Laboratory tests of the rotating disc dilutor: calculated and observed dilution

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Updated abstract

Intrusive measurements of engine exhaust aerosols are difficult because of the very high particle number densities and the extremely dynamic processes present in the particle gas mixture. A rapid and controlled dilution near the source that brings the number densities down and at the same time slows down coagulation and condensation processes is a very tractable approach in studying exhaust products. Matter Engineering AG has developed a new dilution system for submicron aerosols, called the Rotating Disc Dilutor, which has been described by Heuglin et al (1997). We present results from laboratory tests performed using a slightly modified Rotating Disc Dilutor.

The performance of the dilution system as a function of particle size was determined by performing several dilution experiments with particles of different sizes, at different temperature (room temperature and 150°C), and different rotation speeds of the disc. A Differential Mobility Analyser was used to generate monodisperse ammonium sulphate aerosols in the sizes 9.8, 26.9, 73.8 and 202.5 nm. Number densities were measured before and after the dilutor, using a CPC TSI 3022A and a CPC TSI 3010, respectively. The relation between the rotating frequency and dilution factor was determined experimentally. A tendency of size dependency can be seen, where the apparent dilution factor decreases with decreasing size.

The observed dilution was compared to the theoretical value calculated from the number and volume of the cavities, flow and rotation frequency. Our observations show a clear difference between the calculated and the observed dilution. Observations also differ from values given in the calibration sheet provided by Matter Engineering. The calibration curve given by the manufacturer is not a characteristic of the rotating disc, but includes losses in the system (e.g. in the provided sample line and internal PVC hoses).

Future work within the EMIR-1 project includes study of engine exhaust from a Scania Diesel engine using a Rotating Disc Dilutor, a tandem DMA, thermodenuder and two CPCs.

References

Heuglin, Ch., L. Scherrer; H. Burtscher; **An accurate, continuously adjustable dilution system (1:10 to 1:104) for submicron aerosols;** Journal of Aerosol Science, 1997, Vol 28, No 6, pp. 1049-1055.

Organisation

Work has been done as part of PhD studies within the EMIR-1 project which deals with sampling and measurement methods for exhaust gas particulate emissions. EMIR-1 is a project within the Swedish cooperation programme 'The Green Car' for the development of environmentally friendly vehicles. Project participants include the Royal Institute of Technology, AVL MTC, Saab Automobile, Scania CV, Volvo Car Corporation and Volvo Technology Corporation.

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Acknowledgements

EMIR-1 project participants:

- AVL MTC
- Saab Automobile
- Scania CV
- Volvo Car Corporation
- Volvo Technology Corporation

EMIR-1 Sampling and measurement methods for exhaust gas particulate emissions

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Motivation:

- Measurements of exhaust aerosols are difficult
  - High particle number densities
  - Dynamic processes
- Dilution and sampling conditions influence the measurements

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Rapid and controlled dilution

- near the source
- bring the number densities down
- slow down coagulation and condensation processes

