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Real-time exhaust particle measurements with a high-resolution low-pressure cascade impactor

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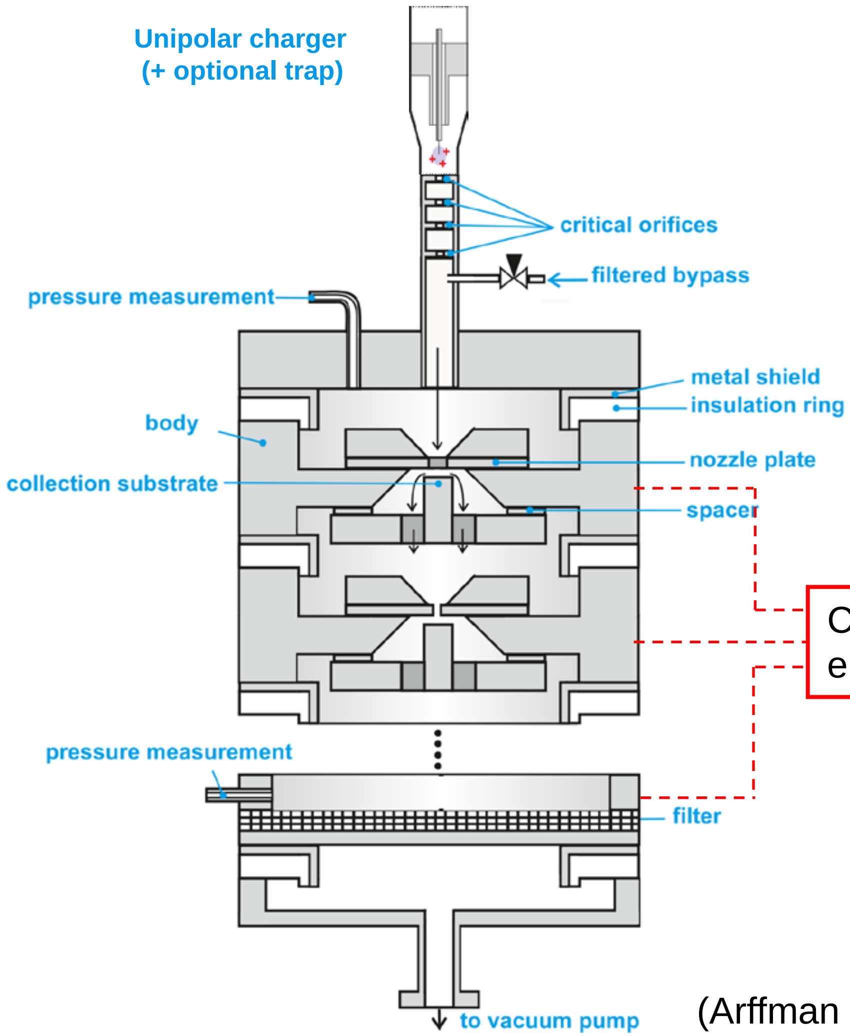
Motivation

- Electrical detection combined to a cascade impactor provides a real-time measurement technique of **aerodynamic** particle size distribution (ELPI; Keskinen et al., 1992)
- Current ELPI: wide size range but low channel resolution in the sub-100 nm particle size range (4 channels), and particle bounce
- Aim is to maximize the nanoparticle resolution of ELPI by confining the measurement size range to ~ 5 – 200 nm (typical for exhaust aerosols)
- This is achieved by introducing a new HRLPI cascade impactor for ELPI

Design considerations of HRLPI

- Short throat length slit nozzles (Arffman et al., 2012)
  → steep cut-curves and minimized overlap of kernel functions
- Separate pressure reduction inlet
  → possible to adjust correct impactor upstream pressure + smaller fine particle losses
- Low jet velocities by using high slip correction regime
  → minimized particle bounce probability
- Sensitivity vs. pumping capacity: low sample flow rate compensation with an efficient charger

