Comparison of Particle Measurements by Various Instruments

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7-42-27 Jindaiji-higashi-machi, Chofu, Tokyo 182-0012, JAPAN

Abstract

Inter-laboratory correlation exercise at NTSEL in Japan was made in September 2005. This focuses on comparison of particle measurements by various instruments (GPMS, NTSEL, SPCS, EEPS, LII, and DDMA) in detail. The differences between particle measurements by various instruments and the relation between them are discussed from transient measurement data. In this exercise, 3 cars were tested such as, golden vehicle (Golden), gasoline direct injection vehicle (JV-1), DI diesel car with DPF (JV-2) for Japanese market.

It includes both filter based particulate mass measurements and real-time particle number measurements to be performed in parallel on light-duty vehicles under transient conditions on a chassis dynamometer. The driving cycle used is the New European Driving Cycle (NEDC). Regulated gaseous emissions are measured at the same time as particulate and particle emissions, using established regulatory measurement techniques. Addition to normal measurements (regulated gas analyzer, PM filter weighing and Golden Particle Measurement System), LII (Laser Induced Incandescence), DDMA (Dual Differential Mobility Analyzer), Horiba SPCS and NTSEL system (MD-19 + secondary dilution and 3010D) were adopted to exhaust gas analysis. NTSEL particle counting system and Horiba SPCS constructed according to PMP recommendation well reproduced the results acquired with GPMS. Horiba SPCS performed the lowest COVs in whole experiments.

LII and DDMA indicate almost same repeatability compared with GPMS. LII can detect particles without dilution; nevertheless DI gasoline vehicle emits lower particles than detection limit of LII. The quite different particle profiles as a function of particle diameter between gasoline direct injection vehicle and diesel vehicle with DPF were obtained using DDMA.

Particle concentrations acquired with 3 systems (GPMS, NTSEL, SPCS) meet each other very well. NTSEL particle counting system and Horiba SPCS constructed according to PMP recommendation well reproduced the results acquired with GPMS.

LII and DDMA indicate almost same repeatability compared with GPMS.

LII can detect particles without dilution; nevertheless JV-2 emits lower particles than detection limit of LII. The quite different particle profiles as a function of particle diameter between gasoline direct injection vehicle and diesel vehicle with DPF were obtained using DDMA. The characteristics of diesel vehicles and gasoline direct injection vehicle were shown by the real time measurement results by EEPS, DDMA. But there were differences between these measurement values.

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Objectives

The objective is to estimate various particle measurement systems (GPMS, NTSEL, SPCS, EEPS, LII, DDMA) to compare performances of these instruments by measuring particulates emitted from current diesel vehicles with DPF and direct gasoline injection vehicle.

Notes

- GPMS: Golden Particle Measurement System of PMP (CPC)
- NTSEL: MD-19+Secondary dilution +TSI 3010D(CPC)
- SPCS: Horiba SPCS (CPC)
- EEPS: Engine Exhaust Particle Sizer
- LII: Laser Induced Incandescence
- DDMA: Dual Differential Mobility Analyzer

Test Vehicles

Name	Golden Vehicle	JV-1	JV-2
Transmission Type	6 Speeds Manual	Automatic	5 Speeds Manual
Engine Type	DI, Common Rail Diesel + Inter Cooler Turbo +DPF	Gasoline Direct Injection	DI, Common Rail Diesel + Inter Cooler Turbo +DPF,
Displacement	1997cc 4cylinder	2998cc V6	1998cc 4cylinder
Market	EU **(EURO IV)**	JP **(25% Reduction of 2000 Regulation in Japan)**	JP **(New Short-term Regulation in Japan)**

Test Modes

NEDC (New European Driving Cycle) Cold

Instruments (Number Counting)

GPMS (Golden Particle Measurement System)

Rotary Disc Dilutor (MD-19) + Evaporation Tube + Secondary Dilution + CPC(3010D)

NTSEL System

Rotary Disc Dilutor (MD-19) + Evaporation Tube + Secondary Dilution + CPC(3010D)

Horiba SPCS

Horiba original primary dilutor + Evaporation Tube + Secondary Dilution + CPC(3010D)

Instruments (Real Time Counting)

LII (Laser Induced Incandescence)

Soot Measurement, No Dilution、Average Particle Size Measurement simultaneously

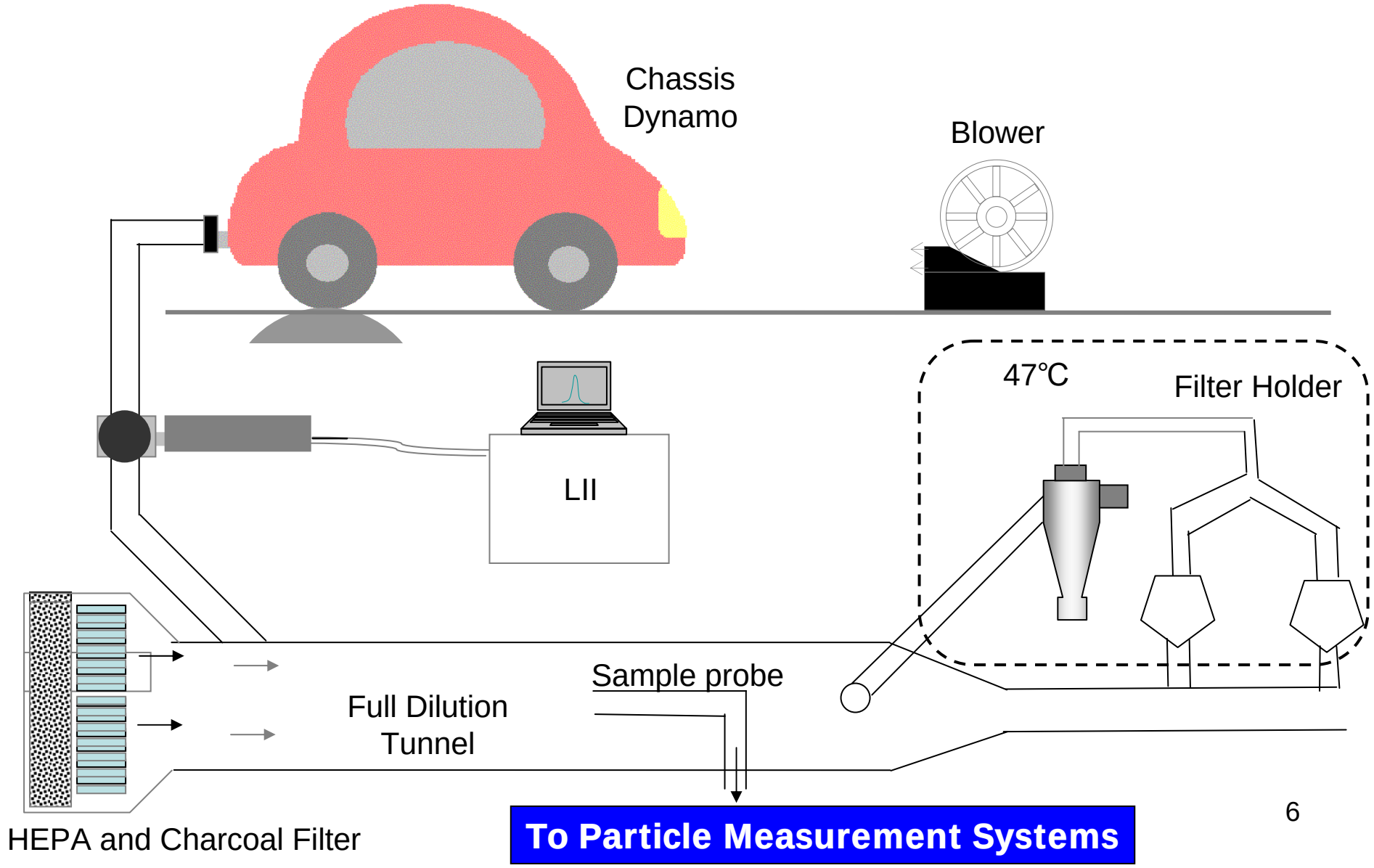
EEPS (Engine Exhaust Particle Sizer)