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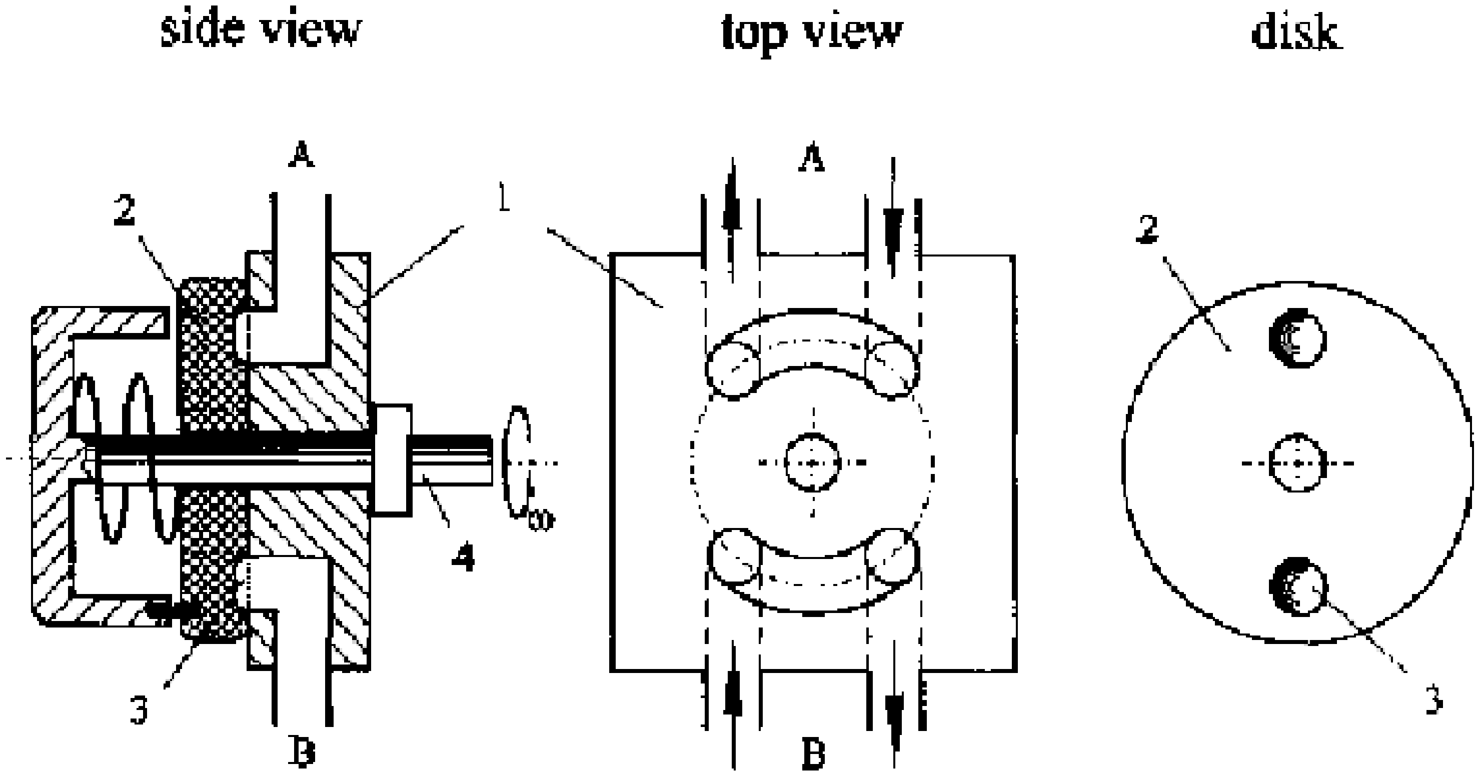
The Rotating Disc Dilutor



A aerosol channel

B dilution gas channel

1 body

2 rotating disk

3 disk cavity

4 axis of rotation

Heuglin, Ch; Scherrer, L.; Burtscher, H: **An accurate, continuously adjustable dilution system (1:10 to 1:10^4) for submicron aerosols** Journal of Aerosol Science, 1997, Vol 28, No 6, pp. 1049-1055.

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Scope

- Determine the performance as a function of particle size
- Small scale dilution experiments
  - particles of different sizes
  - different temperatures (RT and T=150°C)
  - different rotation speeds of the disc

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Experimental set-up

- Ammonium sulphate $(NH_4)_2SO_4$
- DMA
  - D_P: 9, 26, 73 and 202 nm
- 2 CPC
  - before dilution: TSI 3022A
  - after dilution: TSI 3010 F_S = 1,013 L/min
- 2-cavity disc
- Dilution unit slightly modified
  - Internal peristaltic pump exchanged for external one
  - PVC tubing replaced by conductive one
  - 3m hose replaced by 20cm conductive hose

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Experimental procedure

- Determine the relation between dilution ratio and rotating frequency
  - Rotation frequency fixed
  - Scan the sizes
    - Data rate 1 Hz
    - 500 data registrations for each size
  - Sizes and frequencies were interleave to avoid systematic errors due to drift