HRLPI components



(Arffman et al., 2014)

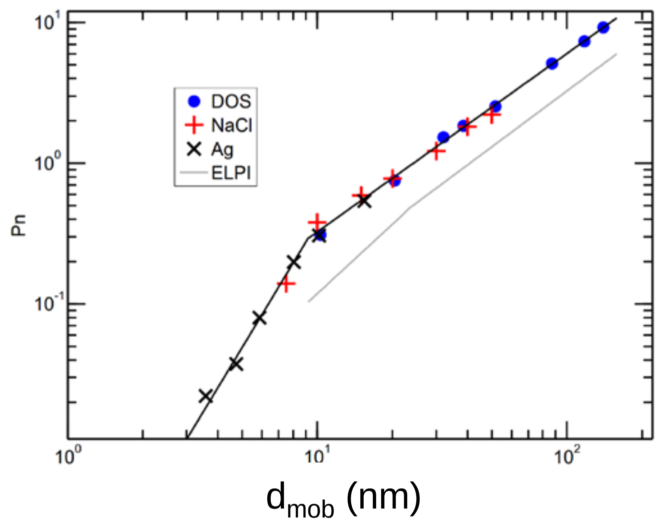
- Impactor fits to ELPI body
- 10 impactor stages and a filter stage
- Sample flow rate 1.1 lpm
- Operation pressure 40 mbar
- Pressure reduction with a separate inlet: atmospheric → 40 mbar
- Size range ~ 5 – 200 nm
- Lowest cutpoint stage **7.7 nm,** largest cutpoint 142 nm
- A miniature corona charger

HRLPI impactor stage

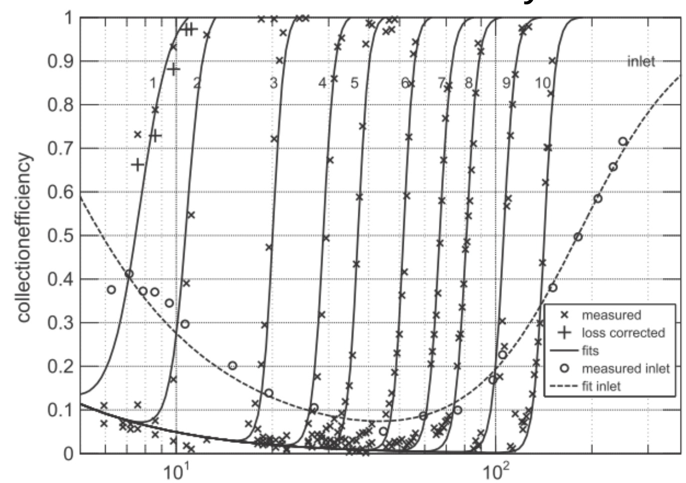
Calibration results

- Electrical calibration method (Keskinen et al., 1999)
- Monodisperse particles through a DMA or SCAR instrument (Yli-Ojanperä et al., 2010)

