DFM
Danish National Metrology Institute

EMRP –

European Metrology Research Programme

Danske aktiviteter indenfor partikelmetrologi

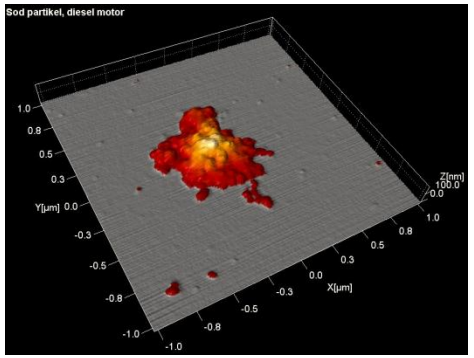
Metrologidag 20. maj 2014

Kai Dirscherl

kdi@dfm.dk

Danish Fundamental Metrology
Matematiktorvet 307
DK-2800 Kgs. Lyngby
Denmark

Overview

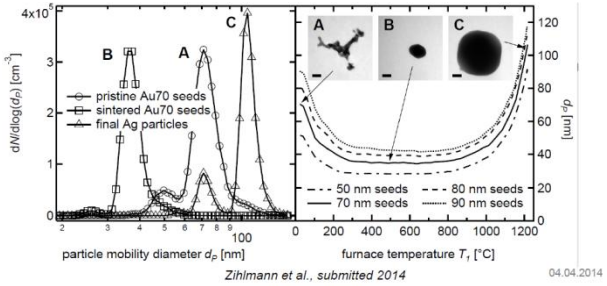


§ Particle Emission -
et europæisk “Joint Research Project”

§ Sodpartikler -
målestørrelser – udfordringer – anbefalinger

§ Partikelmetrologi i Danmark -
Videnstransfer – serviceydelser – forskningsopgaver

§ Opsummering



Sodpartikler: regulative opgaver

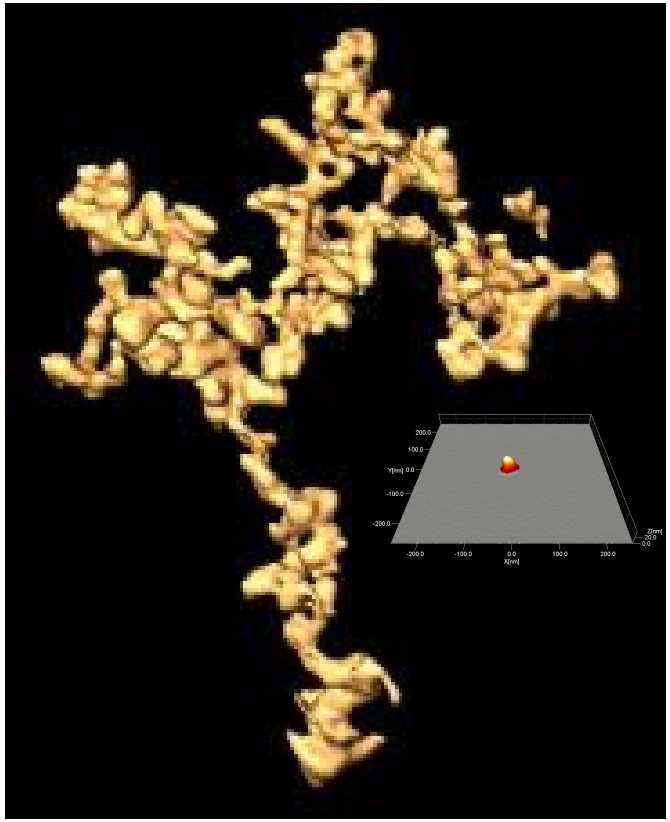
§ Sodpartikler: urene kulpartikler fra ufuldstændig forbrænding af hydrocarboner,
  -) WHO (2012) "kræftfremkaldende"
  -) stor forårsager af global opvarmning