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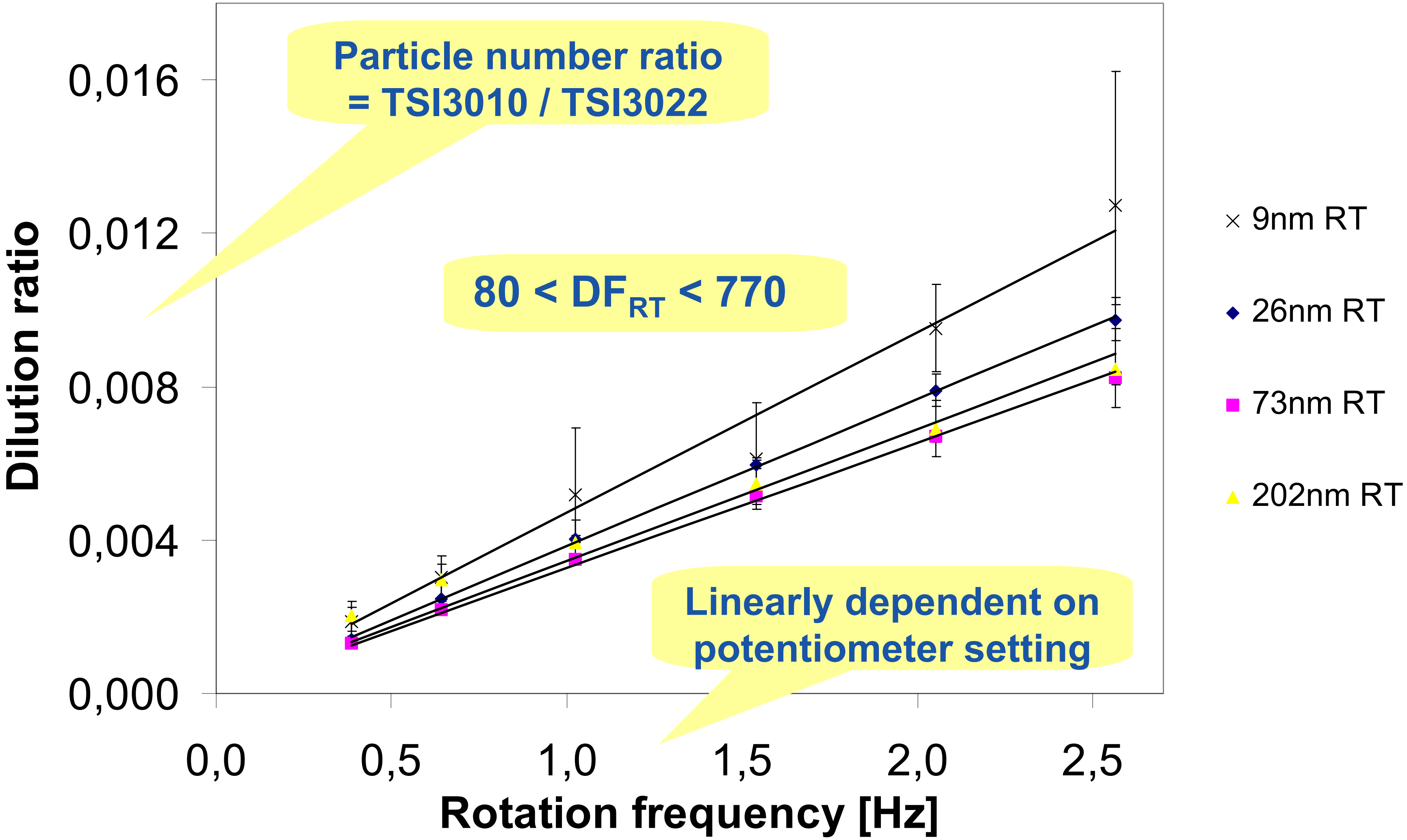
Dilution ratio against rotating frequency at RT



