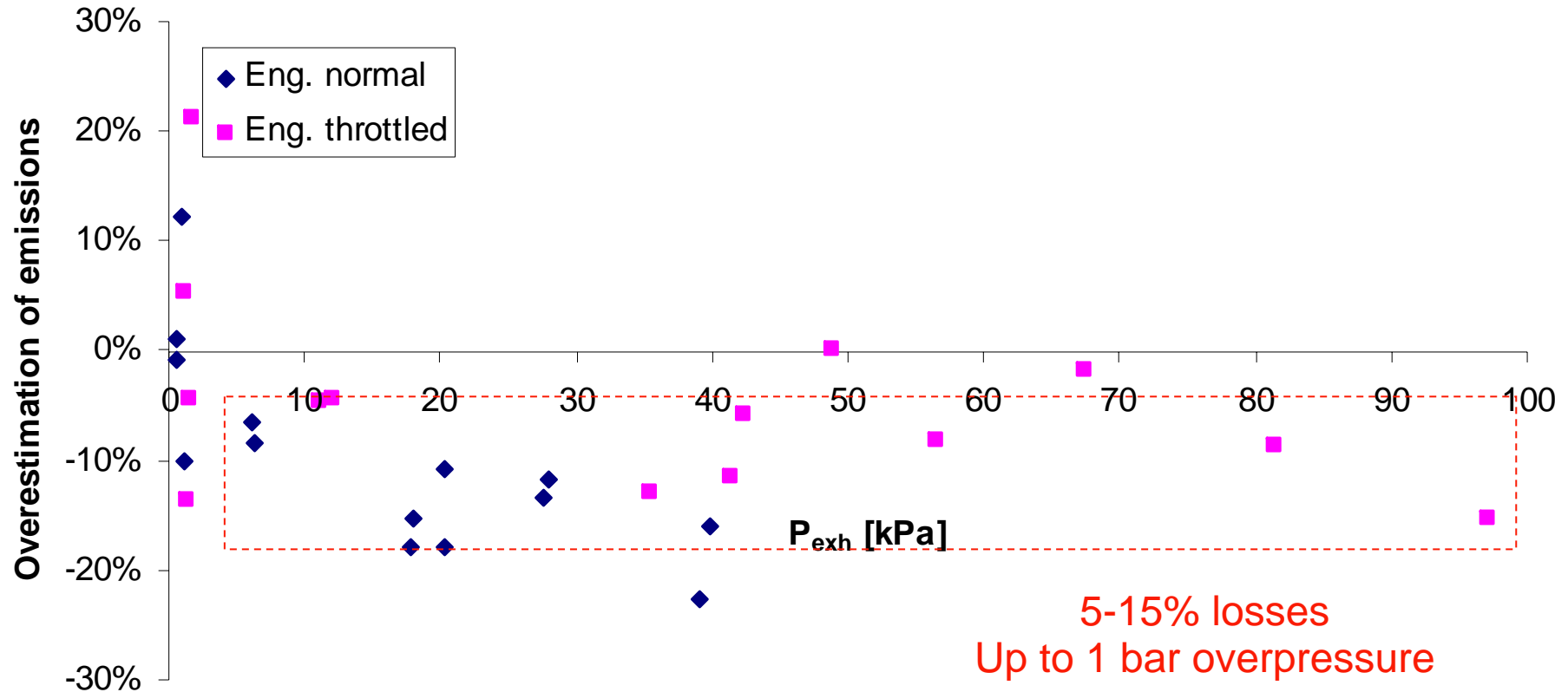
PRESSURE EFFECT ON APC MEASUREMENT



APC was connected directly to the raw exhaust with the tailpipe sampling kit (TK) (no pressure reducing unit (PRU))