Real Time Particle Measurement of each Mobility Diameter

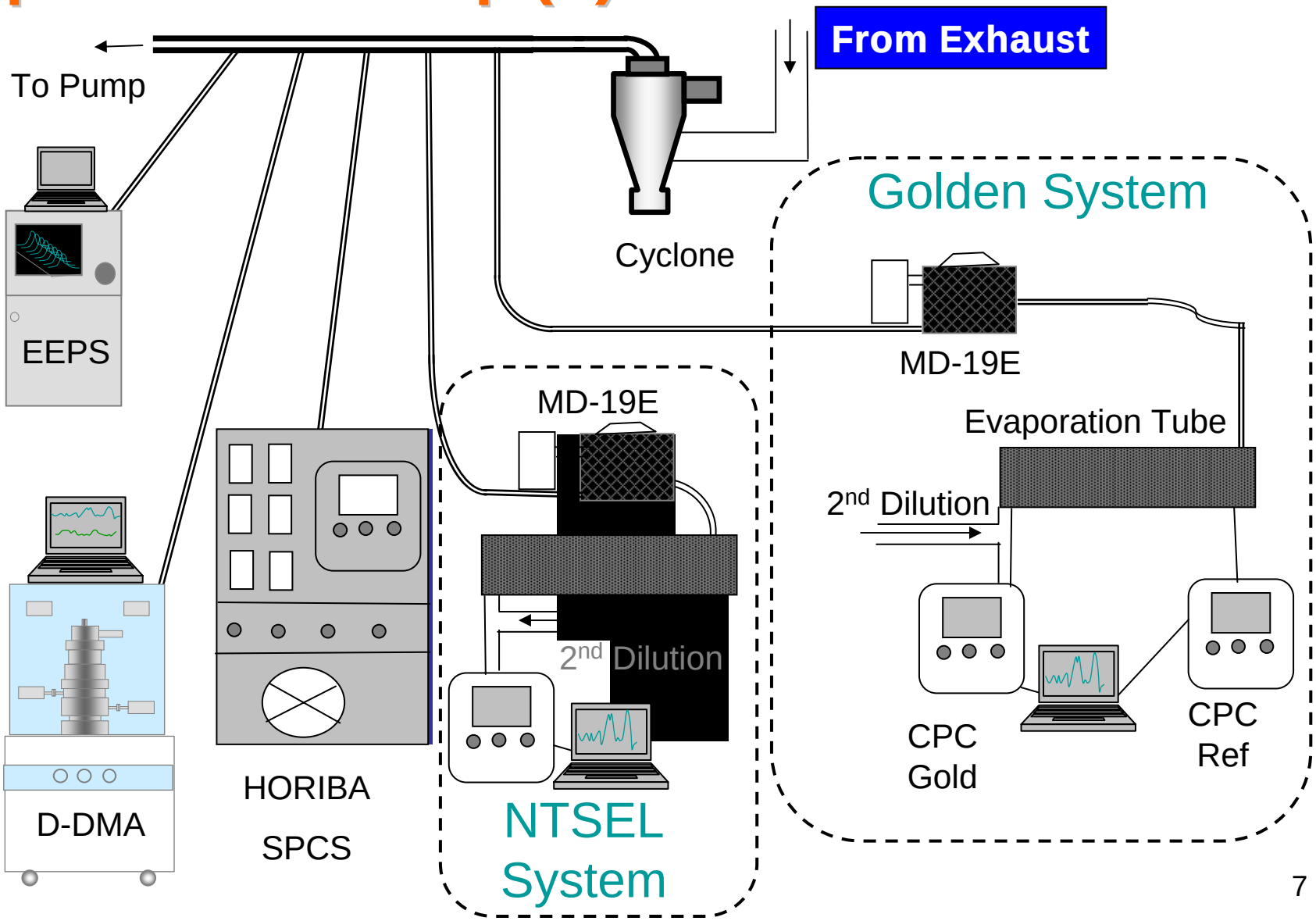
DDMA (Dual Differential Mobility Analyzer)

Real Time Particle Measurement of 2 Typical Diameter (Accumulation mode particle (about 75nm), Nuclei mode particle (about 20nm))