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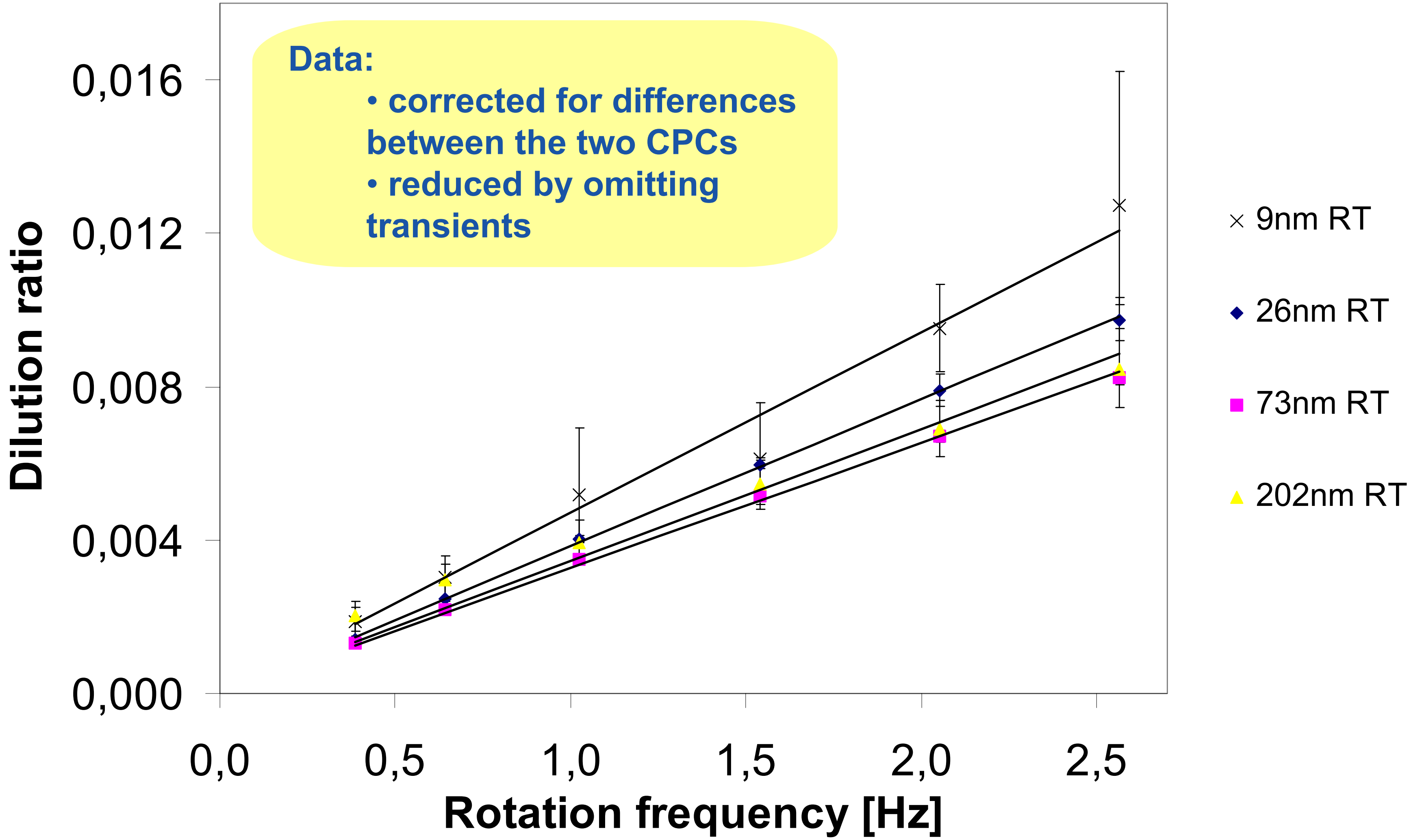
Dilution ratio against rotating frequency at RT



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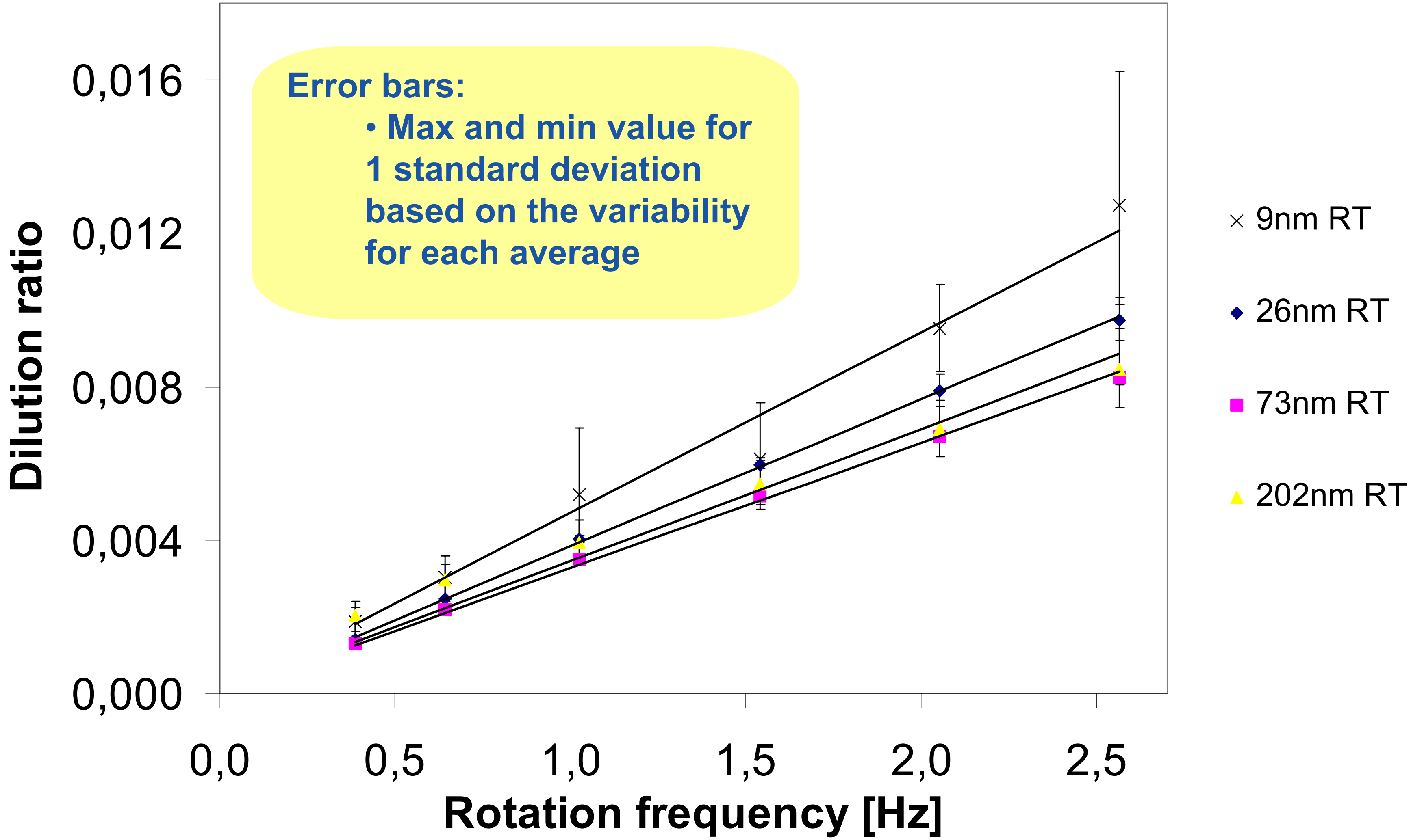
Dilution ratio against rotating frequency at RT



