PM Emission Inventories Scientific Workshop

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EMISSION FACTORS OF SEVERAL PARTICLE PROPERTIES FROM CURRENT DIESEL PASSENGER CARS

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Topics

Create speed-dependent emission factors curves for particle exhaust emission

- effect of **vehicle technology** improvements on particle emission factors
- effect of decreasing **fuel sulphur content** on particle emission factors
- statistical validity of the emission factors, conducing **analysis of variance**
- effect of developing emission factors curves using ARTEMIS **sub-cycles**

PM mass [g km^{-1}]

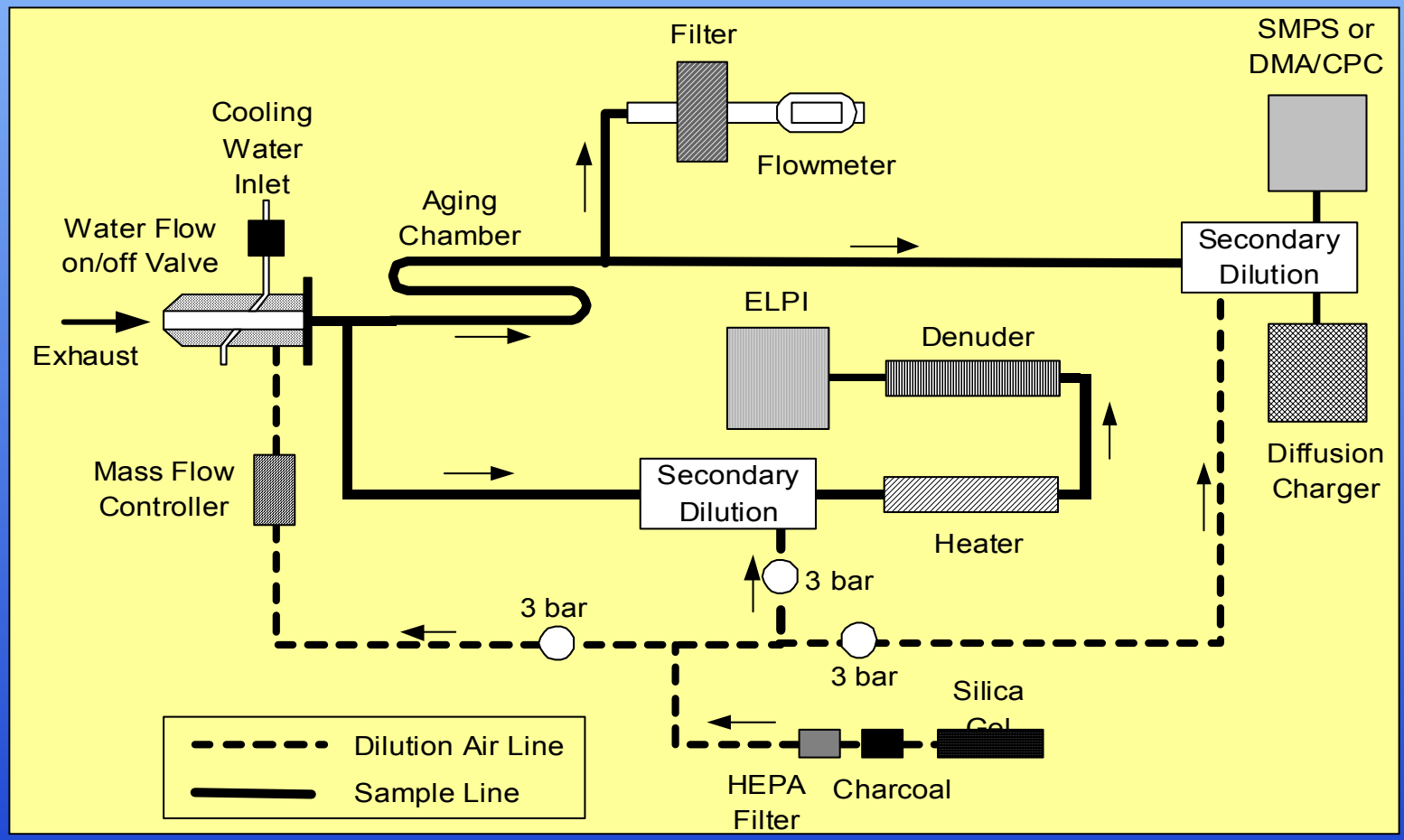
PM active surface [cm^2 km^{-1}]

PM total particle [# km^{-1}]

PM solid particle [# km^{-1}]

Particle size distribution [dN dlogdp $^{-1}$]

Sampling system



Information collect over a test

Instrument	Property	Size resolution	Temporal resolution
Condensation Particle Counter (CPC)	**Particle number concentration**	**One channel >7 nm**	**1 s (transients)**
Scanning Mobility Particle Sizer (SMPS)	**Particle sizing and concentration**	**64 channels per decade**	**90 s (steady states)**
Electrical Low Pressure Impactor (ELPI) + thermodenuder (TD)	**Solid particle sizing and concentration**	**First 8 channels with filter stage 7nm-1 μm**	**1 s (transients)**
Diffusion Charger (DC)	**Active surface**	**One channel 7nm – 1 μm**	**1 s (transients)**