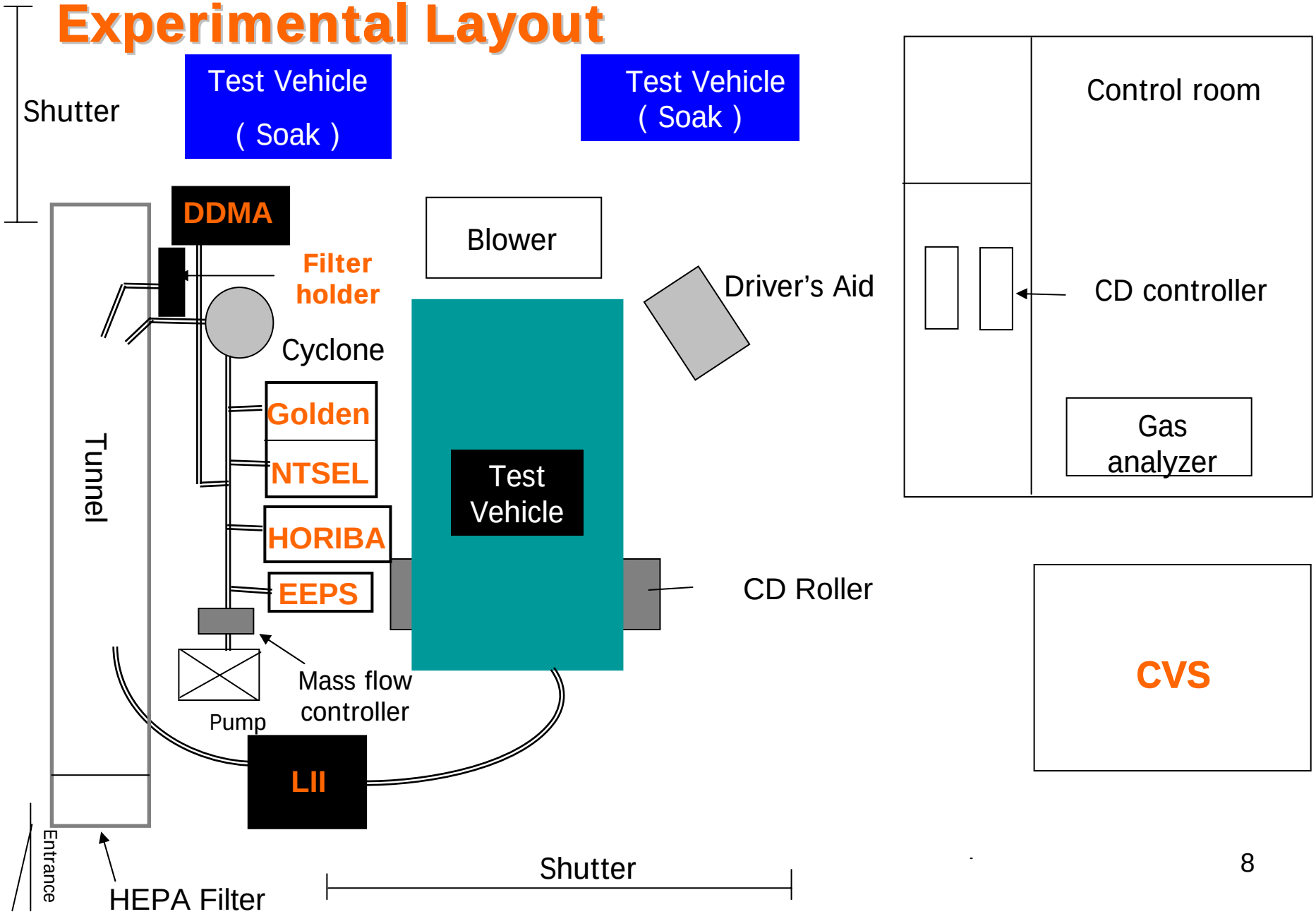
Experimental Setup (1)-CD, Full Dilution Tunnel