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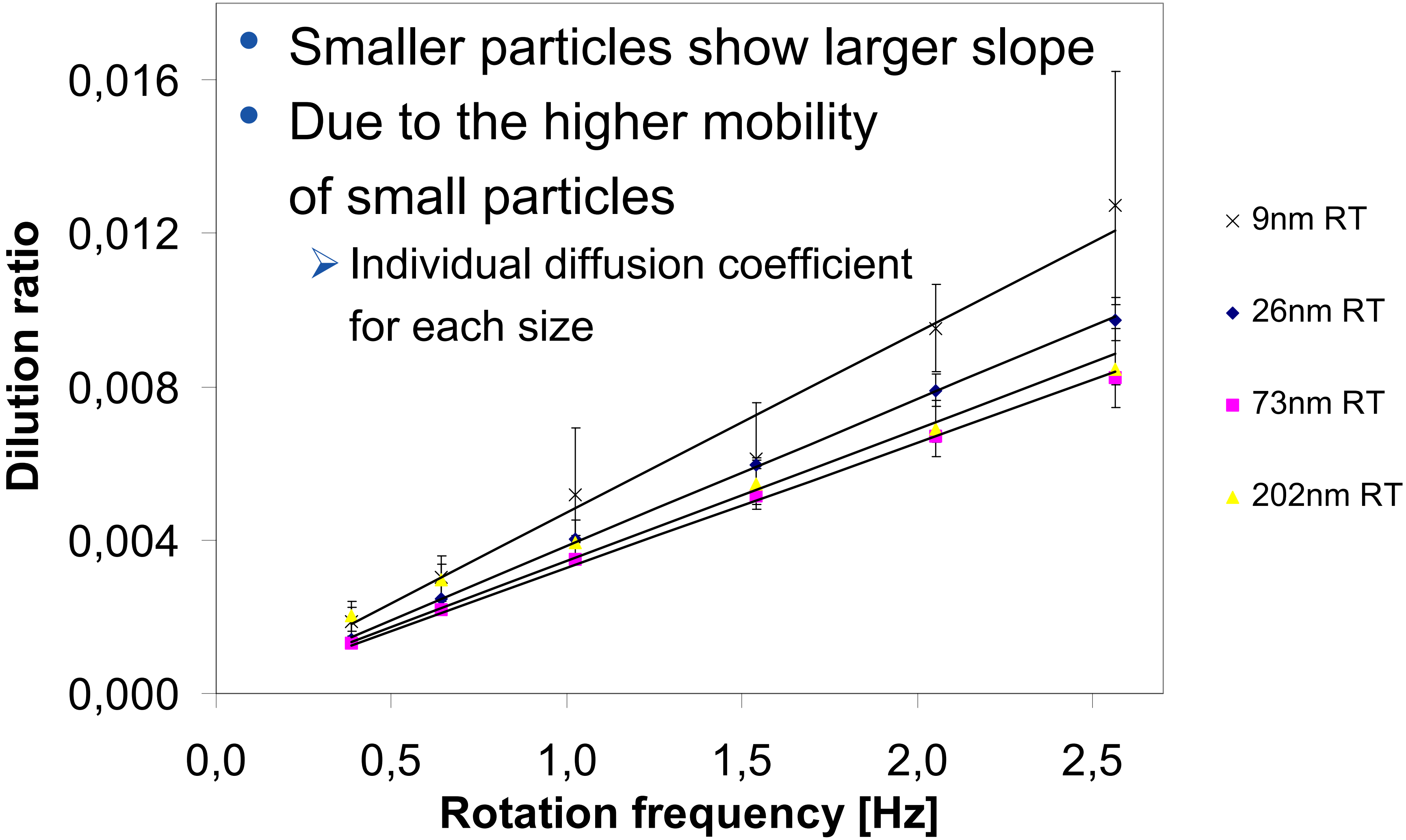
Tendency of size dependency