Vehicle sample

Conventional diesel → 5 EURO III
2 EURO II
1 “simulated” EURO I

DPF equipped → 5 vehicles

Fuel used

Diesel fuels	Sulfur (mg/kg)	
D2	280	
D3	38	
D4	8	
D5		3

Driving cycles

Standard driving cycles → hot UDC

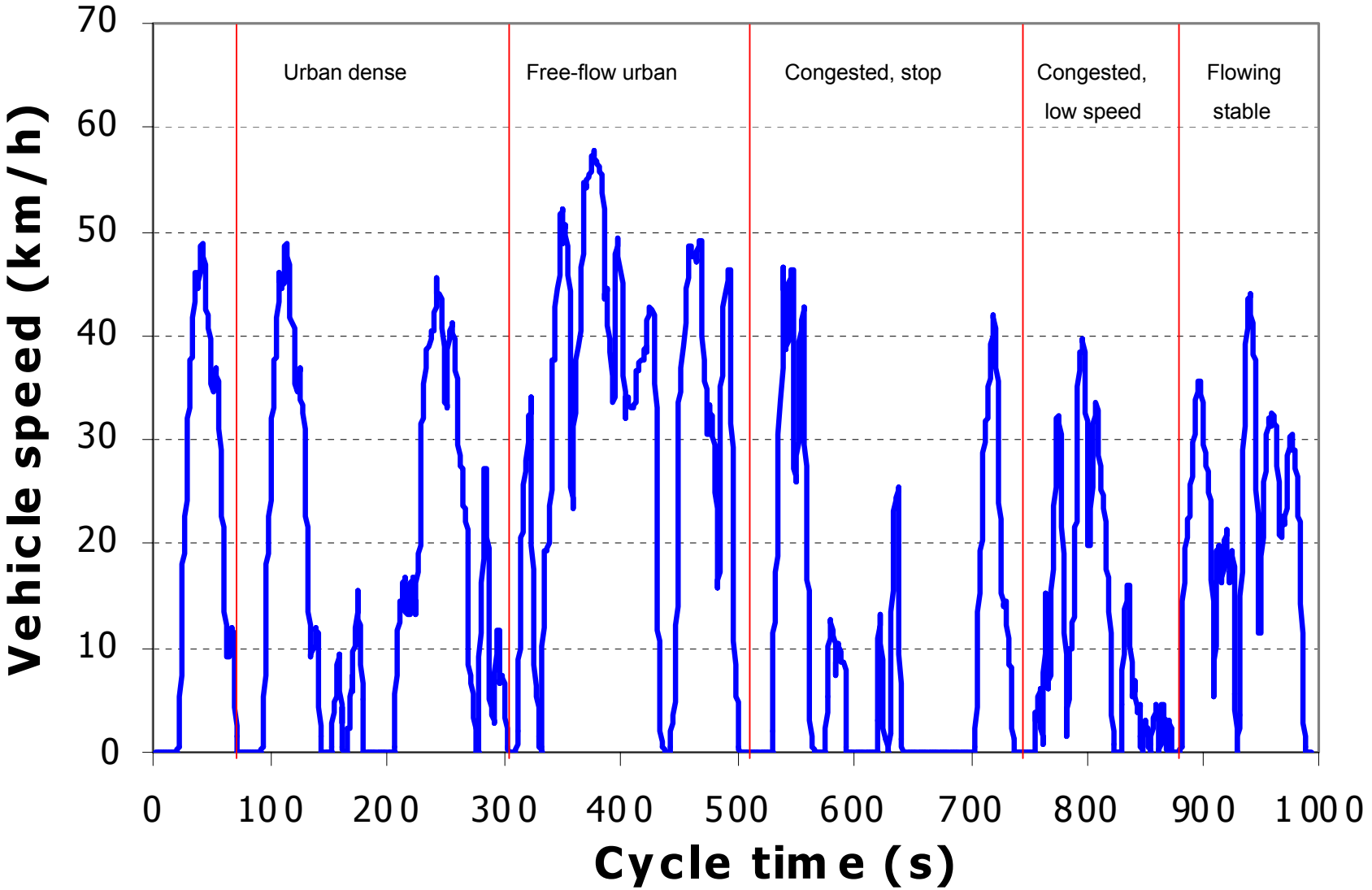
EUDC

Real world driving cycles → ARTEMIS urban

ARTEMIS road

ARTEMIS motorway

ARTEMIS urban



Driving cycles

Standard driving cycles → hot UDC

EUDC

Real world driving cycles → ARTEMIS urban

ARTEMIS road

ARTEMIS motorway

Steady states → 50 kmh^{-1}

90 kmh^{-1}

120 kmh^{-1}

Results

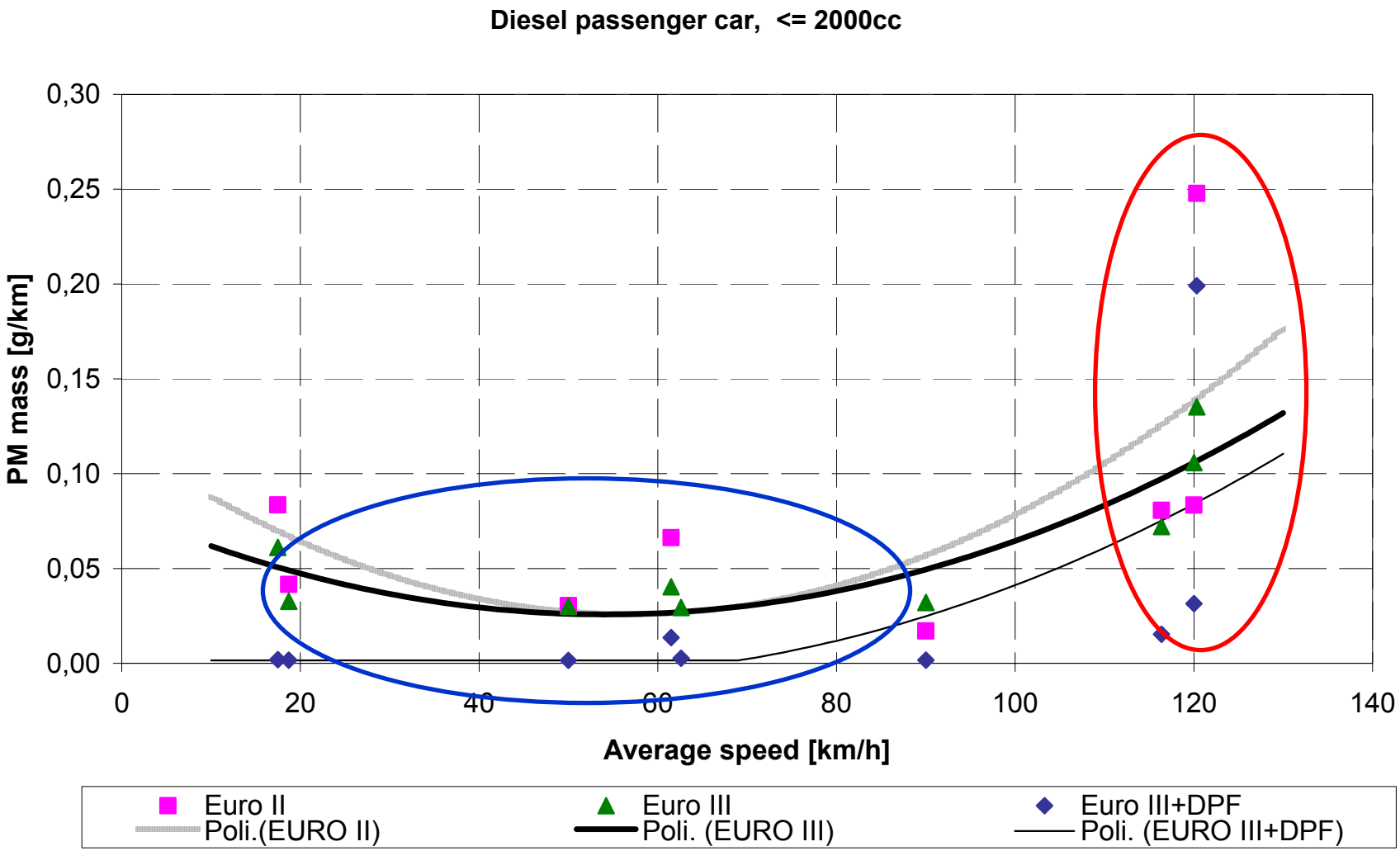
1 effect of **vehicle technology** improvements on particle emission factors

2 effect of decreasing **fuel sulphur content** on particle emission factors

3 statistical validity of the emission factors, conducing **analysis of variance**

