Particle Measurement Programme - Analysis of Errors

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Analysis of errors

1. Explanation of approach used

2. Application to particle number concentration measurements

3. Application to volatile particle removal efficiency measurements

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Approach

Based on GUM

***G**uide to the Expression of **U**ncertainty in **M**easurement*

BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML

ISO, Geneva, First Edition 1993.

GUM Universal Procedure

$$Y = f(X_1, X_2, \ldots)$$

Y is to be measured

X_i are *influence quantities*

Each influence quantity has a *standard uncertainty* $u(x_i)$

Each $u(x_i)$ has a *sensitivity coefficient* $c_i = \frac{\partial f}{\partial x_i}$

The *combined standard uncertainty* $u_c(y) =$

$$\sqrt{c_1^2 u^2(x_1) + c_2^2 u^2(x_2) + \ldots}$$

The *expanded uncertainty* $U = k\, u_c(y)$

(typically $k = 2$ for 95% confidence)

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Aims of NPL PMP report

Find significant contributions to uncertainty of results

- highlight where these need to be evaluated
- highlight where these need to be constrained

Make rough estimate of full measurement uncertainties

Cannot be fully rigorous or definitive

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Simplified procedure used

1. *Clarify what is being measured*

2. *Identify factors affecting the result ("influence quantities")*

3. *Quantify the limits on these factors ("*$u(x_i)$*")*

4. *Quantify the effect of each on the result ("*$c_i.u(x_i)$*")*

Conclusions and rough totals ("U")

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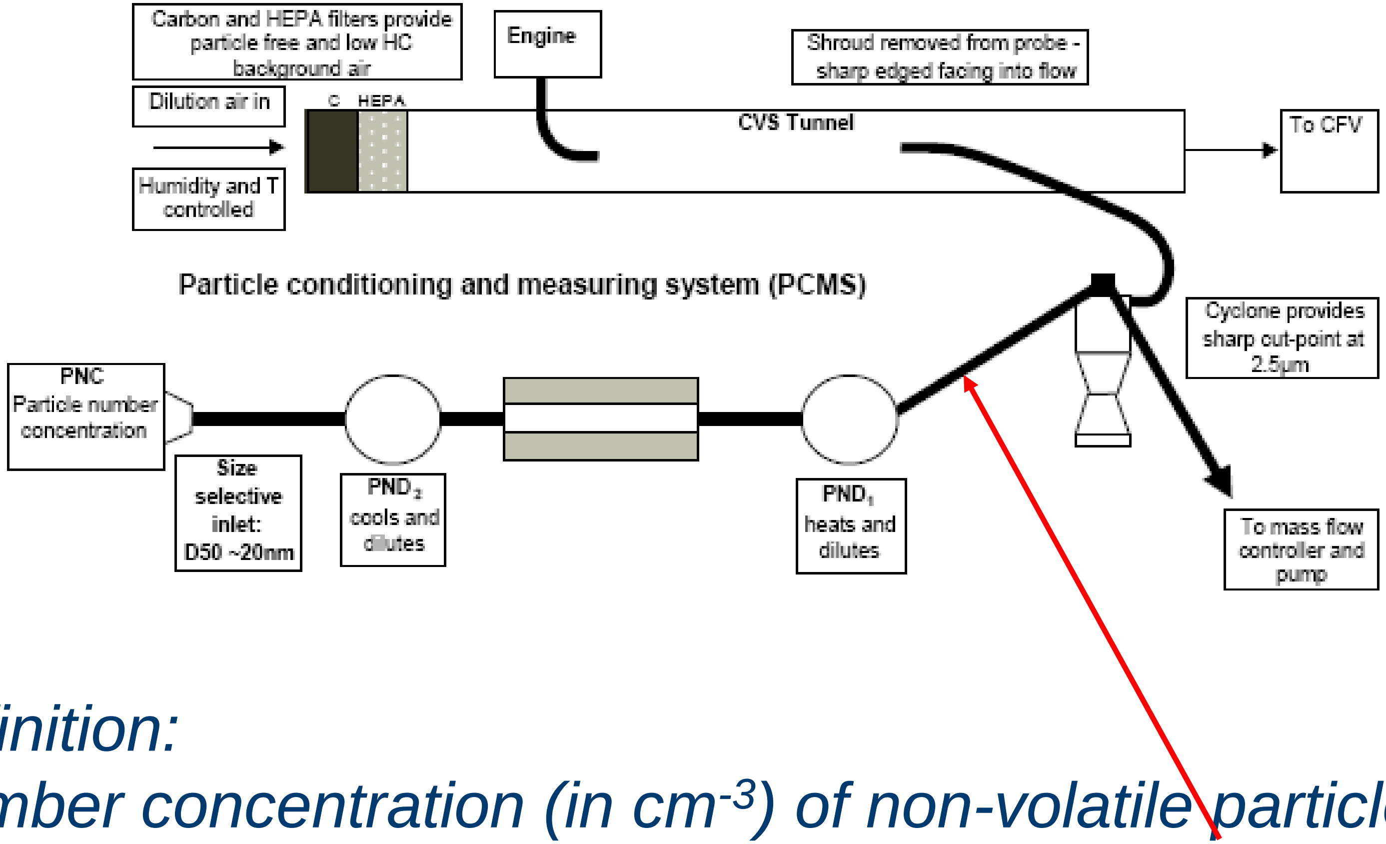

Definition:

Number concentration (in cm^{-3}) of non-volatile particles in the nominal size range 23 nm – 2.5 μm at the PCMS inlet.

