

# A new, traceable METAS calibration service for particle counters

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## The need for traceable CPC calibration

- Particle number concentration has become an increasingly important metric in vehicle emission control.
- The Euro 5b and 6 vehicle emission standards restrict the number of allowable particles emitted per km. → **Traceability is indispensable for the calibration of CPC's used for type approval!**



Fig. 1: Type approval of light vans and passenger cars according to Euro 5b and 6 relies on the measurement of particle number concentration. (Example image by airqualitynews.com)

- The counting efficiency of a CPC depends on the surface chemistry of the measured aerosol particles → **The right choice of calibration aerosol is crucial!**
- The sizing accuracy of SMPS systems depends on the accuracy of the counting efficiency of the CPC in use.

## Traceable CPC calibration at METAS according to ISO 27891

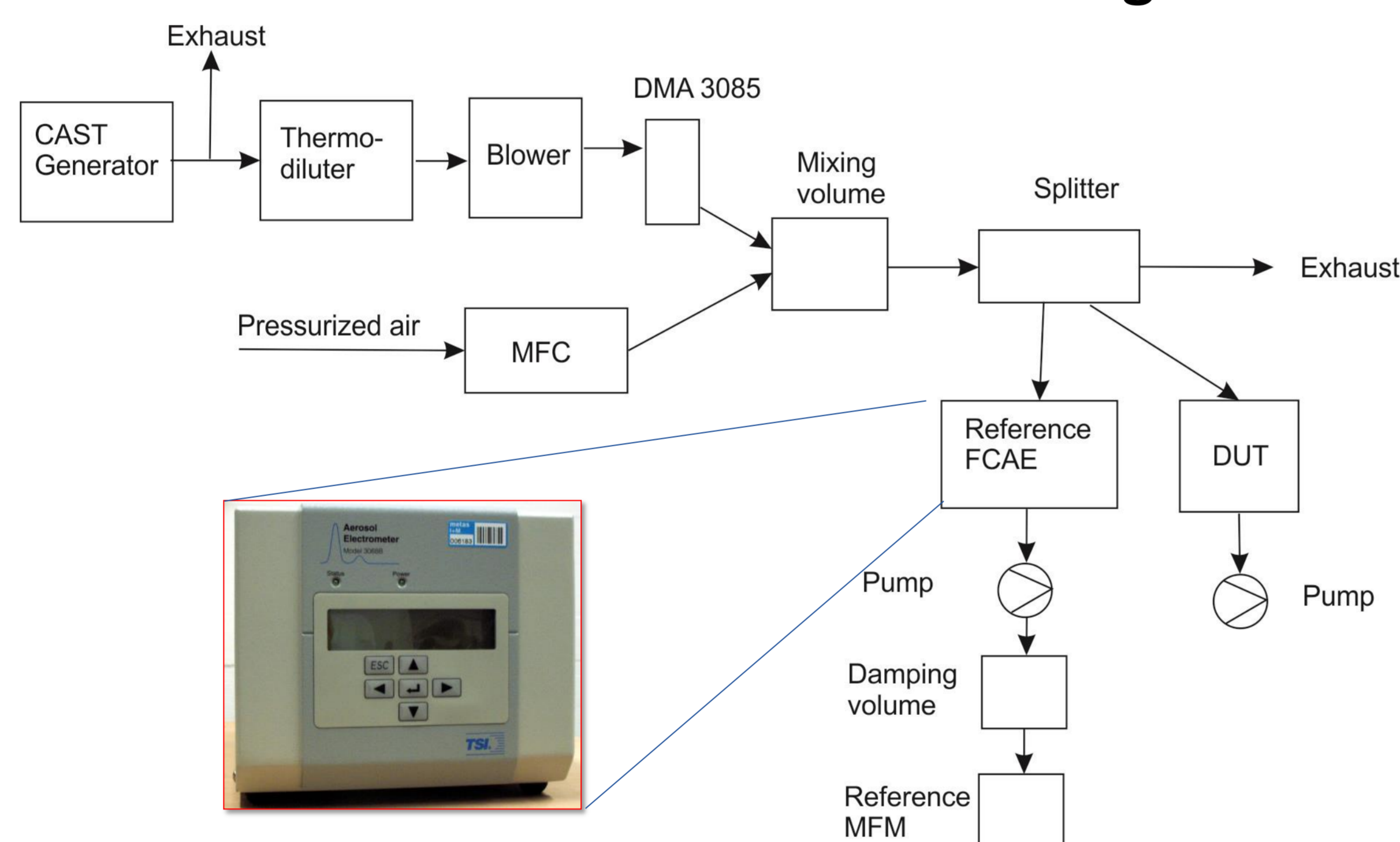


Fig. 2: Experimental setup for the measurement of the CPC cut-off curve against a reference electrometer (FCAE) with CAST soot. The measurement of particle number concentration is traceable to the units of electric current (FCAE), volume and time (Reference MFM), for which primary standards are available at METAS.