4 effect of developing emission factors curves using ARTEMIS **sub-cycles**

1 - Effect of vehicle technologies



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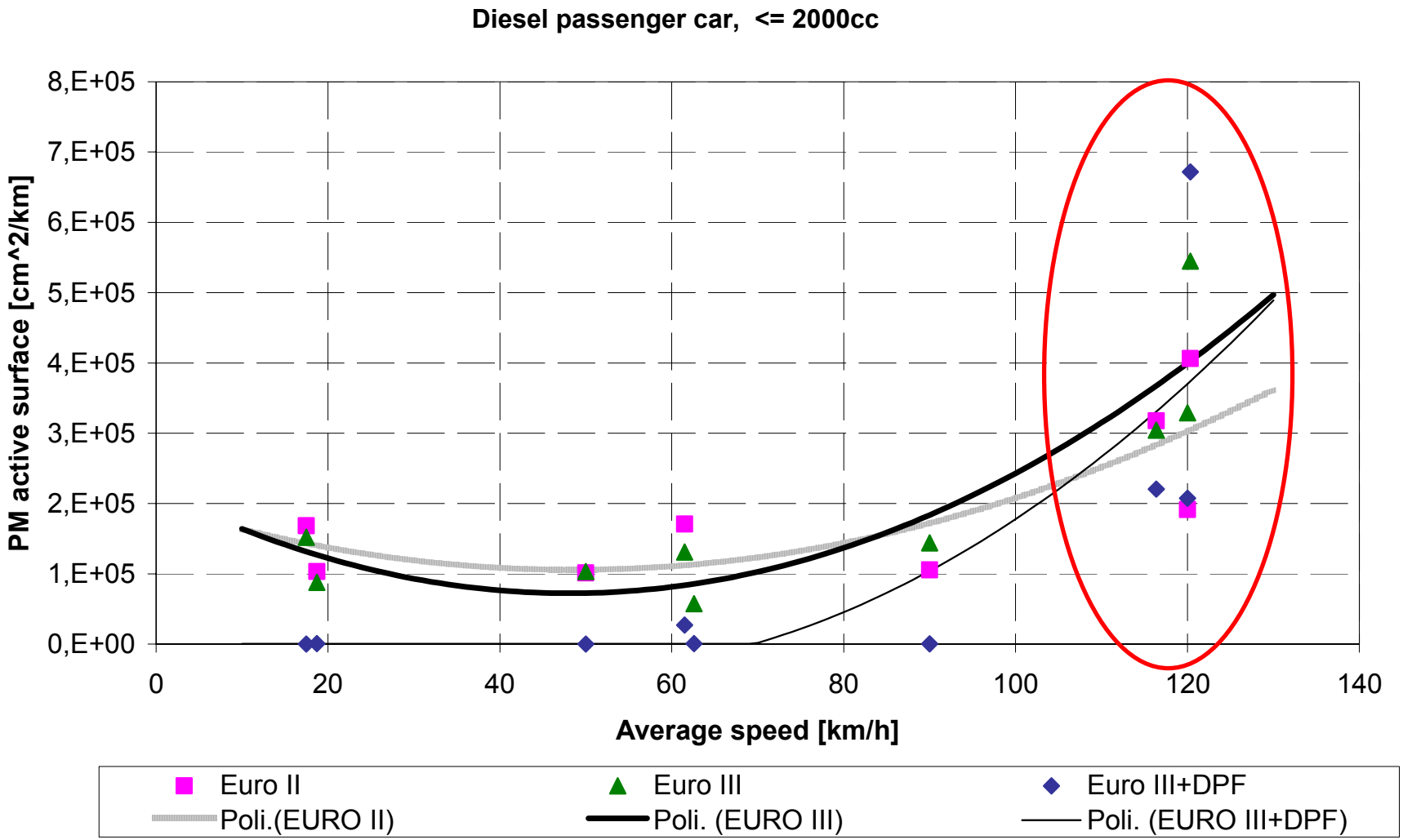

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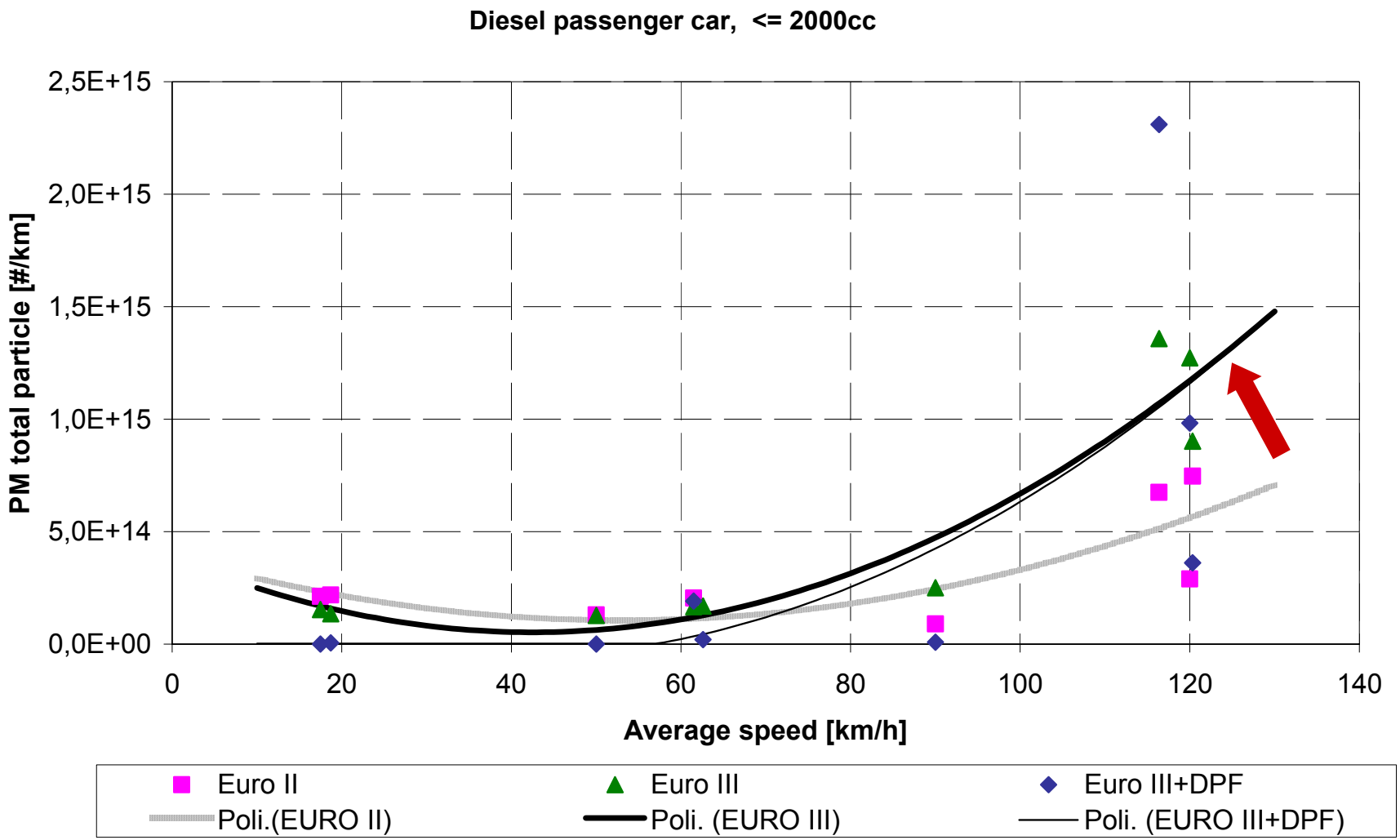

