Particle number emissions from various vehicles

using the proposed PMP method

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Emission standards for LDV

Particle number regulation will be introduced from Euro 5b

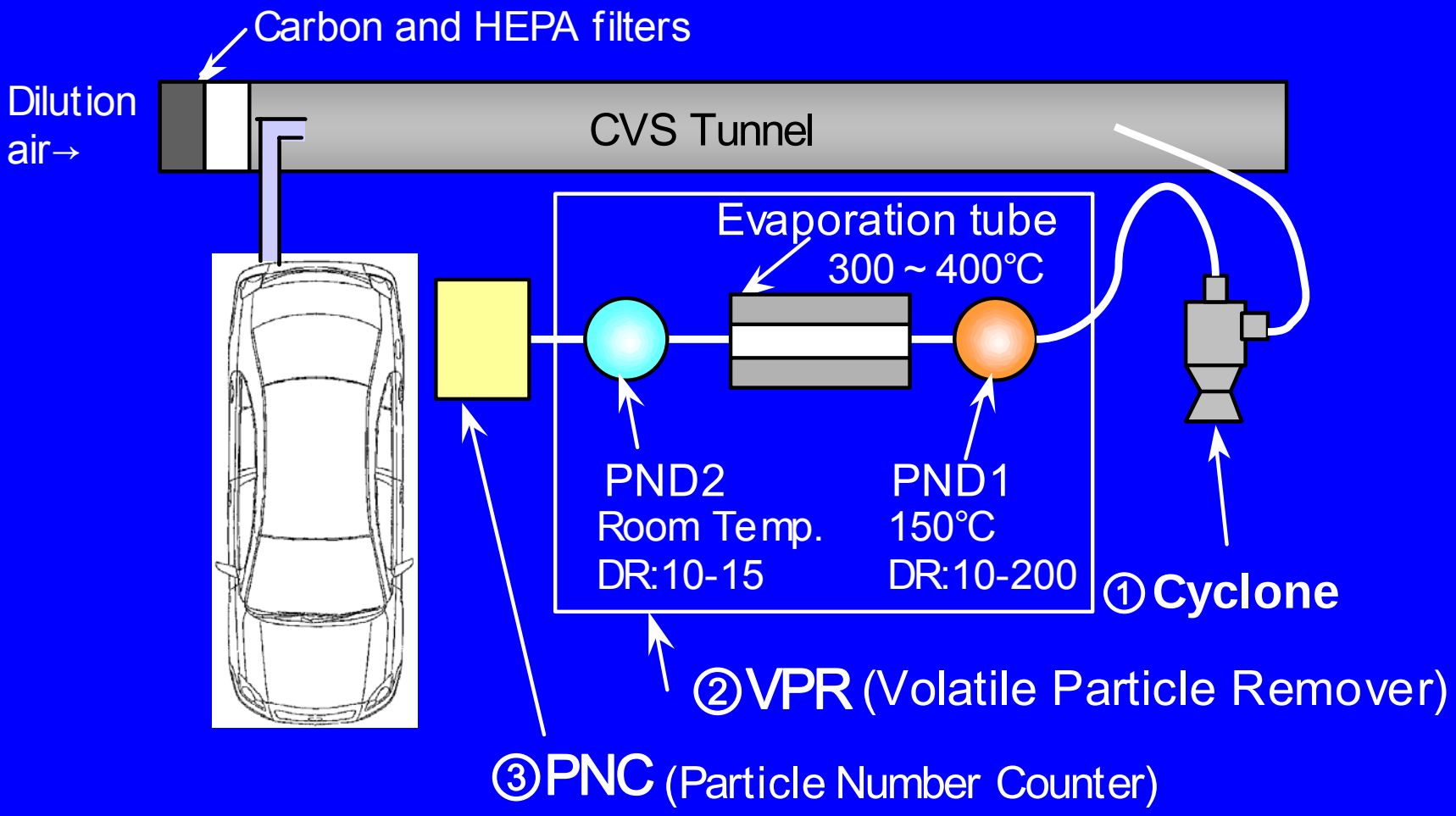
	Particle number(#/km)		Particulate mass(mg/km)	
	Diesel	Gasoline*2	Diesel	Gasoline*2
Euro5a 2009 ~			5.0	5.0
Euro5b 2011 ~	6.0×10^{11}		4.5	4.5
Euro6 2014 ~	6.0×10^{11}	undecided*1	4.5	4.5

*1 The particle number limit to be defined before Euro 6

*2 Application to direct injection engines only

Schematic of particle sampling system

Measured particle :
solid particles between 23nm and 2.5μm in diameter



Objectives

1. Evaluation of particle number emissions
2. Clarification of the accuracy of particle number measurement
3. Clarification of the challenges for particle number measurement