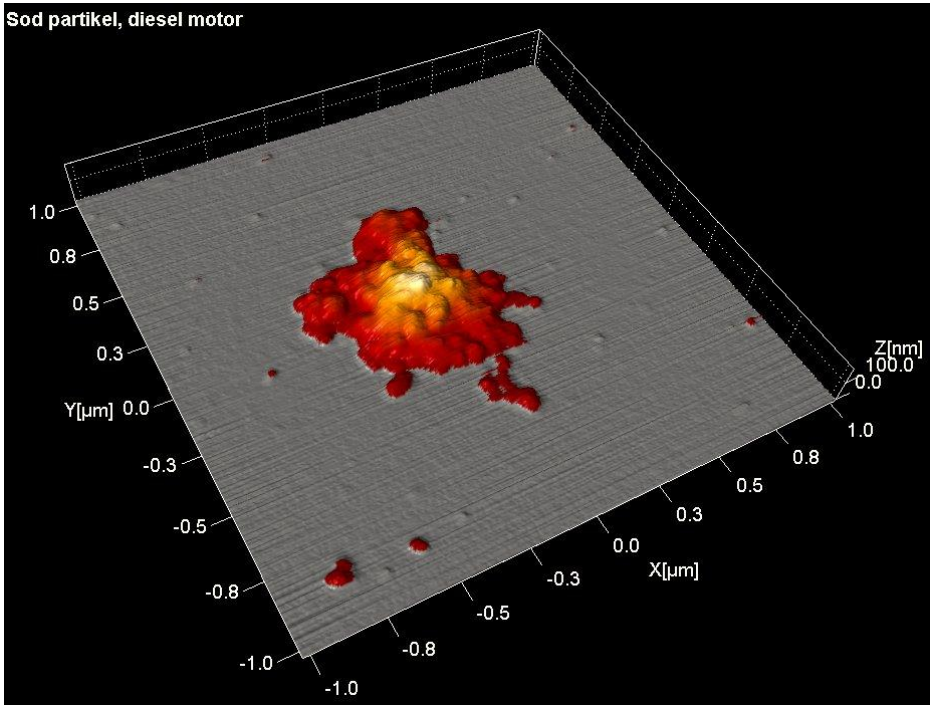
Foto:autobild

§ **Euro 5 / 6 standards regulation 715/2007 for diesel vehicles (i kraft siden 2013):**

„Maks. 600 milliarder partikler per kørt km"

Sodpartiklernes mange ansigter





Dieselpartikler (~ 1 µm) består af primærpartikel af kulstof (30 nm)

PartEmission (2011-2014)

et fælles forsknings project (JRP) støttet af Europæsik Metrologi Forsknings Program (EMRP)

DFM
Danmarks Nationale Metrologiinstitut

JRC
EUROPEAN COMMISSION

ie
Institute for Energy

METAS

Partikelreference-
størrelse
form
materiale
tællemetode

NPL
National Physical Laboratory

MIKES

PTB

TROPOS
Leibniz Institute for Tropospheric Research

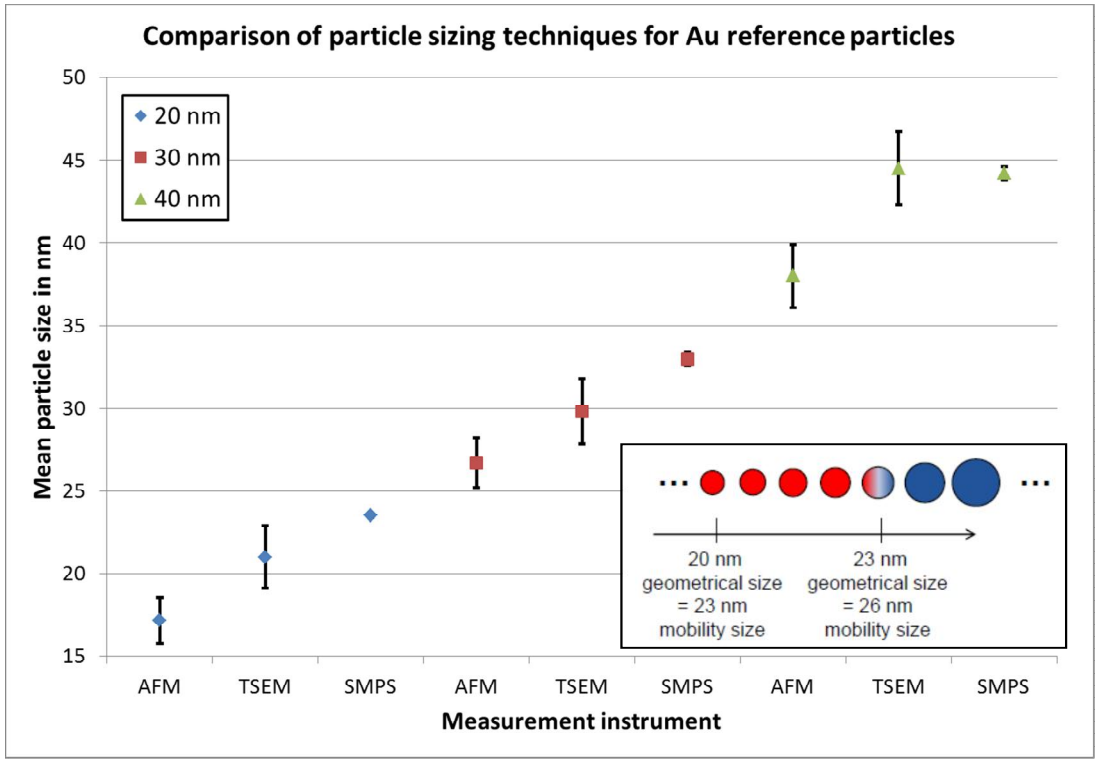
EMRP
European Metrology Research Programme
Programme of EURAMET