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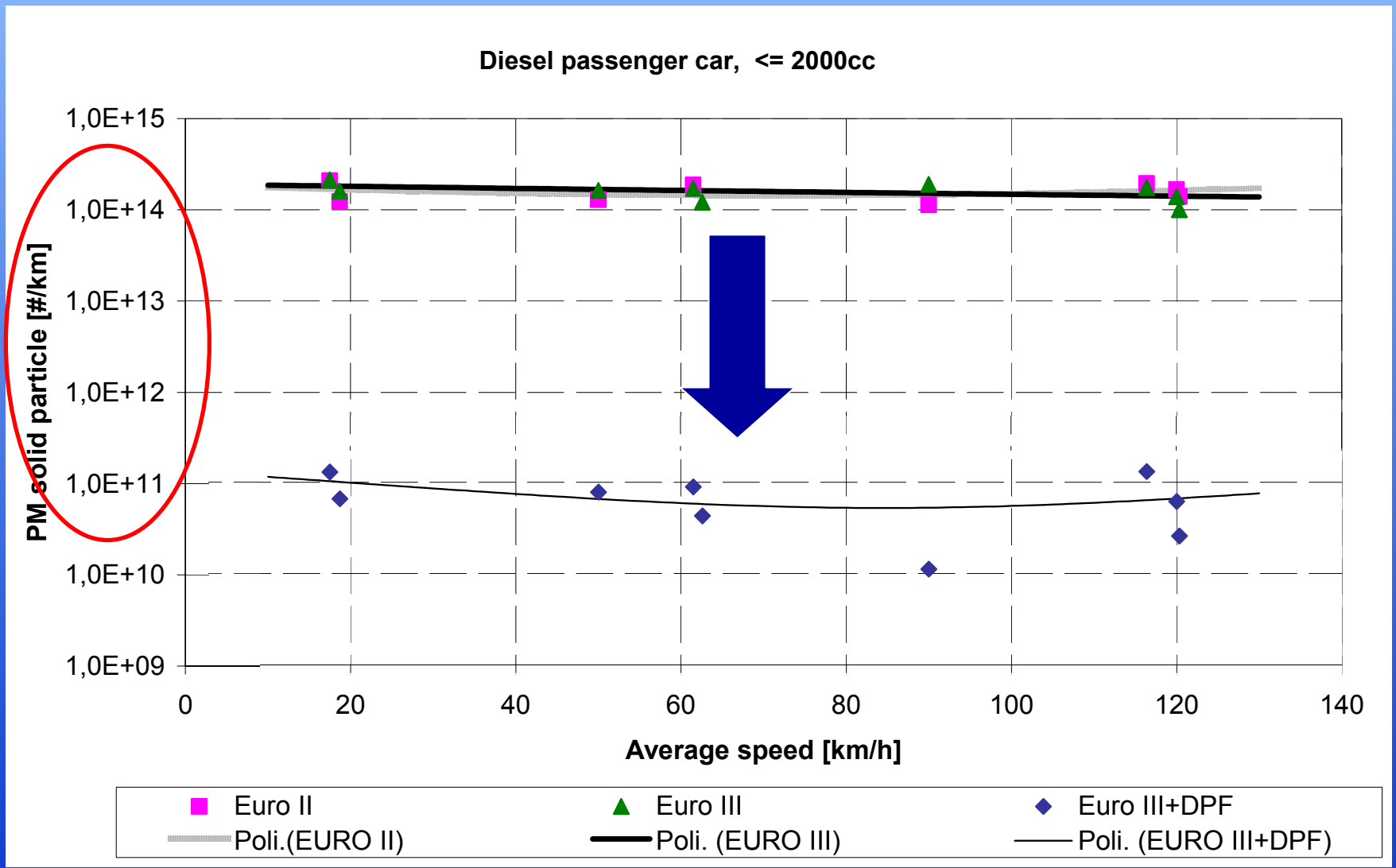

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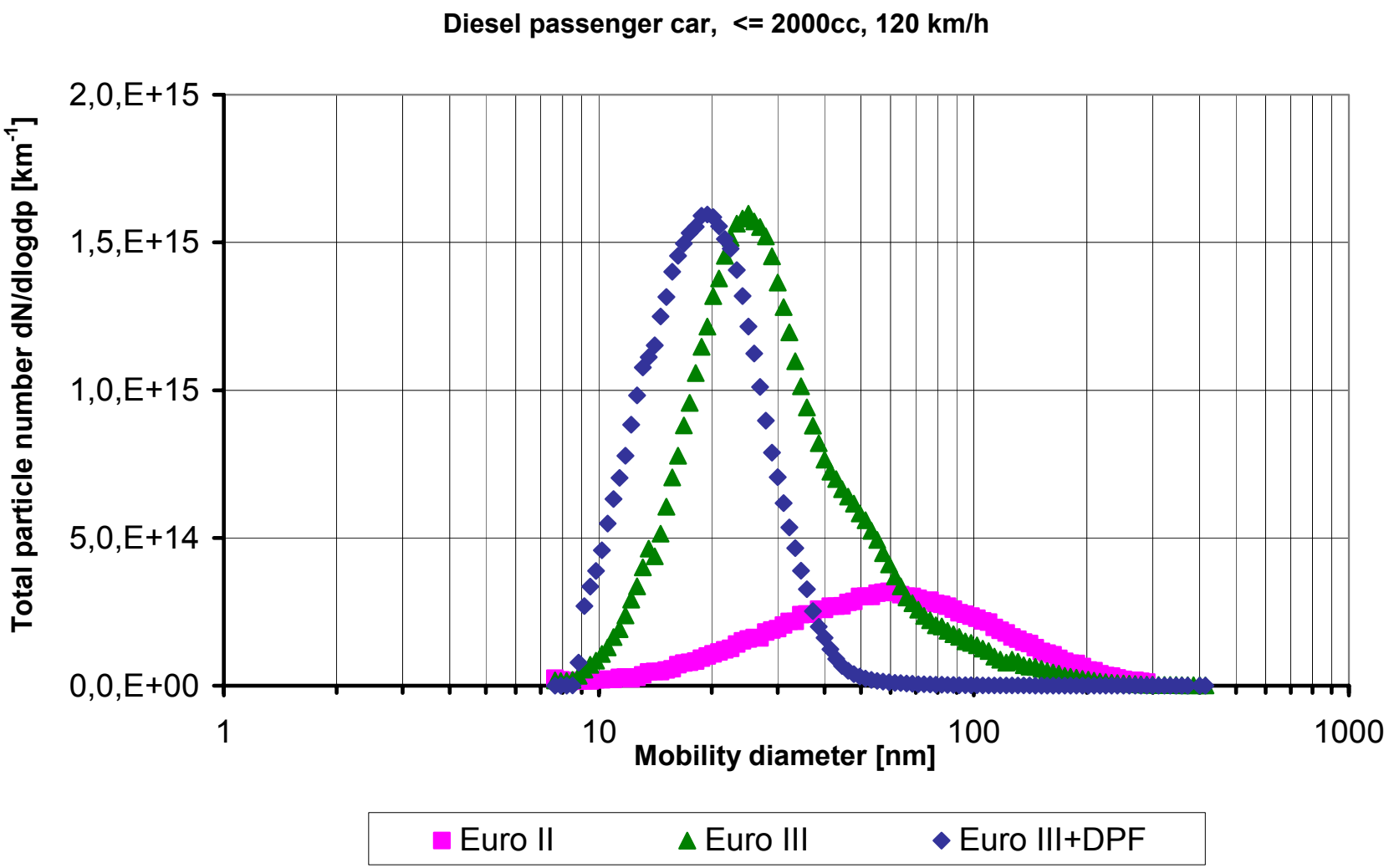

