# Fine Particle Emissions from a DI Gasoline Vehicle with NOx Storage Catalyst

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Abstract

A DI gasoline vehicle is one of promising solutions for both the reduction of global warming gas ($CO_2$) and the improvement of fuel consumption in gasoline passenger cars. The lean-burn combustion in a DI gasoline engine is usually used in order to reduce $CO_2$ emission and to improve fuel consumption. In this lean condition it is not easy to reduce NOx emission by an after-treatment system because of average $O_2$ rich atmosphere in the exhaust gas. NOx storage-reduction catalyst is one of sophisticated solutions for NOx reduction in average $O_2$ rich atmosphere in the exhaust gas. The rich spikes of HC are used to make the area of local rich gas as reductant of NOx in the NOx storage-reduction catalyst.

A DI Gasoline Engine with NOx storage-reduction catalyst has the possibility to emit fine particles by the rich spikes of HC. Due to significant reduction of PM from diesel engines, a new PM measurement method for very small amounts of PM is now discussing for future PM regulation such as particle number counting.

In such a situation it is one of important issues to investigate the behavior of particle emission from a DI gasoline passenger car that will have the large contribution of particle emission among LD vehicles.

This study shows the emission behavior of fine particles from a DI gasoline passenger car with NOx storage-reduction catalyst on the market. The characteristics of fine particle number emissions were examined by means of ELPI in the tailpipe.

Test vehicle has a DI gasoline engine with NOx storage-reduction catalyst. Displacement volume is 2997 cc, compression ratio is 11.3. Chassis dynamometer is used. Particle size distributions are measured by SMPS, ELPI. Exhaust gas temperatures also are measured at before and after of catalyst. The experiments in 40, 60 km/h constant speed condition, 10・15 mode in Japan and CD34 mode (in future transient mode in Japan) were carried out.

Spikes of high particle concentration are generated corresponding to rich spike of A/F. In response to A/F spikes, boost pressures increase and exhaust gas flow

decreases. In addition to rich spike generation by a direct fuel injection to the combustion chamber, the throttle control to enlarge A/F spikes is operated by throttling to reduce intake air. As the result of too rich mixture situation, a lot of particles will generate in the combustion chamber.

Exhaust gas temperature keeps between 300 and 400 Celsius degrees in constant speed conditions. Particles of number concentration spikes will be not volatile particles because of active three-way catalyst and NOx storage-reduction catalyst. A DI-gasoline vehicle with NOx storage-reduction catalyst shows spike emissions of particle number concentration periodically in constant speed condition from cause of rich spike of NOx reduction control. The spikes show characteristic phenomena of NOx storage-reduction catalyst system without DPF by rich spikes.

In whole range of 10-15 mode at hot start condition, the concentration of 214nm particles is high. In acceleration condition the concentration of 84 – 136 nm particles is high. In deceleration (70→50 km/h) the concentration of 45 nm particles is high. It was observed in the case of HD diesel engines that high number concentration particles generate in deceleration. As no combustion in the cylinder takes place in deceleration, particles will generate by nuclear condensation from lubricant oil evaporated in the combustion chamber or hydrocarbons desorbed from exhaust pipe wall. In high exhaust gas flow condition (high speed), small particles are emitted because of short residence time. In acceleration, the particle concentration is high and particle size become large because of coagulation of particles. CD34 mode (Future transient mode in Japan) also show the same tendency as 10・15 mode.

The conclusions are obtained as follows;

In the constant driving condition the spike-like emission of high particle number concentration was clearly recognized especially. This spike-like emission seems to be caused by the rich spike of HC for NOx storage-reduction catalyst. The particle size in the peak of this spike-like emission was from 40 to 80 nm. In the transient driving condition also the same spike-like particle number emission was recognized, too.

These spikes show characteristic phenomena of NOx storage-reduction catalyst system without DPF by rich spikes. The reduction of spike-like particle emission will became one issue to resolve for a DI gasoline passenger car with NOx storage-reduction catalyst in the near future.

# Fine particle emissions from a DI gasoline vehicle with NOx storage catalyst

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# Introduction(1/2)

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In this lean condition, it is not easy to reduce NOx emission by an after-treatment system because of average $O_2$ rich atmosphere in the exhaust gas.

NOx storage-reduction catalyst is one of sophisticated solutions for NOx reduction in average $O_2$ rich atmosphere in the exhaust gas.

The rich spikes of HC are used to make the area of local rich gas as reductant of NOx in the NOx storage-reduction catalyst.

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# Introduction(2/2)

A DI Gasoline Engine with NOx storage-reduction catalyst has **the possibility to emit fine particles by rich spikes of HC.**

