Improved PN measurement with PPS-M using dynamic trap switching

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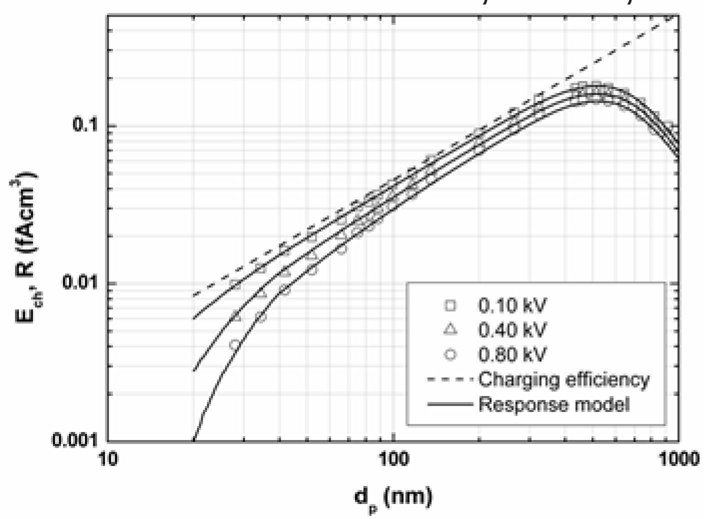
Background

- PPS-M has been used for automotive PN/PM measurements commercially since 2011

- Sensor uses a diffusion charger and escaping current measurement to produce fast, repeatable and robust signal at high temperature measurement

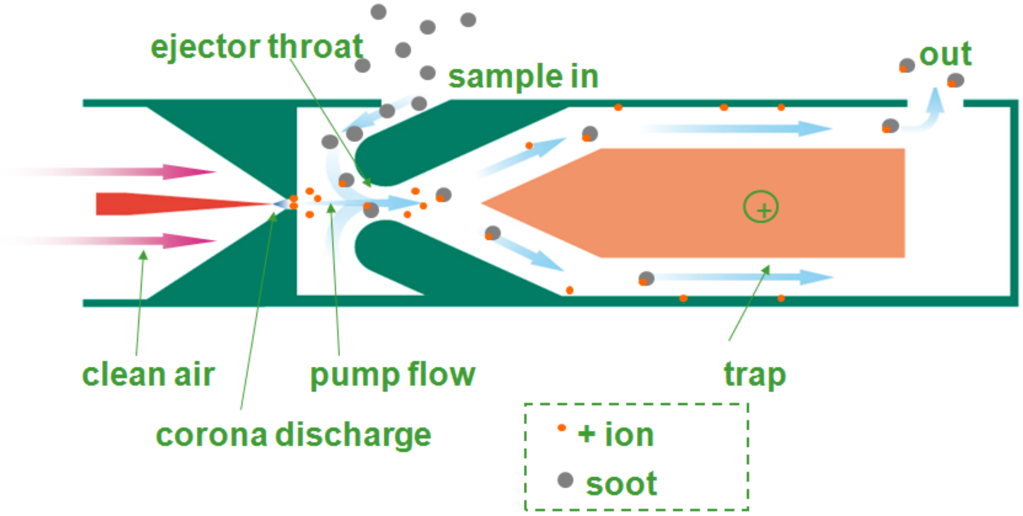
- Signal size dependency introduces uncertainty when particle size changes
  - Getting size information reduces uncertainty