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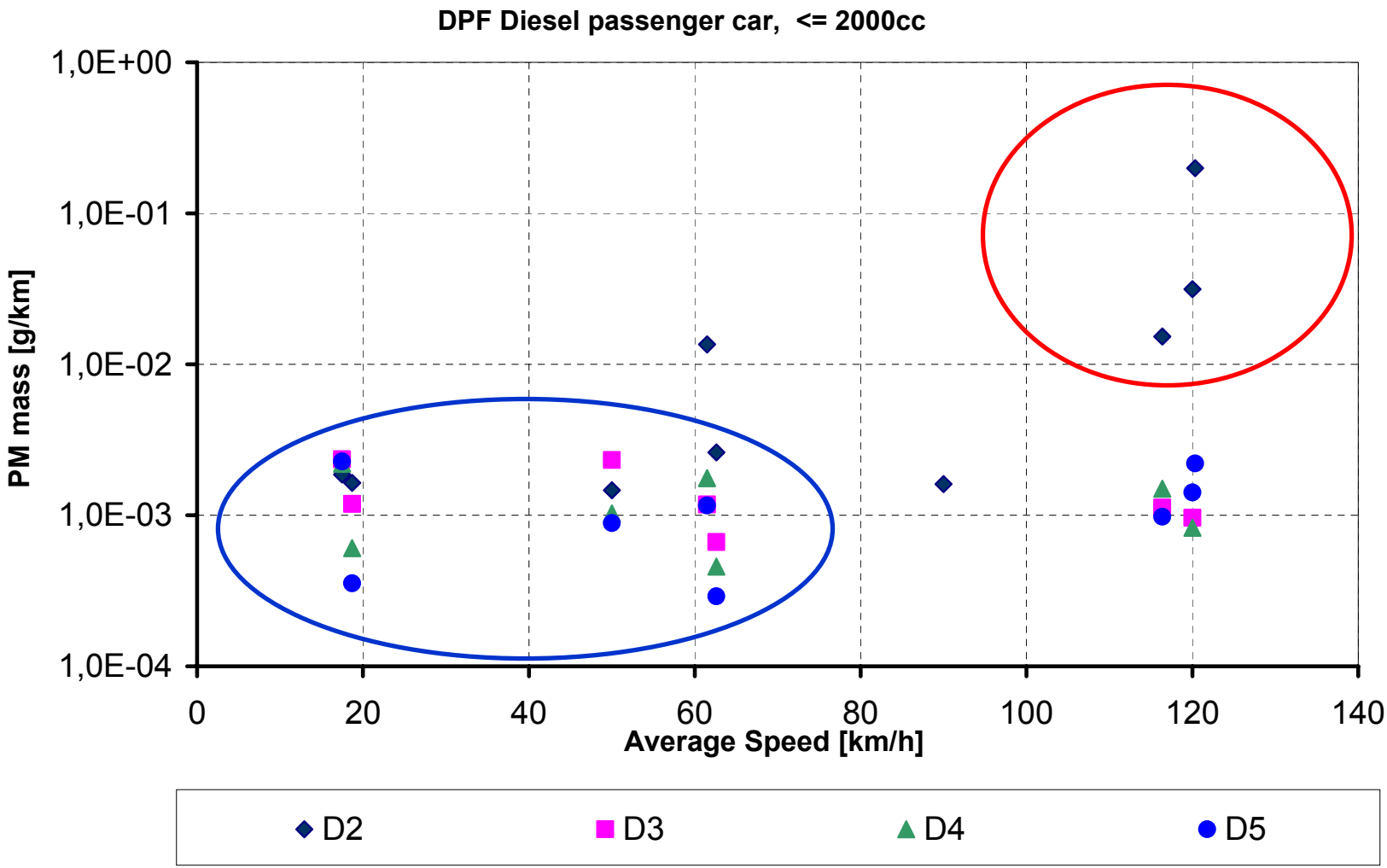
2 - Effect of sulphur content of fuel on emission



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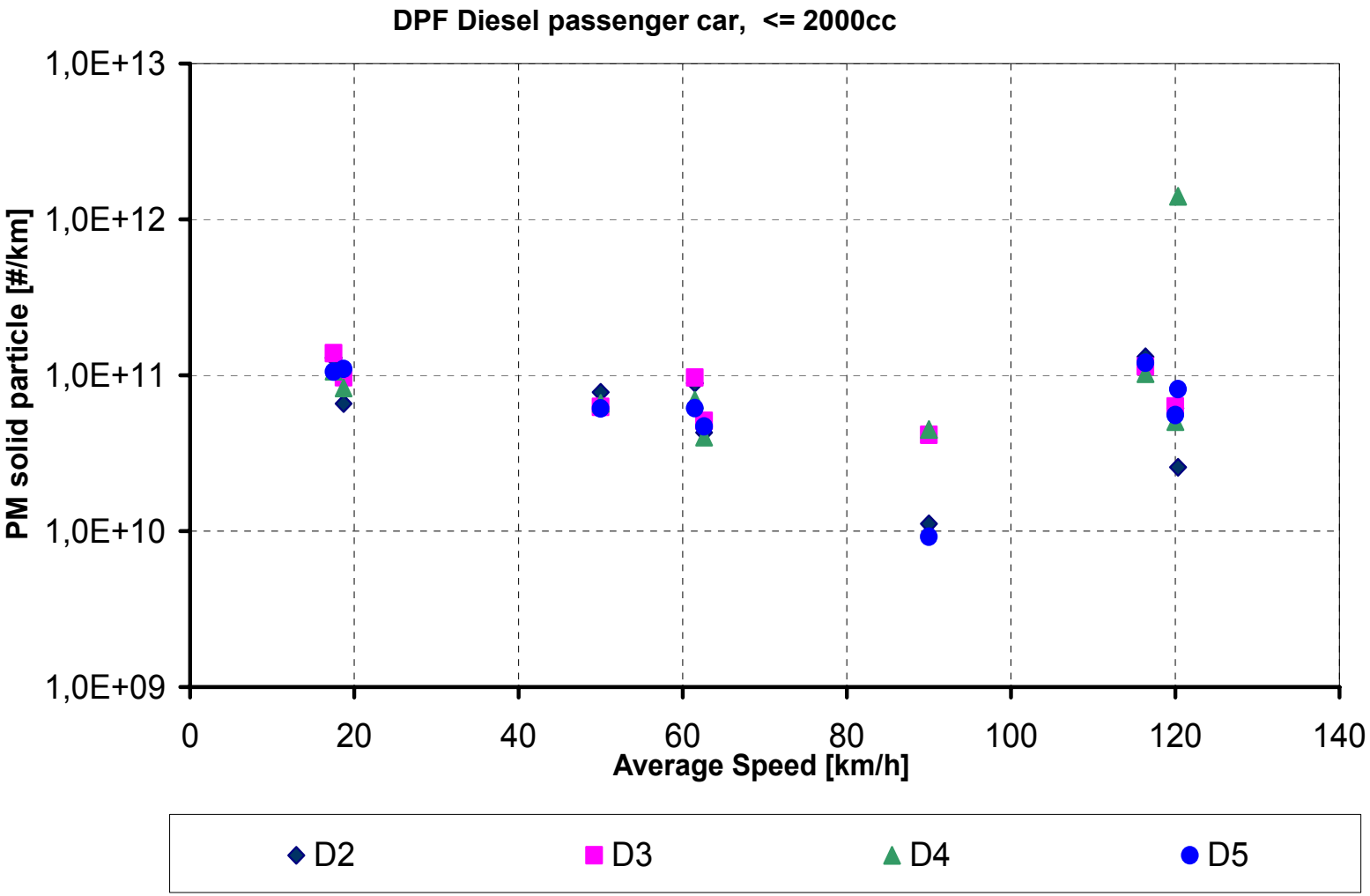