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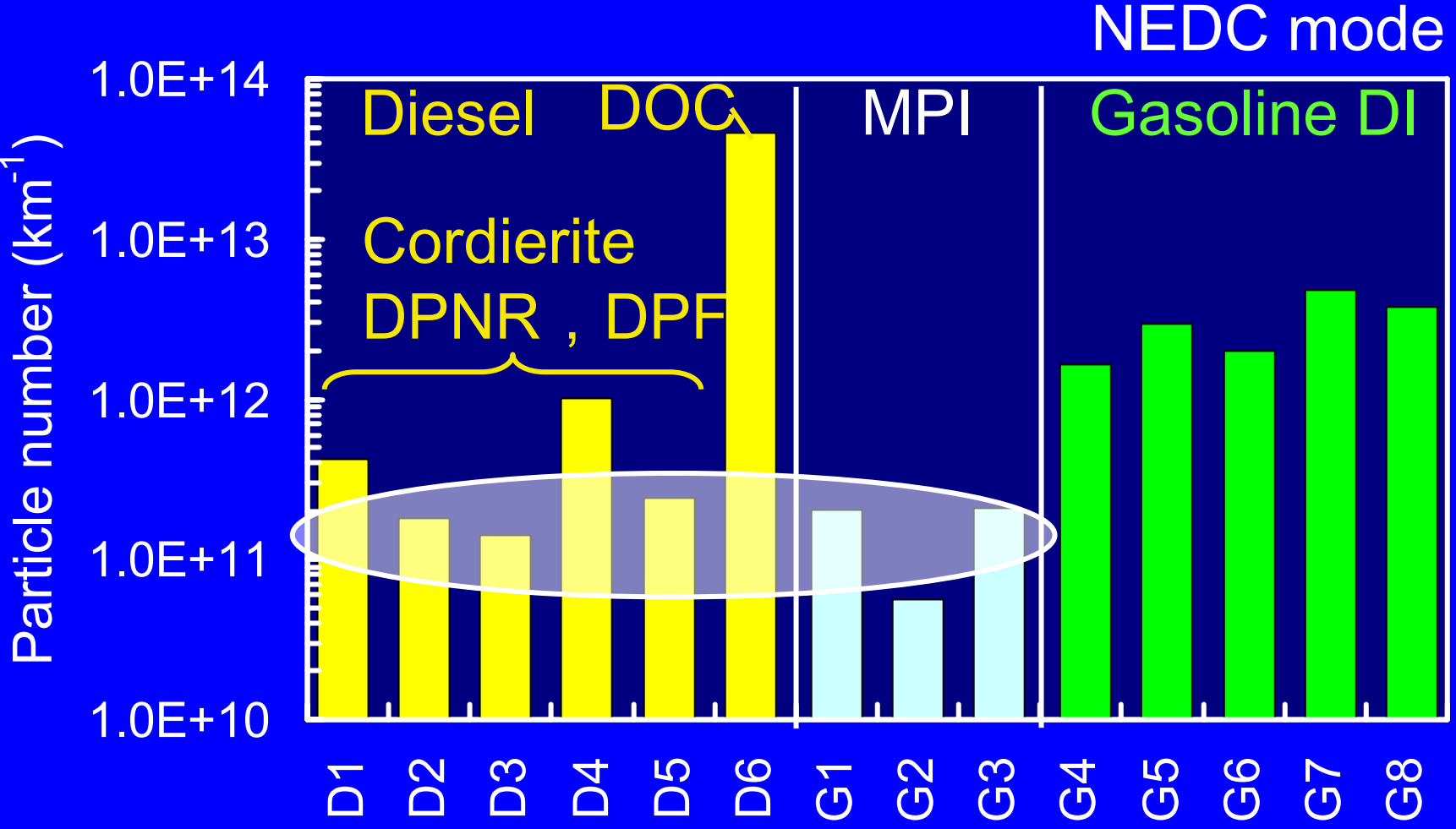
Specification of the test vehicles

	Fuel	Engine type	Engine displacement (L)	After treatment system	Emission regulation
D1	Diesel	DI, L4	2.0	DPNR	Euro4
D2		DI, L4	2.2	DPNR	Euro4
D3		DI, L4	2.2	DPNR	Euro4
D4		DI, L4	2.2	DPF	Euro4
D5		DI, L4	2.0	DPF	Euro4
D6		DI, L4	2.2	DOC	Euro4
G1	Gasoline	MPI, L6	3.0	3way Cat.	LEV
G2		MPI, V6	3.0	3way Cat.	Euro4
G3		MPI, V6	4.0	3way Cat.	Euro4
G4	Gasoline	DI, V6	3.0	3way Cat.	J-SULEV
G5		DI, V6	2.5	3way Cat.	Euro4
G6		DI, V6	3.0	3way Cat.	Euro4
G7		DI, V6	2.5	3way Cat.	Euro4
G8		DI, V8	4.6	3way Cat.	Euro4