- Smaller particles show larger slope
- Due to the higher mobility of small particles
  - Individual diffusion coefficient for each size



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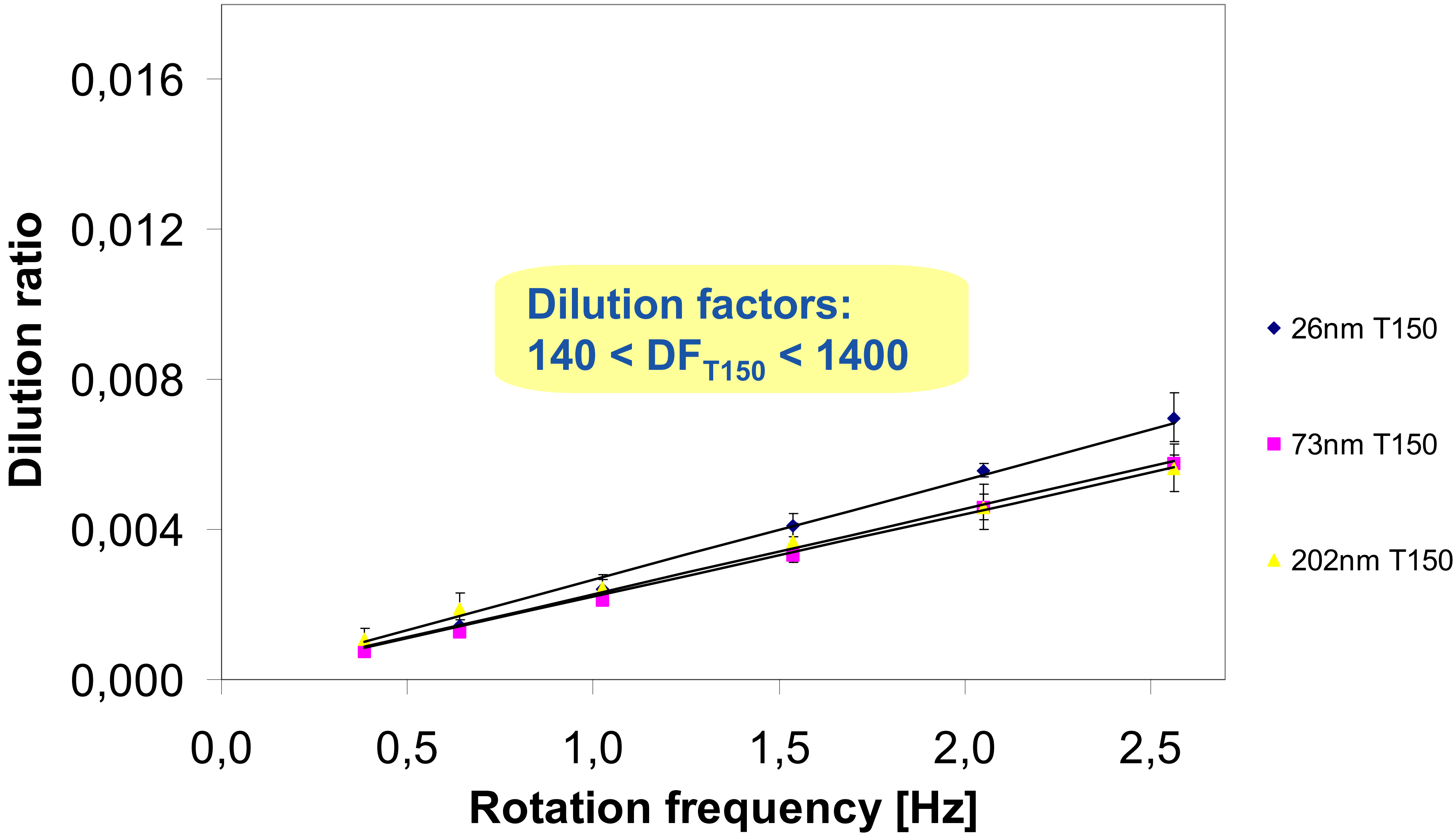
Dilution ratio against rotating frequency at T150