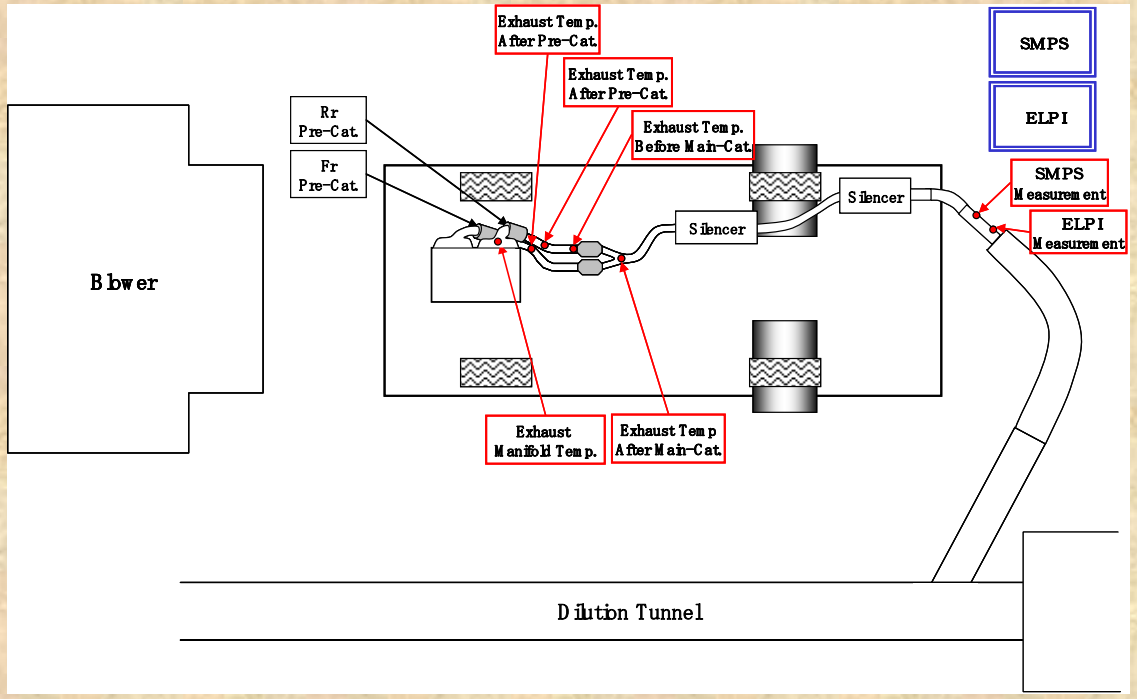
Due to significant reduction of PM from diesel engines, a new PM measurement method for very small amounts of PM is now discussing for future PM regulation such as particle number counting.

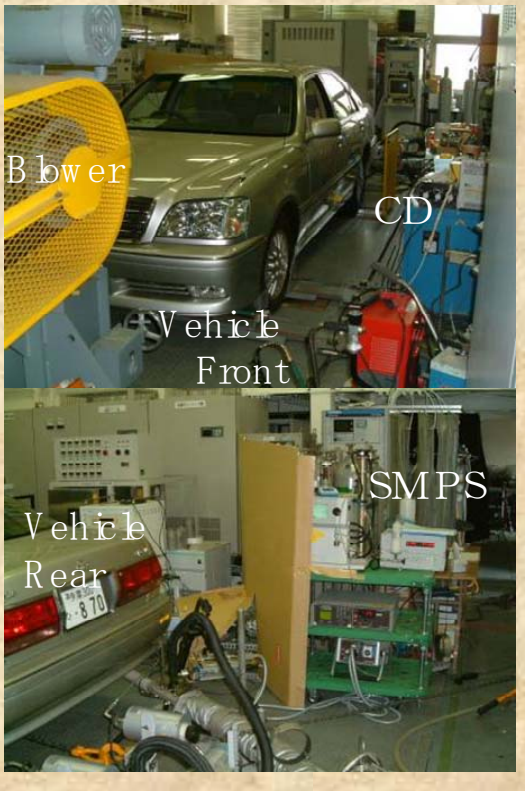
It is one of important issues to investigate the behavior of particle emission from a DI gasoline passenger car that will have the large contribution of particle emission among LD vehicles .

This study shows the emission behavior of fine particles from a DI gasoline passenger car with NOx storage-reduction catalyst on the market.

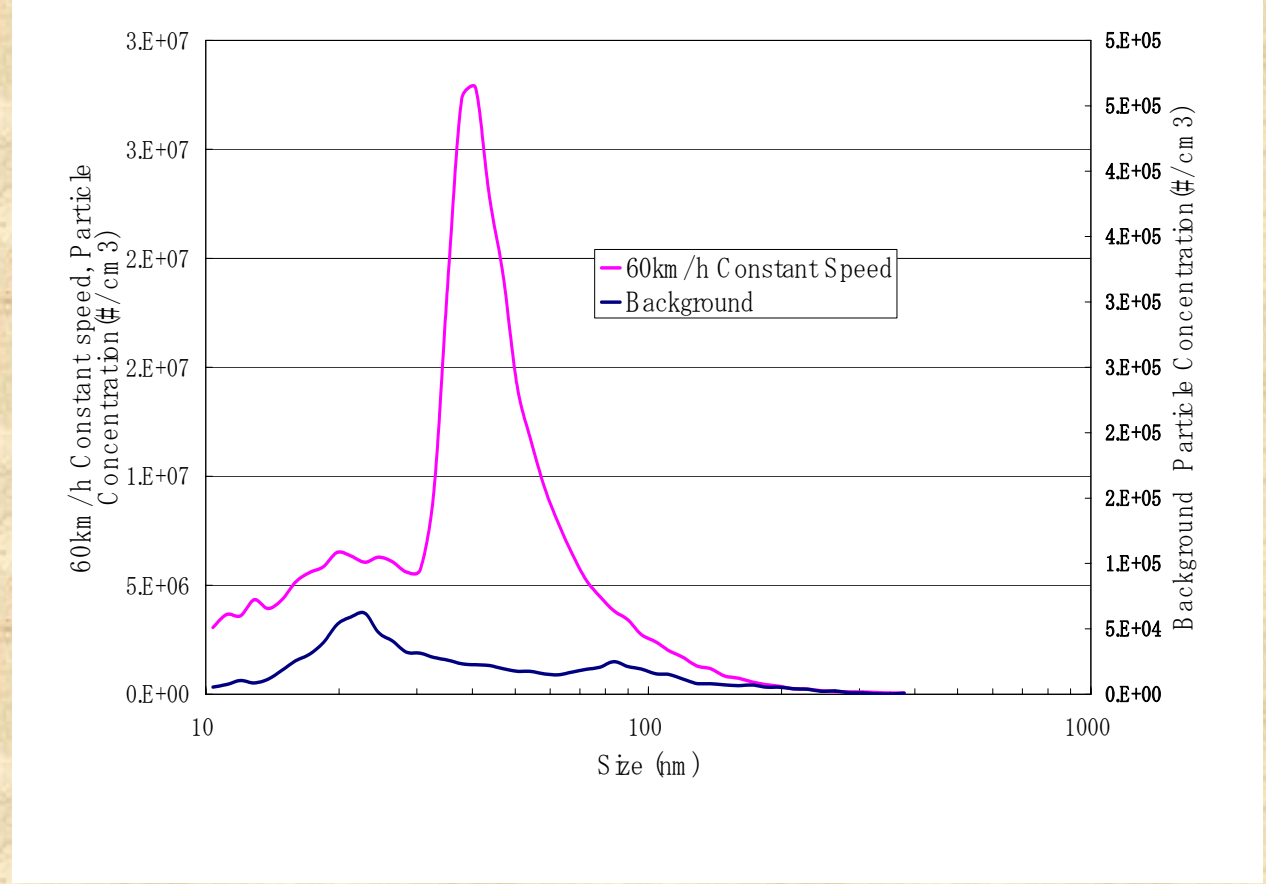
# Test vehicle specification and arrangement for testing