Pn

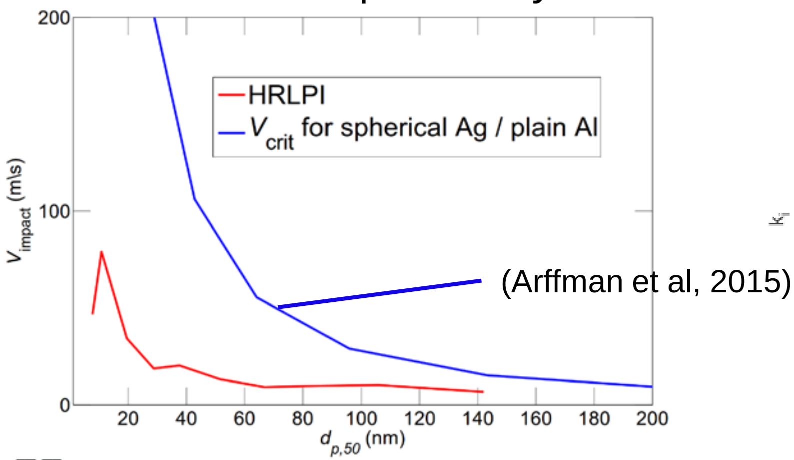


Collection efficiency

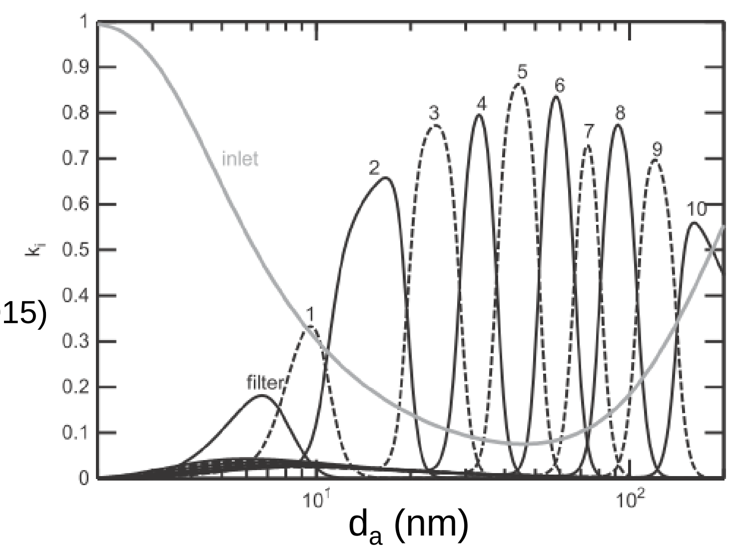


- High steepness
- Minor cross talk

Bounce probability