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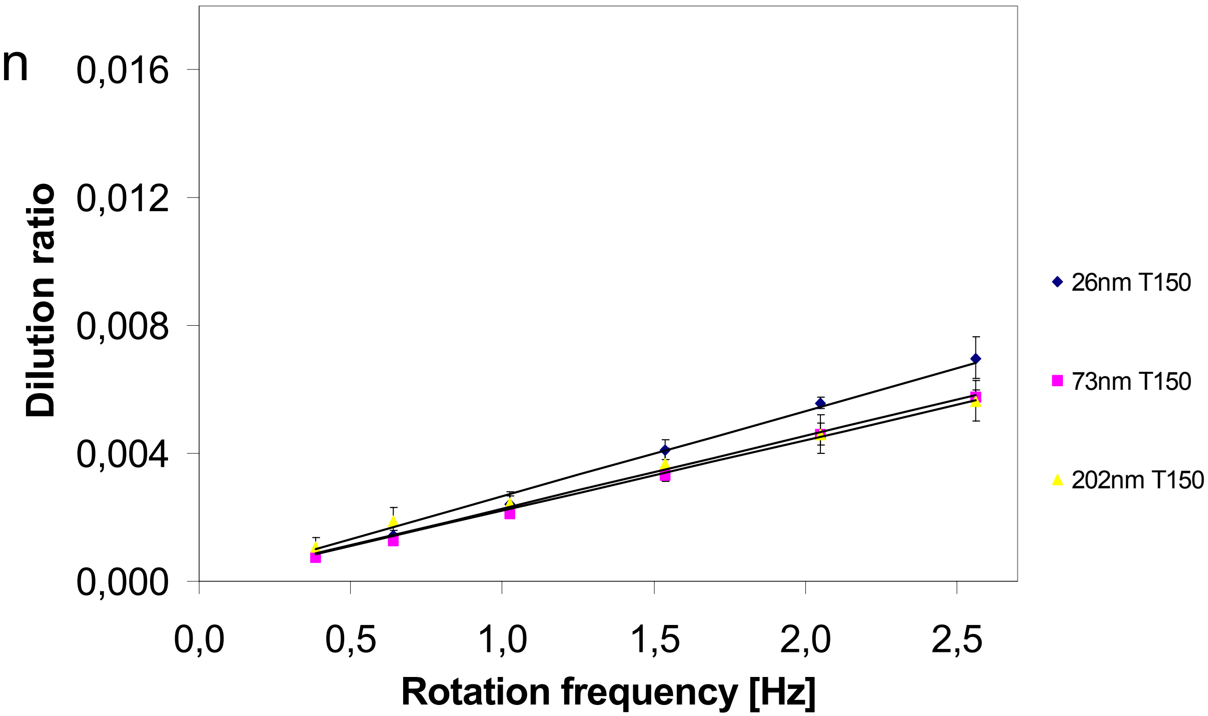
Low number density sizes are omitted

- Baseline stray counts were occasionally above the actual value
  - due to contamination of the optics of the CPC
  - rotation frequency shall be adjusted to achieve adequate number concentrations



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The observed dilution was compared

- with the theoretical value
  - calculated from number and volume of cavities, sample flow and rotation frequency
- with the values given by the manufacturer