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

Emerging requirements for measuring pollutants from automotive exhaust emissions

http://www.ptb.de/emrp/partemission.html

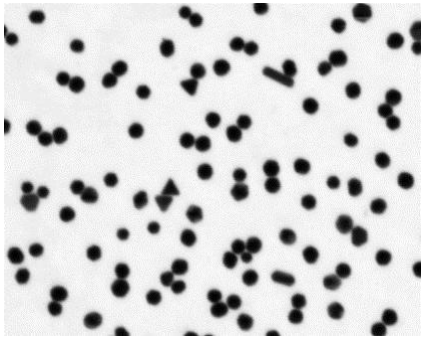
PartEmission / partikelstørrelse:
Kalibrering af partikeltæller med reference partikler

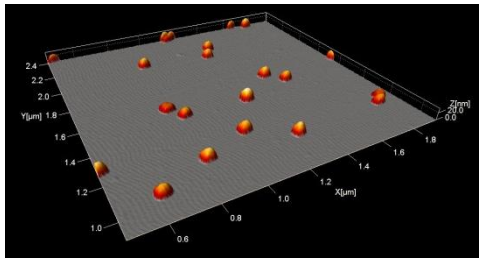


European Metrology Research Project on Particle Emission http://www.ptb.de/emrp/partemission-publications.html, ENV02 WP1 D1.1.1.pdf

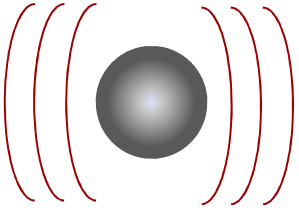
At the nanometer scale, the shells of different physical interaction do not neccessarily coincide with the compact particle shape.

SEM: diameter





AFM: height



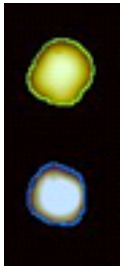
SMPS: Mobility diameter

PartEmission / partikelmorfologi:
Ækvivalens af forskellige reference partikler

Paired populations	E_n
M_{23} – M_{41}	-0.3
M_{23} – G_{41}	6.0
M_{41} - G_{41}	3.5

		Roundness (a.u.)
Average	M_{23}	0.85
	M_{41}	0.87
	G_{41}	0.60
Standard uncertainty of average	M_{23}	0.02
	M_{41}	0.06
	G_{41}	0.04