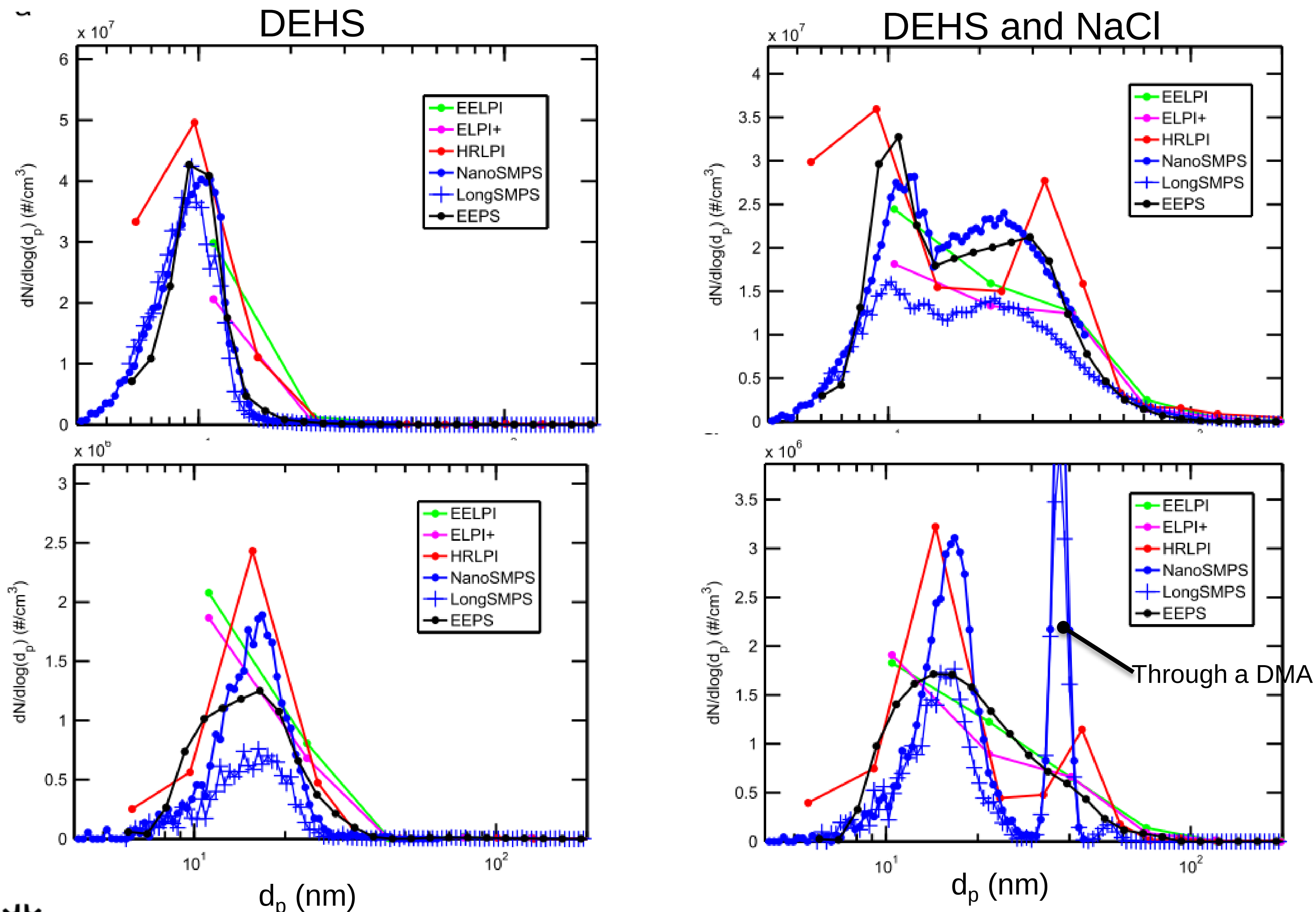


Kernels



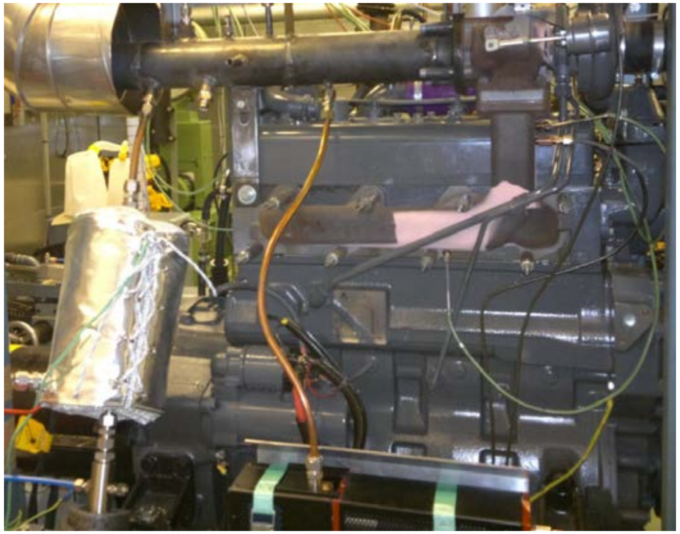
Laboratory tests

- Cutpoint concept: C = I/PneQ

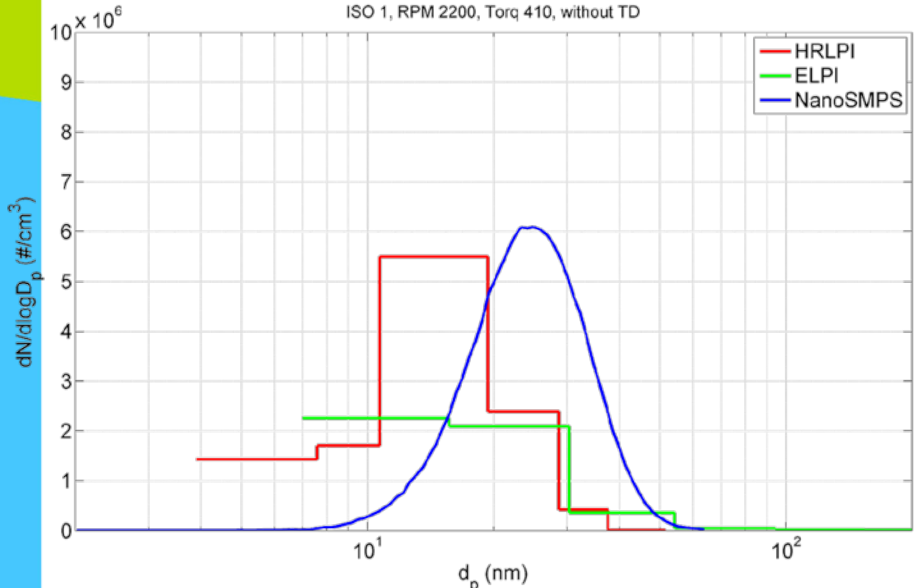


