SAMPLING AUTOMOTIVE EXHAUST WITH DILUTION AND/OR ADSORPTION OF VOLATILE SPECIES

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Presented by Juha Tikkanen
Dekati Ltd.

Presentation outline

- Objectives
- Measurement setup
- Result of instrument testing
- Corrections for instruments
- Final results
- Conclusions

Objectives

- Searching for nucleation tendency
- Comparison of instrument performance with soot and volatile hydrocarbon laden exhaust
- Validation of loss correction methods

Professor David Kittelson, Minnesota University: Truck exhaust plume measurement

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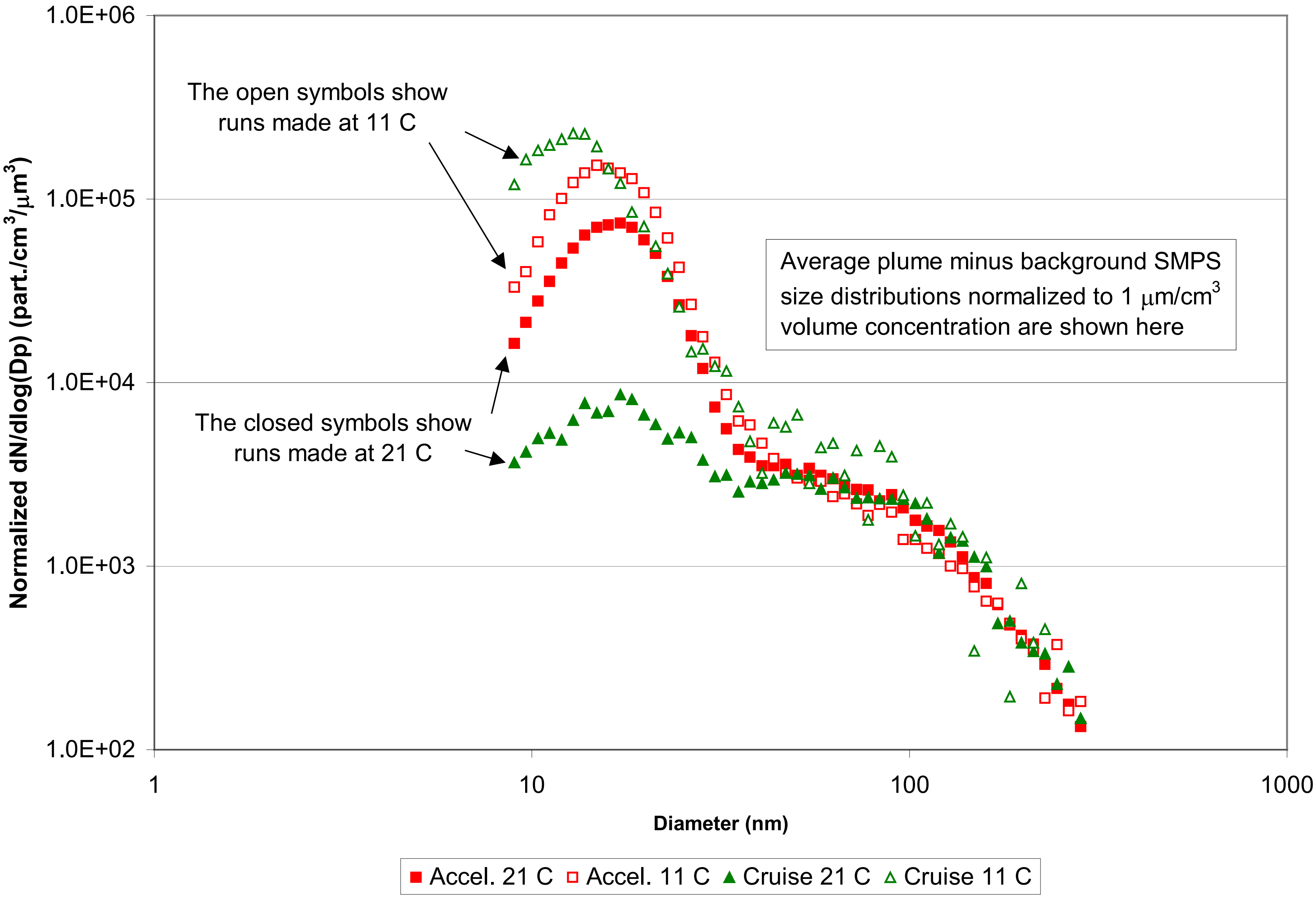
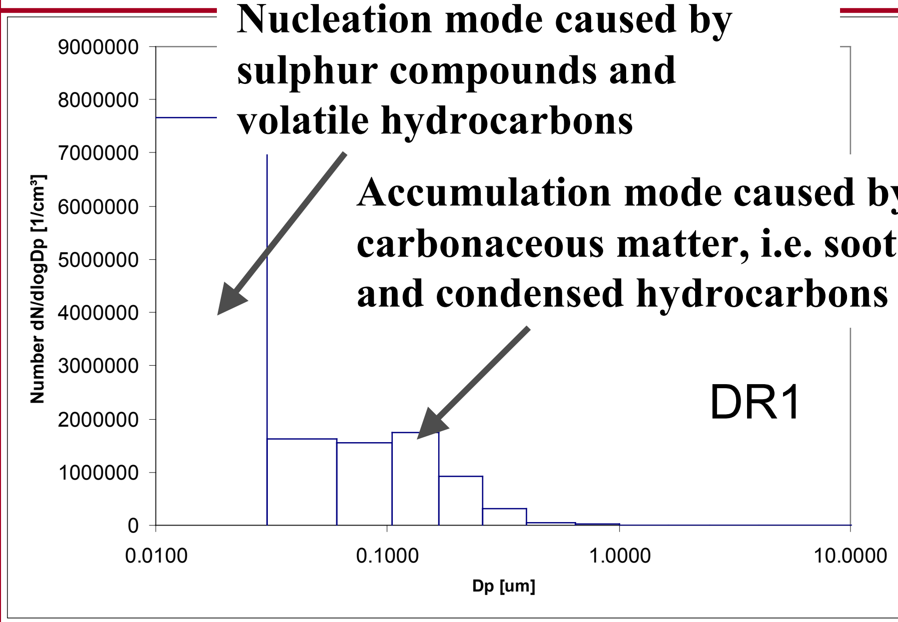
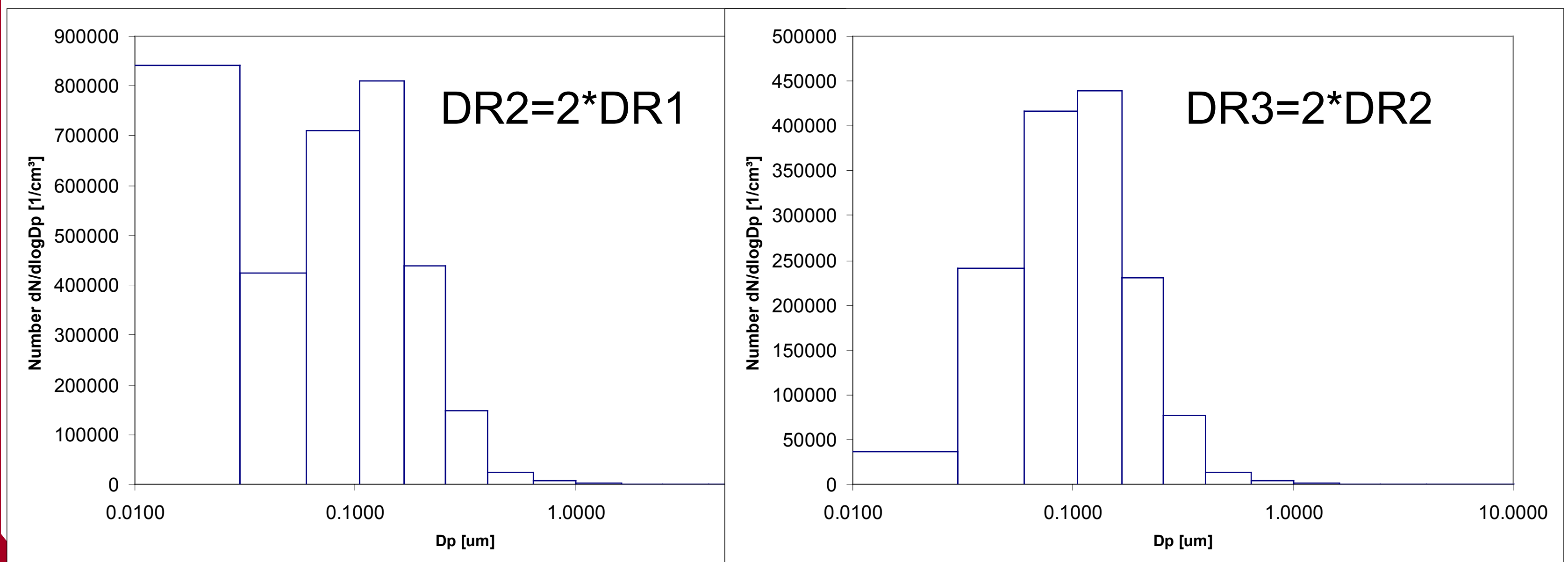