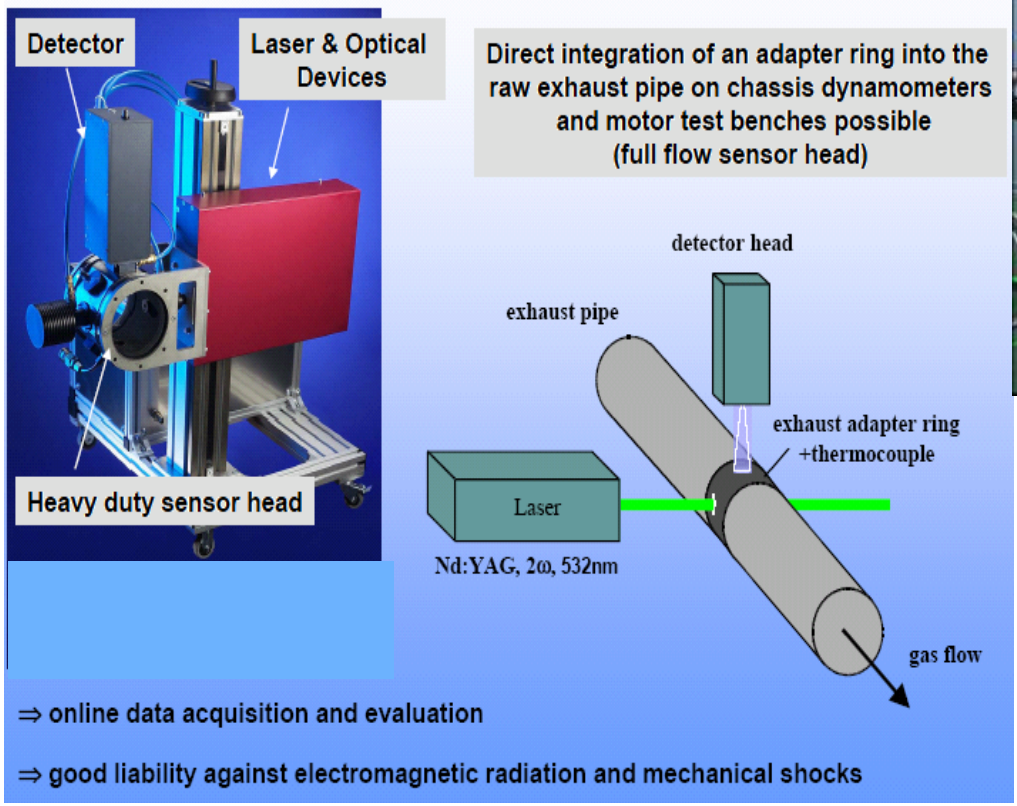
Experimental Setup (2)-Instruments

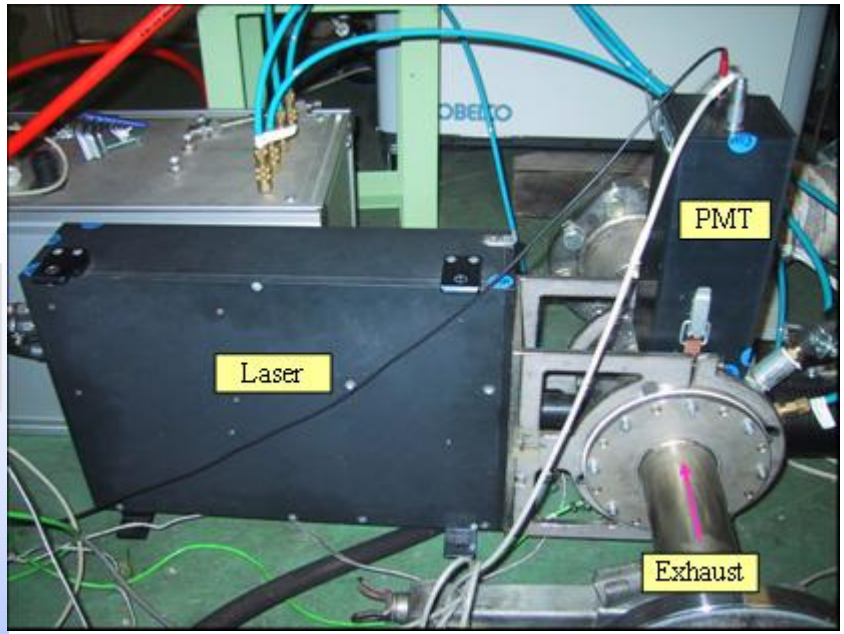


Experimental Layout



LII: Laser Induced Incandescence Soot Analyzer

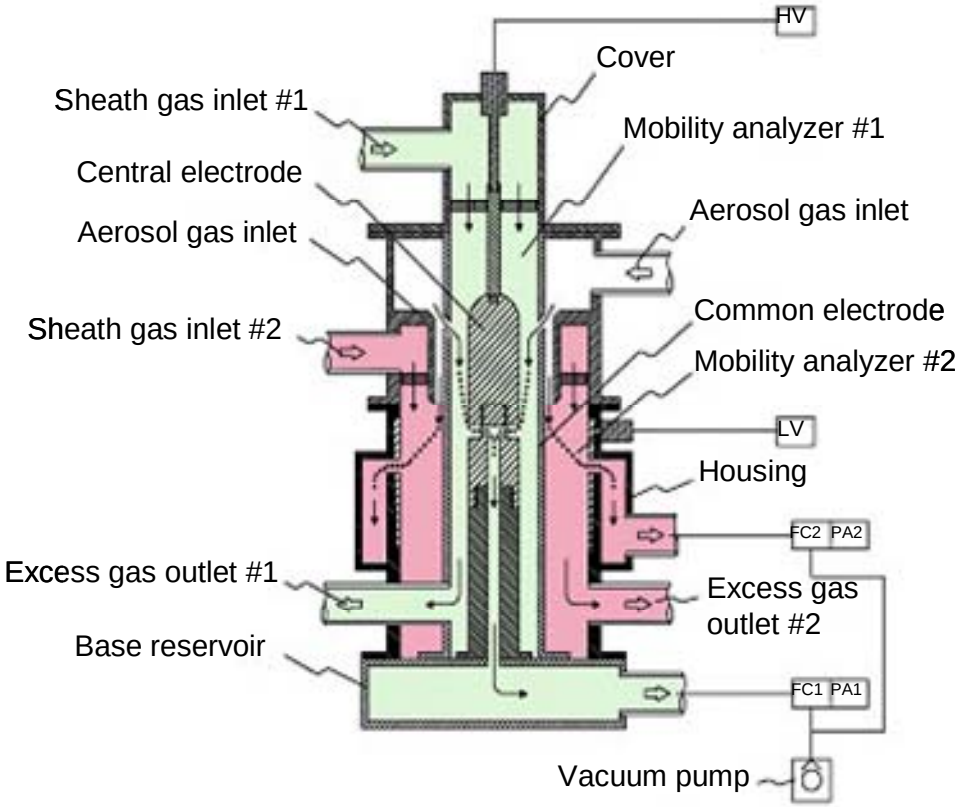




LII measurement can be achieved only connecting exhaust pipe to this instrument because there is no necessity to dilute exhaust gas.

Courtesy of ESYTEC

DDMA (Dual-type DMA)



Overview of prototype DDMA

The inner section measures accumulation particles and the outer section measures nuclei mode particles.