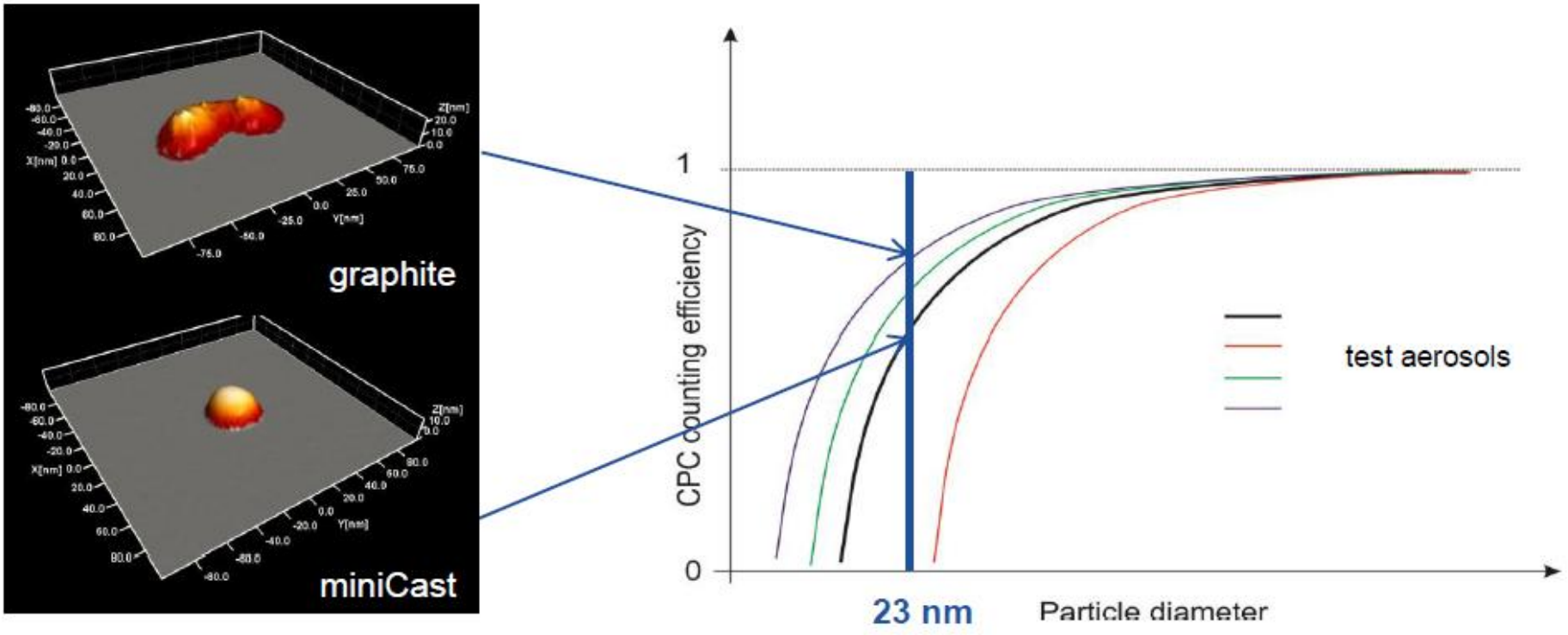
miniCAST 41 nm



miniCAST 23 nm

graphite 41 nm

PartEmission:
Skal reference aerosol ”efterligne” sodpartikler ?



Test med forskellige partikelmaterialer viser, at partikeltæller er følsomme for materiale, form og størrelse.