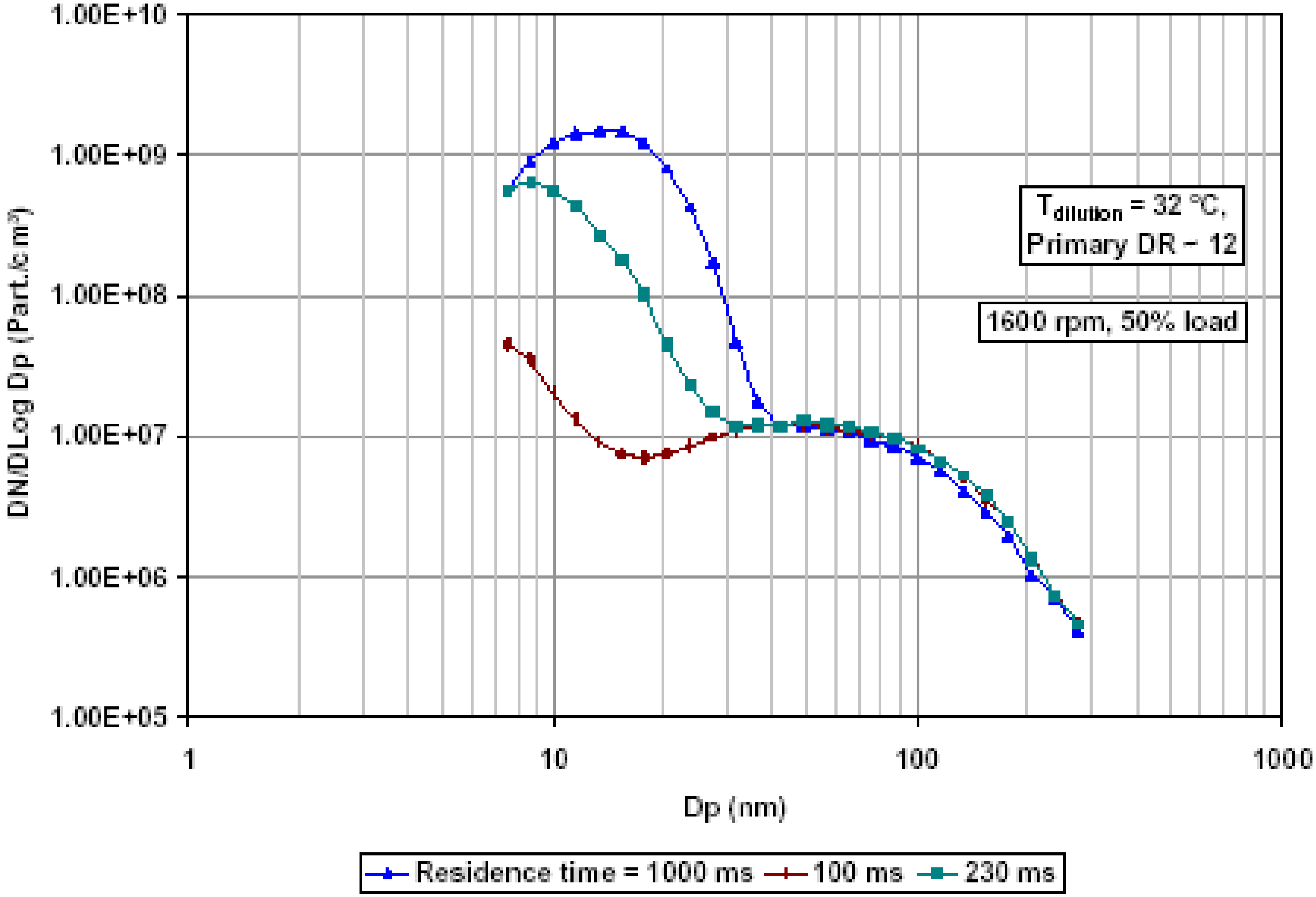
Effect of dilution ratio



- ❖ Diesel exhaust
- ❖ Dilution air 22°C, residence time 1.5s



Effect of sample residence time



Presented by Professor Kittelson / University of Minnesota

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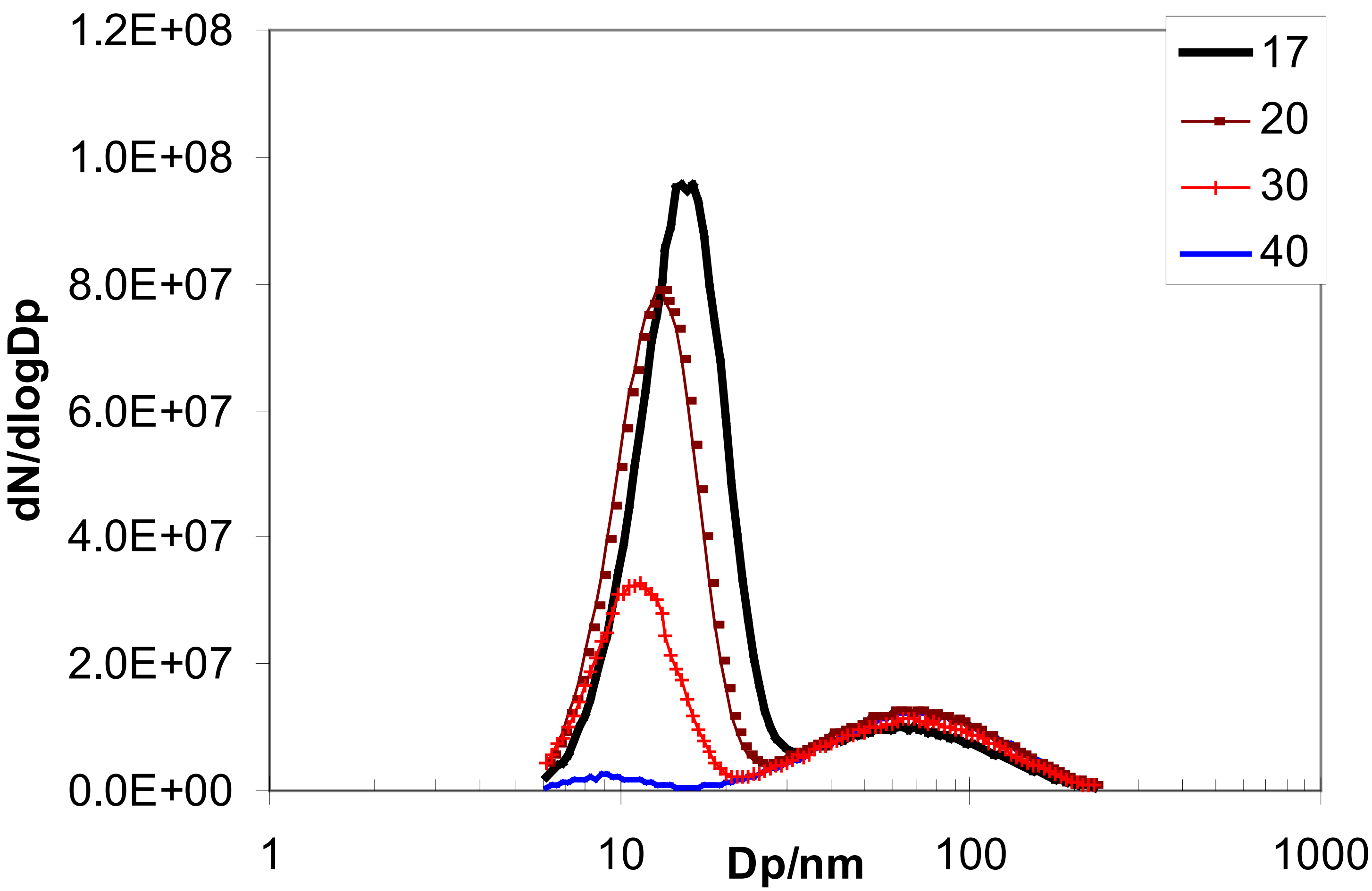
The effect of dilution air temperature