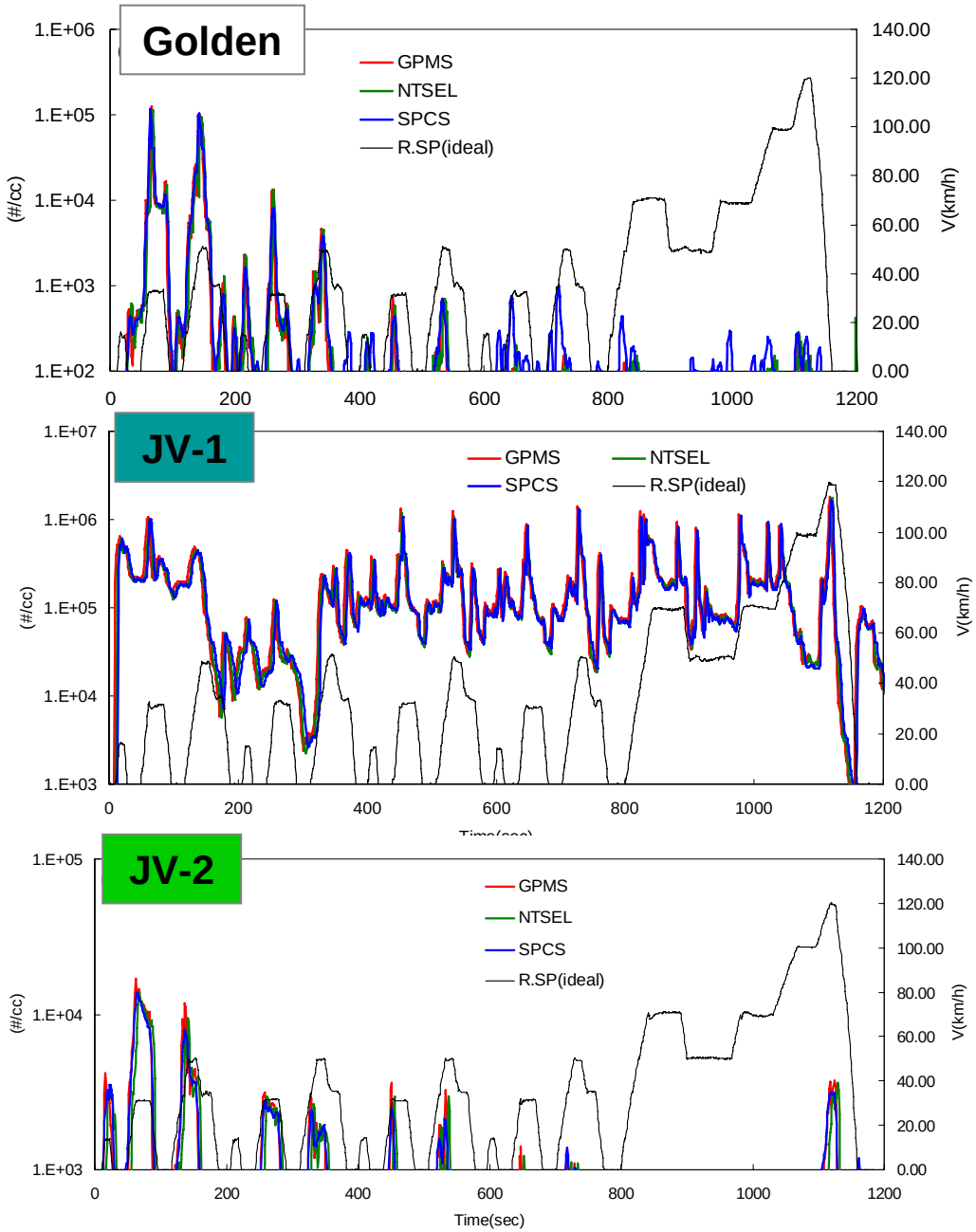
Courtesy of Wyckoff Co., Ltd(2004ETH)

Results

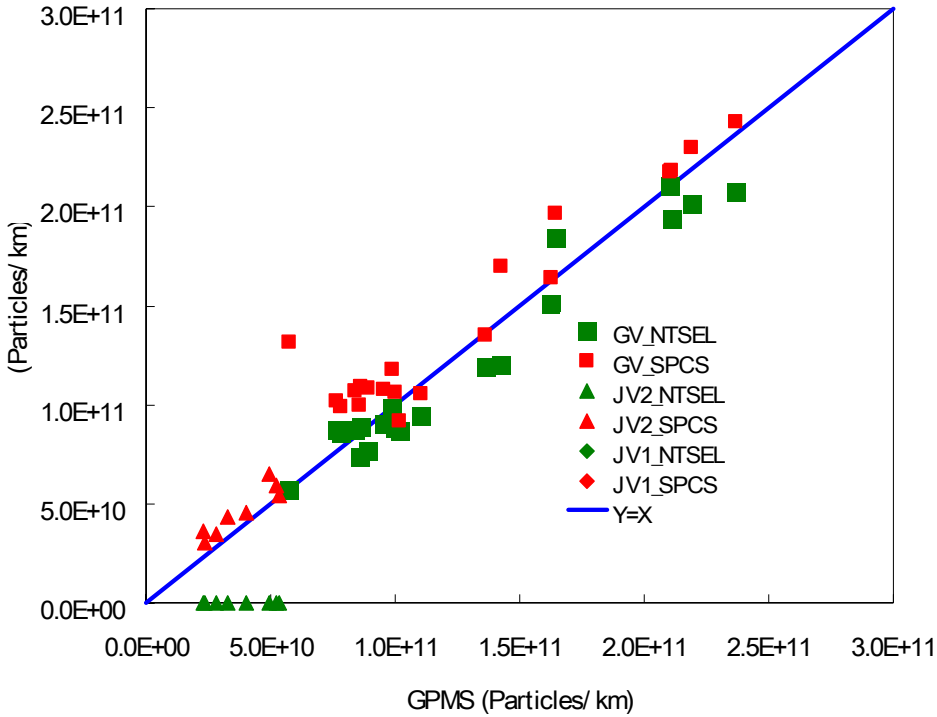
Typical examples of Particle concentration (GPMS, NTSEL, SMPS)

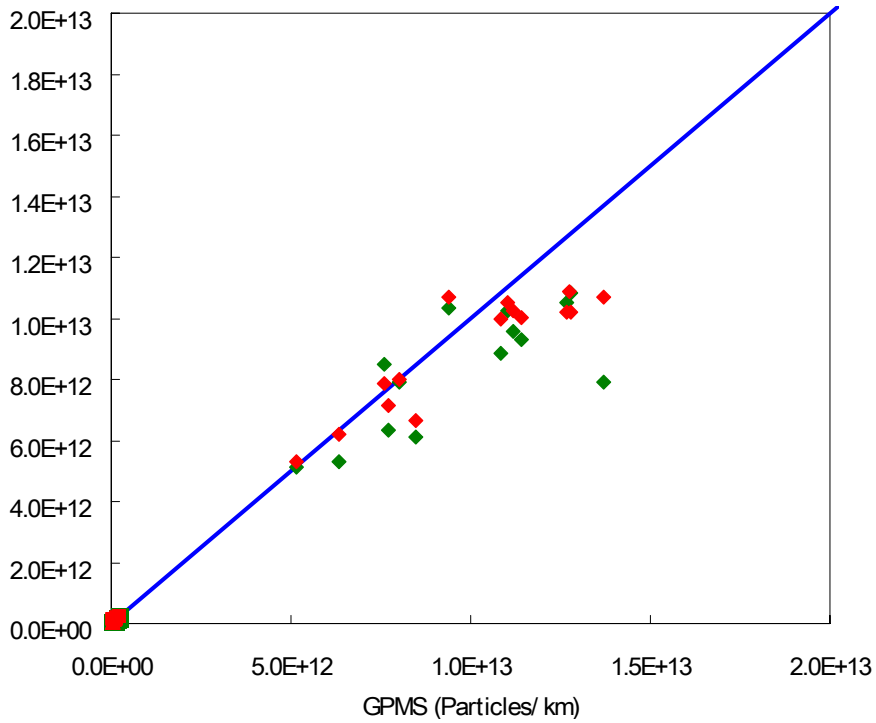
These results acquired with 3 systems meet each other very well.