Particle number emissions

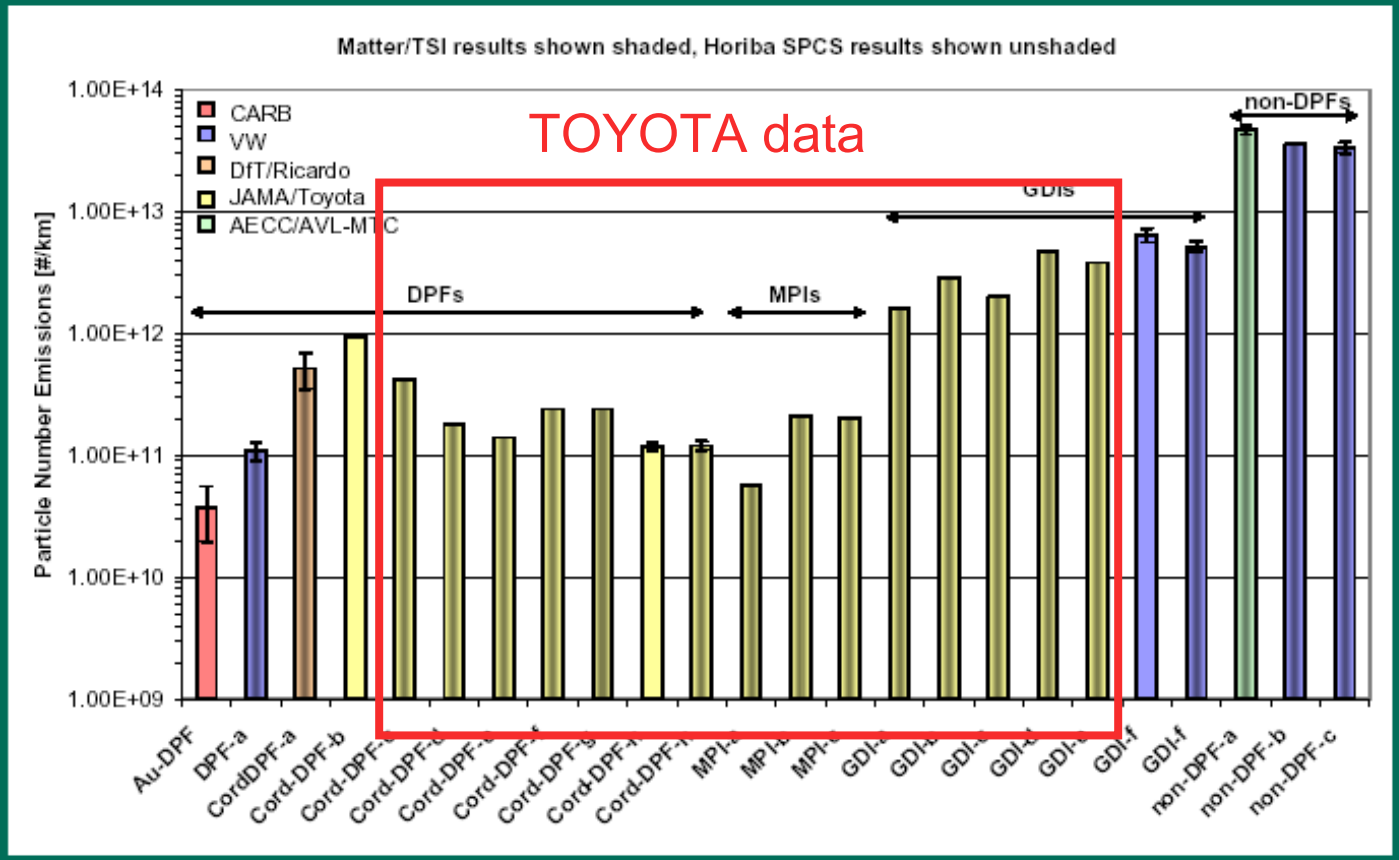
DPNR and DPF results are roughly similar to MPI