Courtesy of J. Ristimäki / Tampere University of Technology
DG TREN Particulates-programme

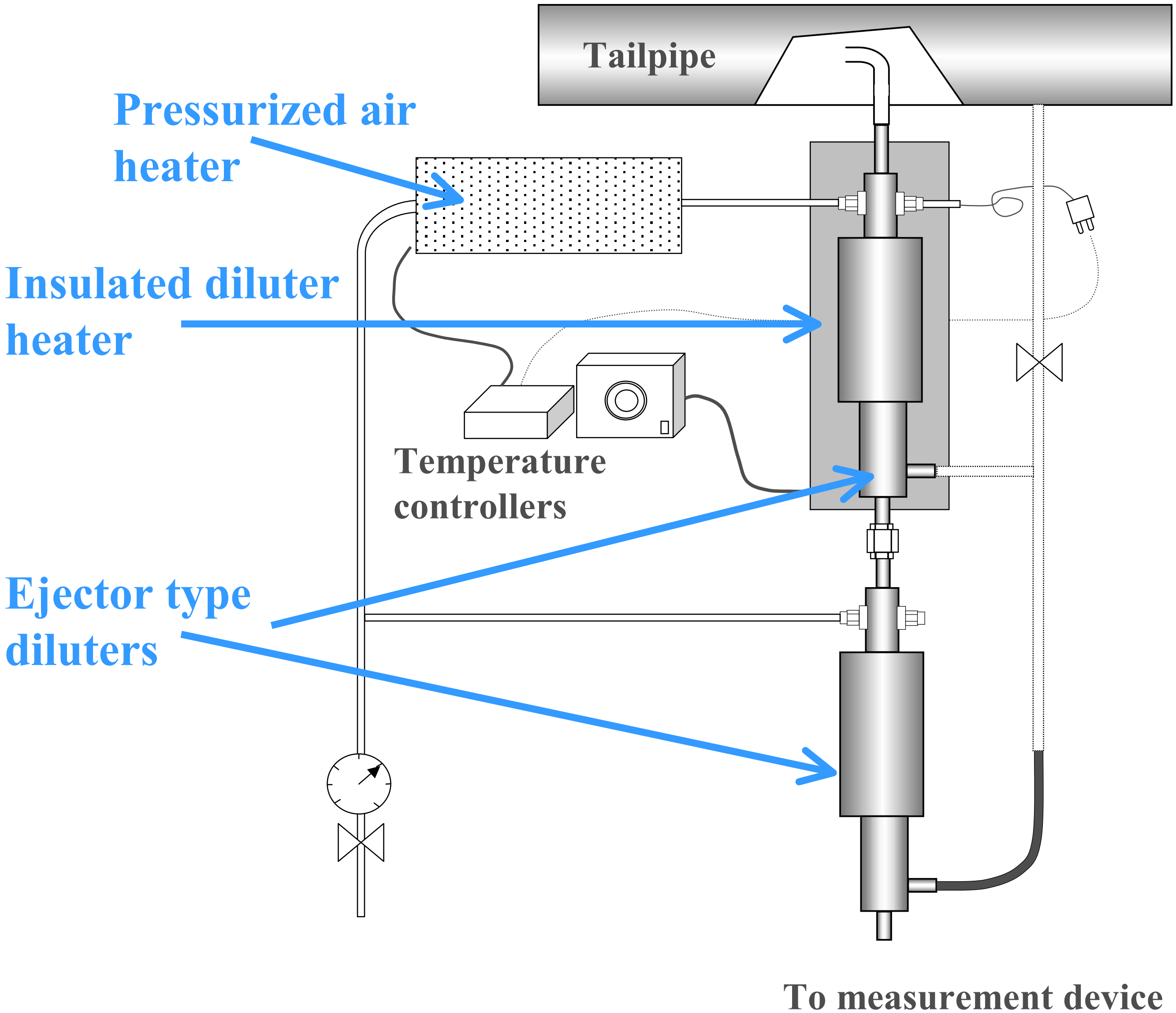
Instruments tested

Dekati Double Diluter (DD)

Dekati Thermodenuder (TD)

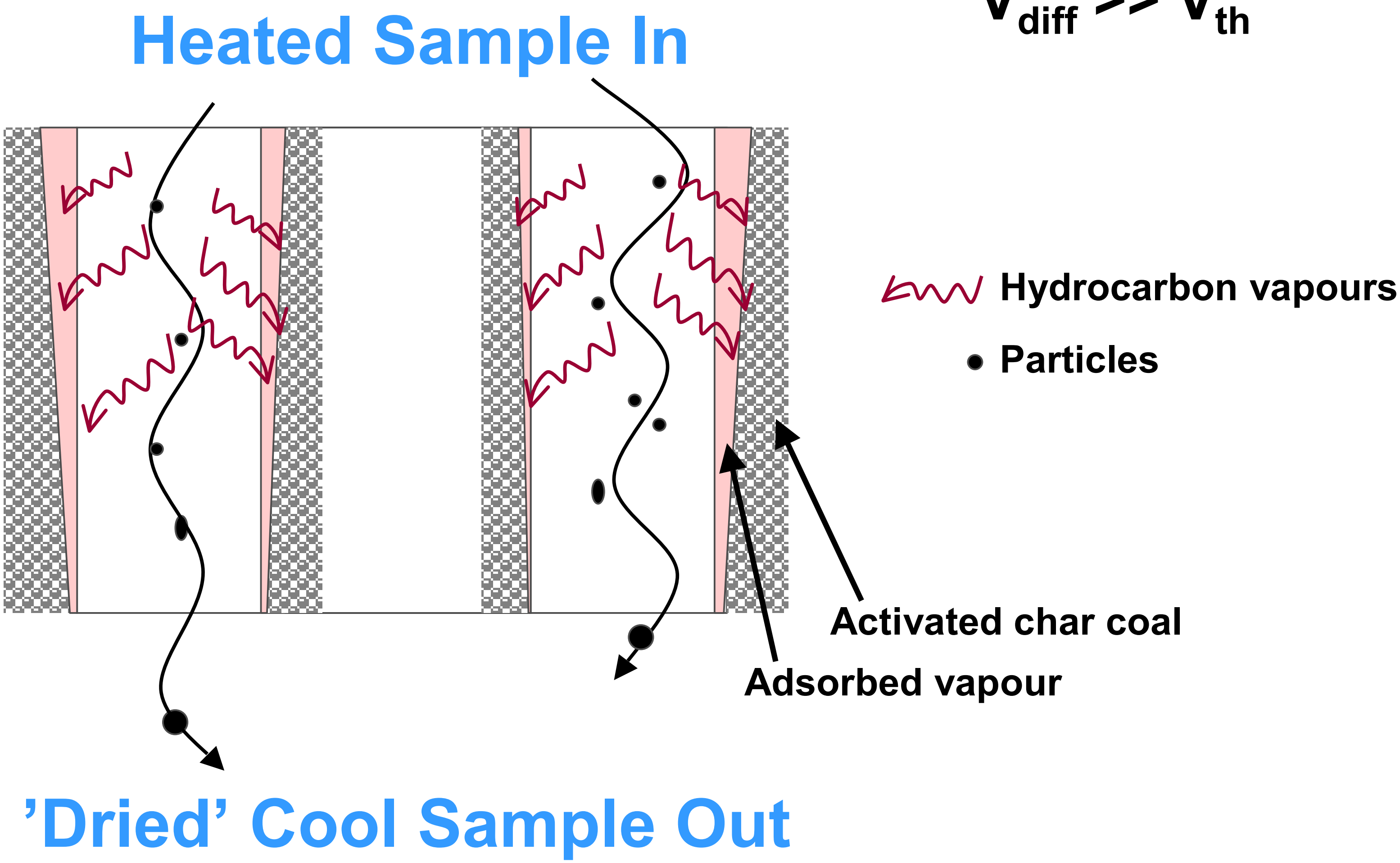
Dekati Fine Particle Sampler (FPS)