Overestimation of the APC emissions as a function of the exhaust gas pressure

PRESSURE REDUCING UNIT

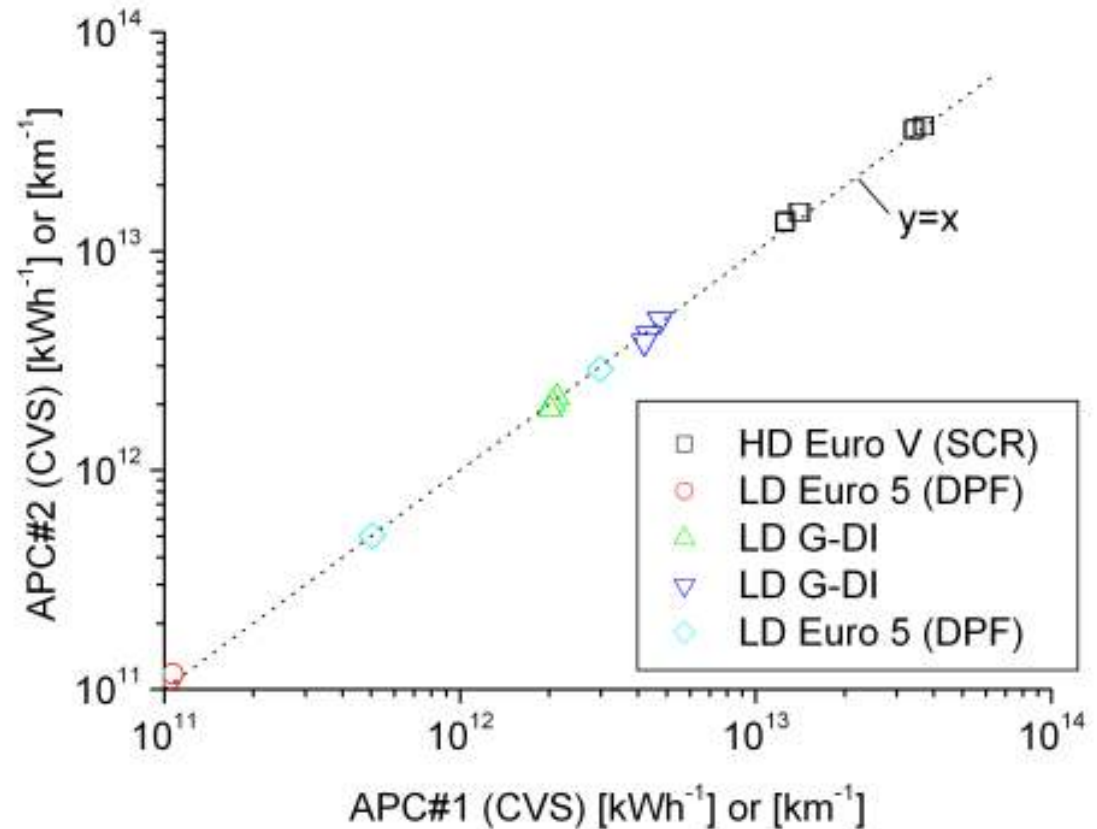


APC was connected to the raw exhaust through the pressure reducing unit (PRU) and the tailpipe sampling unit (TK) for temperature stabilization
 Losses with the pressure reducing unit.



COMPARABILITY OF APCs

- Two well calibrated systems of the same manufacturer (AVL) on average <4% difference
- 95% of devices within $\pm 10\%$



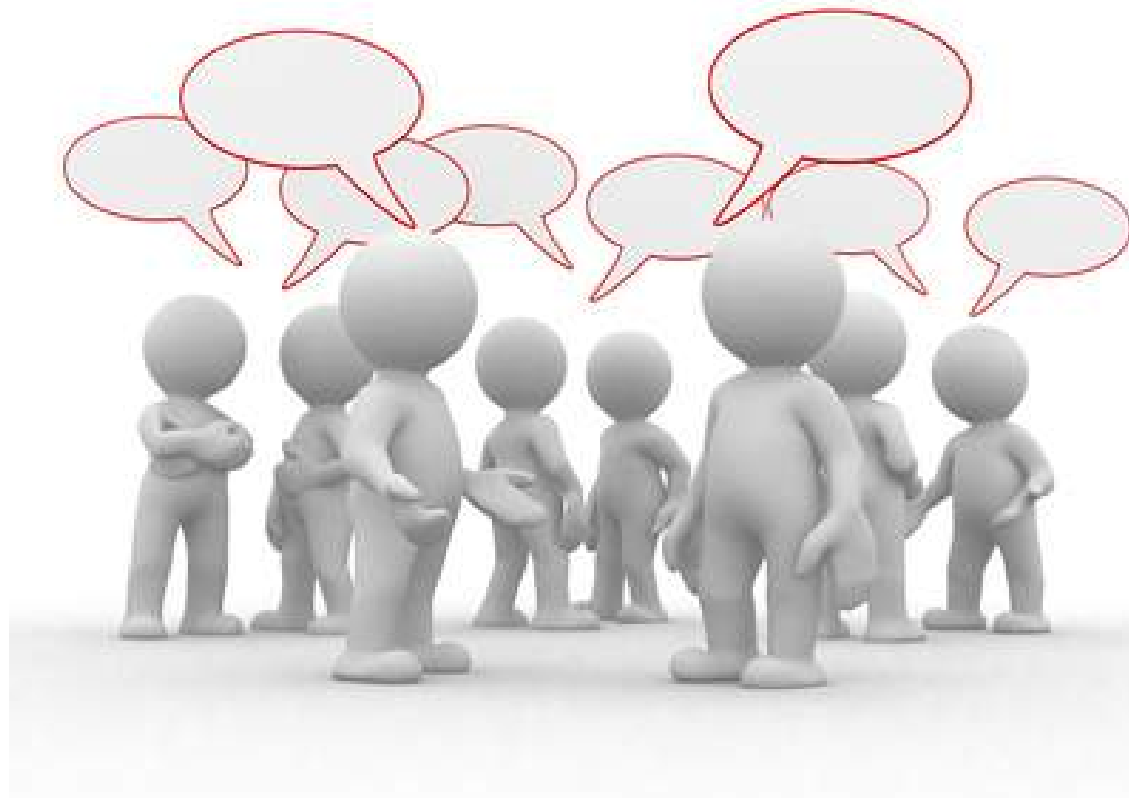
Comparison of two PN systems (APCs from AVL) both connected to the CVS for one heavy duty engine (different test cycles) and two different APCs for four different light duty vehicles (for the NEDC cycle).

HD=Heavy Duty, LD=Light Duty, SCR=Selective Catalytic Reduction for NO_x, DPF=Diesel Particulate Filter, G-DI=Gasoline Direct Injection.

PARTICLE NUMBER MEASUREMENT – FROM ECE-R83
TO ECE-R49



THANK YOU FOR YOUR ATTENTION



QUESTIONS ?