| | |
|---|---|
| Engine tyep | DOHC, 4 valve, 6 cylinders in line |
| Bore×Stroke (mm) | 86.0×86.0 |
| TotalDisplacement (cc) | 2997 |
| Compression ratio | 11.3 |
| Fuelsupply method | Direct injection |
| Maximum output<net> kW (PS))(r/min) | 162 (220) (5,600) |
| Emission controlsystem | TWC+Nox strage-reduction catalyst, EGR |
| Type of fuel | Premium unleaded gasoline |
| 10-15 mode fuelconsumption (km/L) | 11.4 |

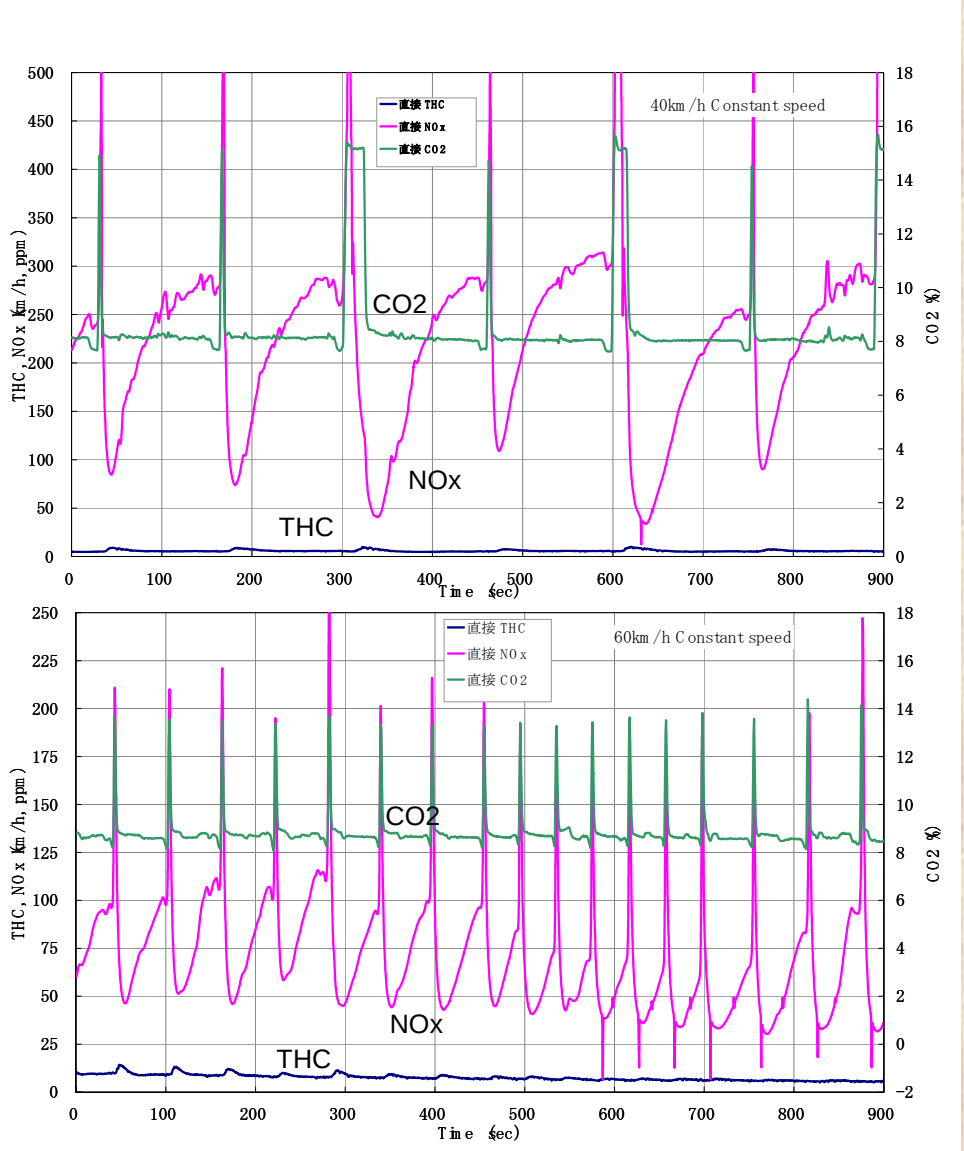


# Particle number distribution in background and 60 km/h constant speed



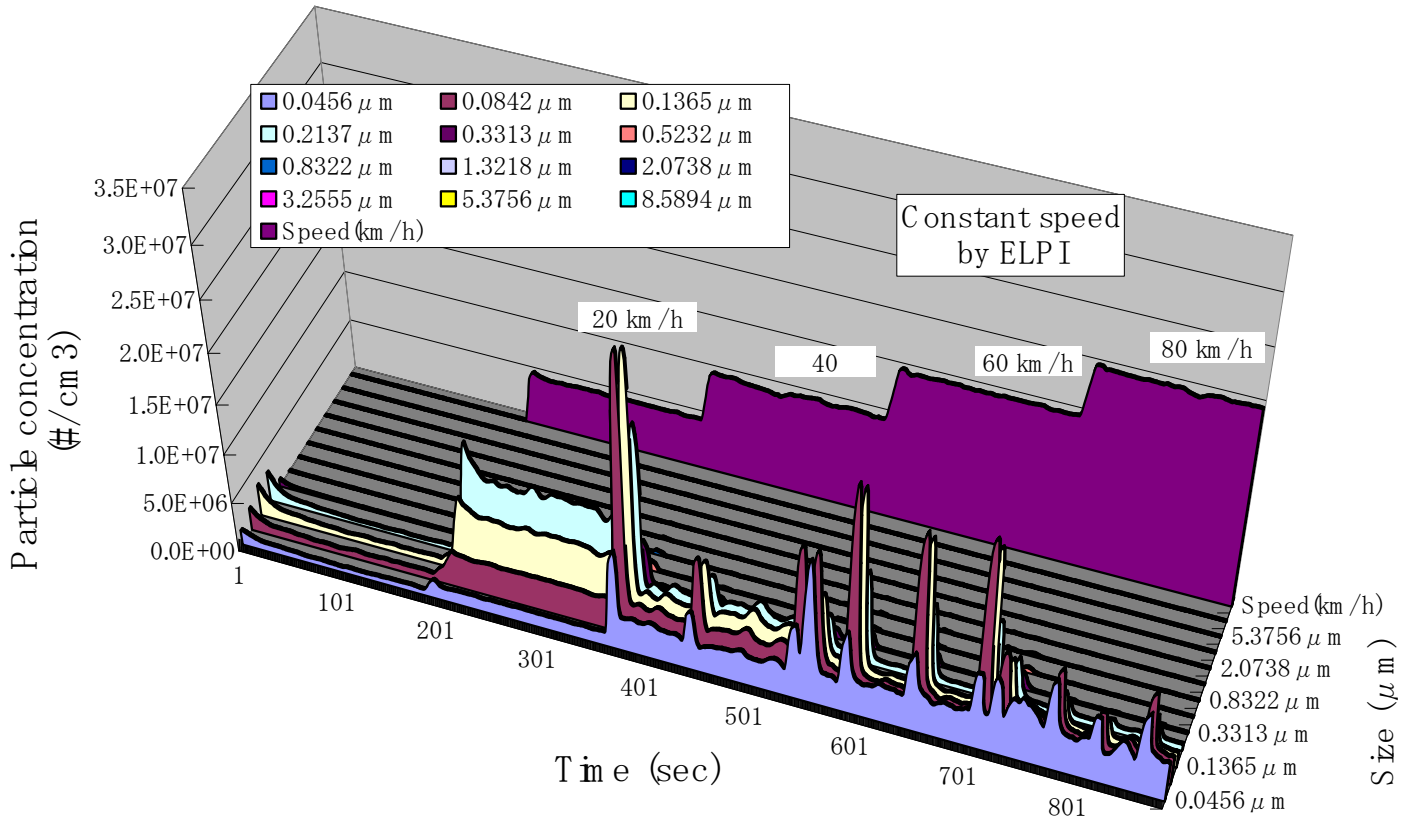
# Exhaust emission characteristics in 40, 60 km/h constant speed condition