Heavy-duty nonroad diesel engine (Tier 4i)

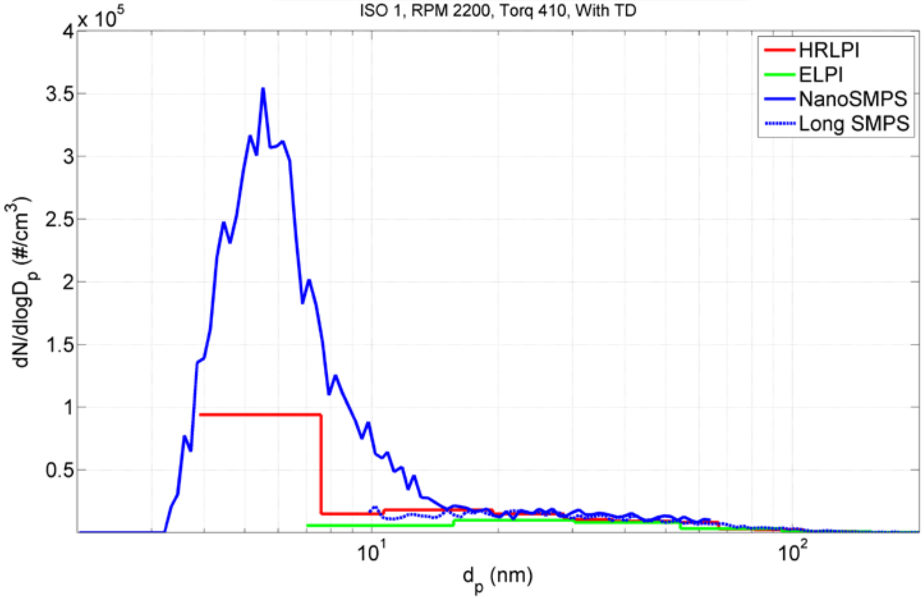
Sampling: porous tube diluter, ageing chamber, ejector diluter, (thermodenuder), instruments