Particle number data in PMP

Consolidation of Particle Number Data

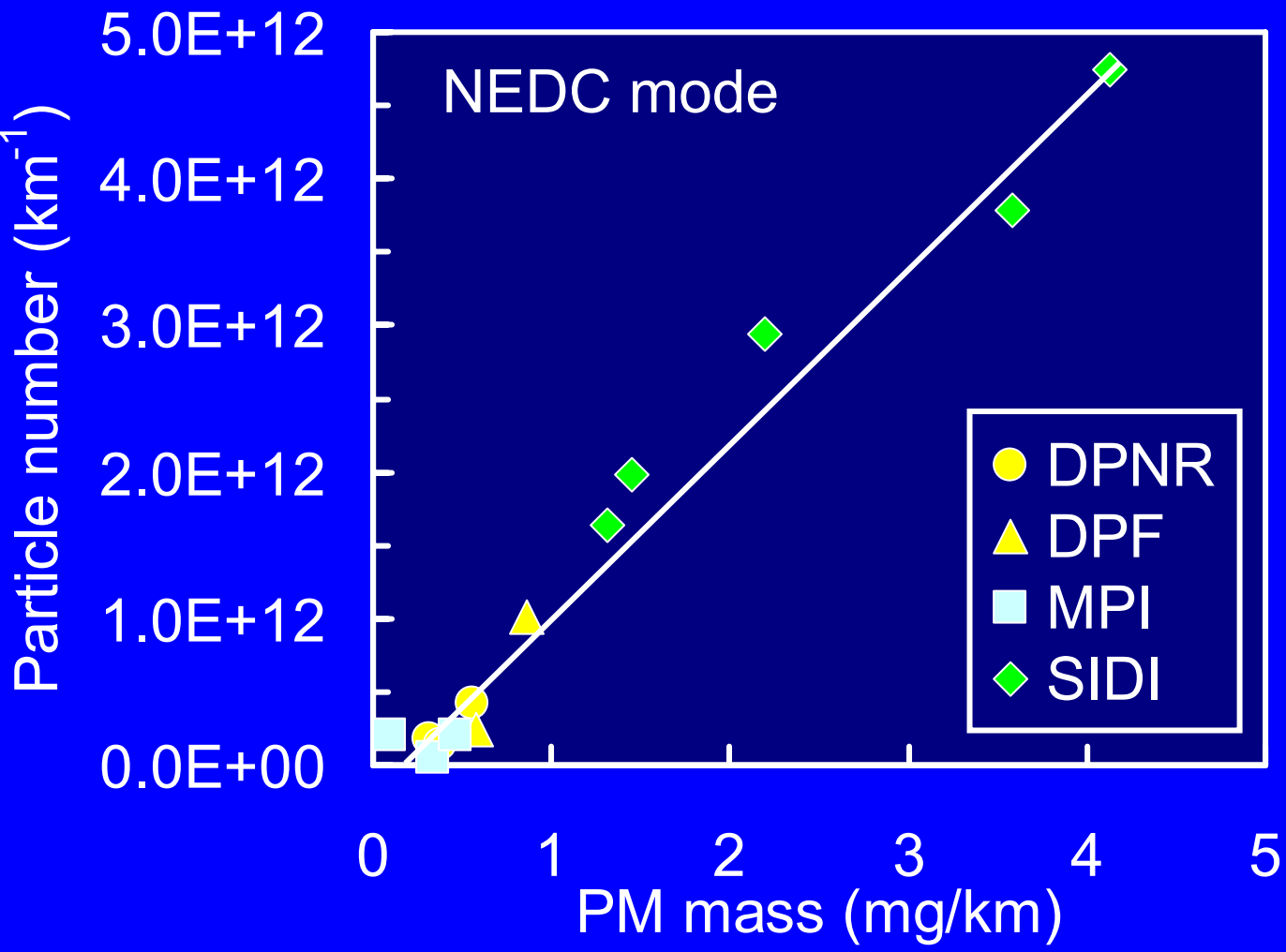
Department for Transport



the source : PMP progress since GRPE 55, GRPE-55-29,2008

Correlation between PM mass and number