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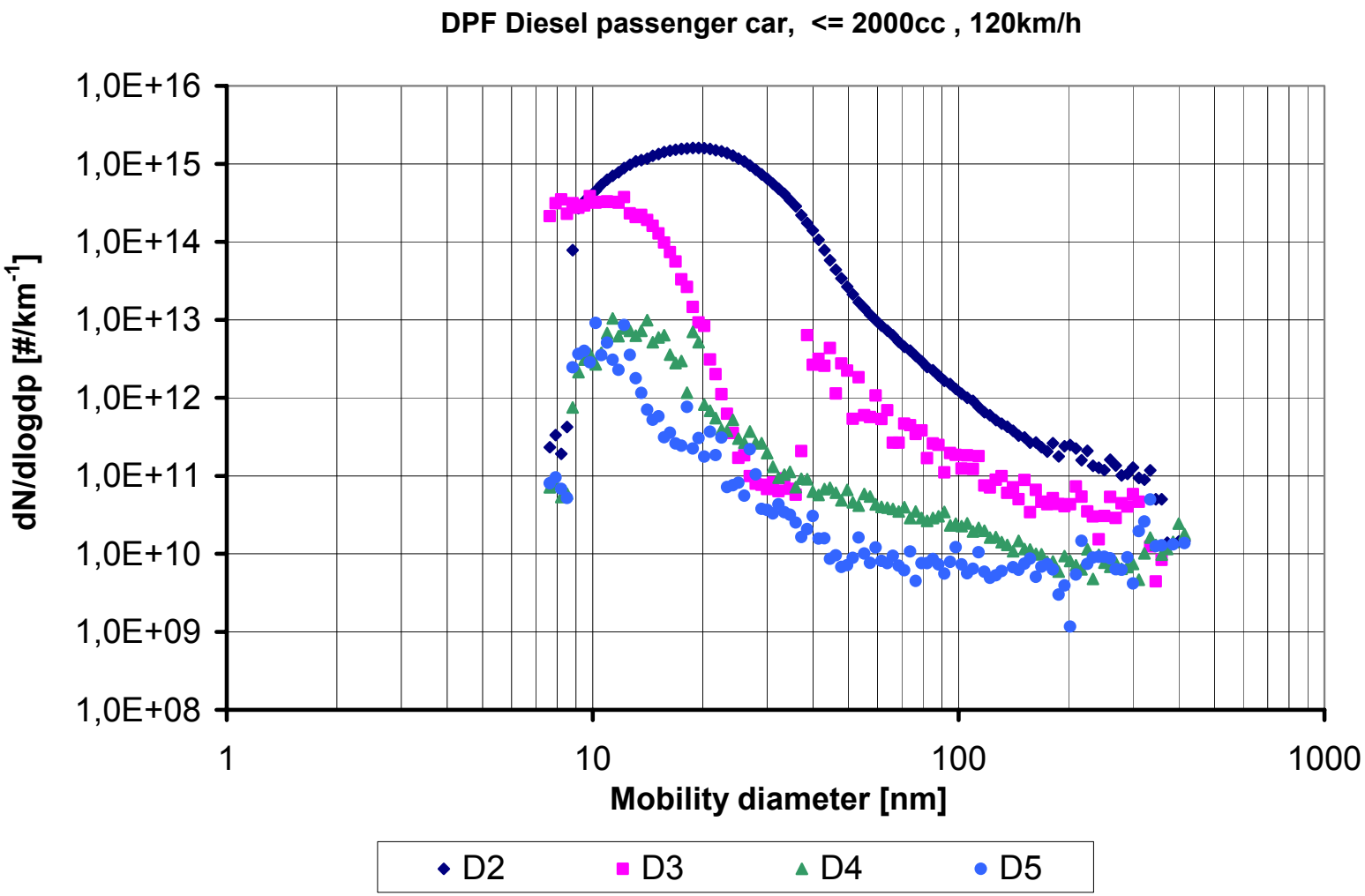

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3 - analysis of variance

In order to explore whether there are significant effects on emissions using DPF, a parametric analysis of variance was applied to the emission factors, considering three speed ranges :

<= 40 km/h

40-90km/h

> = 90 km/h

Kruskal-Wallis test

Kruskal-Wallis test

- All the measure assembled into a single set of size N.
- All data are rank-ordered from lowest to highest and returned to the sample.
- Mean ranks in each group (Mg) is calculated
- Mean the mean of the N ranks in all groups combined (Mn) is calculated
- Between-groups sum of squared deviates is calculated as:

$$SSbg(R)=\Sigma\ [ng(Mg—Mn)^2]$$

- Statistic:

$$H = \frac{SSbg(R)}{\frac{N(N+1)}{12}}$$

3 - analysis of variance

PM mass

	Average speed cycle <40 km/h	Average speed cycle 40-90 km/h	Average speed cycle >90km/h
Chi-Square	22,791	26,539	13,017
Degree of freedom	3	3	3
Asymp. Sig.	,001	,001	,005

	Average speed cycle <40 km/h	Average speed cycle 40-90 km/h	Average speed cycle >90km/h
Chi-Square	6,604	3,691	2,136
Degree of freedom	2	2	2
Asymp. Sig.	,037	,158	,334

3 - analysis of variance

PM active surface

	Average speed cycle <40 km/h	Average speed cycle 40-90 km/h	Average speed cycle >90km/h
Chi-Square	28,913	32,443	5,613
Degree of freedom	3	3	3
Asymp. Sig.	,001	,001	,132

PM solid particle number

	Average speed cycle <40 km/h	Average speed cycle 40-90 km/h	Average speed cycle >90km/h
Chi-Square	33,883	25,941	39,602
Degree of freedom	3	3	3
Asymp. Sig.	,001	,001	,001