Dekati double diluter setup DI-2000



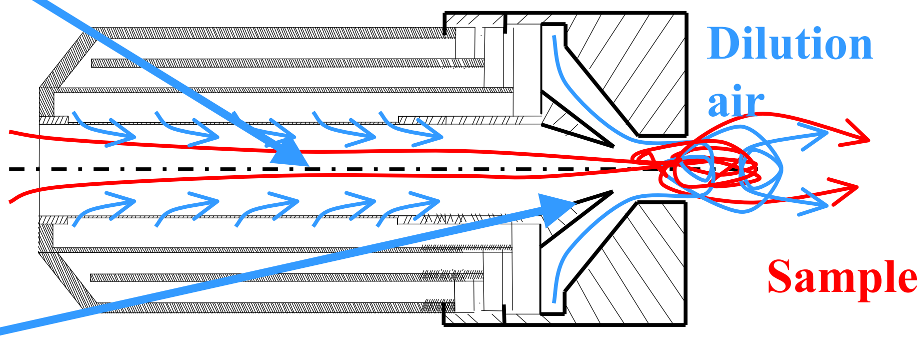
Dekati Thermodenuder

$$V_{diff,\ vapour} >> V_{diff,particle}$$
$$V_{diff} >> V_{th}$$



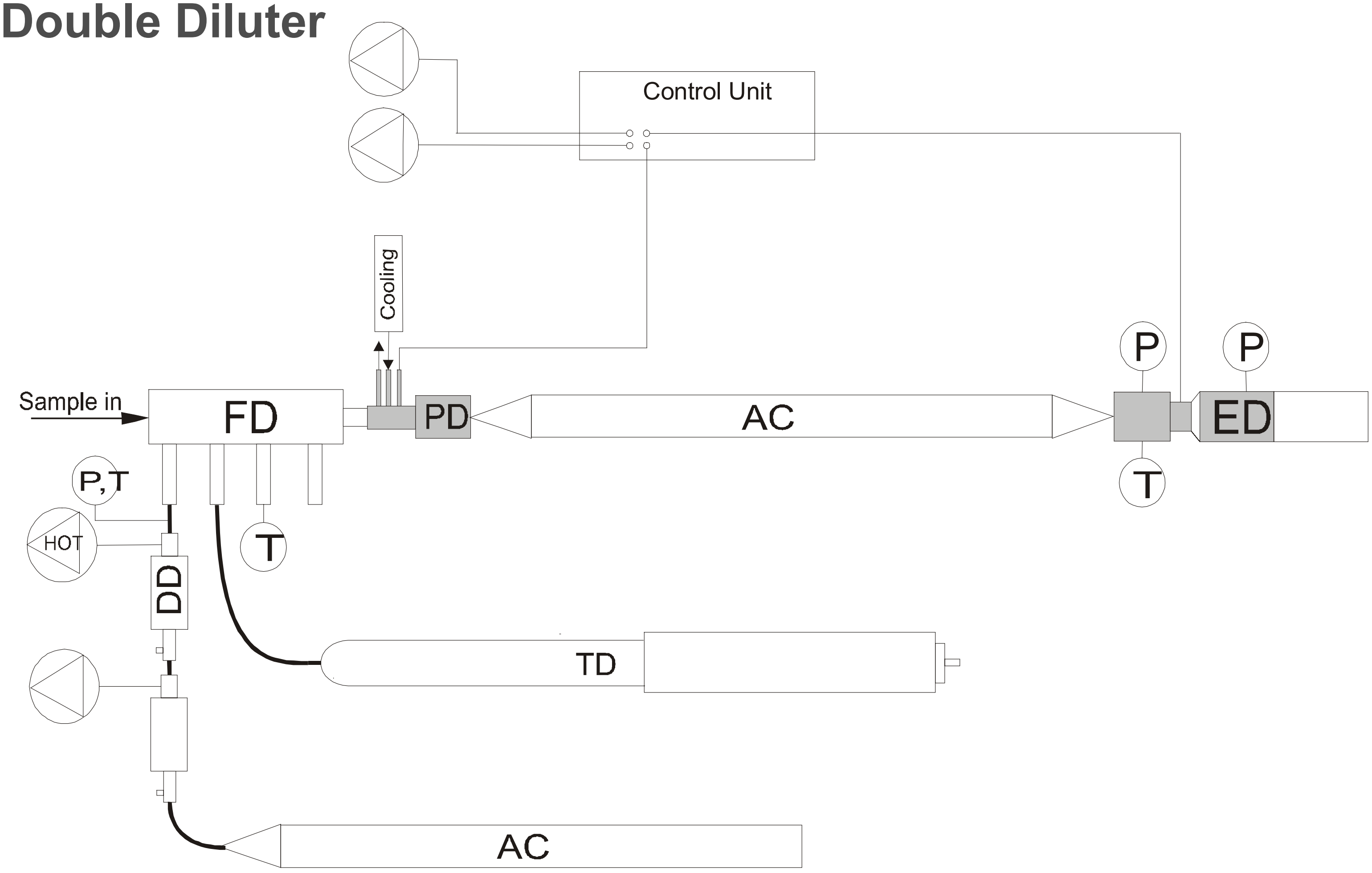
Dekati Fine Particle Sampler

- Porous tube:
  - Less losses
  - Controlled mixing
  - Hot/cold dilution
- Ejector
  - Pump
  - Further dilution
- Combined
  - Possibility for continuous DR adjustment
  - Less losses to ejector



Testing setup

FD Flow divider
AC Ageing Chamber
TD Thermodenuder
DD Double Diluter
PD Primary Diluter (FPS)
ED Ejector Diluter (FPS)
P,T Pressure, Temperature recording



