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Short test cycle for brake wear particle emission measurements

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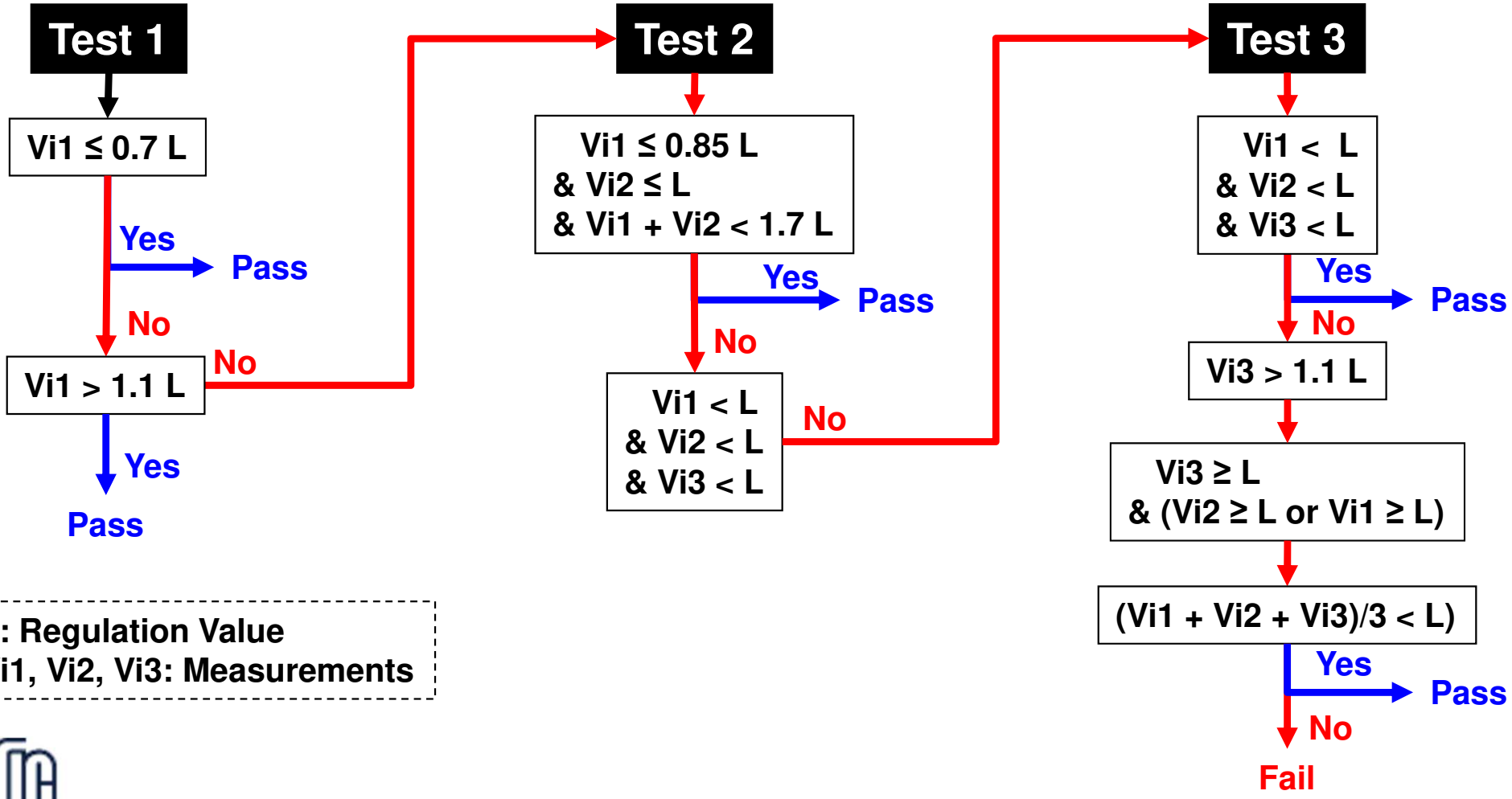
Why is a short brake cycle needed?

- The 4.4h test cycle is very well established and compatible with real consumer driving behavior, including high frequency braking and long driving distances.
- The 4.4h cycle does not cover inter-day reproducibility, and cannot check the drift originating from the shifting sensitivity and background level of the instruments (or matter of concern with saturation of electrometers or crystal microbalances).