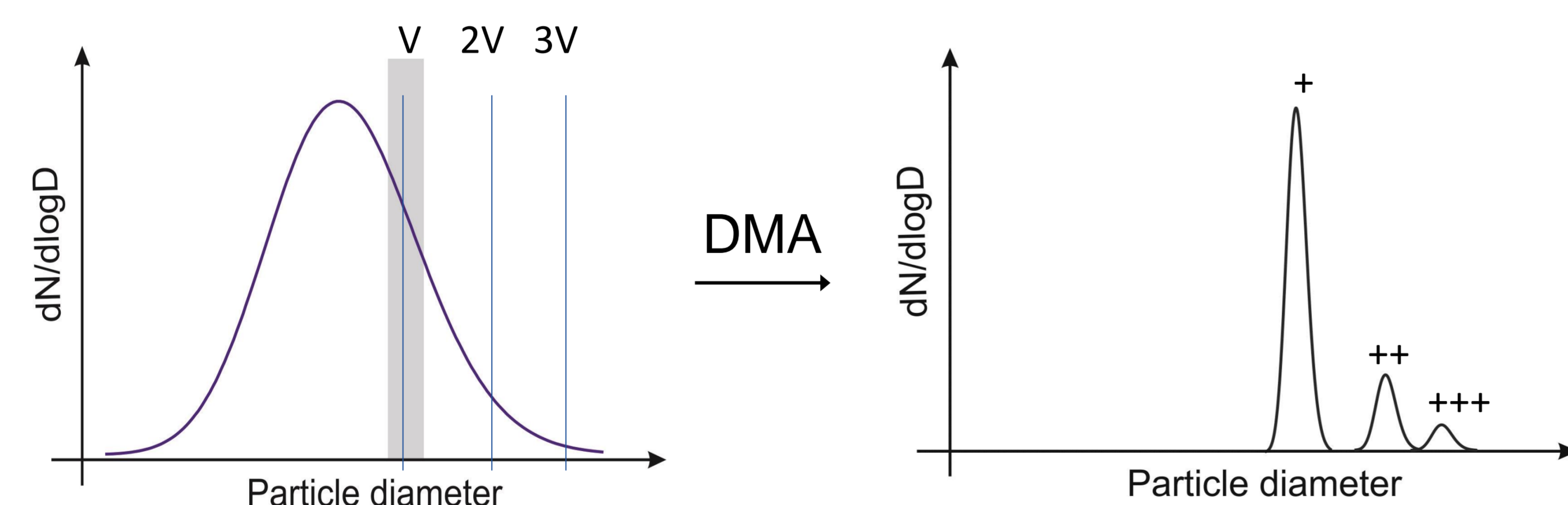


Fig. 3: The broad initial size distribution leads to the presence of multiply charged particles with «wrong» sizes downstream the DMA.