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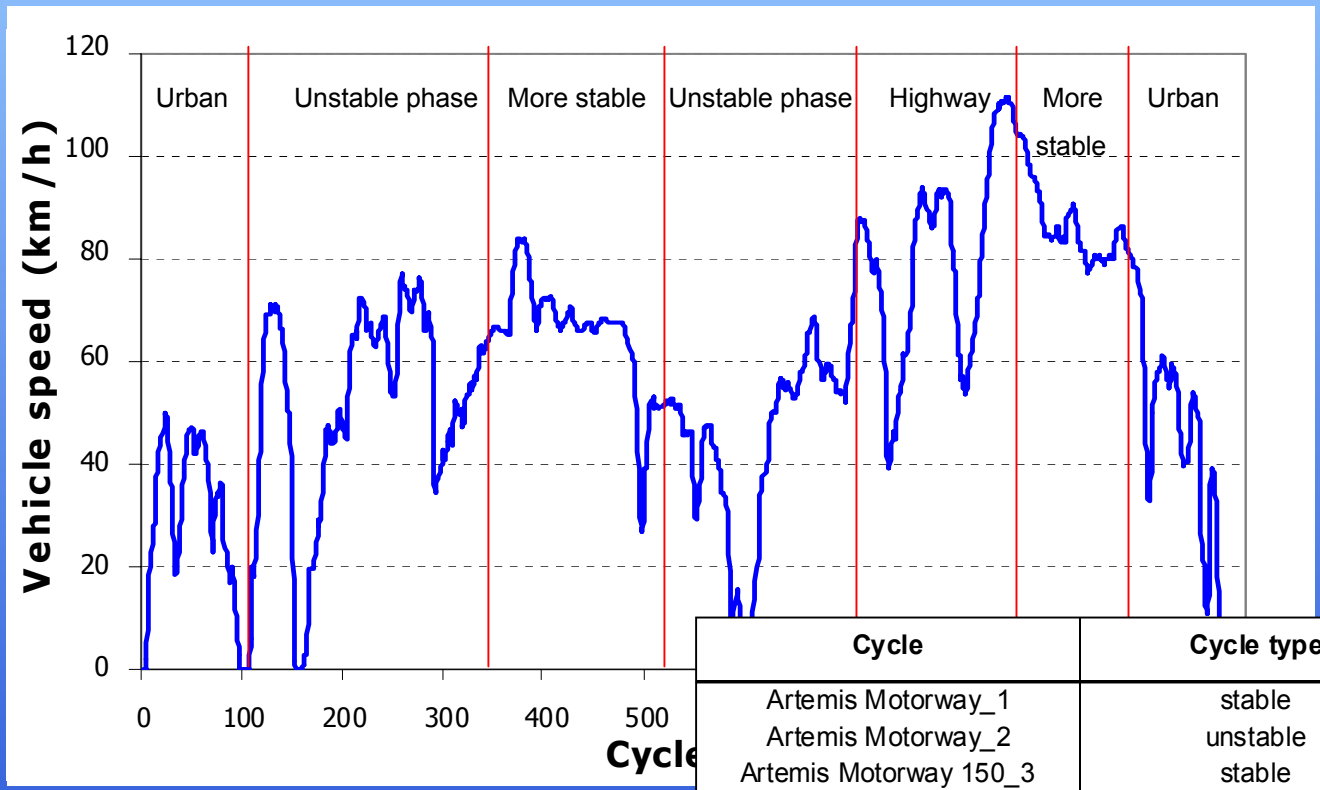
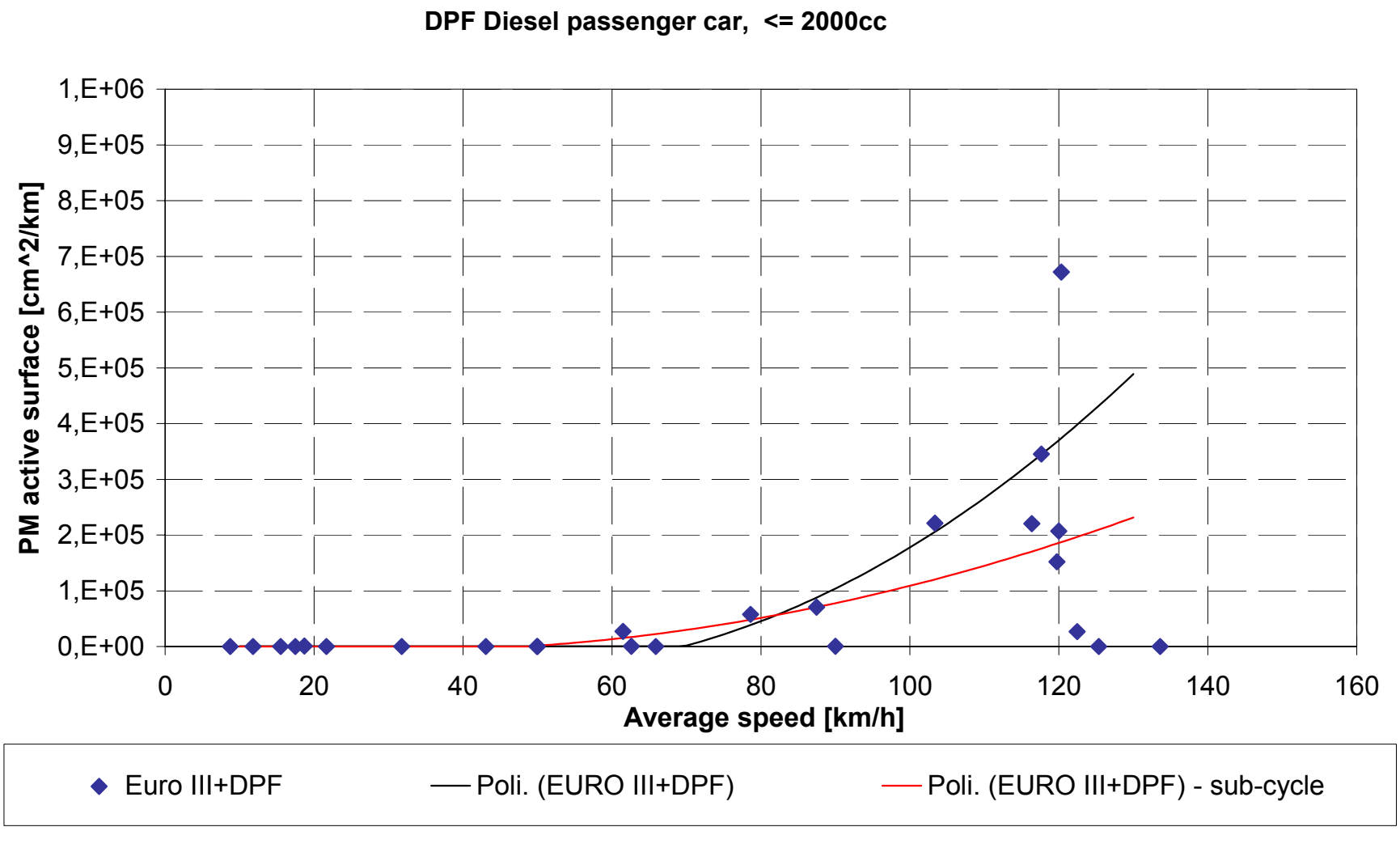
ARTEMIS road