The data are shown as corrected data by dilution factor.



Correlation among number counting instruments





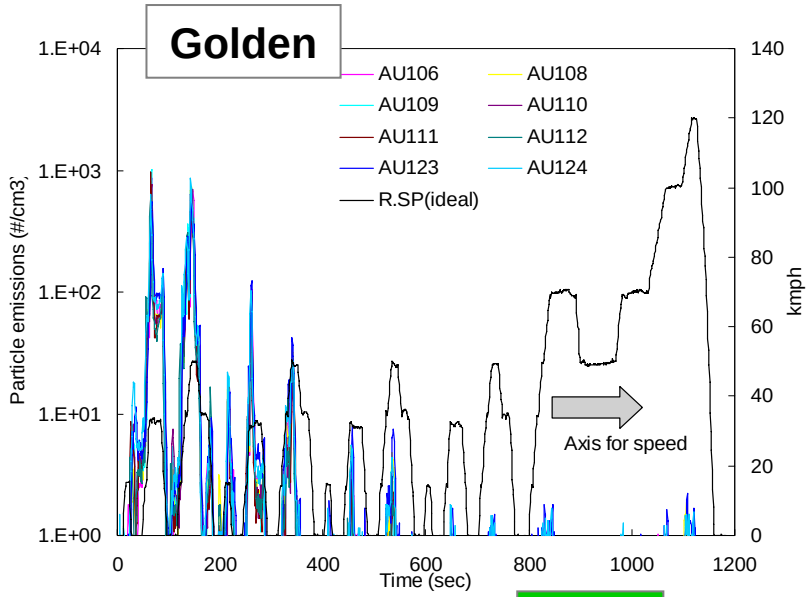
Three instruments (GPMS, NTSEL system and Horiba SPCS) had high correlation in this experiment.

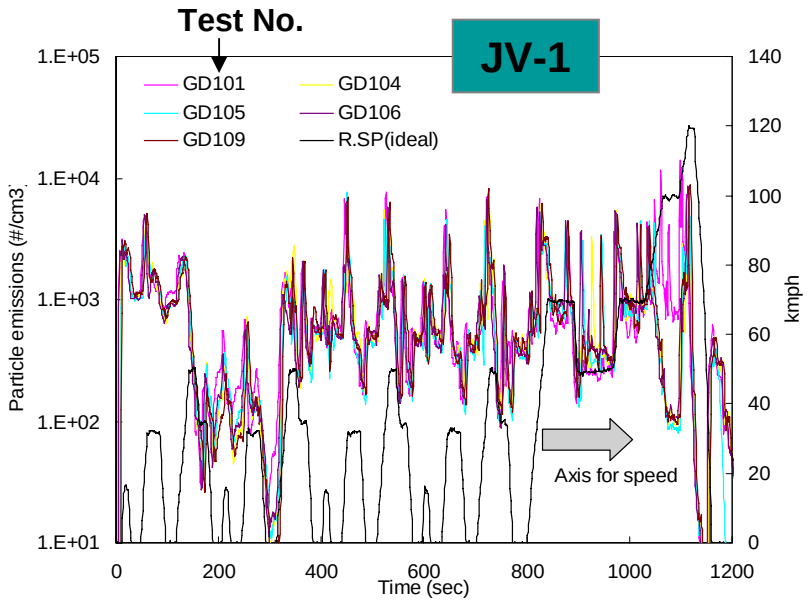
The value of SPCS is larger than that of other instruments.

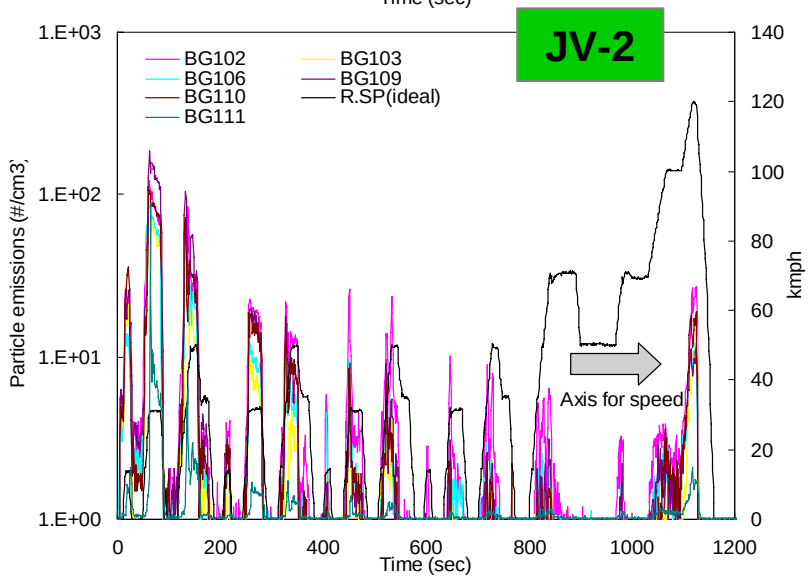
→ The loss of SPCS by 1st dilution is small compared to others ?