【e.g. Regulation Test Process of Emission Measurement】



L: Regulation Value
Vi1, Vi2, Vi3: Measurements

Generation of a short brake cycle

- To evaluate inter-day reproducibility while controlling costs, data from short test cycles are desirable.
- The short trips can be picked up from the original 92 short trips, based on the ranking in one of four average speed bins, the stop interval, and the product of deceleration and brake time.

【Brake cycle (4.4h cycle)】

92 short trips

⇩

Four bins
(Low, Middle, High, Extra High)
average speed,
stop interval,
deceleration * brake time

⇩

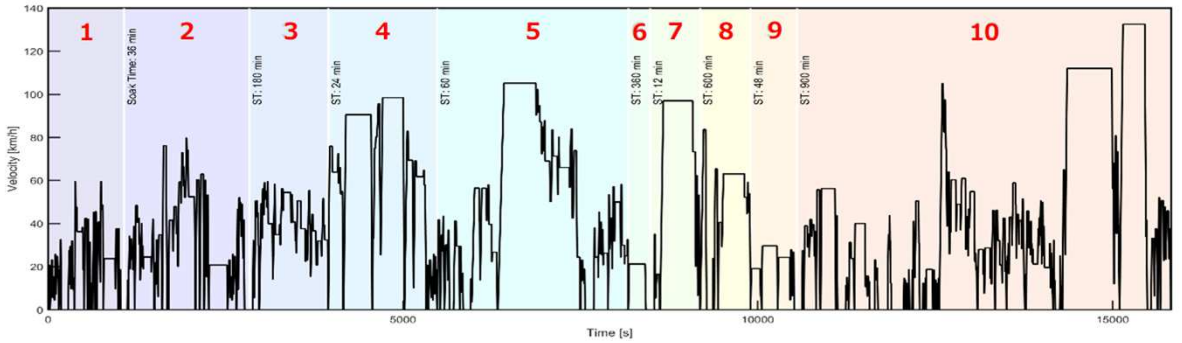
Take the short trips to model short brake cycle

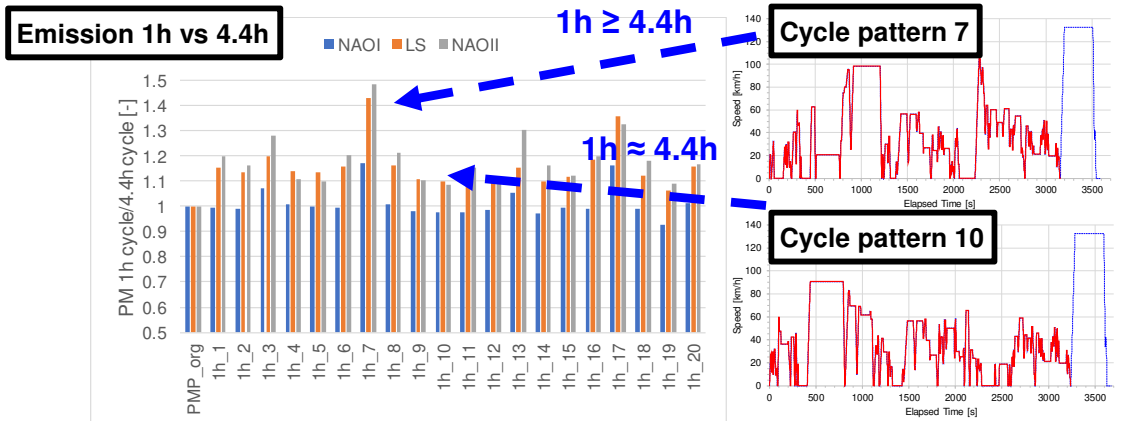
⇩

【 Short brake cycle (1h cycle)】

Comparison of the distributions with original cycle emission levels

Trip	1	2	3	4	5	6	7	8	9	10
Cycle [min]	18	29	19	26	45	5	12	12	11	88
Soak [min]	36	180	24	60	360	12	600	48	900	---