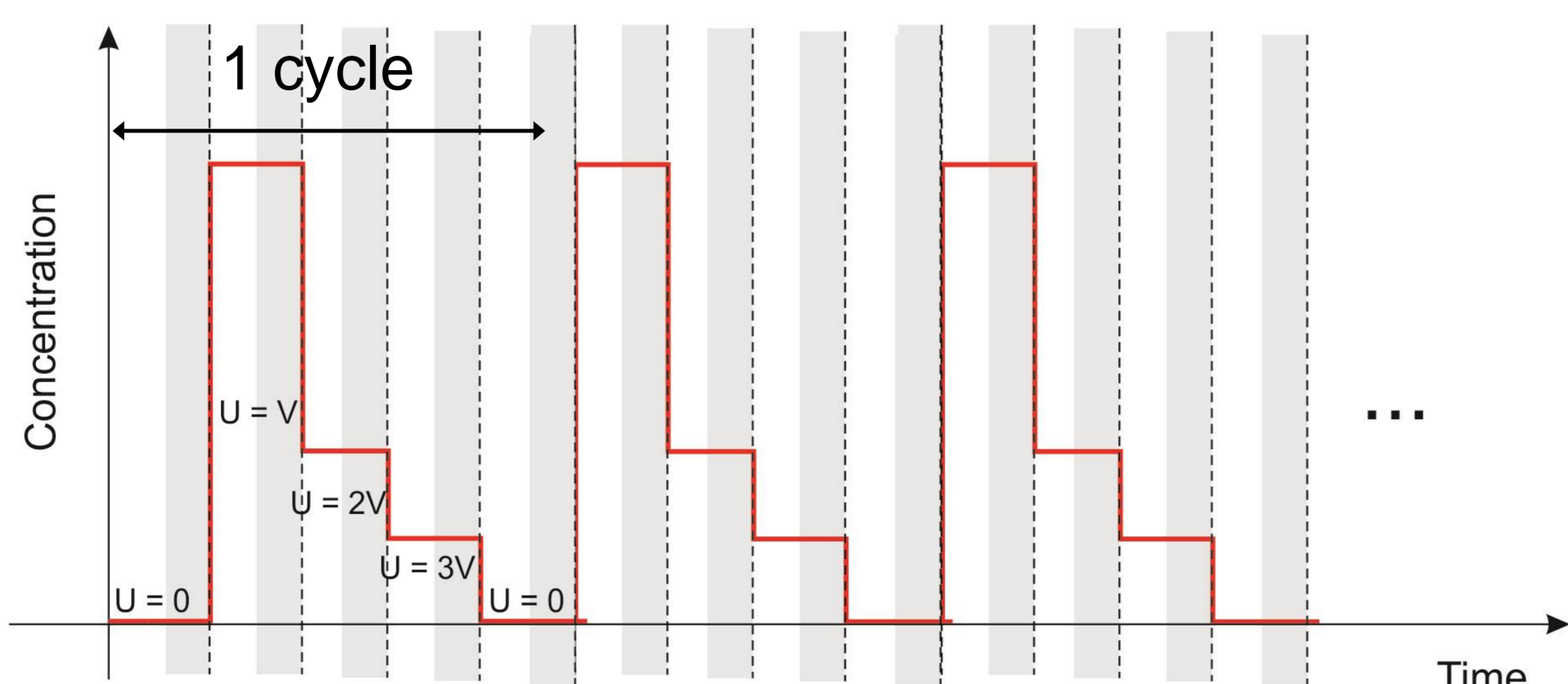


Fig. 4: Measurements at int. multiples of the initial DMA voltage are performed to find and subtract the correct number of unwanted larger particles.

## Calculation of the counting efficiency

- The counting efficiency of the DUT is calculated according to

$$\eta_{DUT,a} = \frac{C_{N,DUT}}{C_{N,ref}} \cdot \eta_{ref} \cdot \beta \cdot \sum_{p \geq 1} \varphi_p \cdot p$$

$$\eta_{CPC,b} = \frac{C_{N,DUT} - \eta'_{DUT} \cdot C_N \cdot \sum_{p \geq 2} \varphi_p}{C_{N,ref} - \eta_{ref} \cdot \beta \cdot C_N \cdot \sum_{p \geq 2} \varphi_p \cdot p} \cdot \eta_{ref} \cdot \beta$$

$$\eta_{DUT} = \frac{\eta_{DUT,a} + \eta_{CPC,b}}{2}$$

where  $C_{N,DUT}$  = concentration measured by DUT,

$C_{N,ref}$  = concentration measured by reference FCAE,

$C_N$  = true particle concentration at device inlet,

$\varphi_p$  = fraction of particles with  $p$  elementary charges,

$\eta_{DUT}, (\eta'_{DUT})$  = (plateau) counting efficiency of the DUT,

$\eta_{ref}$  = counting efficiency of the reference FCAE,

$\beta$  = flow splitter bias

- Measurements at DMA voltages  $U = 2V$  and  $U = 3V$  are performed in each measurement to determine  $\varphi_2$  and  $\varphi_3$ .
- Calculation of  $\varphi_2$  and  $\varphi_3$  requires the knowledge of particle charging probabilities (according to *Wiedensohler, 1988*)
- At least 6 cycles, each including a zero balance of the FCAE, are taken for each measurement. The final  $\eta_{DUT}$  is the average over all cycles.
- The flow splitter bias depends on particle size, i.e. it is determined for each measurement.

## Example uncertainty budget for an engine exhaust CPC

	Dp = 23 nm	Dp = 70 nm
$\eta_{DUT}$	45.6 ± 1.0 % (k=2)	89.0 ± 0.6 % (k=2)
Influence parameter		
$\beta$	59.0 %	27.3 %
$C_{N,ref}$	38.8 %	71.6 %
$C_{N,DUT}$	8.4 %	28.1 %
$\eta'_{DUT}$	0.013%	0.076 %
$\varphi_2$	0.0017 %	0.56 %
$\varphi_3$	3.5e-8 %	0.053 %
Correl. $C_{N,DUT}$ & $C_{N,ref}$	6.2 %	27.7 %

Tab. 1: Relative contributions to the uncertainty budget of the individual influence parameters. The uncertainty of the FCAE aerosol flow is taken into account in the uncertainties of  $C_{N,ref}$ ,  $\varphi_2$  and  $\varphi_3$ .