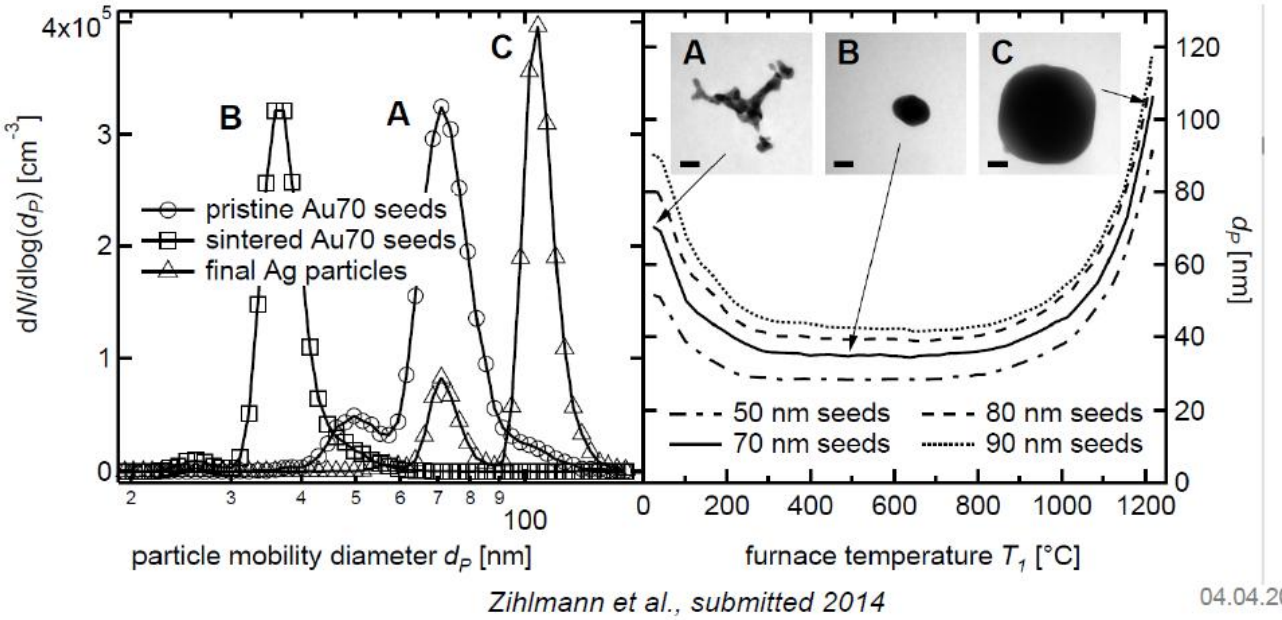
Heterogen nukleerede (sintrede) sølv partikler ”machter” bedst.

PartEmission: Nuværende anbefalinger
(projektet udløber 2014)

- Kalibrering af tællerne sker ved >80 nm med kugleformede reference partikler
- Mobilitetsdiameteren < 80 nm beregnes efterfølgende iht. ISO 15900
- Der findes ikke én type "sod-lignende" reference partikler, men sintrede sølvpartikler anbefales pga. aerosol performance/reproducerbarhed

Fremtidens opgave

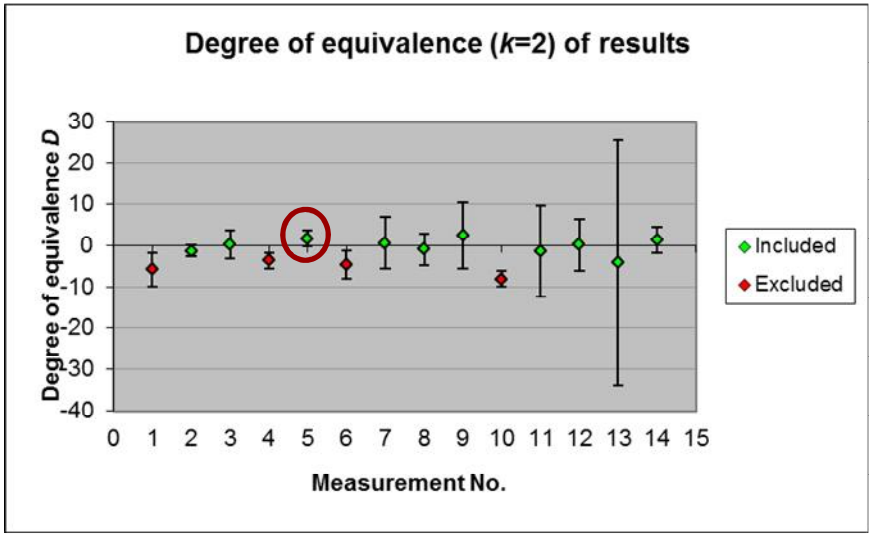
- Kalibreringsydelser for partikelantal i sod-aerosoler skal etableres efter behov