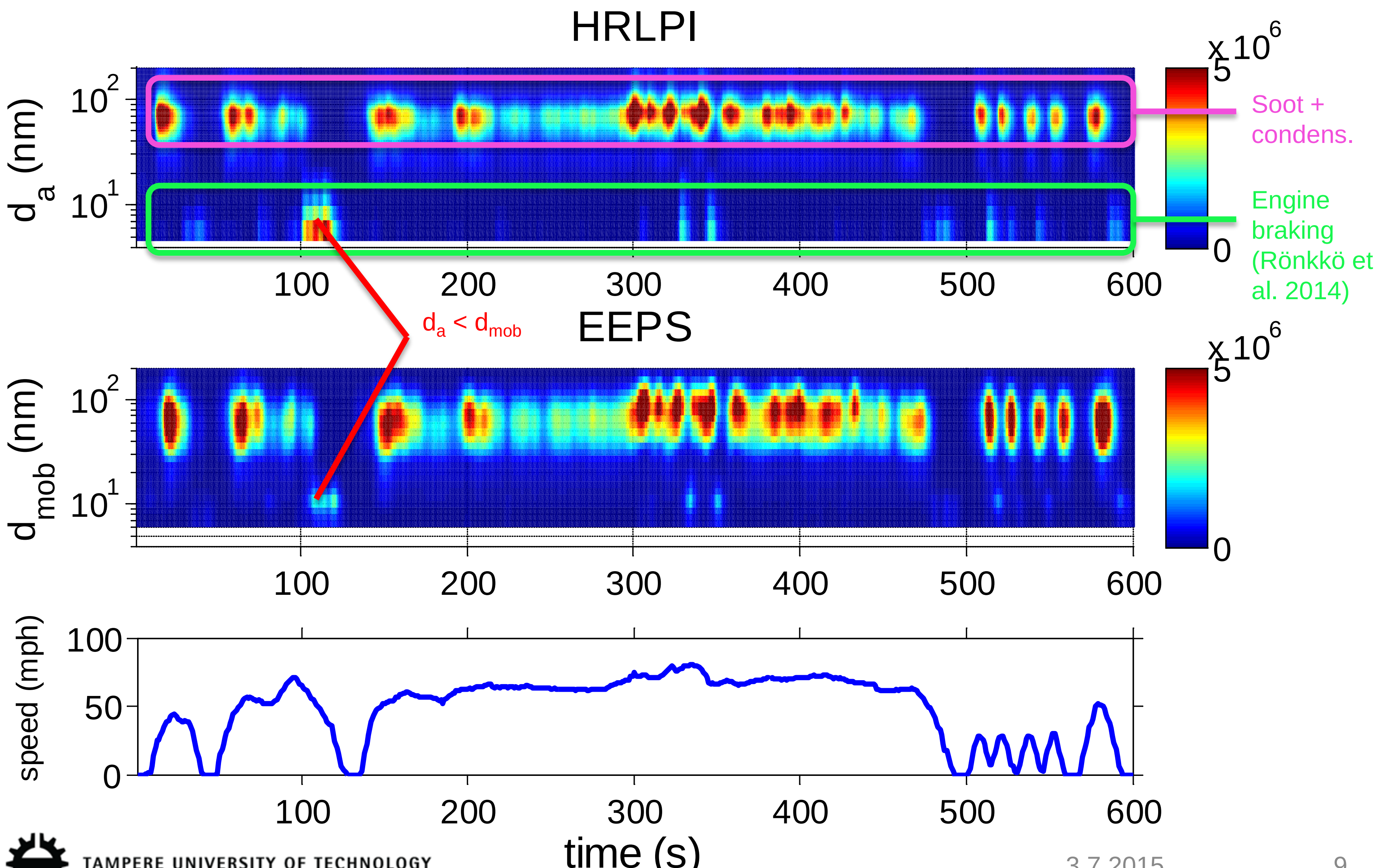
All particles



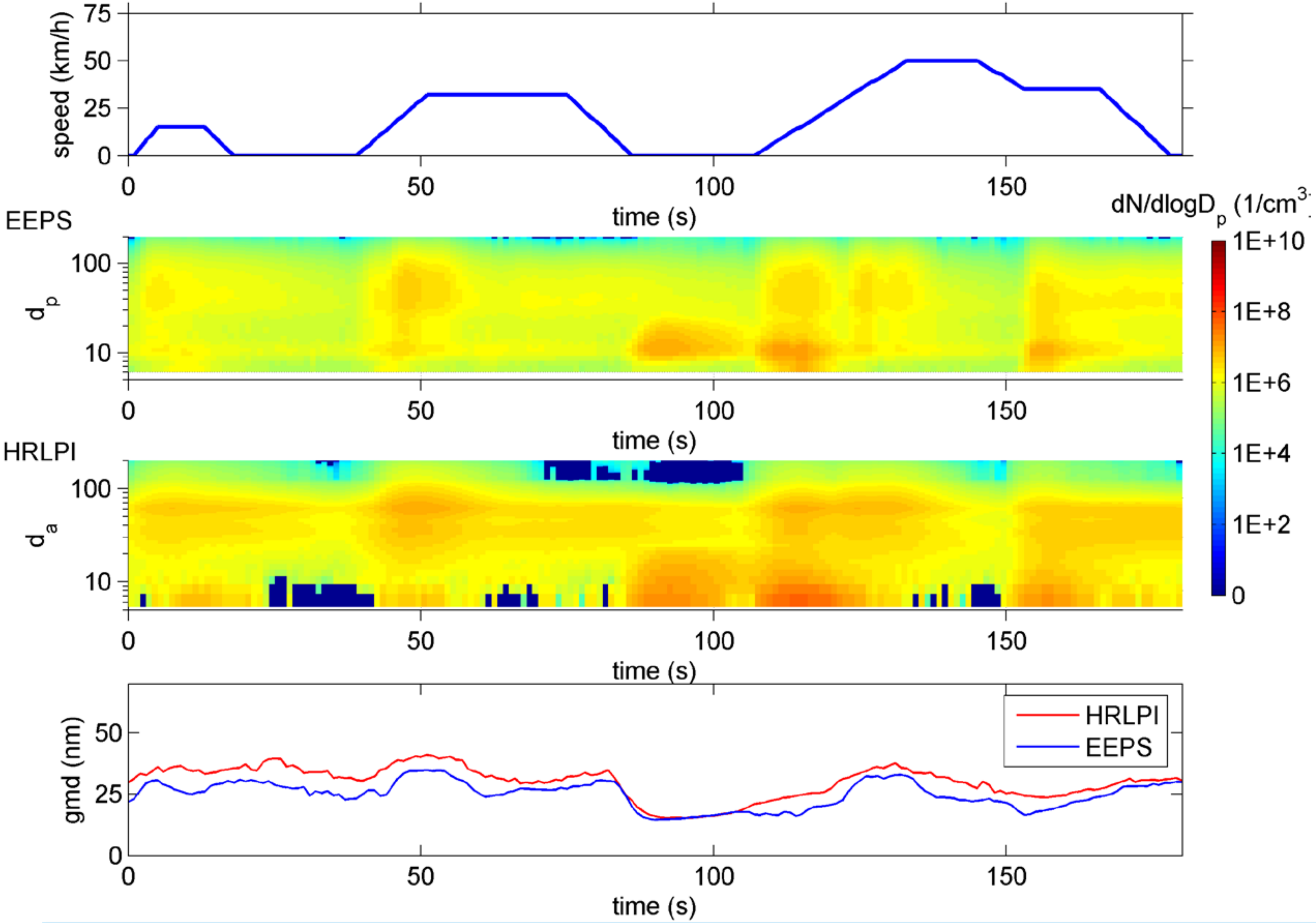
Nonvolatile particles



Diesel passenger car, w/o aftertreatment, US06 cycle



GDI passenger car, UDC part of EUDC



To do…
Real-time particle density analysis by combining EEPS and HRLPI results

Conclusions

- HRLPI is designed to operate in the typical particle size range of vehicle exhaust aerosols
- Sharp cut-curves succesfully implemented to a cascade impactor
- Lowest impaction stage cutpoint 7.7 nm
- Bounce probability minimal
- Increasing native resolution keeps de-convolution and interpretation of results simple
- Real-time exhaust particle density analysis is possible when aerodynamic and mobility particle size distributions are measured simultaneously (e.g. HRLPI & EEPS)

Thank you!

Acknowledgements

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