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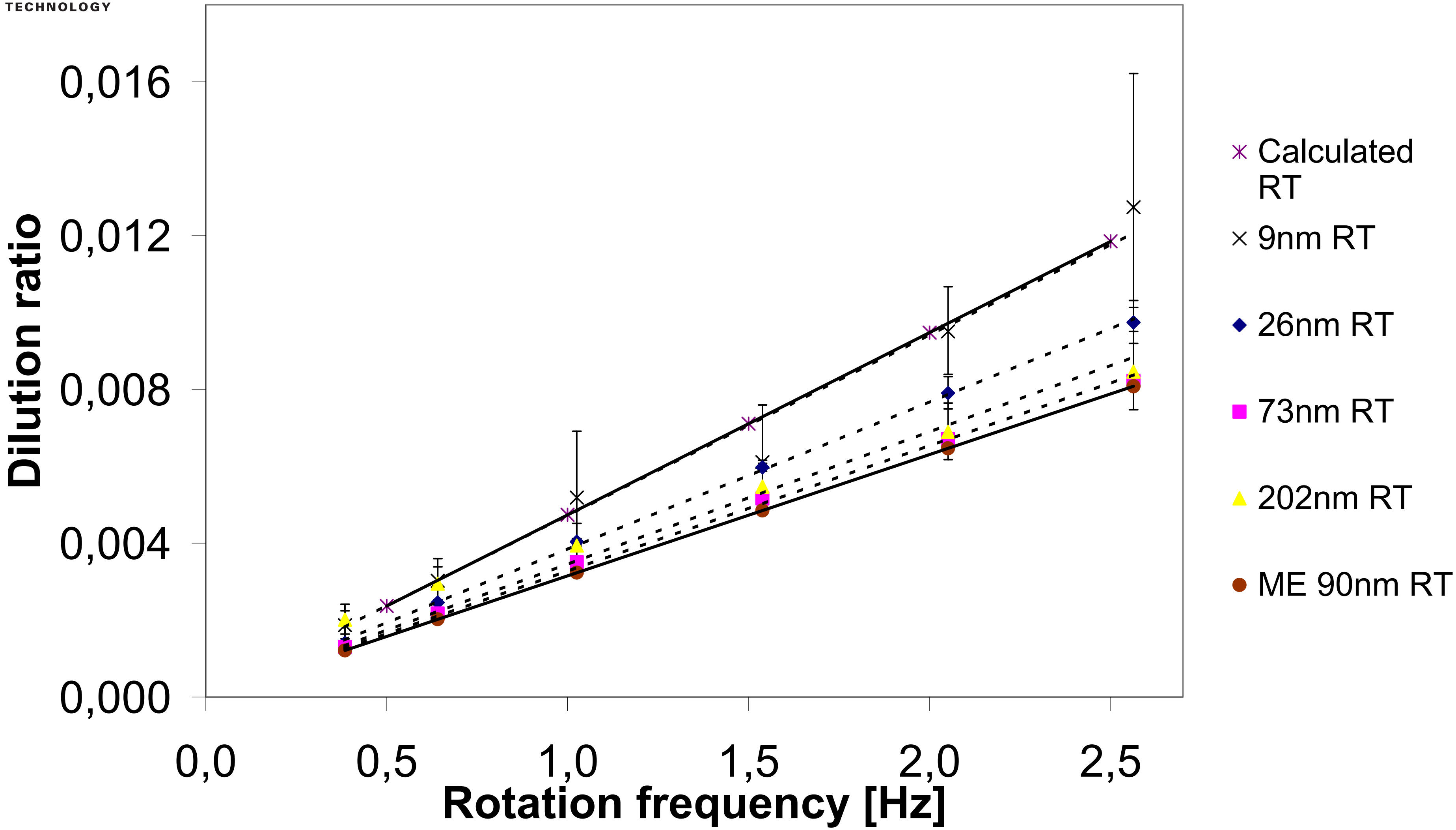
Comparison at RT



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Differences

- between observed and calculated values
  - Losses
  - Efficiency with which the cavities are emptied
- between observed and given values
  - Calibration sheet values include losses in several parts of the equipment
  - For larger particles the observed curves approaches the ones given by the manufacturer

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Summing up

- Size dependency
  - the apparent dilution factor decreases with decreasing size
- Calibration curve given by the manufacturer *is NOT a characteristic for the rotating disc*
  - *includes losses* in the complete system (e.g. in the provided sample line and internal PVC hoses)

- Future work could investigate this, using ultrafine CPCs or electrometers, that were not available in the current study

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Future work

- Rotating disc dilutor + tandem DMA + thermodenuder
- Engine exhaust
  - Scania truck engine
  - Passenger car

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