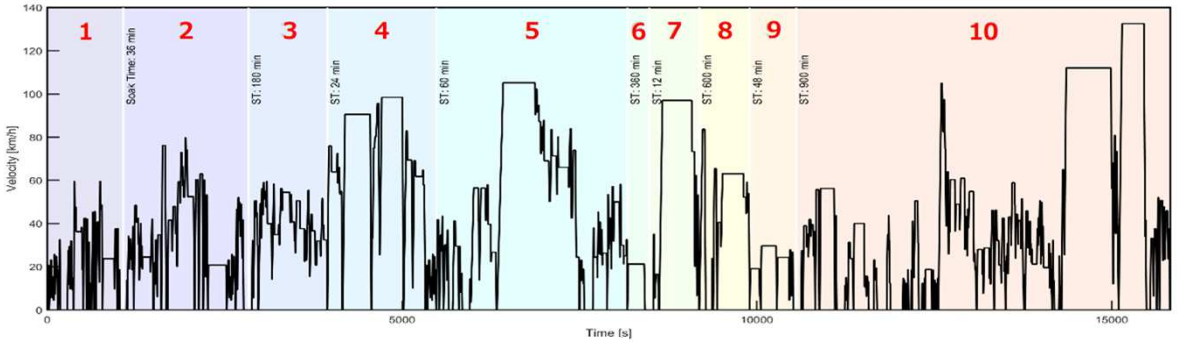


Outline of short brake cycle

- ◆ The short brake cycle (1h cycle) is similar in outline to the original brake cycle (4.4h cycle).
- ◆ Intraday reproducibility test, given soak time for brake cooling, available (e.g. n=3 with 1h soak: 1h test -> 1h soak -> 1h test -> 1h soak -> 1h test)

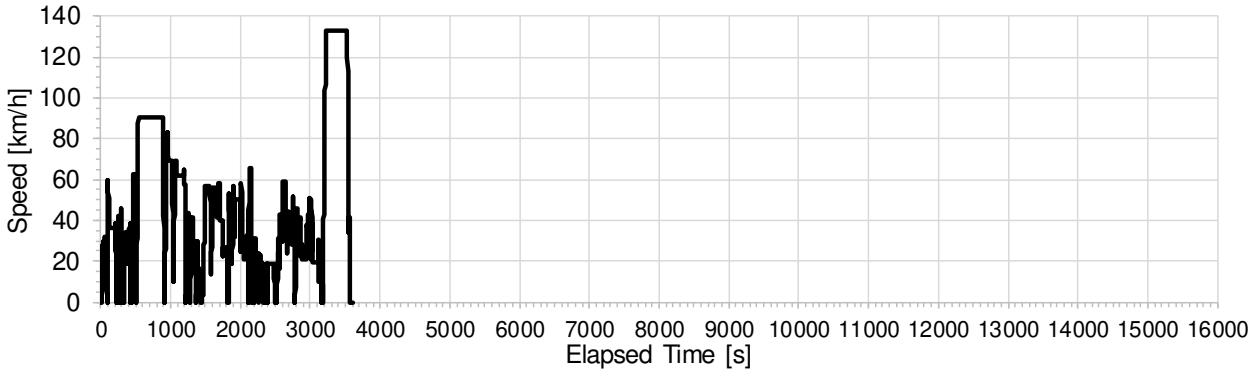
【Original Brake cycle (4.4h cycle)】

Trip	1	2	3	4	5	6	7	8	9	10
Cycle [min]	18	29	19	26	45	5	12	12	11	88
Soak [min]	36	180	24	60	360	12	600	48	900	---



- 4h 24min (4.4h) duration
- Average speed of 44 km/h and maximum speed of 133 km/h
- Deceleration 0.49 – 2.18 m/s² (mean of 0.97 m/s²)