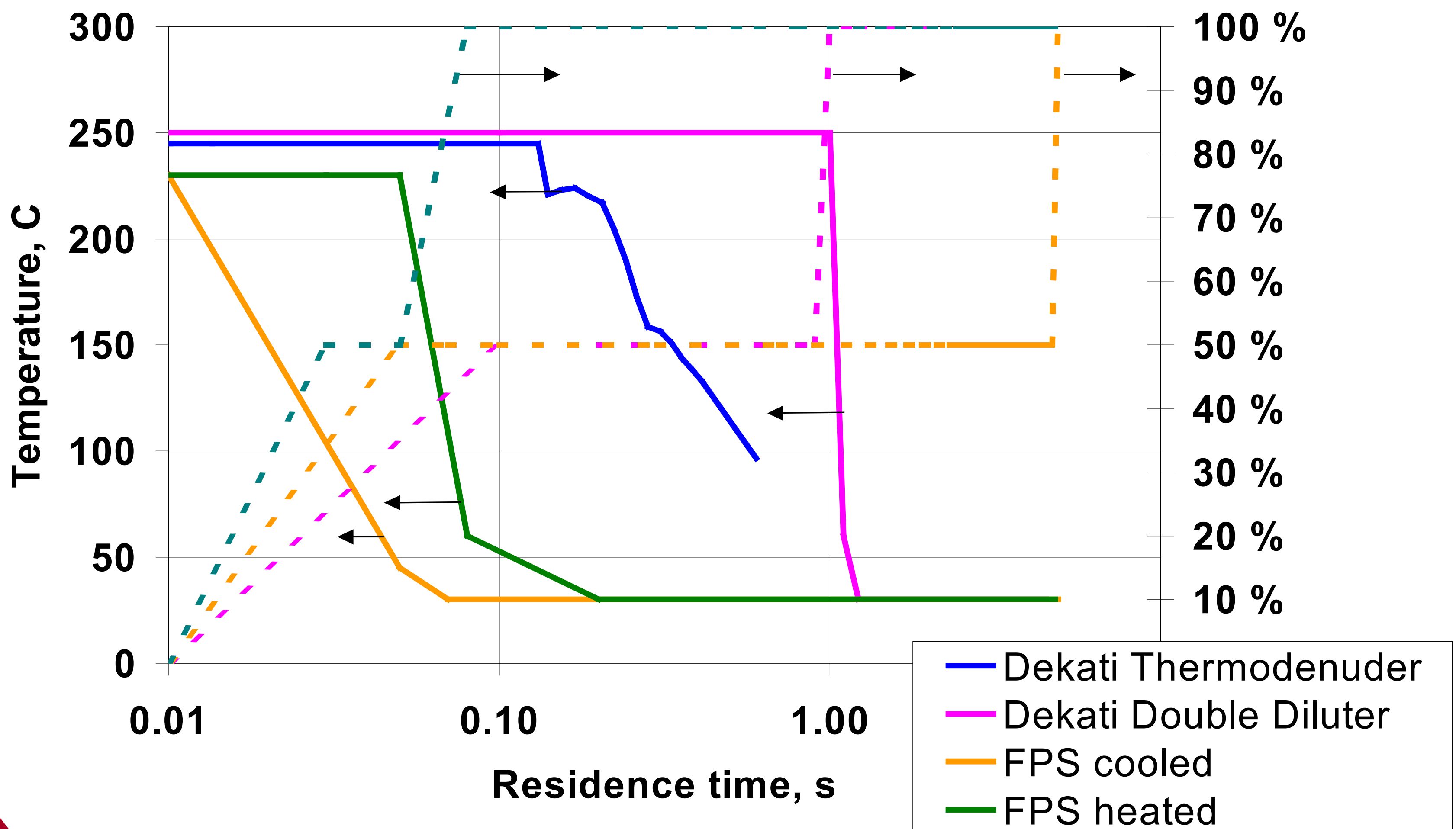
Sampling parameters

		DD	TD	FPS
Primary dilution ratio	-	6	-	11 / 13*
Secondary dilution ratio	-	16	-	9 / 9*
Primary dilution air temperature	°C	250	-	23 ± 4 230
Secondary dilution air temperature	°C	ambient	-	ambient
Heater temperature	°C	-	250	-
Ageing chamber	-	+	-	+
Residence time	s	4.5	1	4.9

*estimated dilution ratio

Temperature gradients

- Measured or Approximated temperature gradients within instruments (solid lines)
- Amount of dilution air added (dashed lines)



Corrections for results

❖ DD correction

- depends on particle size, but can be approximated with 5 % for particles < 1 µm

❖ TD particle penetration

- depends on particle size according to equation:

$$1-\eta = -9.7 \cdot \ln(D_p) - 0.5 \cdot Q + 68,\ D_p \langle\ 70\ nm$$

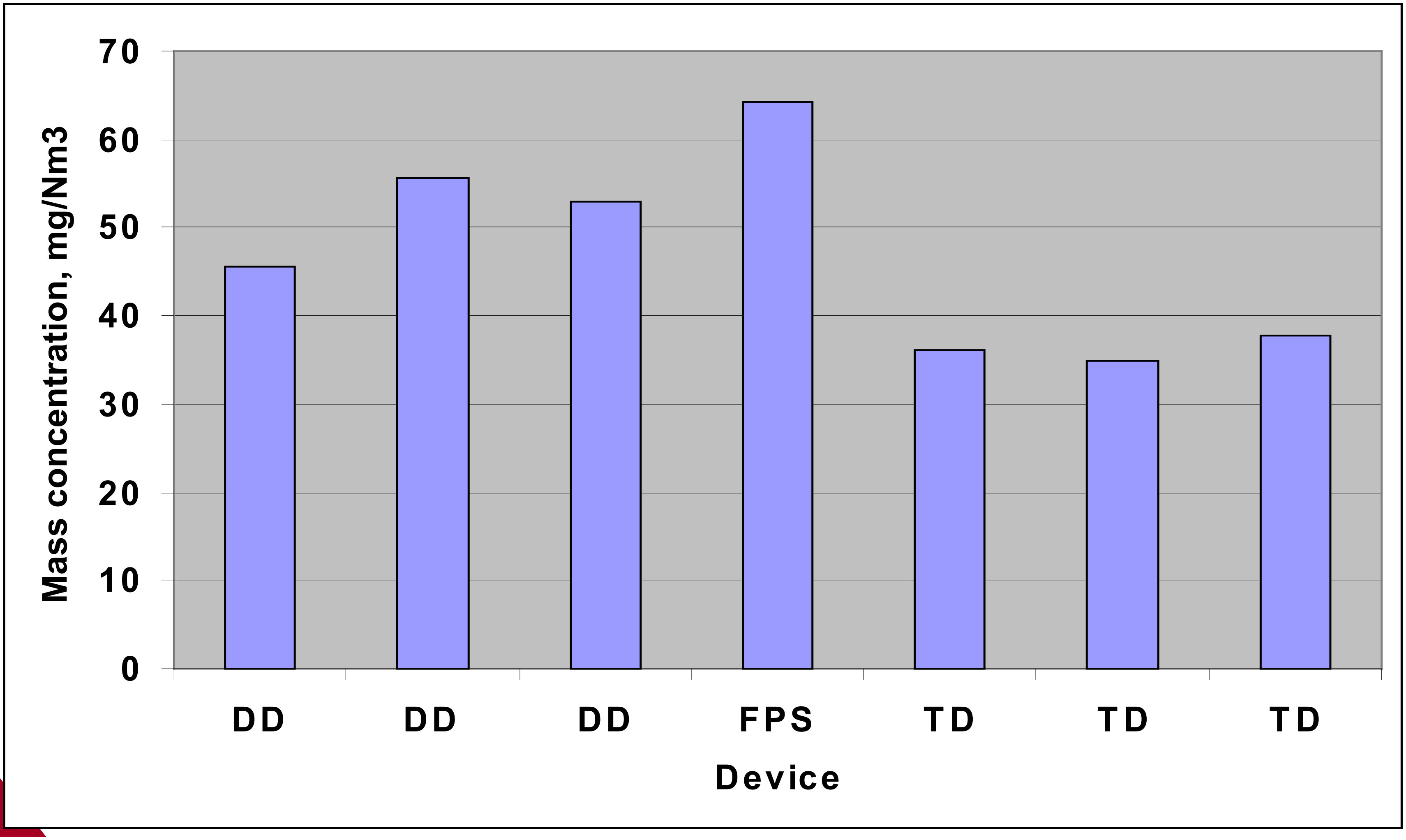
$$1-\eta = -0.5 \cdot Q + 28,\ 70\ nm \le D_p \le 500\ nm$$