Rostedt et al., AS&T, 2014



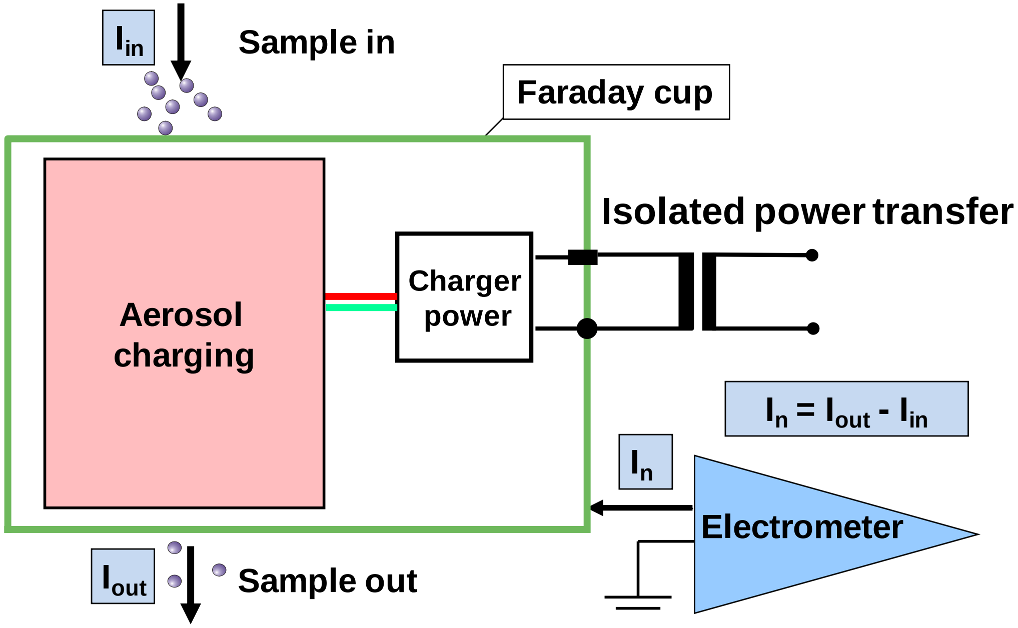
Pegasor sensor: Operation Principle

- Electric measurement principle
  - Wide concentration range
  - Size range $D_p < 1\ \mu m$
  - Combination of air-jet charger and ejector pump
- Non collective consept
  - No clogging collecting filter
- All critical parts shielded by clean air flow
- Cutpoint adjustment possible with the trap voltage



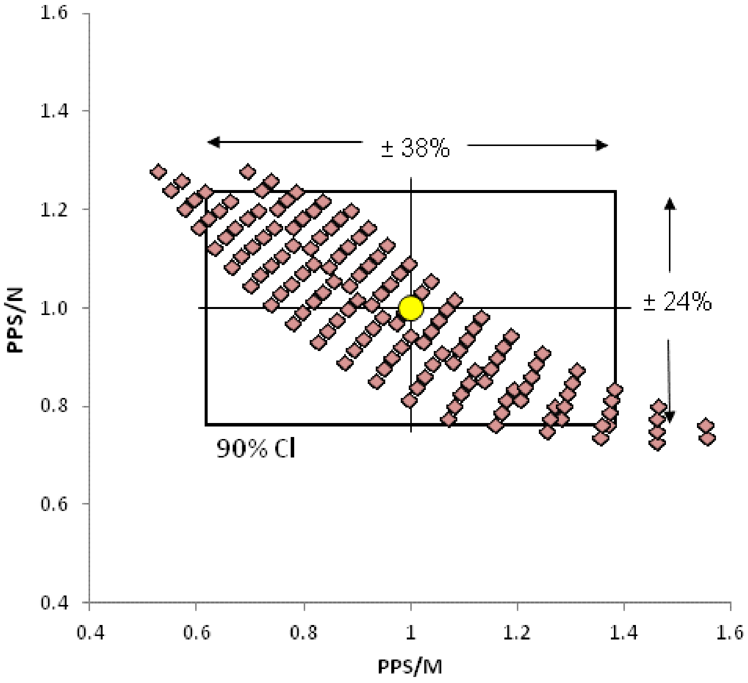
Escaping current concept

- Measured primary signal is the net escaping charge
- No collection of large particles -> low contamination
- Very stable signal path
  - Saturated charge generation
  - Current is measured directly
  - Sensing elements isolated from sample



What about size?