Particle number decreases by reducing PM mass



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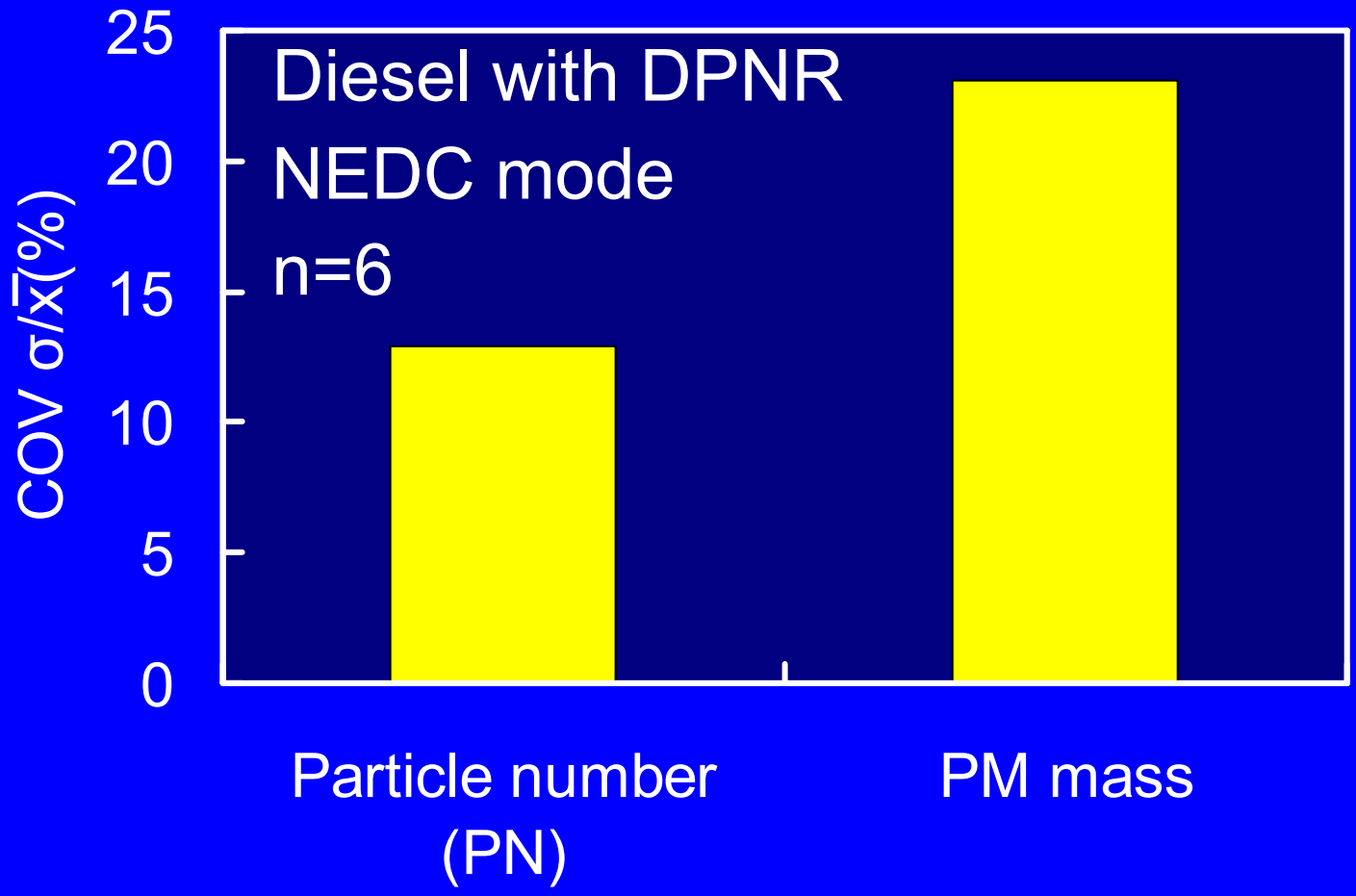
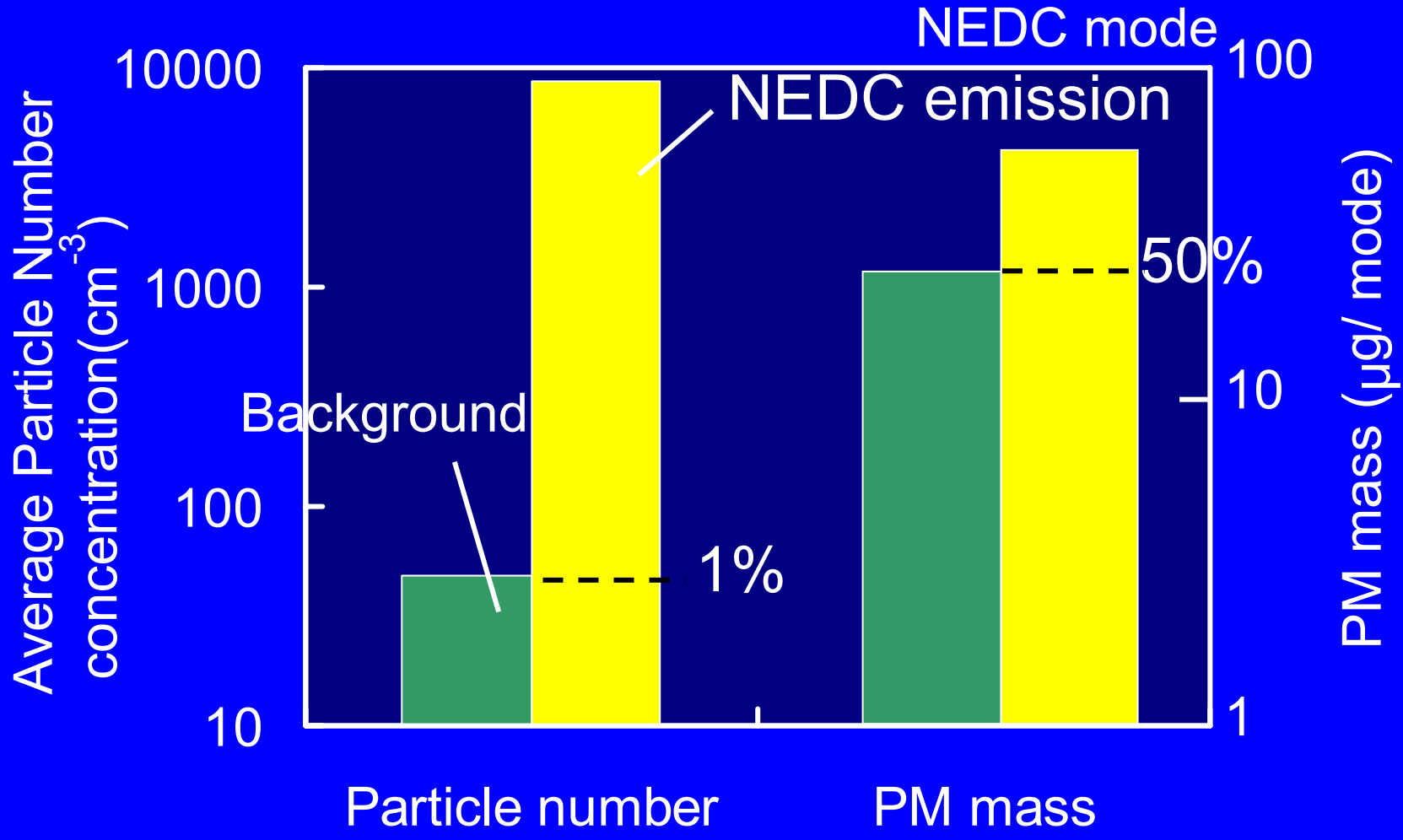
Reproducibility