- for mass correction 21 % at 15 lpm applied

❖ FPS correction under determination

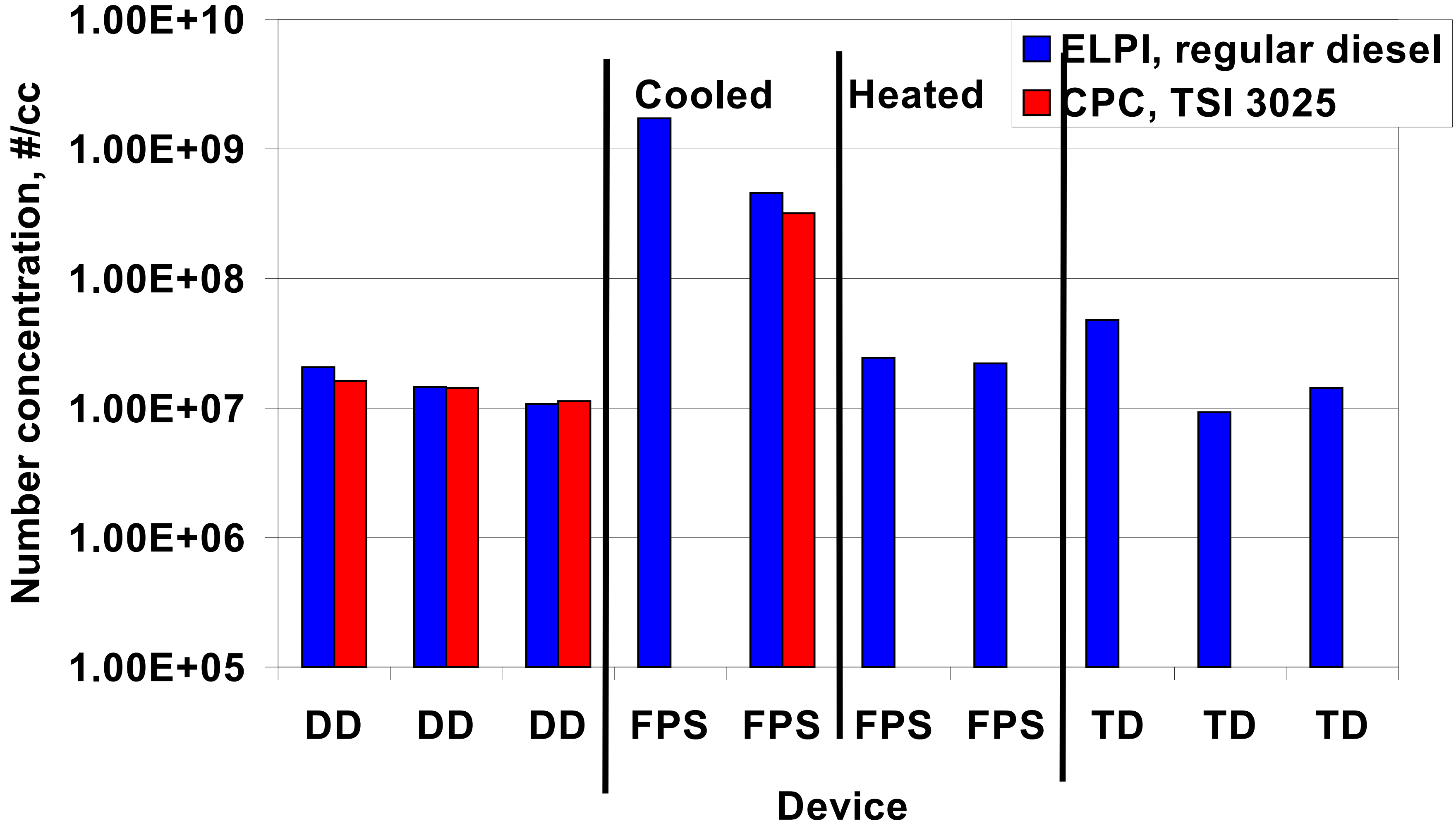
Mass concentration results

- DD and TD results corrected for losses
- Effect of volatiles clearly seen

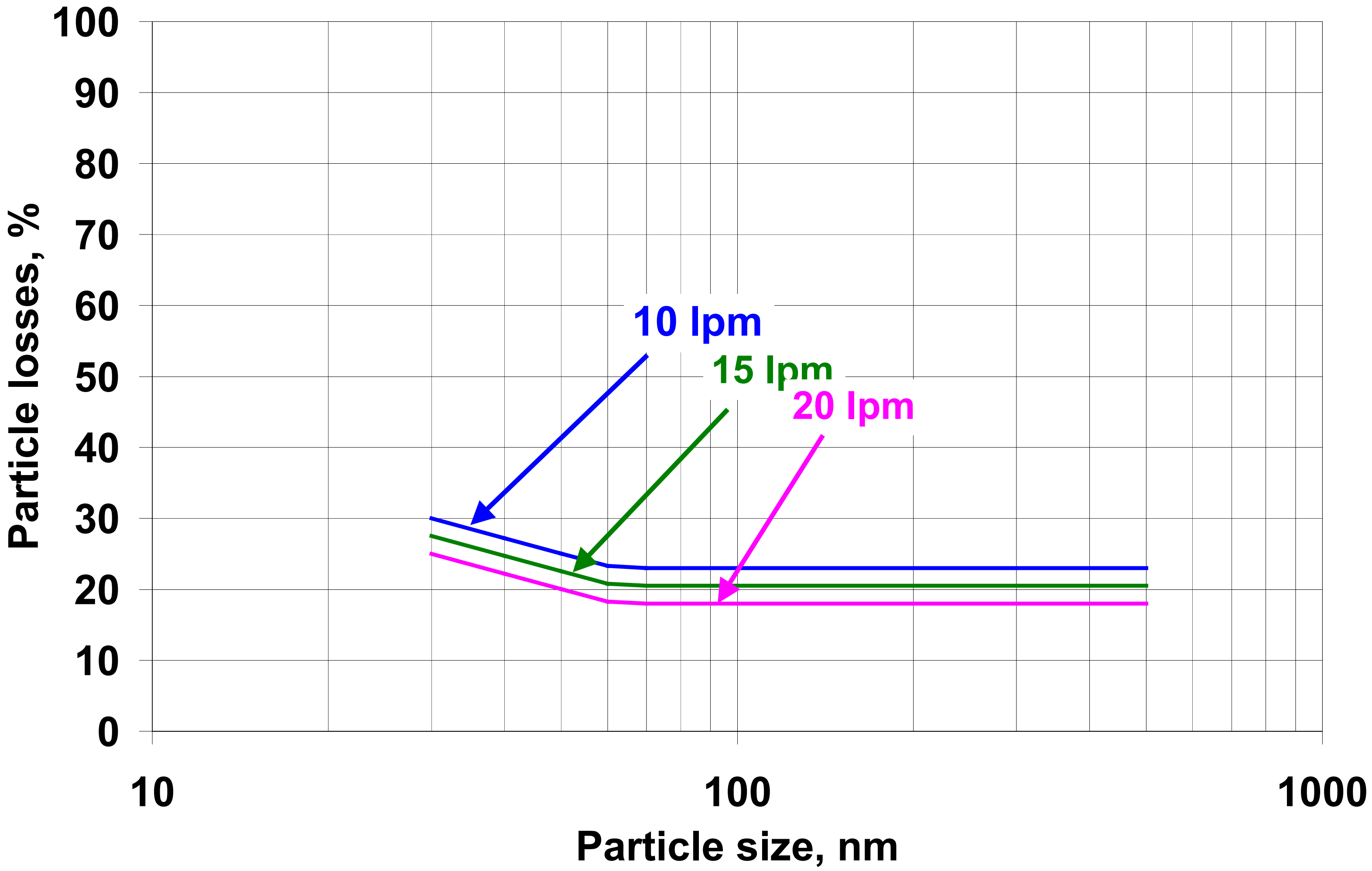


Number concentration results

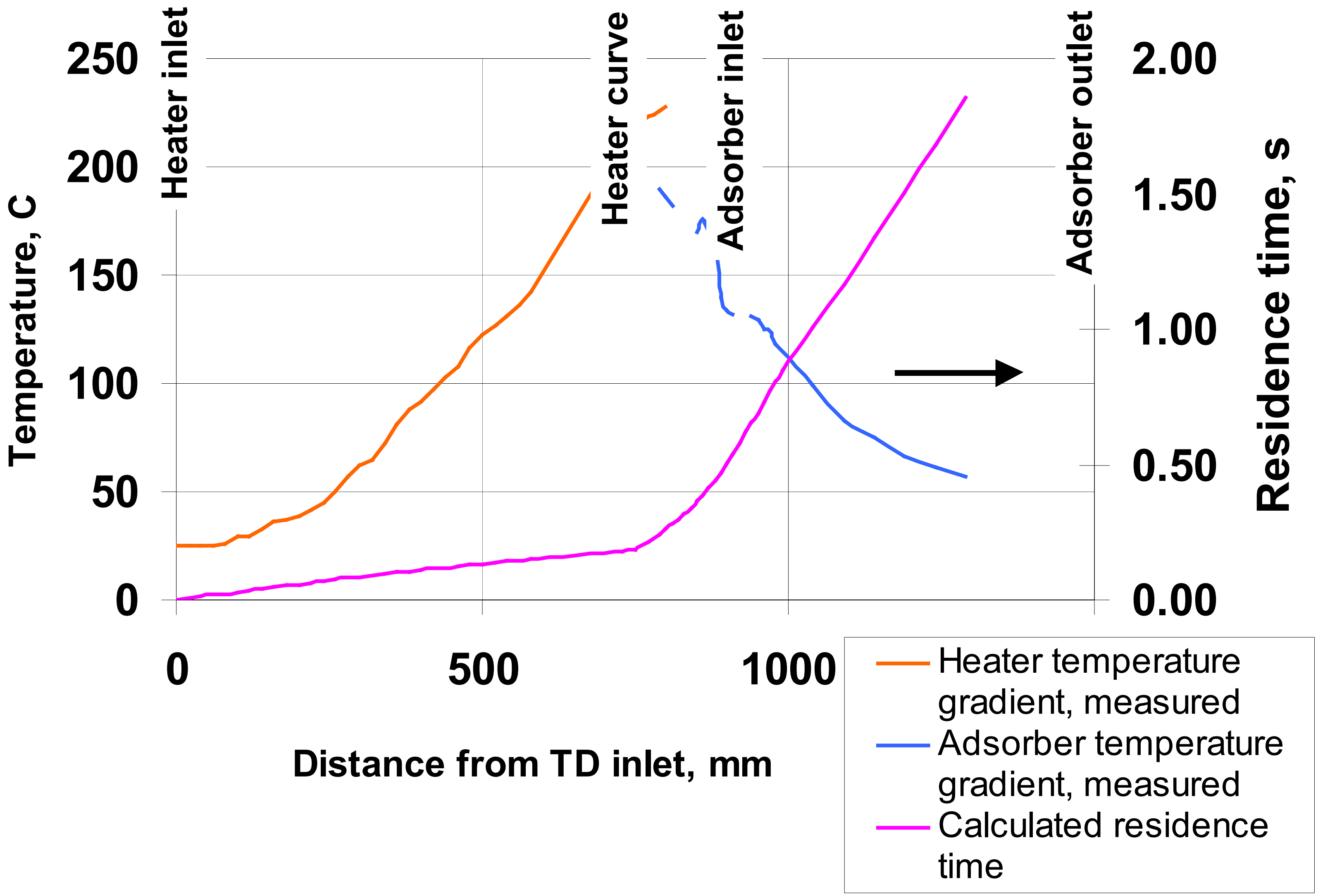
- ELPI and CPC concentrations agree
- Cooled FPS shows high nucleation at low load