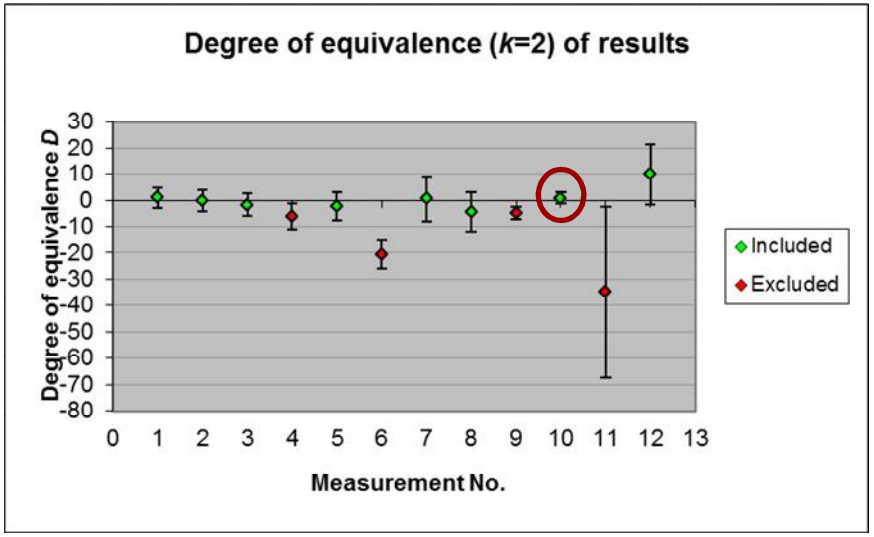


Zihlmann et al., submitted 2014

04.04.2014

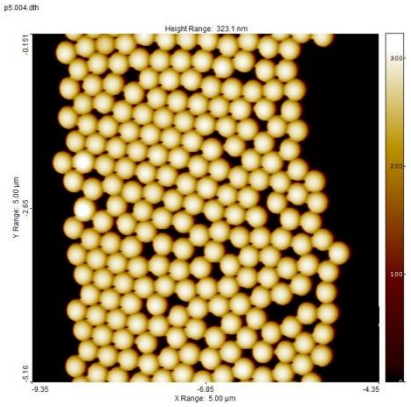
Good performance during international comparison ”Particle size” 2012/13 (preliminary results)