Reproducibility of PN measurement is better compared to PM mass measurement



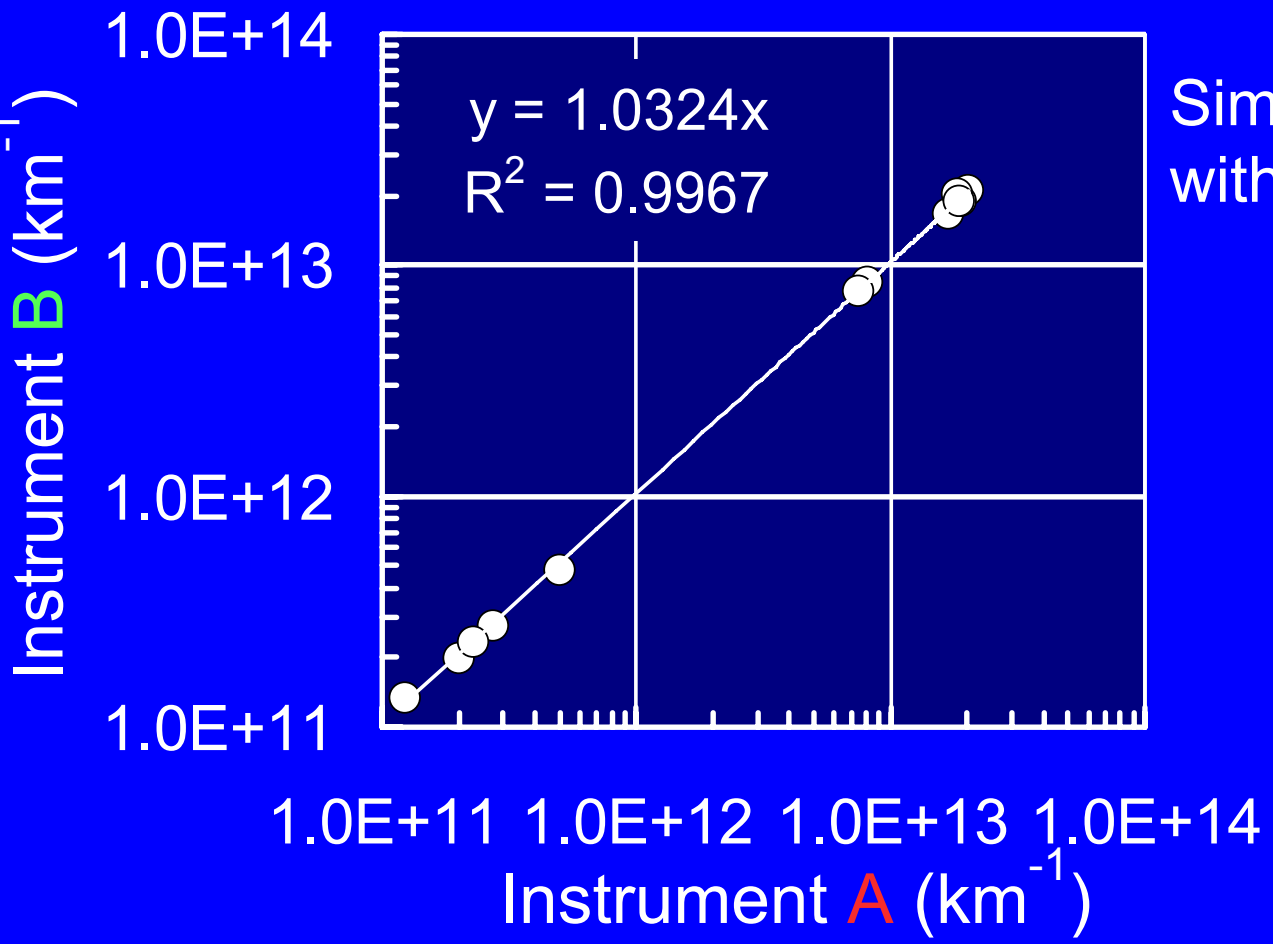
Dilution tunnel background

Particle Number(PN) emission is less affected by PN background



Comparison between same model of instruments

Good agreement with each other
⇒Variation should be confirmed by using more instruments



Simultaneous sampling with instrument A and B

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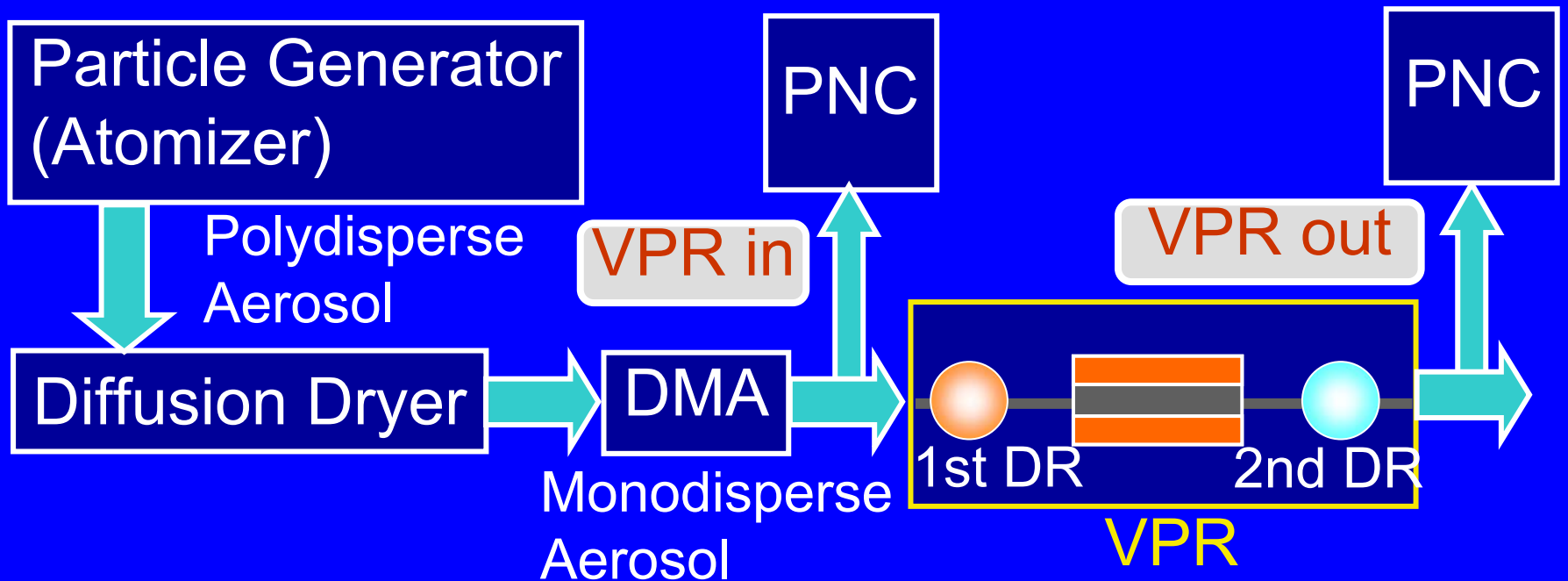
Particle Concentration Reduction Factor (PCRF)