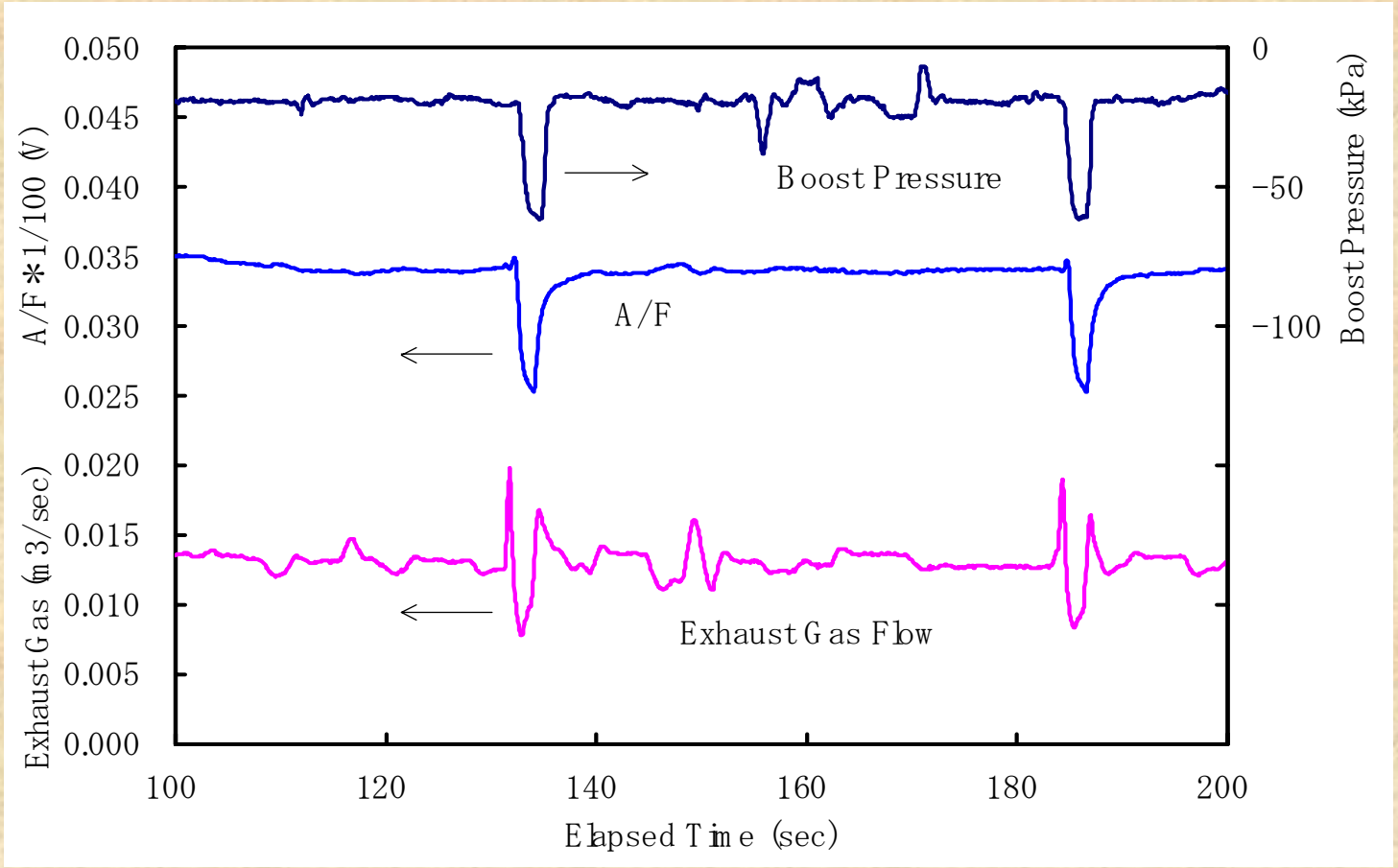
# Exhaust gas, PM emissions in each experiments

| MODE | | 60km/h Const. | 40km/h Const. | 10・15(HOT) | CD34(COLD) |
|---|---|---|---|---|---|
| PM MASS | g/km | 0.0011 | 0.0023 | 0.0184 | 0.0139 |
| CO | g/km | zero | zero | zero | zero |
| HC | g/km | 0.019 | 0.019 | 0.042 | 0.039 |
| NOx | g/km | 0.096 | 0.324 | 0.179 | 0.111 |
| CO2 | g/km | 122.094 | 120.877 | 220.177 | 216.77 |