The air volume is to be corrected to Standard Temperature and Pressure (273.2K and 101.33 kPa)

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Eg PNC calibration accuracy

PNC drift since calibration

Presence of volatile particles

$$C_{inlet} = C_{PNC} \times F(av)_{particle\ dilution}$$

Eg nonlinearity

Reproducibility

Particles in dilution air

Low size cut-off effects

Validity of average

Evaluation

PNC calibration criterion 10% ~ 10%

dilution particle criterion 1 cm^{-3} ~ 3%

(assuming total dilution factor 150 and lowest C_{inlet} of interest 5,000 cm^{-3})

presence of volatile particles (1%) ~ ?

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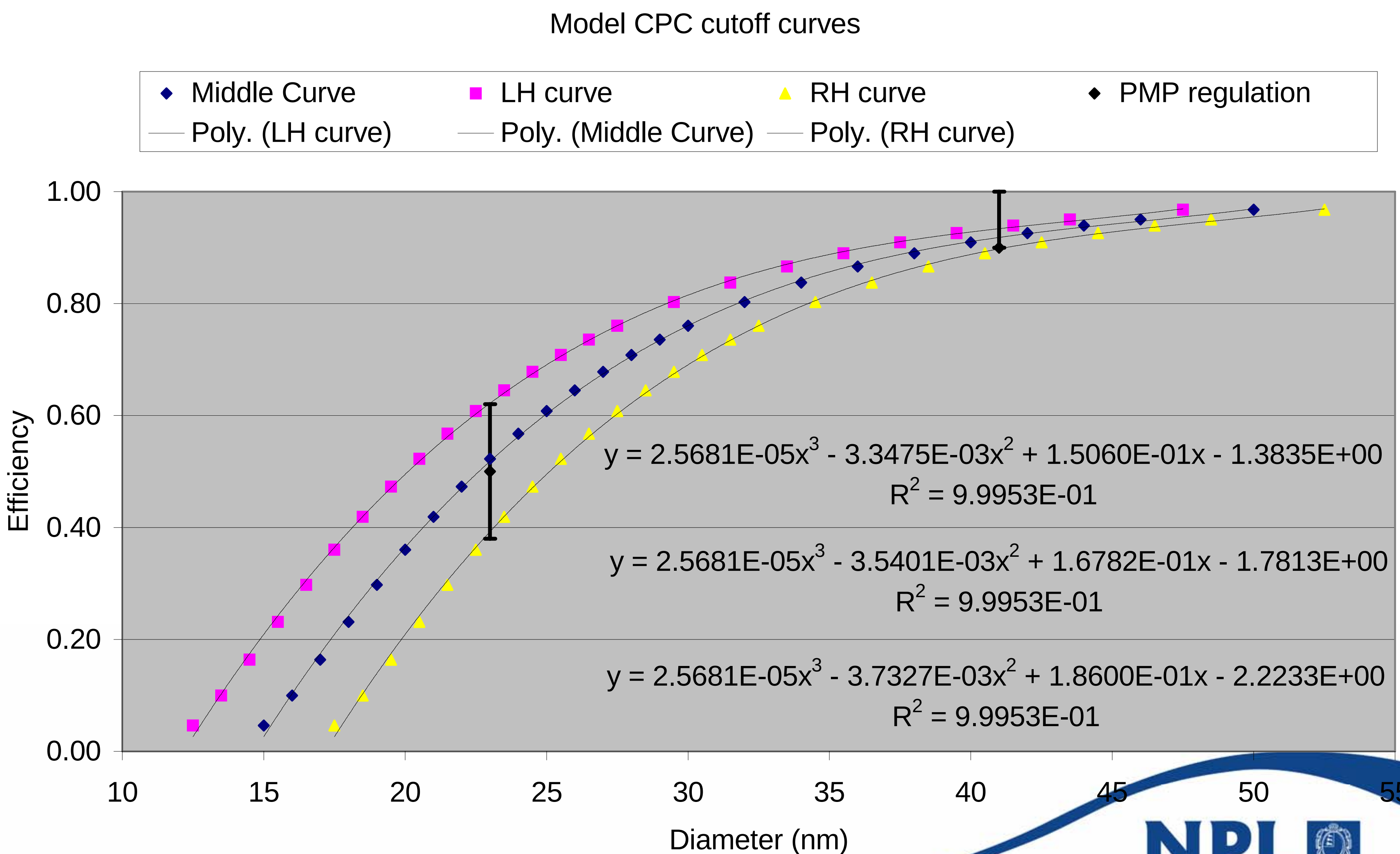
Low size cut off – effect on typical distribution < 1%



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Conclusions for C_{inlet}

The main contribution to uncertainty is likely to be the calibration of the PNC(s)

High dilution factors increase the uncertainty

Reproducibility and test source stability should be routinely quantified

Rough total uncertainties are 15% with single PNC route, 20% with dual PNC route

Definition:
The proportion of tetracontane (C_{40}) particles, of around 30 nm diameter, which having entered the VPR inlet are removed before measurement by the PNC instrument.

Method 1:

$$E_{volatile\ removal} = 1 - (F(av)_{particle\ dilution} / F_{volatile\ particle\ \text{“dilution”}})$$

Method 2:

$$E_{volatile\ removal} = 1 - (C_{PNC}(heater\ on) / C_{PNC}(heater\ off))$$

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VPR efficiency – summary

Absolute accuracy is greatly limited by the small concentrations expected after removal

Better uncertainty could be achieved by using Method 2 and input concentrations much higher than 10,000 cm^{-3}

In general, absolute accuracy is not required, only a demonstration that the >99% requirement is met, and most errors will not compromise this.