## Example CPC cut-off curves

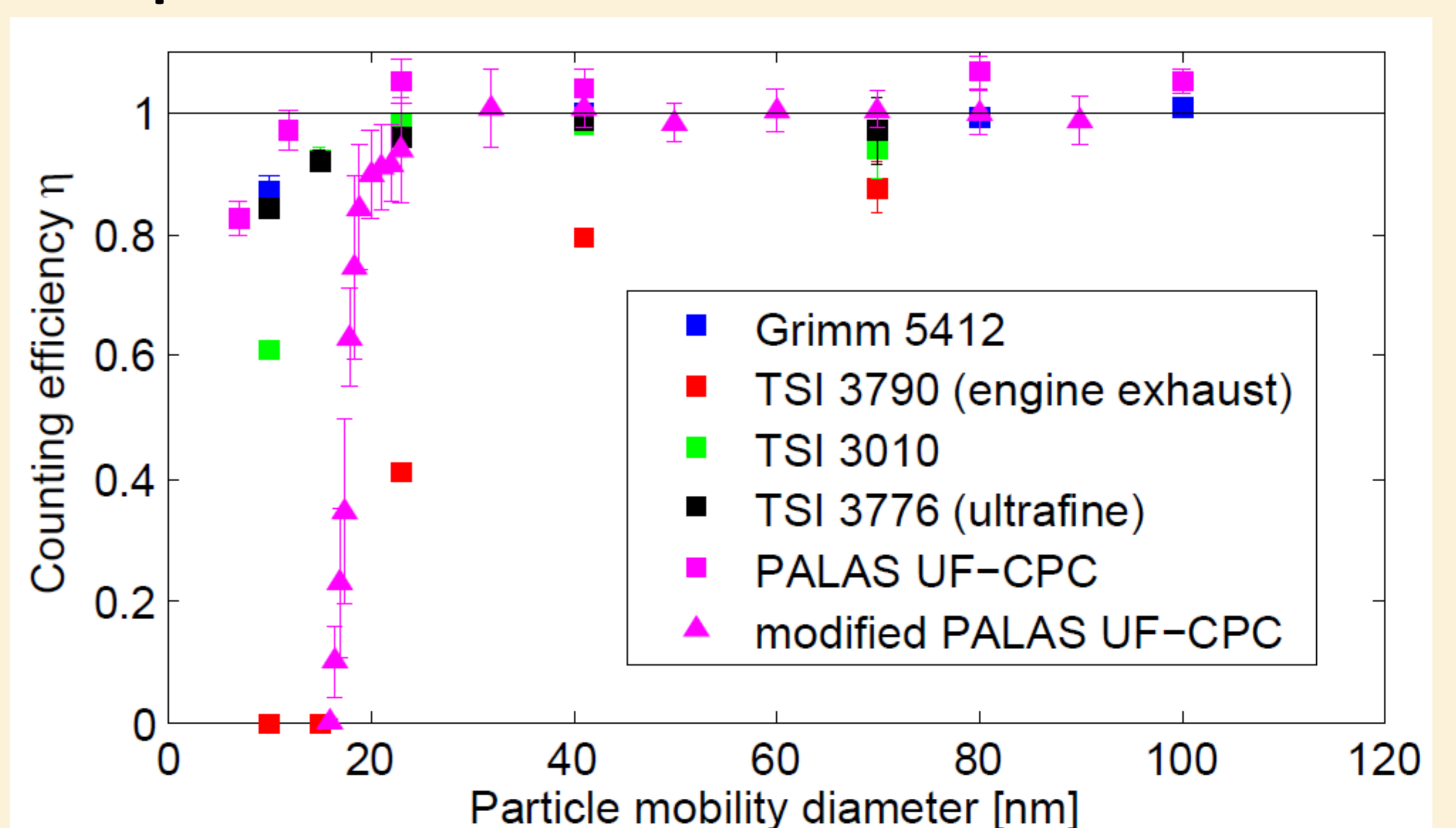


Fig. 5: Examples of CPC cut-off curves measured at METAS according to ISO 27891. Uncertainties indicate 95 % confidence level. The modified PALAS UF-CPC was operated with saturator / condenser temperatures of 21.5 °C / 29.2°C instead of the standard 15°C / 35°C.

### Reference

Wiedensohler, A. (1988). An approximation of the bipolar charge-distribution for particles in the sub-micron size range. *Journal of Aerosol Science*, 19(3), 387–389.