# Particle number concentration in each constant speed condition by ELPI

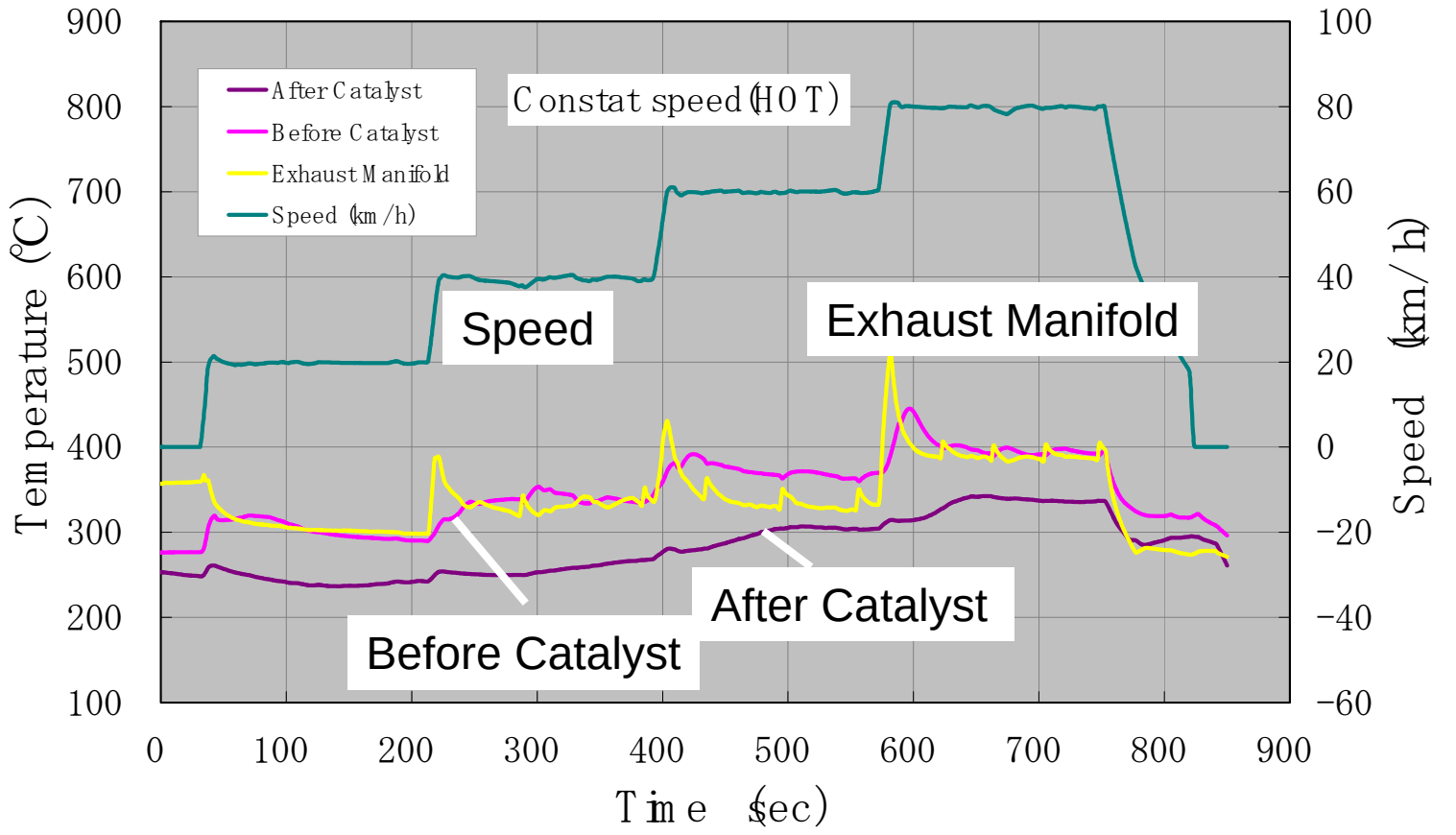


# Throttle valve control at rich spike

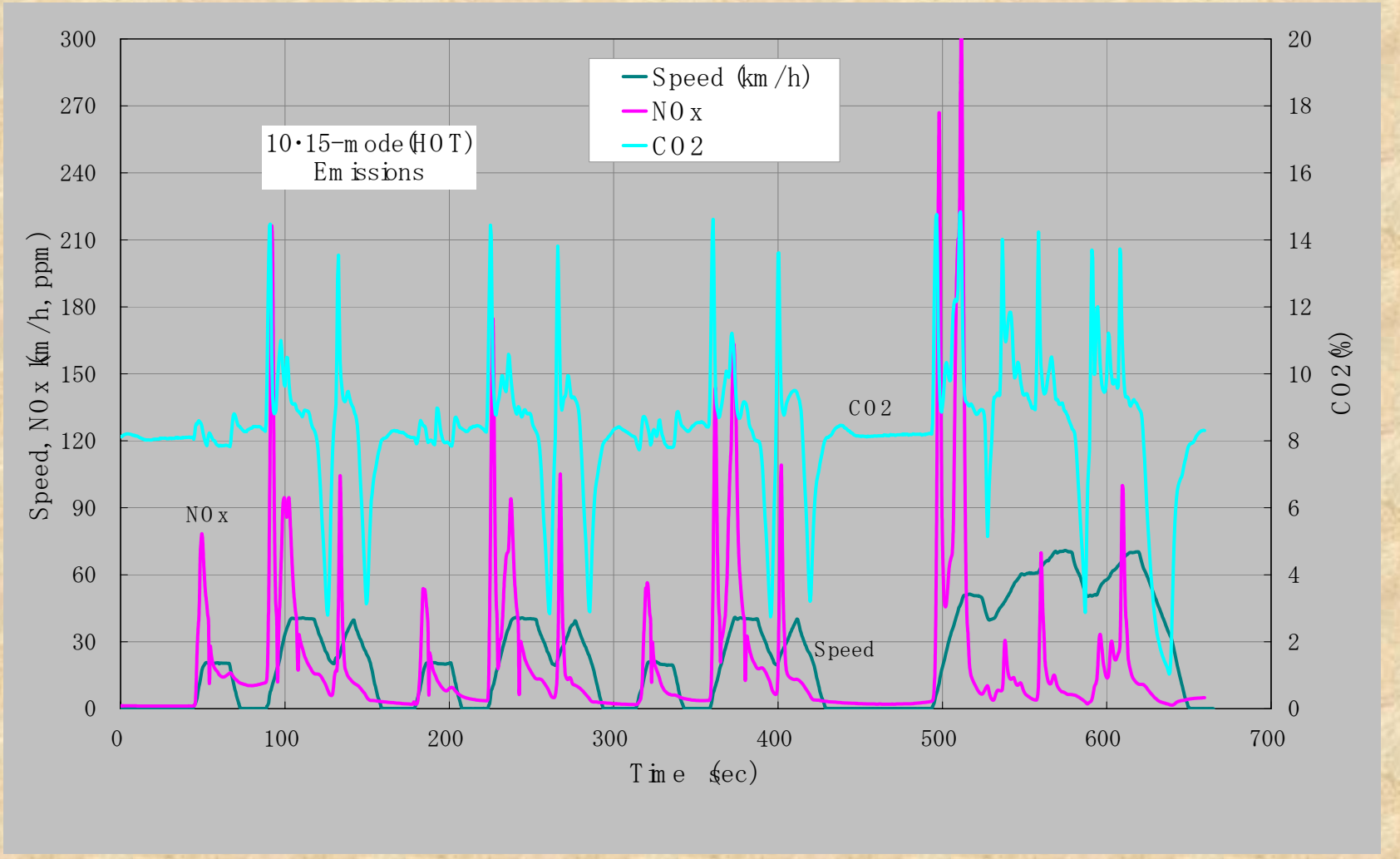