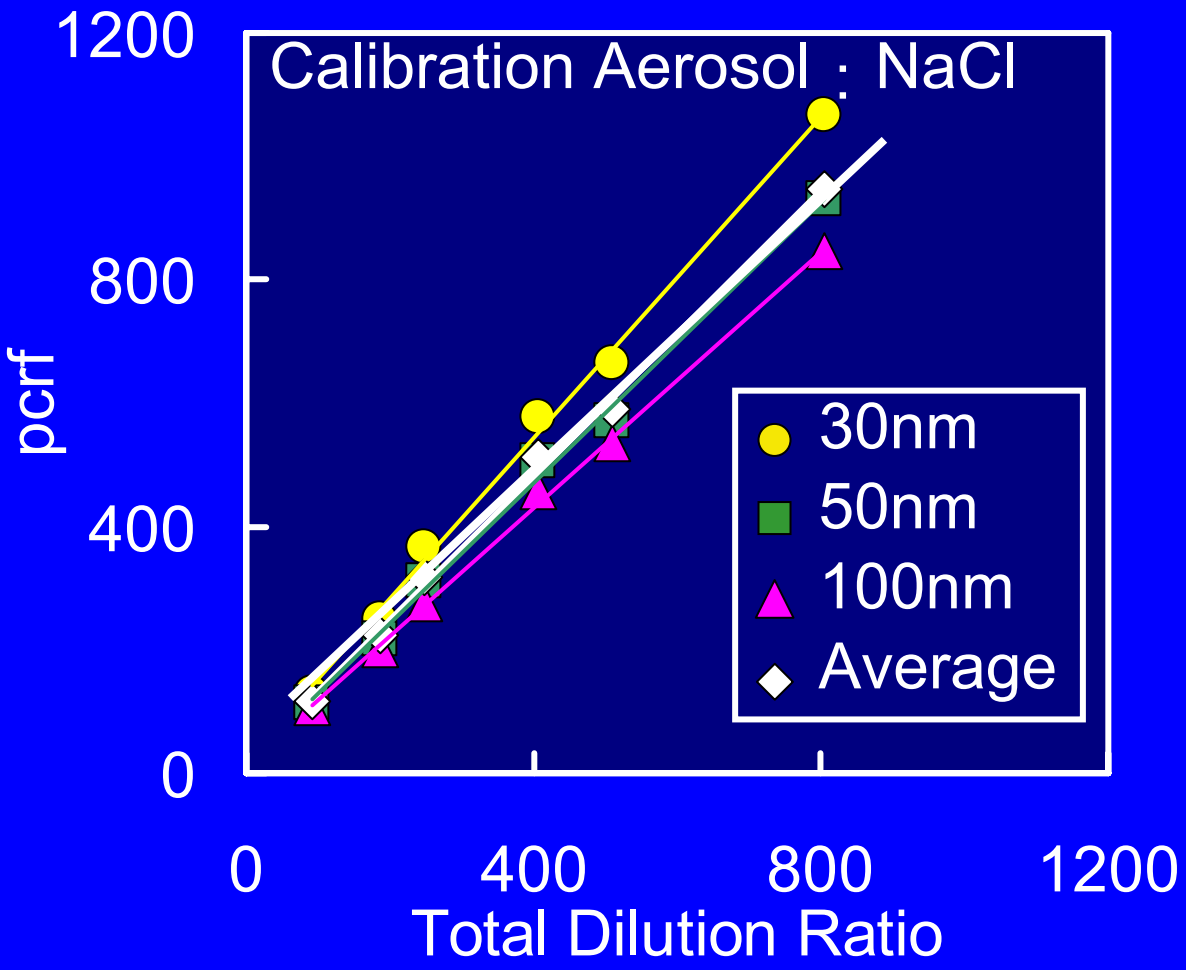
pcrf = VPR in / VPRout

$$\text{pcrf(Average)} = \frac{\text{pcrf(30nm)} + \text{pcrf(50nm)} + \text{pcrf(100nm)}}{3}$$



pcrf in the case of NaCl

pcrf increases with smaller particle diameters



DR : 200

	pcrf
30nm	248.5
50nm	218.1
100nm	200.5
Average	222.4

Equation of particle number emission

$$N = \frac{V \cdot \mathbf{k} \cdot C \cdot \mathbf{pcrf} \cdot 10^3}{d}$$

N : particle number emission (#/km)

V : Volume of the diluted gas at standard conditions(L/test)

k : Calibration factor to correct the particle number counter measurements to the level of the reference instrument

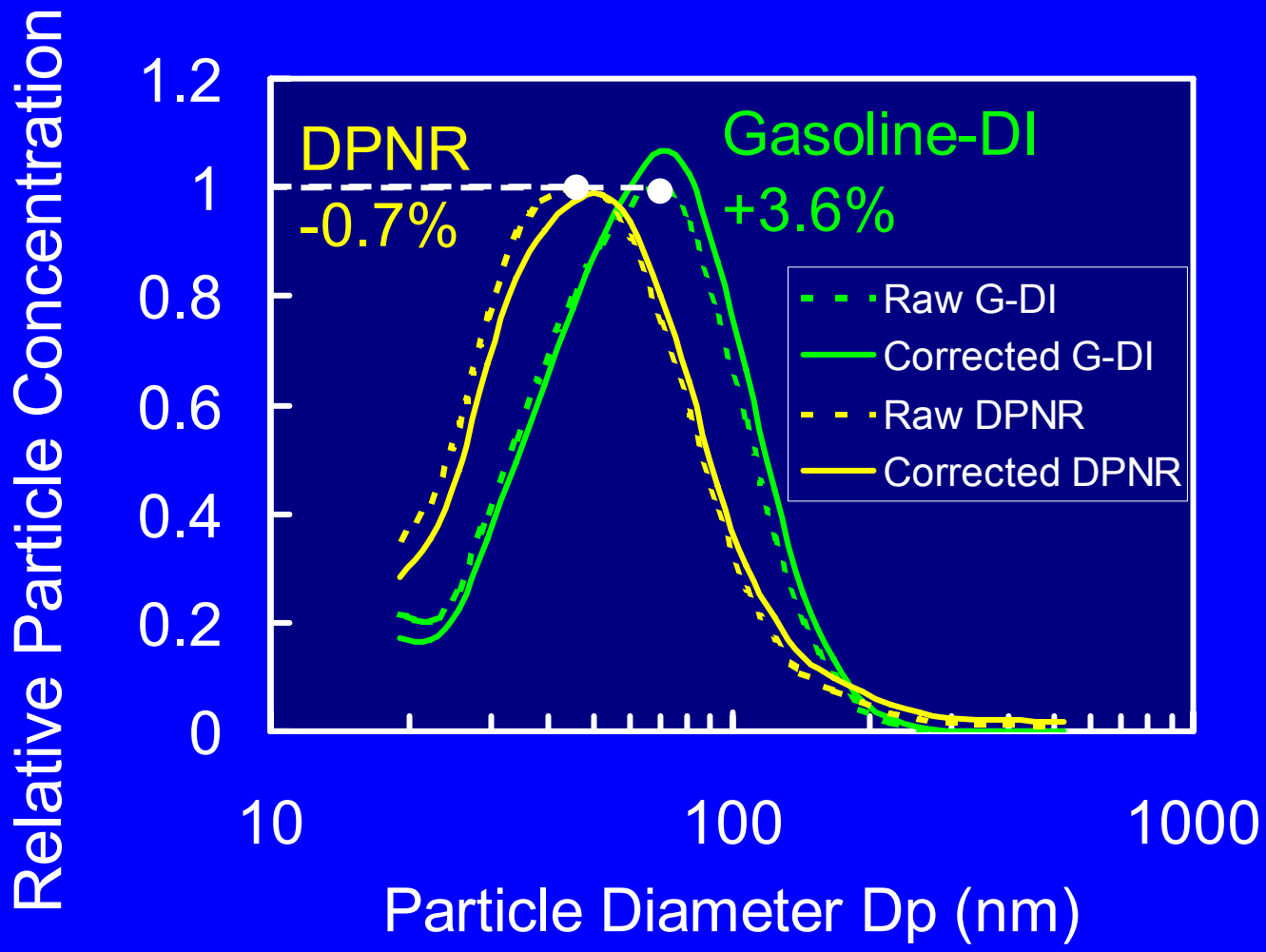
C : Corrected concentration of particles (#/cm^3)