- Diffusion charging has size dependency (Dp1..1.5)
- Getting number or mass in case of varying CMD is problematic
- Two signals at different cutpoints gives an opportunity to infer mean (charging) size
  - Dual PPS-M (Amanatidis et al., JAS 2016)
  - miniDisc, Partector (Fierz et al., AS&T 2011)
  - With a single PPS-M with successive trap settings (Dal Maso et al., AAQR 2016)
- Adds complexity
- Limited accuracy for the size at the extremes

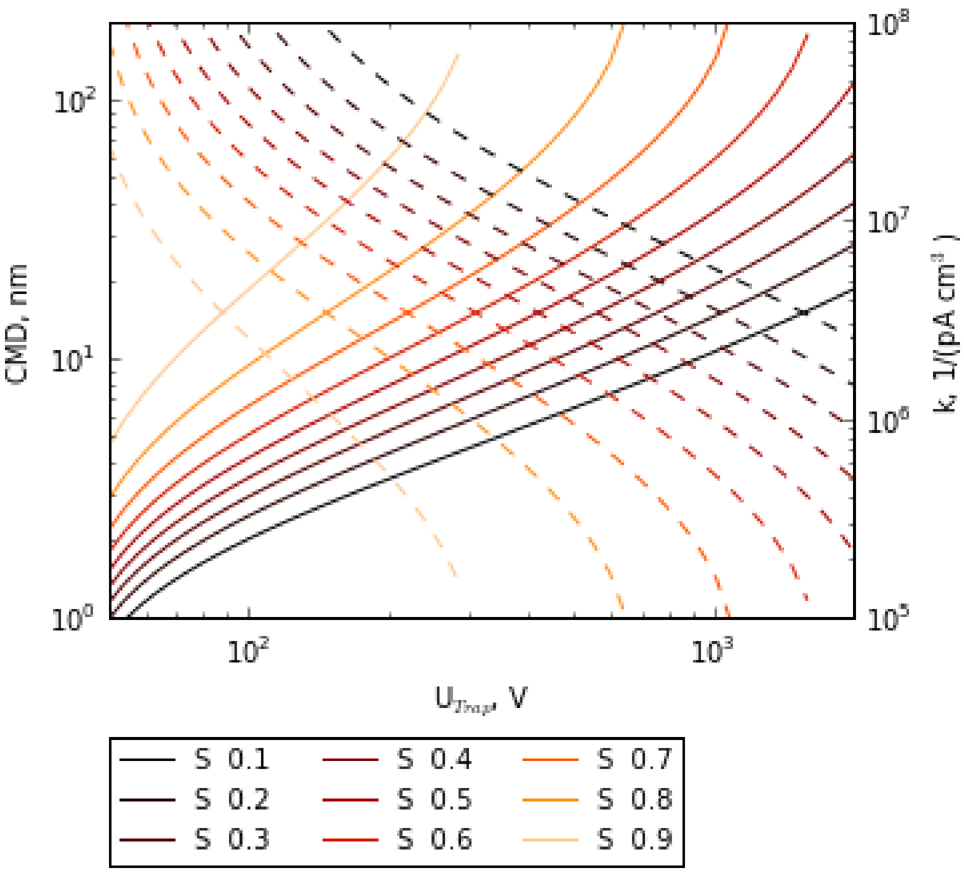


Ntziachristos et al., SAE, 2011

Typical Diesel (and GDI) Range	Magnitude	Min	Max
	Dg [nm]	40	66
	GSD [-]	1.65	1.90
	DF [-]	2.2	2.6
	Number [km^{-1}]	5×10^{11}	10^{14}