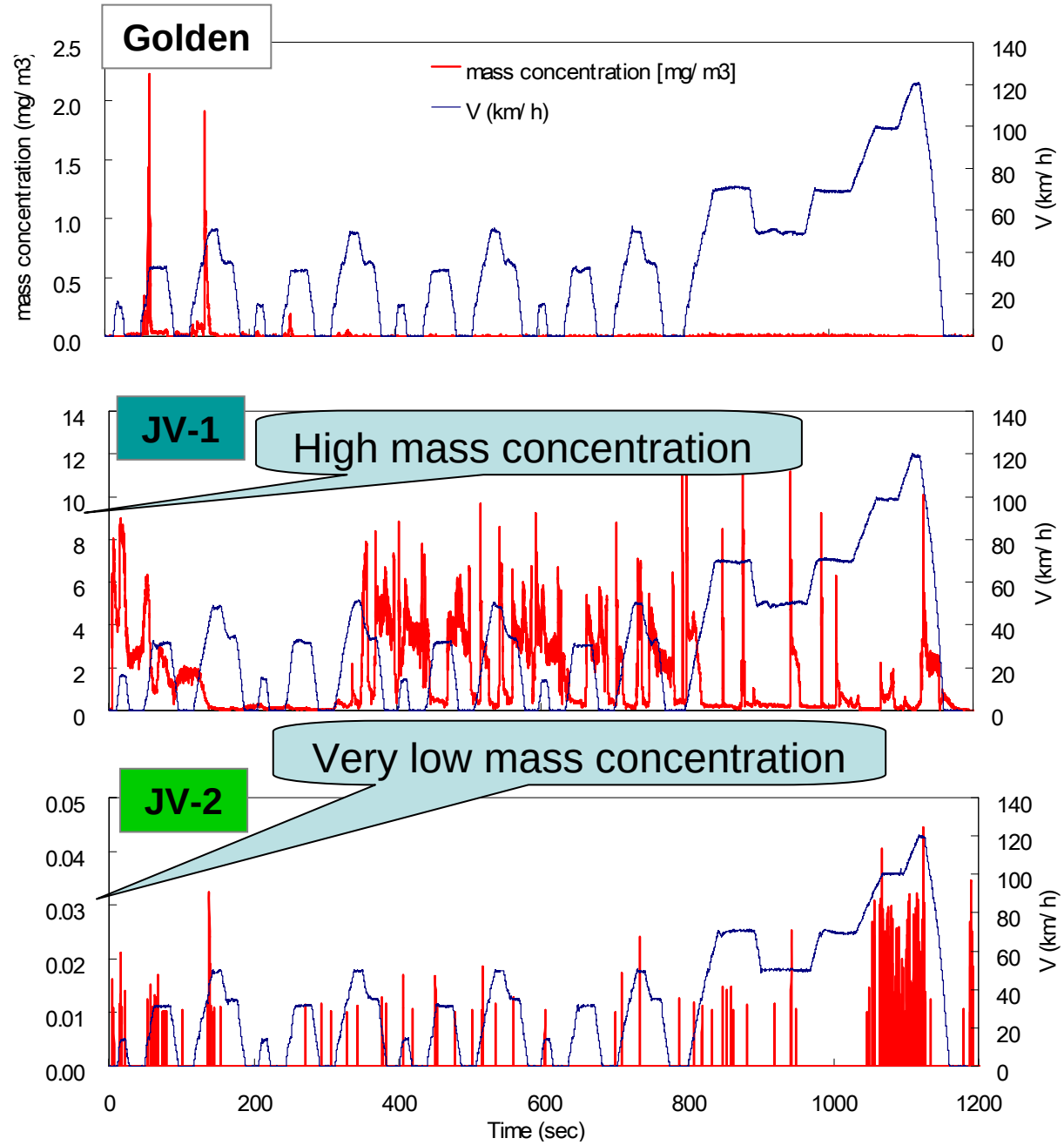
GPMS measurements on each vehicles

- A reproducibility of data is very good.
- Emission patterns are very different among vehicles.