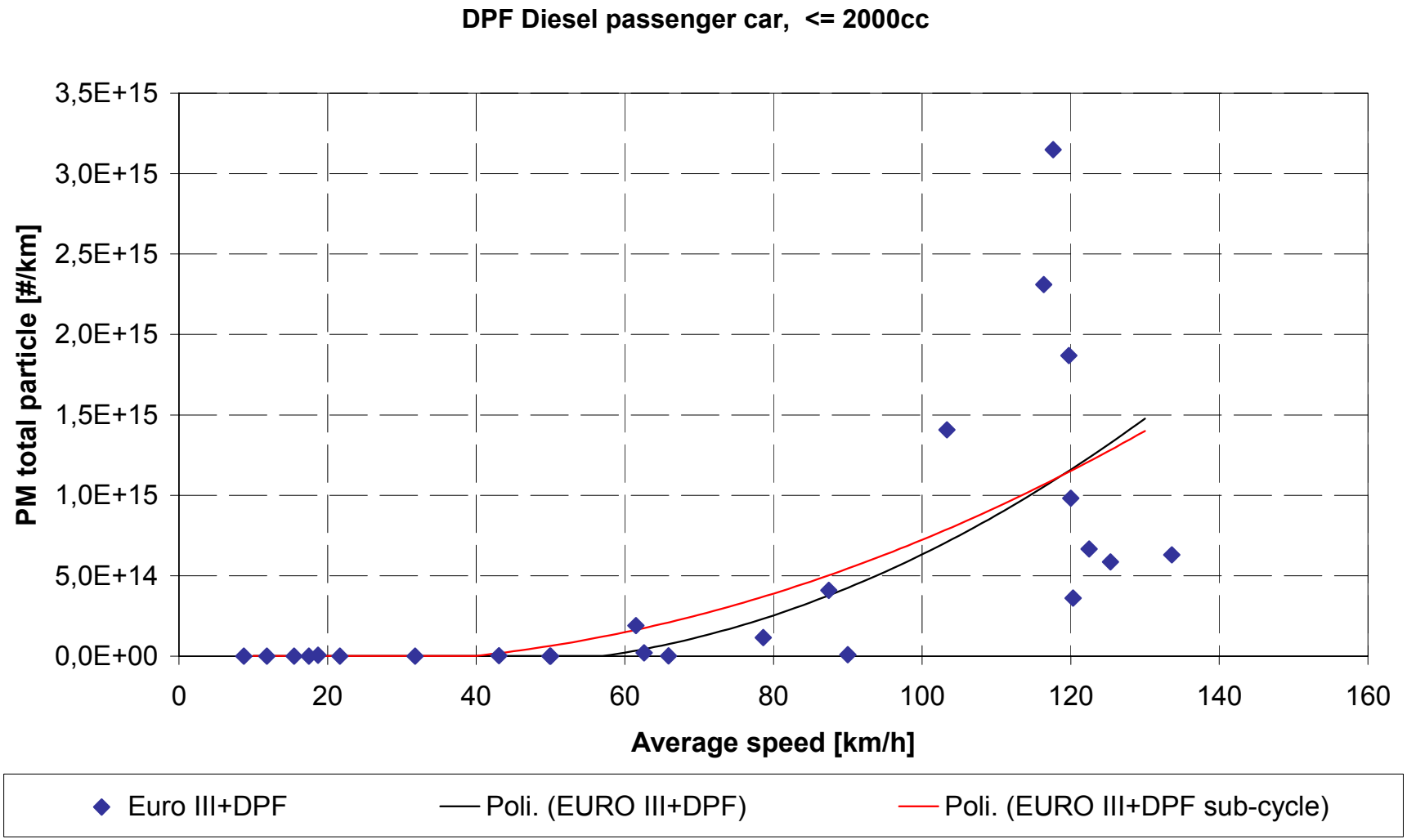


Cycle	Cycle type	Average speed [km/h]	Duration [s]
Artemis Motorway_1	stable	122,5	272
Artemis Motorway_2	unstable	103,4	173
Artemis Motorway 150_3	stable	125,4	182
Artemis Motorway 150_4	unstable	133,6	109
Artemis Motorway_3	stable	117,6	182
Artemis Motorway_4	unstable	119,7	109
Artemis Road_1	unstable phase	49,9	240
Artemis Road_2	more stable phase	65,9	171
Artemis Road_3	unstable phase	43,1	183
Artemis Road_4	highway	78,6	177
Artemis Road_5	more stable phase	87,5	91
Artemis Urban_1	urban dense	15,5	236
Artemis Urban_2	free flow urban	31,8	198
Artemis Urban_3	congested, stops	8,7	243
Artemis Urban_4	congested low speed	11,8	128
Artemis Urban_5	stable	21,7	116

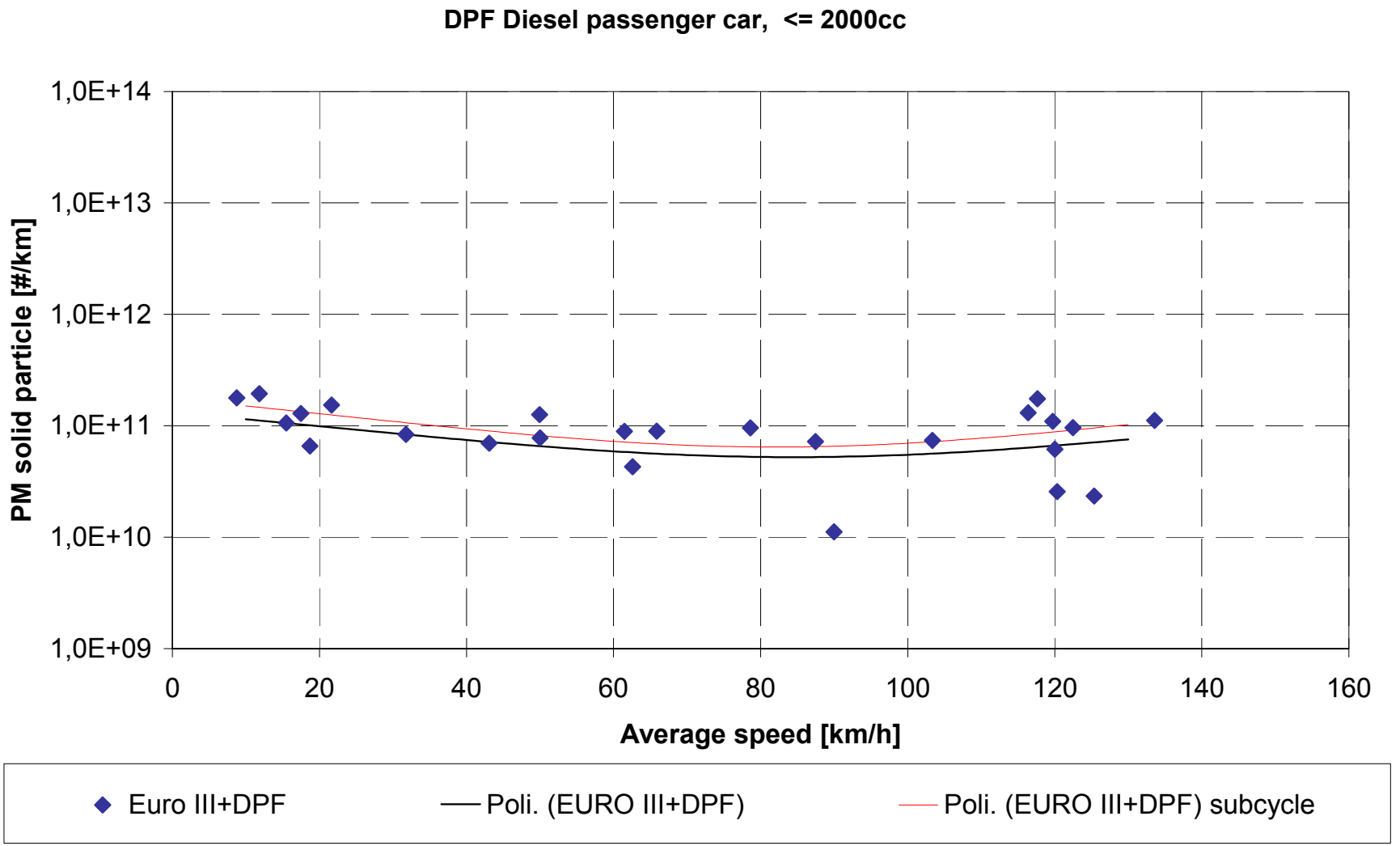
4 - ARTEMIS sub- cycles



4 - ARTEMIS sub- cycles



4 - ARTEMIS **sub- cycles**



Conclusions on technology comparison

- EURO II and EURO III are in a narrow range.
- Trap equipped vehicles are associated to a effective reduction of PM emission, for all metrics. Except for high speed cycle.
- Solid particle emission seems to be insensitive to the cycle type. The DPF vehicle has emission level lower than three order of magnitude for all speed ranges.
- Picks of nucleation mode for EURO III and DPF vehicles at high speed condition.
- The Krustal-Wallis test underlines the differences between vehicles technologies, showing that while DPF vehicle differ from the Conventional ones, the older vehicles seems to belong to the same group for most of the metrics.

Conclusions on fuel sulphur content effect

- EURO II and EURO III seem not affect by fuel content.
- Using high sulphur fuel contents increased DPF vehicle emission factors at high speed.
- Influence of higher sulphur content fuel on nucleation mode for DPF vehicle.

Conclusions on sub-cycles

- The emission factors functions obtained using sub-cycles are similar to those calculated using only the composite cycles