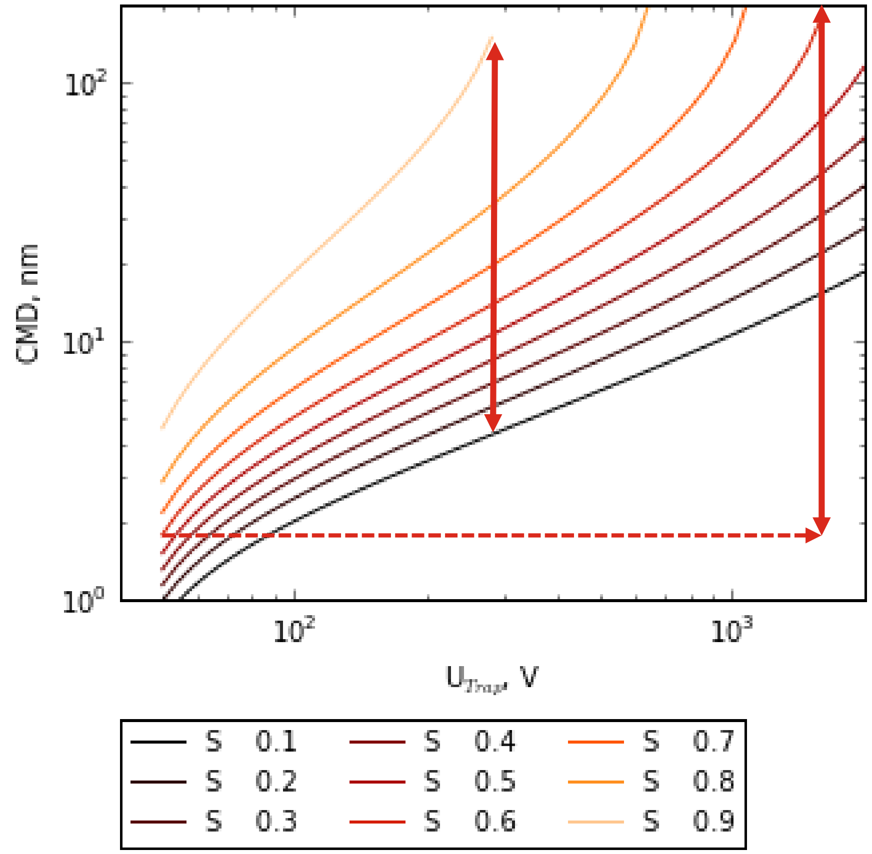
Particle size and number concentration calculation

- Based on the currents from the two instruments, CMD, PM and PN can be calculated. (Amanatidis et al. 2016)
- A choice of instrument setting is made, with compromise in the extremes of the size scale.
    - Choose voltages, read signal ratio
- What if voltage setting is chosen continuously?



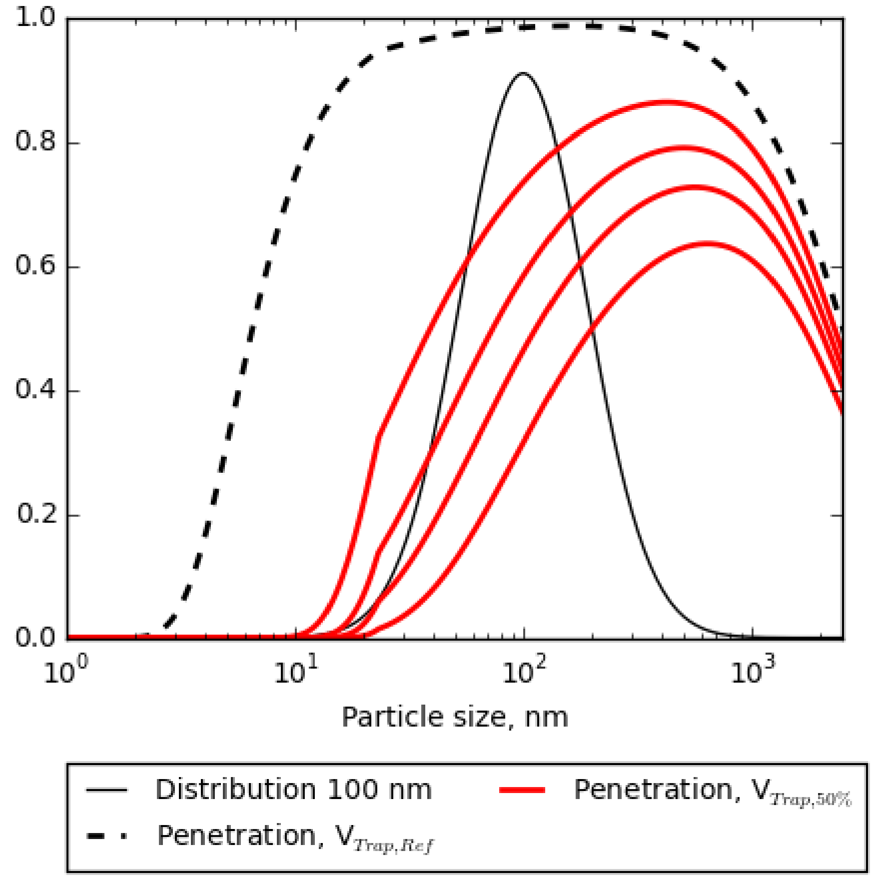
Dynamic trap : range advantages

- Instead of accurately measuring signal ratios, we can very accurately set the trap voltage
- Advantages: S/N kept at maximum, wide dynamic range
  - Dynamic trap: Signal ratio kept at 50% gives cmd dynamic range of 63
  - Static trap: Any constant voltage gives dynamic size range of ~27