Ref. Yamamoto et.al., JSAE20035114 , 2003

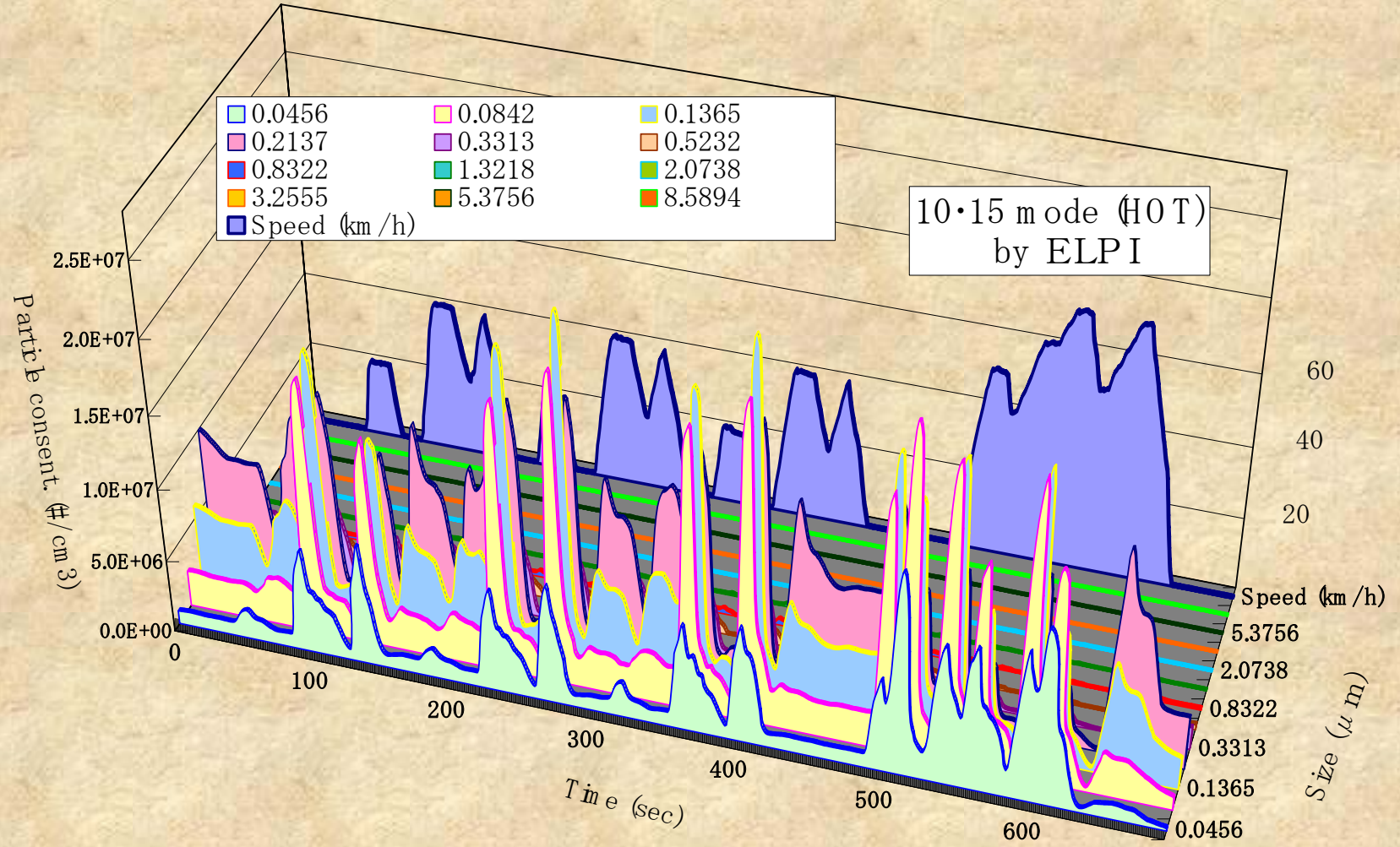
# Exhaust gas temperature in constant speed conditions



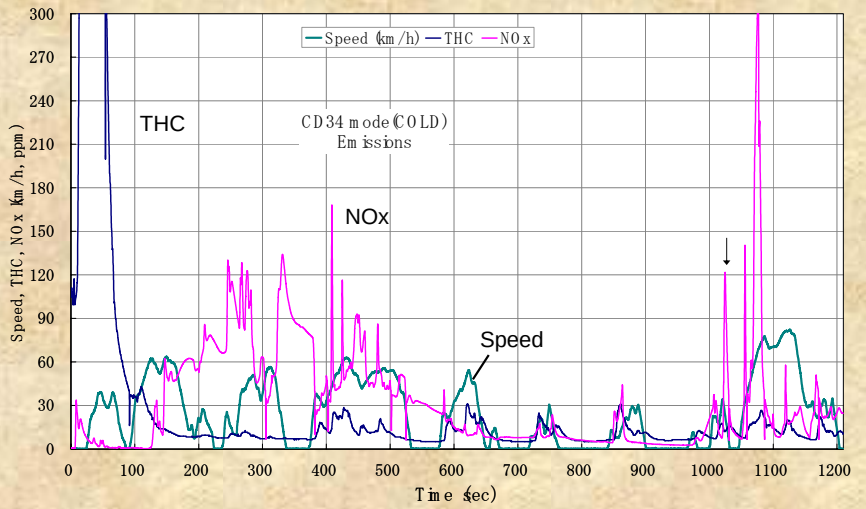