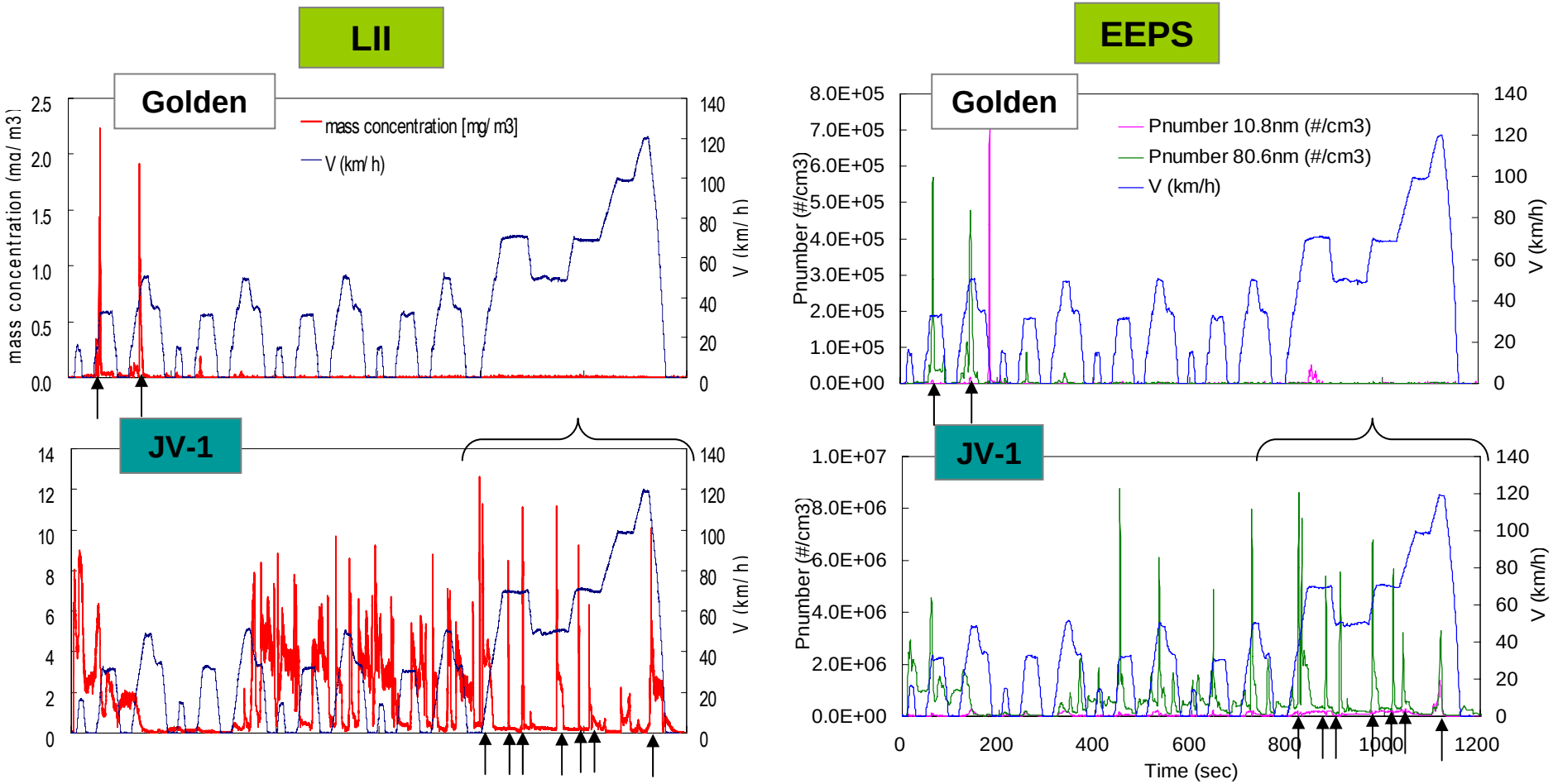




Real time Measurement by LII on NEDC

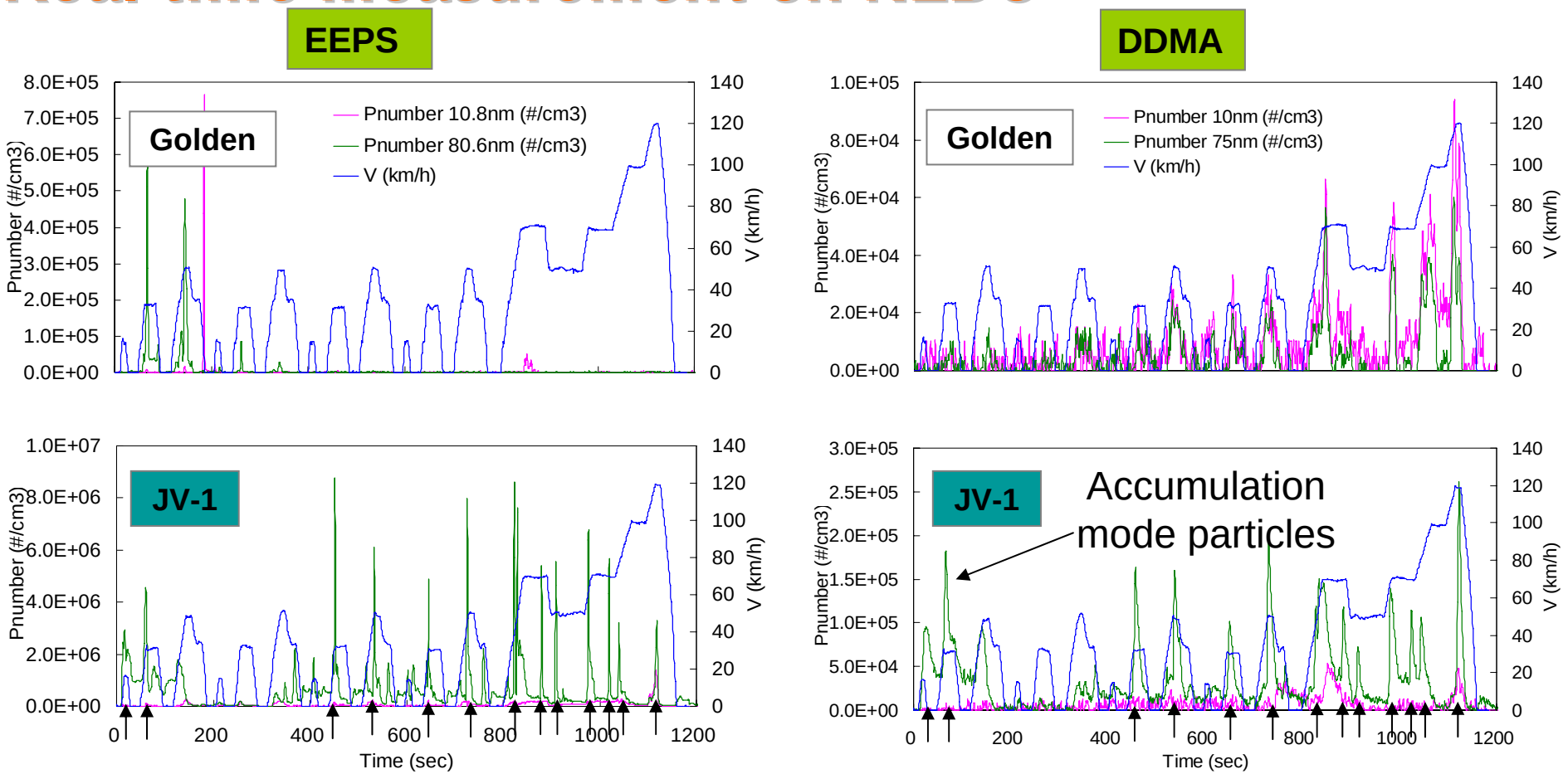
- Repeatability of LII were good in each vehicles.
- A lot of soot were observed in JV-1 (GDI vehicle).
- Soot emission was very low in JV-2 (Diesel vehicle with DPF). The value is near measuring limit.

Comparison between LII and EEPS on NEDC



- In Golden, LII is similar to Pnumber 80.6 nm of EEPS.
- In JV-1, LII is similar to Pnumber 80.6 nm of EEPS in high speed condition. In low condition differences between LII and EEPS exist.

Real time measurement on NEDC



- There are many nucleation mode particles in diesel vehicles.
- Many Accumulation mode particles were observed in JV1 (GDI vehicle) by both EEPS and DDMA. (This result is consistent with LII.)
- Data patterns were similar but differences of values exist.

Conclusions

- Particle concentrations acquired with 3 systems (GPMS, NTSEL, SPCS) meet each other very well. NTSEL particle counting system and Horiba SPCS constructed according to PMP recommendation well reproduced the results acquired with GPMS.

- LII and DDMA indicate almost same repeatability compared with GPMS. LII can detect particles without dilution, nevertheless JV-2 emits lower particles than detection limit of LII. The quite different particle profiles as a function of particle diameter between gasoline direct injection vehicle and diesel vehicle with DPF were obtained using DDMA.

- The characteristics of diesel vehicles and gasoline direct injection vehicle were shown by the real time measurement results by EEPS and DDMA. But there were differences between these measurement values.

Thank you for your attention.

10th ETH Conference on Combustion Generated Nanoparticles,
Zurich, 21-23 August 2006