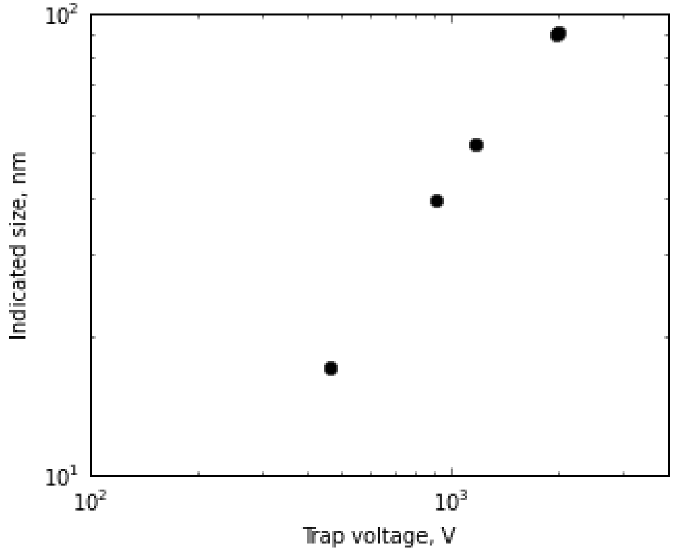
Dynamic trap: Follow the peak of distribution

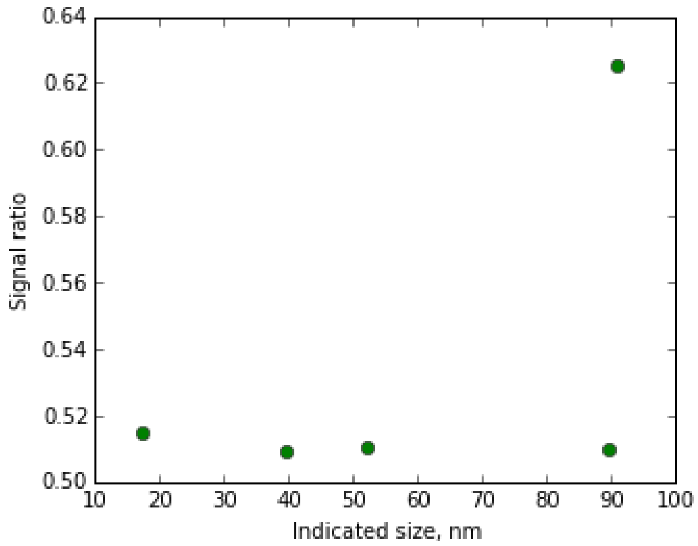
- The dynamic trap is adjusted to find the halfway point of the distribution.
- Size parameter is extracted from the optimal trap voltage
- Size correction for number (and even mass), given single mode distribution
- Caveat: Single mode, constant GSD assumed



Lab testing

- Lab generated size distributions
  - 20, 50, 60, 100 and 200 nm
- Size distribution is captured with trap voltage up to 100nm
- Signal ratio, moving avay from 0.5 can be used to extend the range