# Exhaust emission characteristics in 10・15 mode at hot start condition



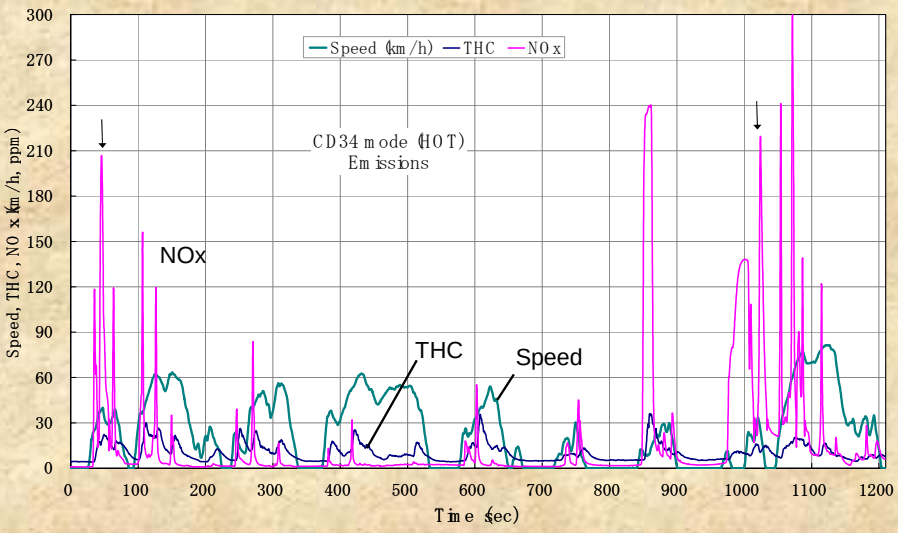
# Particle size distribution in 10・15 mode (HOT) by ELPI