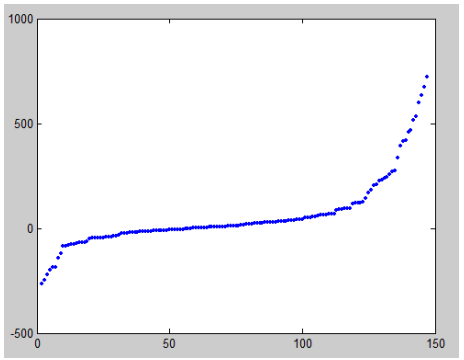


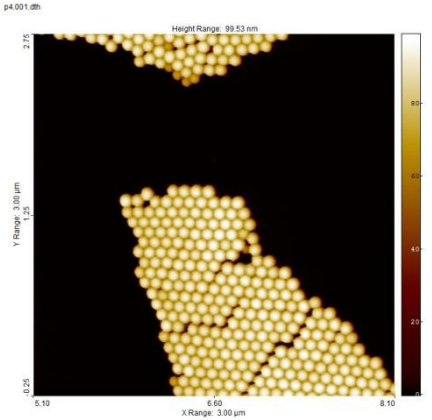


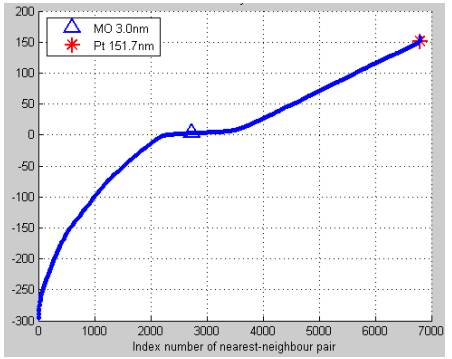
0.100 µm particles

0.300 µm particles



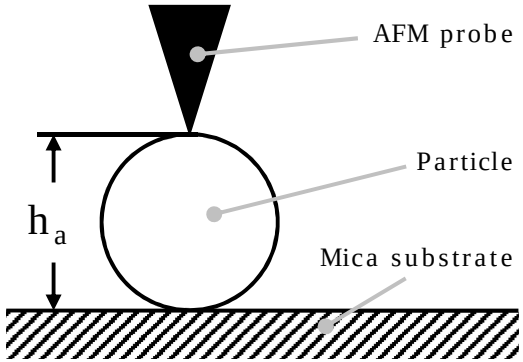




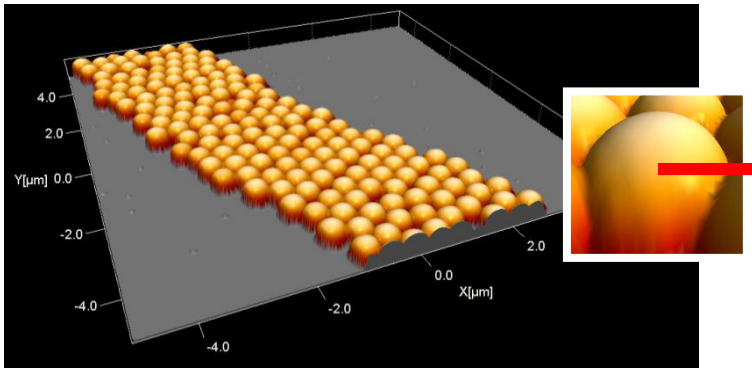


Size-certified nanometer particles traceable to the meter with a metrological Atomic Force Microscope

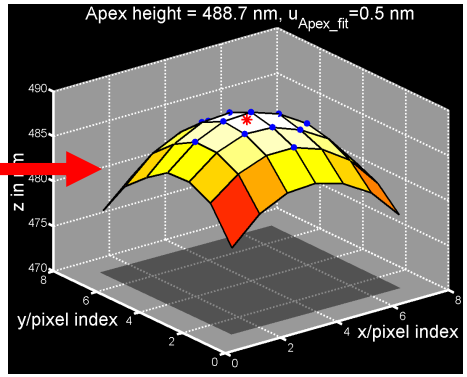
Measurement method

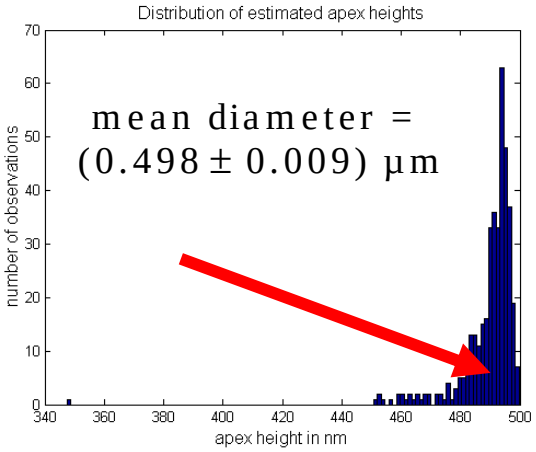


AFM image of particle sample



Data analysis





Result: diameter distribution

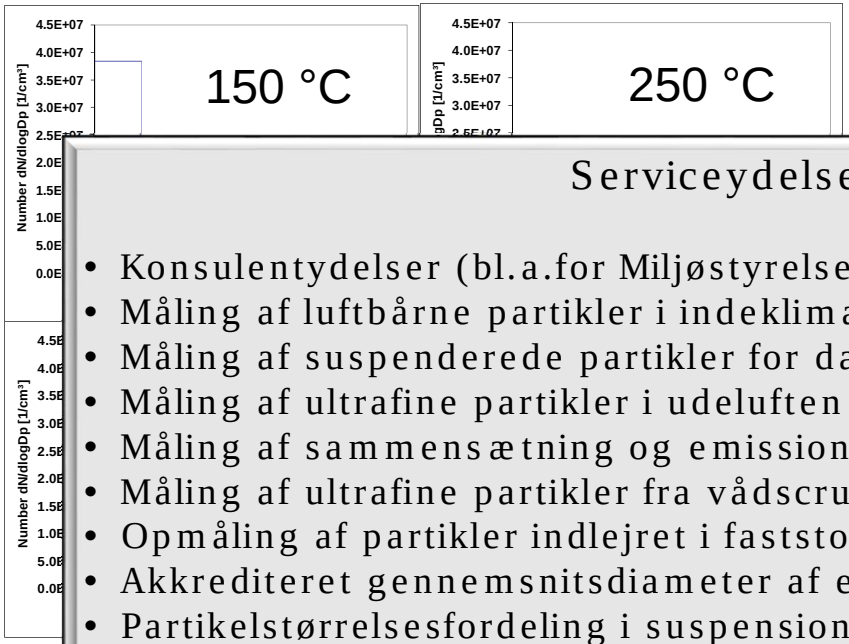
Certification

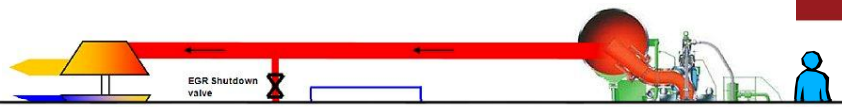
Diameter ranges:	Uncertainties:
from 100 nm	from 5 nm
to 5 000 nm	to 50 nm