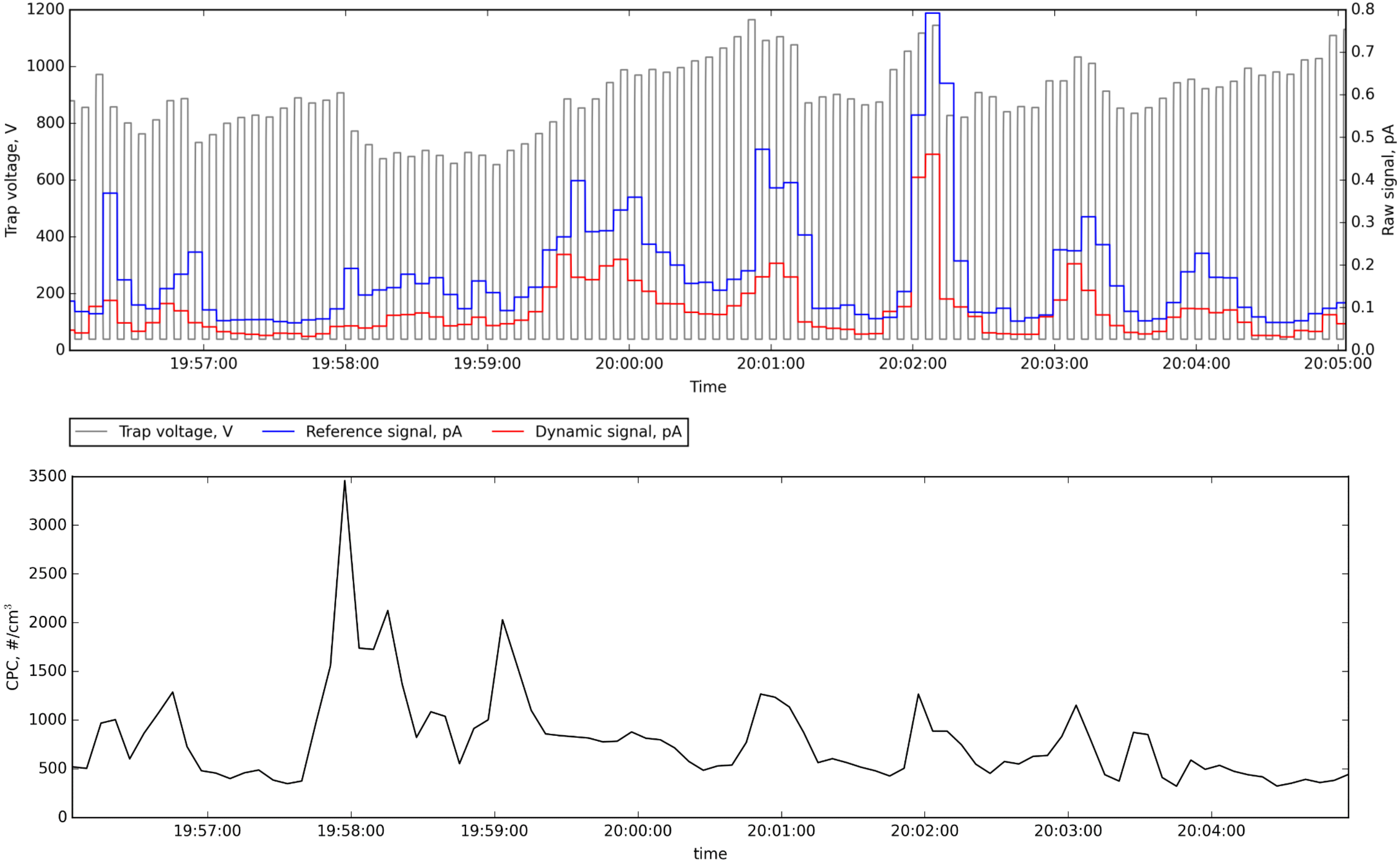


Practical application: roadside ambient air measurement

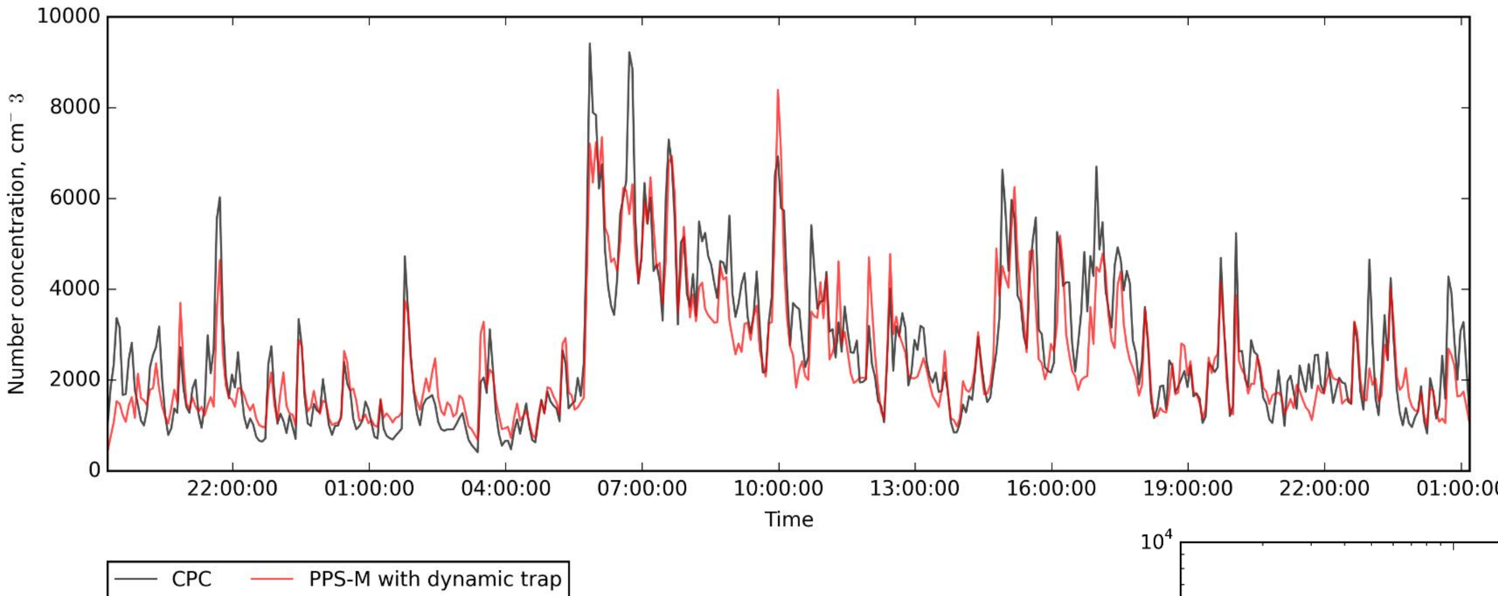
- Busy urban roadside in Helsinki
- Inlets at ~3m height, 1m from roadside
- Comparison with
  - CPC in a warm cabin
  - PPS-M, sample heated ambient+40C to dry the sample

- Further information:
  - www.hsy.fi
  - fmi.cityzer.fi

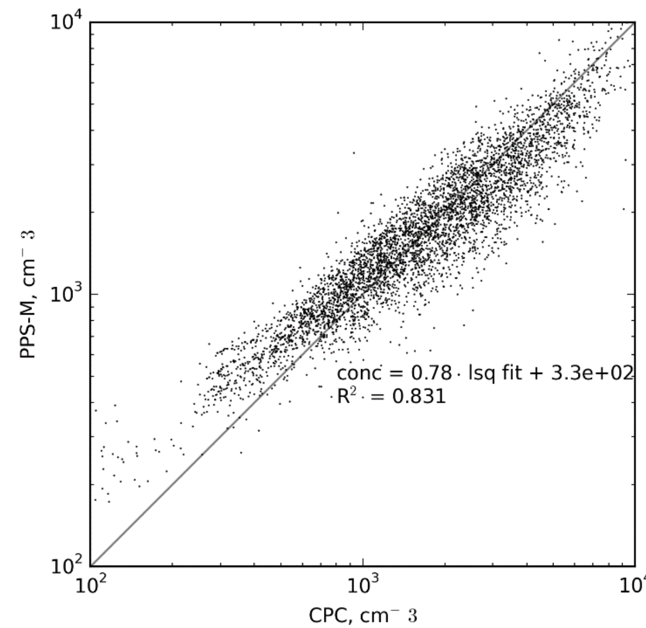
Example raw signals



CPC comparison, final result



- A good match over long and varying sample is achieved, even for short timescale (with modest filtering)



Conclusions

- Dual-PPS-M type analytics can be done with one instrument by sequential trap switching
  - Particle size, number and mass
- Adjusting the dynamic trap voltage offers wider particle size range, up to 200 nm
- Cost of time sharing is reduction in time resolution
- Development for faster time response needed for faster transient response

- Applications at this stage:
  - Slow transient measurements: Ambient measurements, power generation, marine, local steady state size calibration at dynamometer.

Thank You!

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