Thermodenuder losses

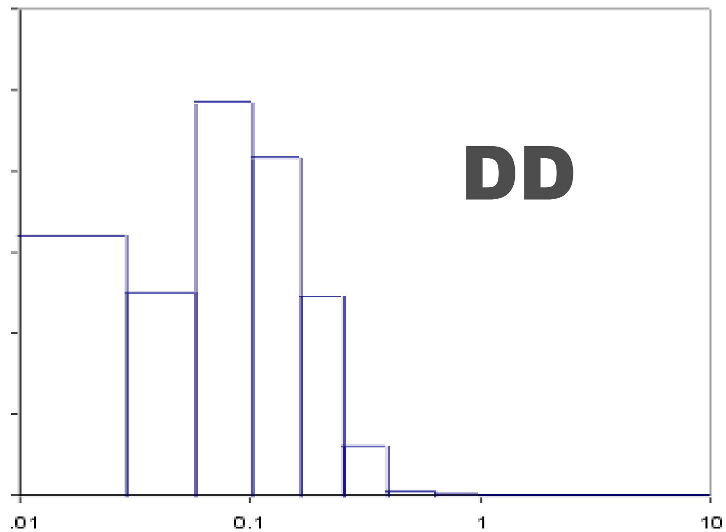


Thermodenuder temperature profile and residence time

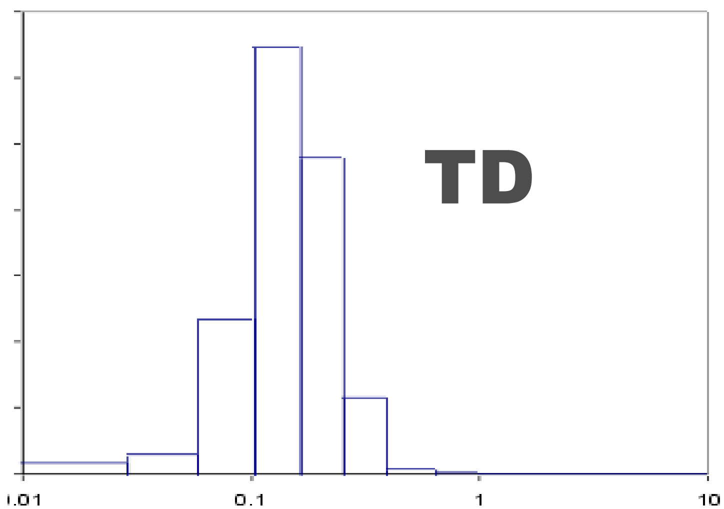


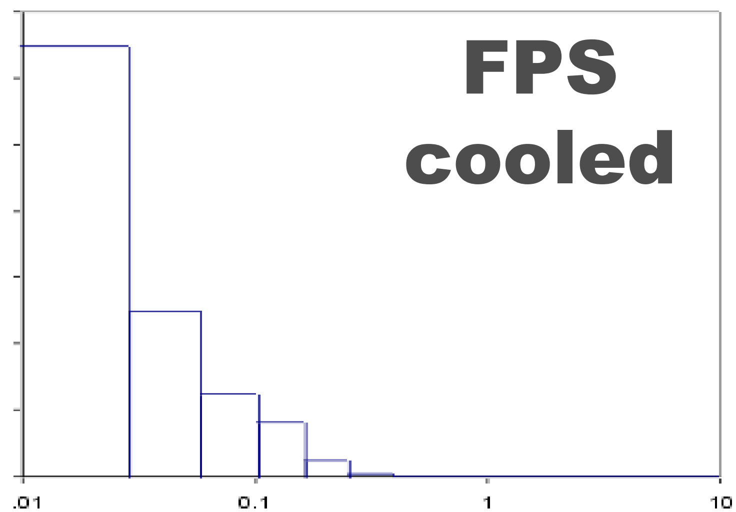
Typical number size distributions

- Low load
- Minimum 15 repetitions



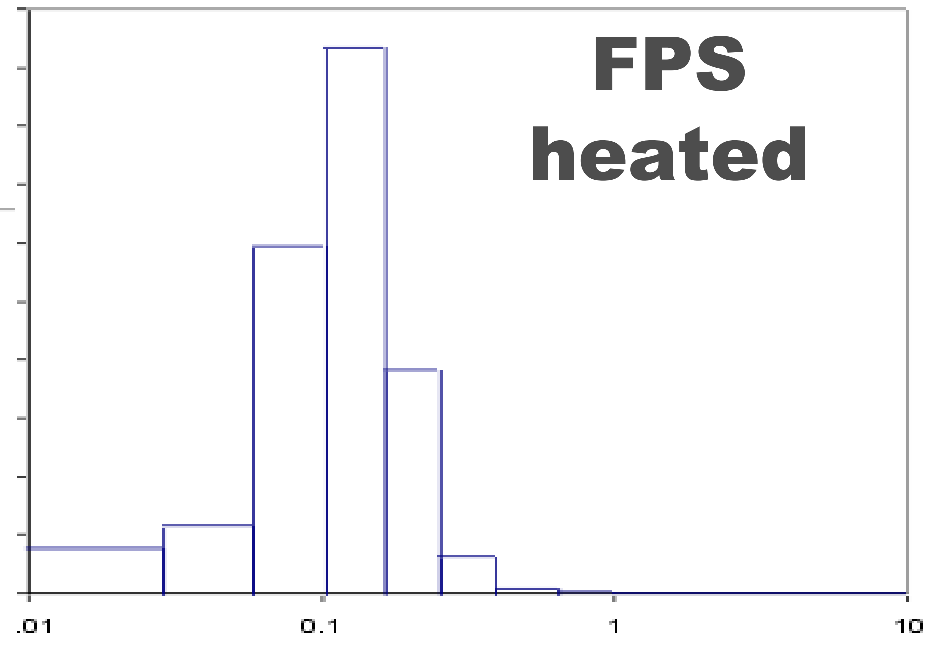
- Soot mode repeatable
- Nucleation mode tendency can be studied
- Results not corrected for losses