【 Short brake cycle (1h cycle)】



- 1h duration

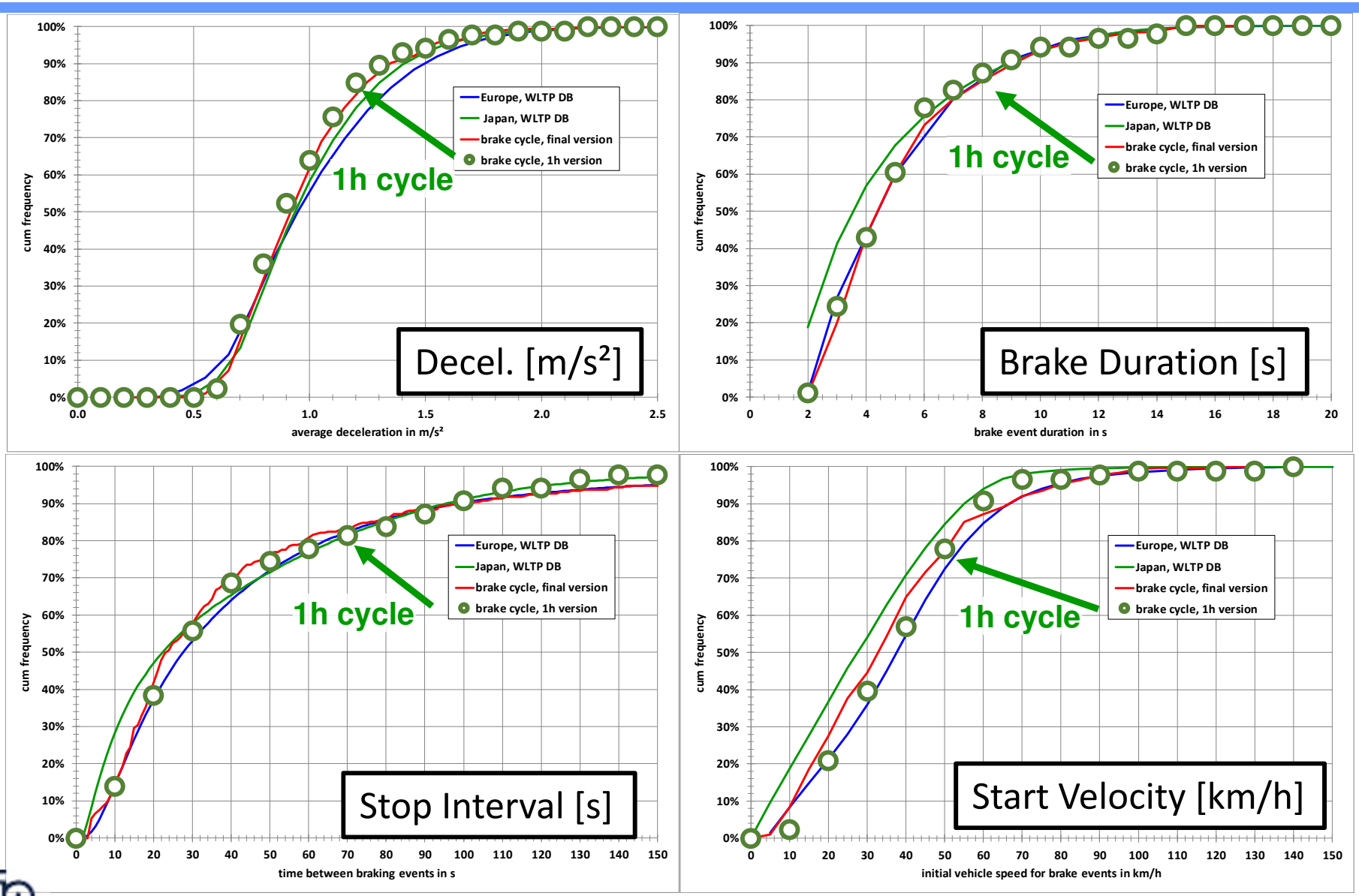
  Average speed of 47 km/h and maximum speed of 133 km/h

  Deceleration 0.53 – 2.18 m/s² (mean of 0.95 m/s²)

Short trip No. (with adjustment idling time for 1h duration):
4, 5, 6, 10, 14, 16, 20, 23, 31, 33, 37, 39, 40, 41, 45, 51, 56, 62, 64, 69, 70, 74, 75, 82, 84, 87, 89