$pcrf$: mean particle concentration reduction factor of the VPR at the dilution setting used for the test

d : distance corresponding to the operating cycle (km)

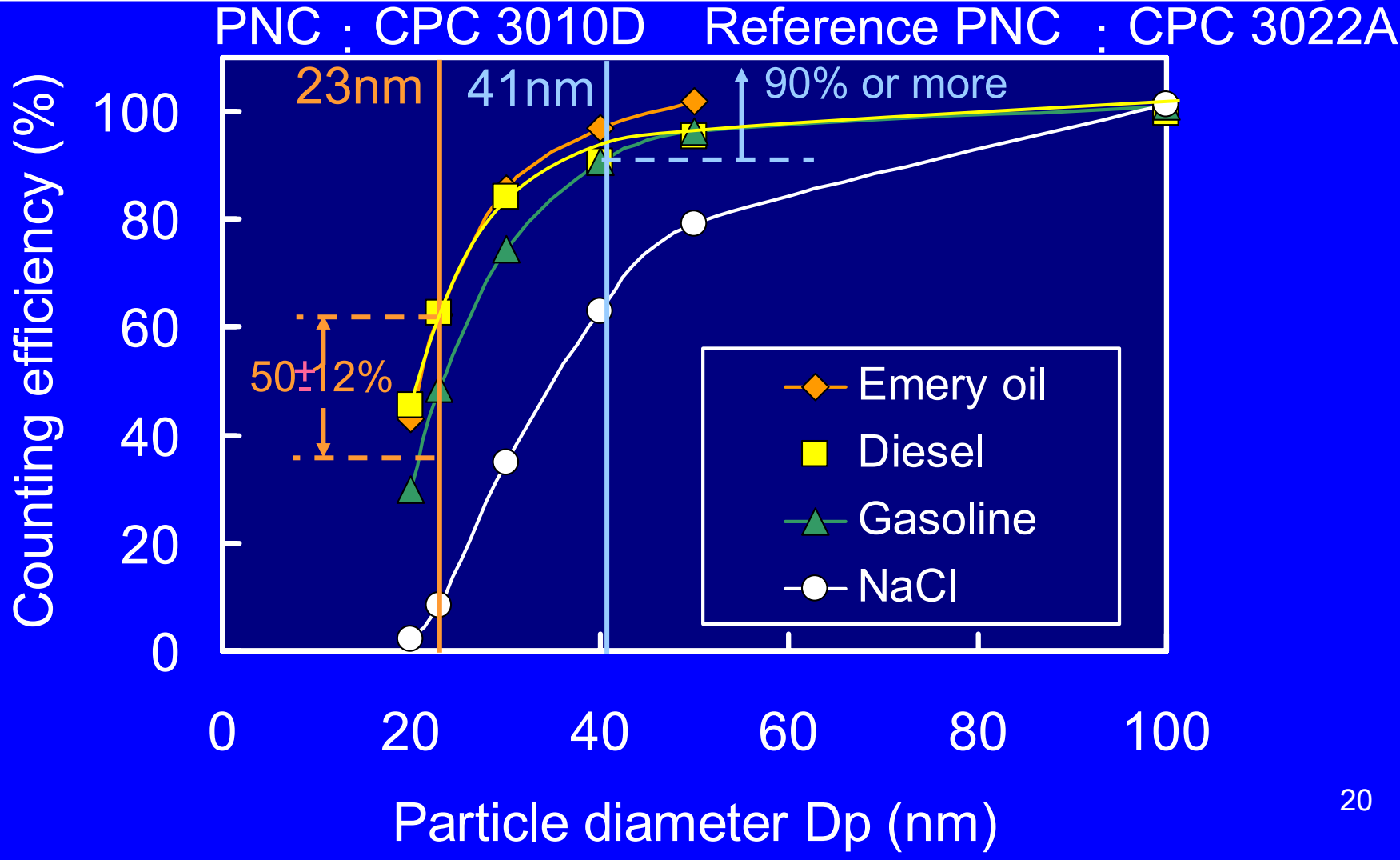
pcrf correction results

pcrf correction result varies with size distribution



PNC calibration - counting efficiency -

Counting efficiency of calibration aerosol should be similar to that of exhaust particles



Summary(1)

Particle number emissions

- Particle number emissions from diesel vehicles with DPNR and DPF are roughly similar to that of MPI.
- There is a good correlation between PM and PN.
  Particle number emission decreases as PM mass is reduced by DPF introduction into the diesel vehicles.

Measurement accuracy

- Reproducibility of particle number measurement is better than that of PM mass measurement below 1mg/km.

Summary(2)

Particle number measurement issues

VPR

Particle size distribution affects pcrf correction

PNC

Particle material affects counting efficiency

➡ It is necessary to clarify the influence of the particle size distribution and the particle material in order to improve the measurement accuracy.