# Exhaust emission characteristics in CD34 mode test at COLD and HOT condition

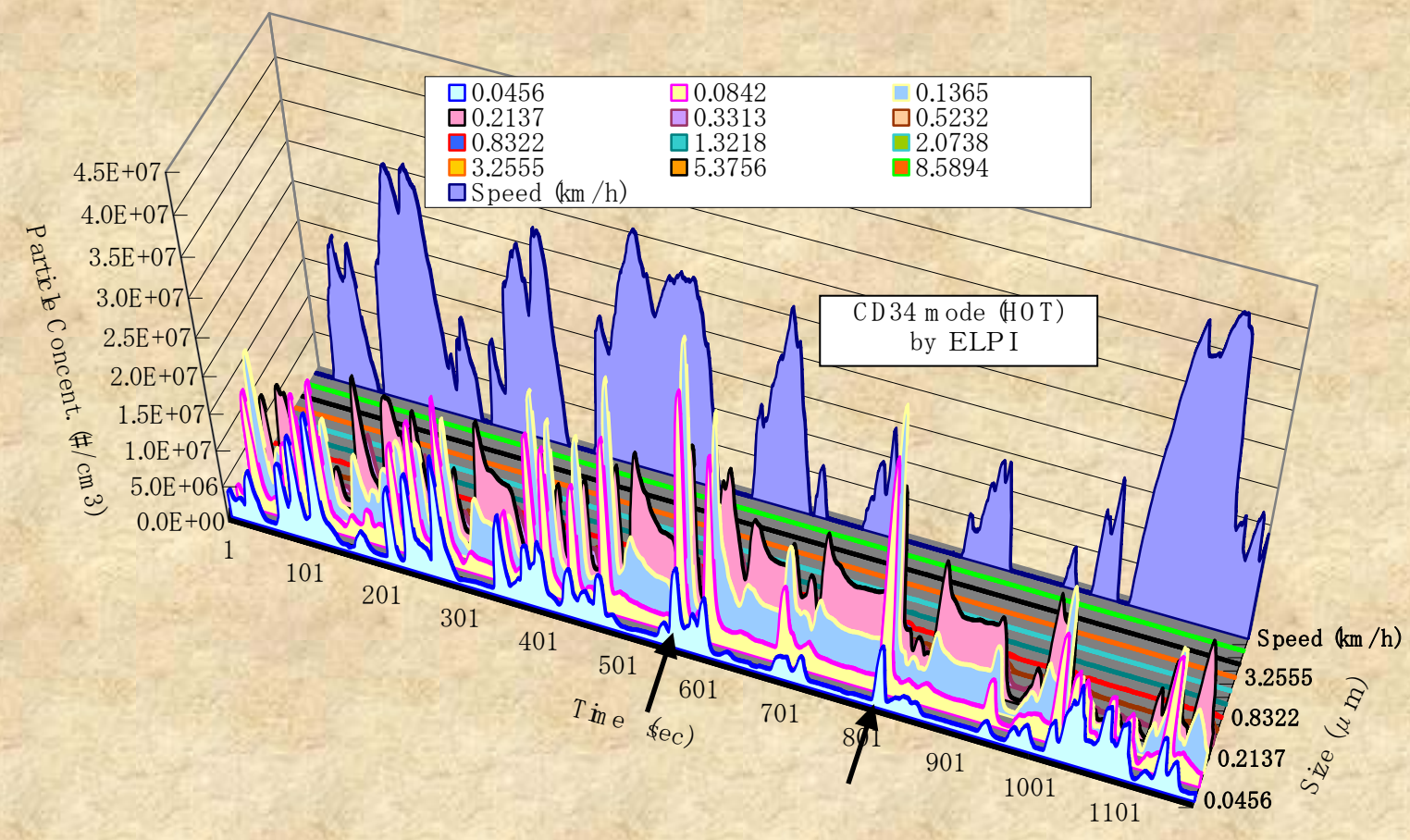



COLD condition




HOT condition

# Particle size distribution in CD34 mode (HOT) by ELPI

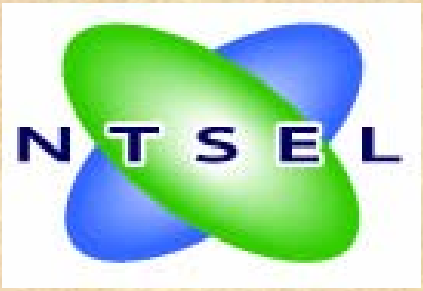


# 4. Conclusions

(1) A DI-gasoline vehicle with NOx storage-reduction catalyst shows spike emissions of particle number concentration periodically in constant speed condition from cause of rich spike of NOx reduction control. These spikes show characteristic phenomena of NOx storage-reduction catalyst system without DPF by rich spikes.

(2) The characteristic of particle number concentration emission shows 84 – 134 nm in acceleration condition and 214 nm in low speed condition except for rich spike regions.

(3) The reduction of spike-like particle emission will became one issue to resolve for a DI gasoline passenger car with NOx storage-reduction catalyst in the near future.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