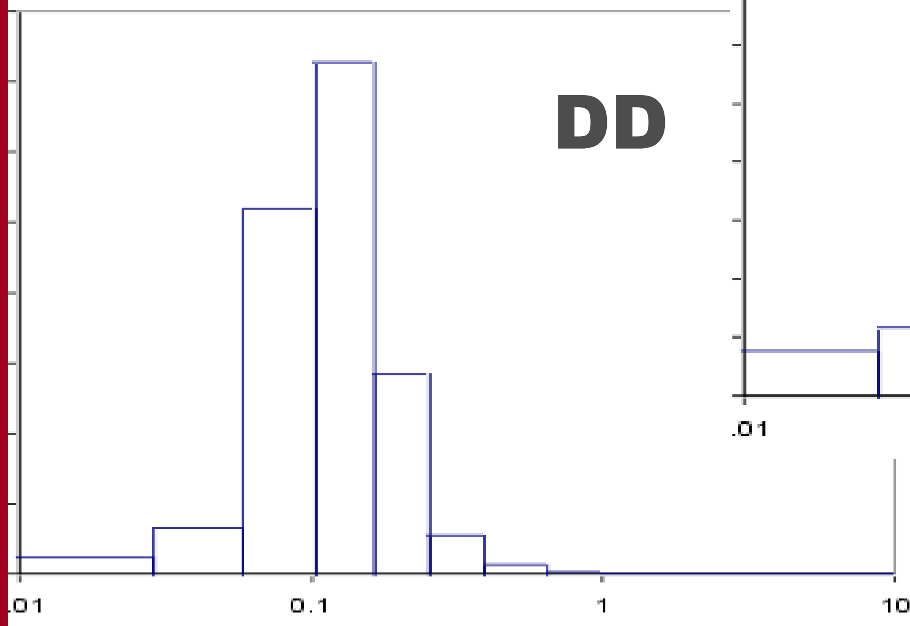




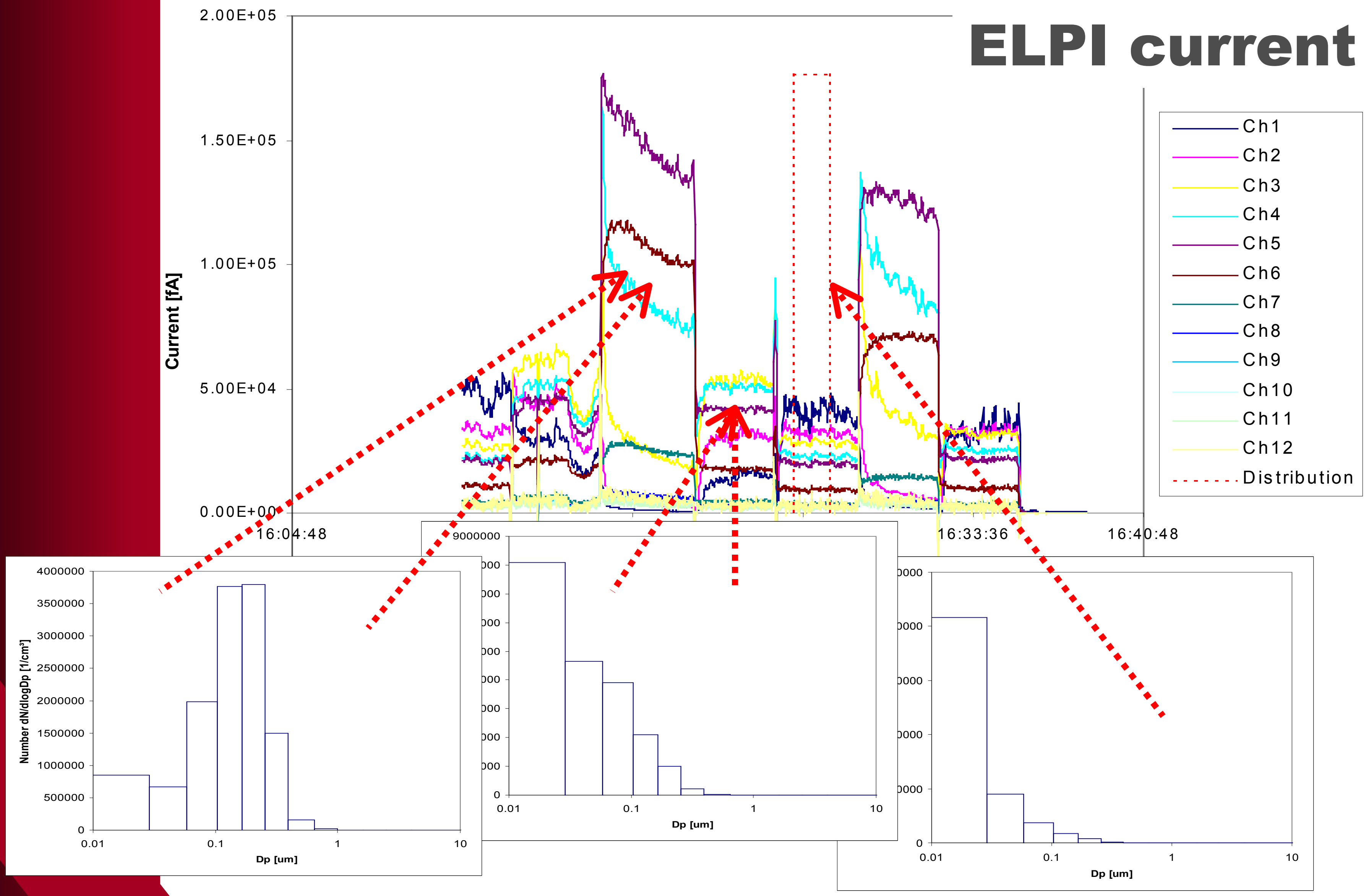
Typical size distributions

❖ Low load, less volatile in exhaust





Effect of dilution ratio



Conclusions

- Successfully applied to diesel exhaust measurements
- Repeatable particle number concentrations for soot particles
- Repeatable particle size distributions
- Effect of volatiles on nucleation and total mass concentration clearly indicated