Comparison of the distributions

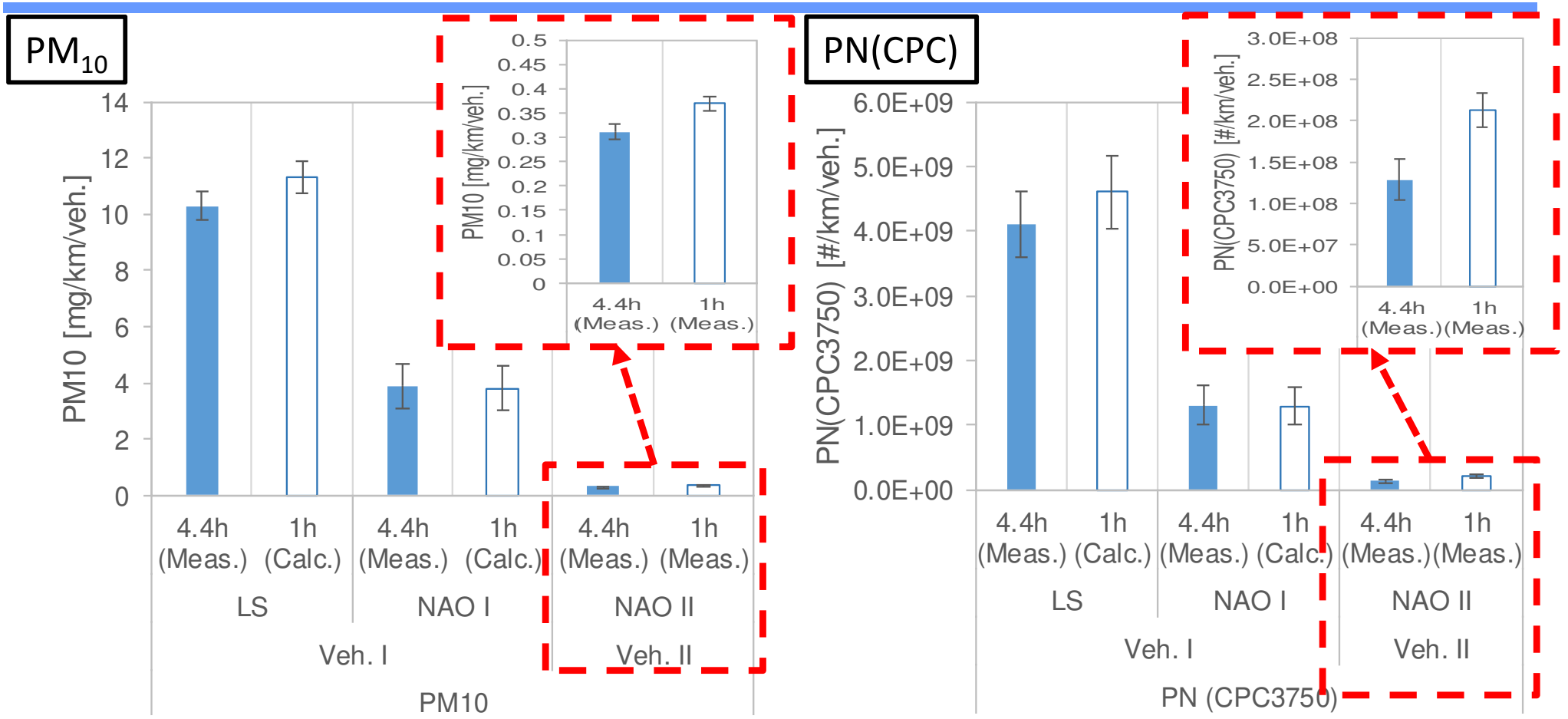
◆ **The newly generated 1h short cycle shows a good fit for the parameter distributions of the 4.4h long brake cycle and driving behavior database.**



Acknowledgment : Data from Heinz Steven (50th PMP meeting presentation)

Comparison of emission levels

- Emission levels of the original cycle were well represented by the short cycle.
- Inter-day reproducibility: ~7% of PM_{10} and ~13% of PN (CPC) for 1h cycle (n=3).
- Intra-day reproducibility: 7 % of PM_{10} and 5 % of PN (CPC) for 1h cycle (n=3),
  5 % of PM_{10} and 7 % PN (CPC) for 4.4h cycle (n=3).
  @ 0.4 mg/km/veh. and $2x10^8$ #/km/veh. of emission levels.



Calc.: Estimation from short trip data during 4.4h cycle measurement
Short trip No.: 4, 5, 6, 10, 14, 16, 20, 23, 31, 33, 37, 39, 40, 41, 45, 51, 56, 62, 64, 69, 70, 74, 75, 82, 84, 87, 89

Conclusions & Next Steps

Conclusions:

- **The 1h short brake cycle can replicate the PN and PM emission levels and driving behavior of the original 4.4h brake cycle.**
- **The short cycle makes data on inter-day reproducibility available, and can be compared to the intra-day reproducibility of the original cycle.**
- **There would be no need for long time and driving distance cycles to minimize variation.**
- **The short cycle can evaluate intraday reproducibility, given enough soak time to cool the brake systems.**

Next Steps:

- **In order to check the robustness of the 1h cycle's value as a representative test, further investigation is required, using different vehicle types and friction materials.**