Certified dispersion (15 ml)

GTS- samarbejde DFM/Teknologisk Institut/Force Technology fortsættes i

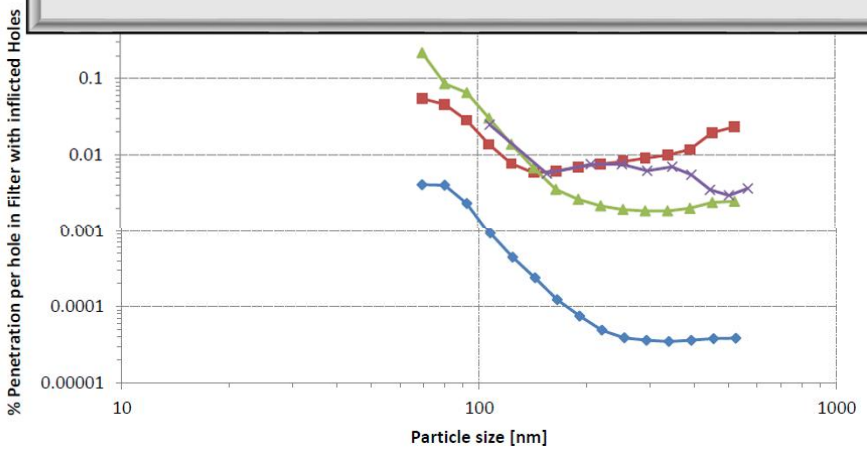
Centre of Excellence for Partikel Metrologi

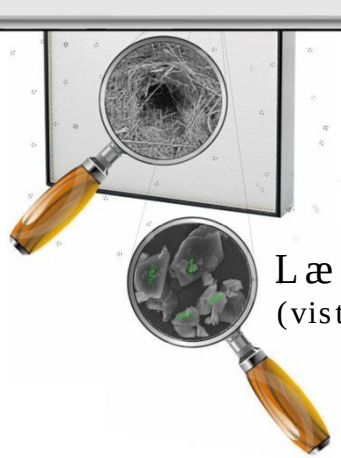




Serviceydelser i Danmark i GTS-regi

- Konsulentydelser (bl.a.for Miljøstyrelsen)
- Måling af luftbårne partikler i indeklimaet i tog
- Måling af suspenderede partikler for dansk industri
- Måling af ultrafine partikler i udeluften omkring lufthavn
- Måling af sammensætning og emissioner af ultrafine partikler fra fly og køretøjer i lufthavn
- Måling af ultrafine partikler fra vådscrubber
- Opmåling af partikler indlejret i faststof ved brug af microCT scanner
- Akkrediteret gennemsnitsdiameter af en partikelpopulation for reference brug
- Partikelstørrelsesfordeling i suspensioner
- Brydningsindeks af partikler i suspensioner
- Akkrediteret kalibrering af partikeltæller for rene rum

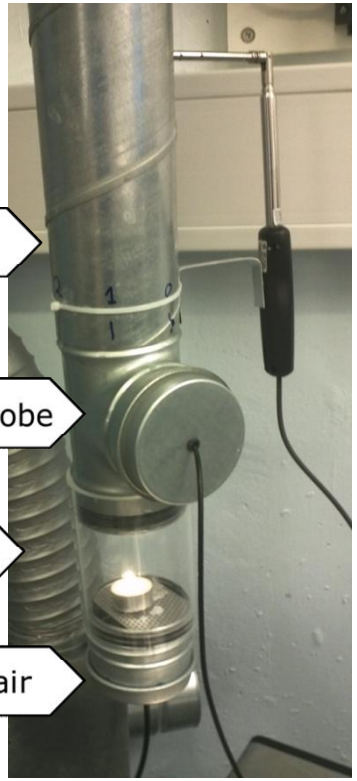


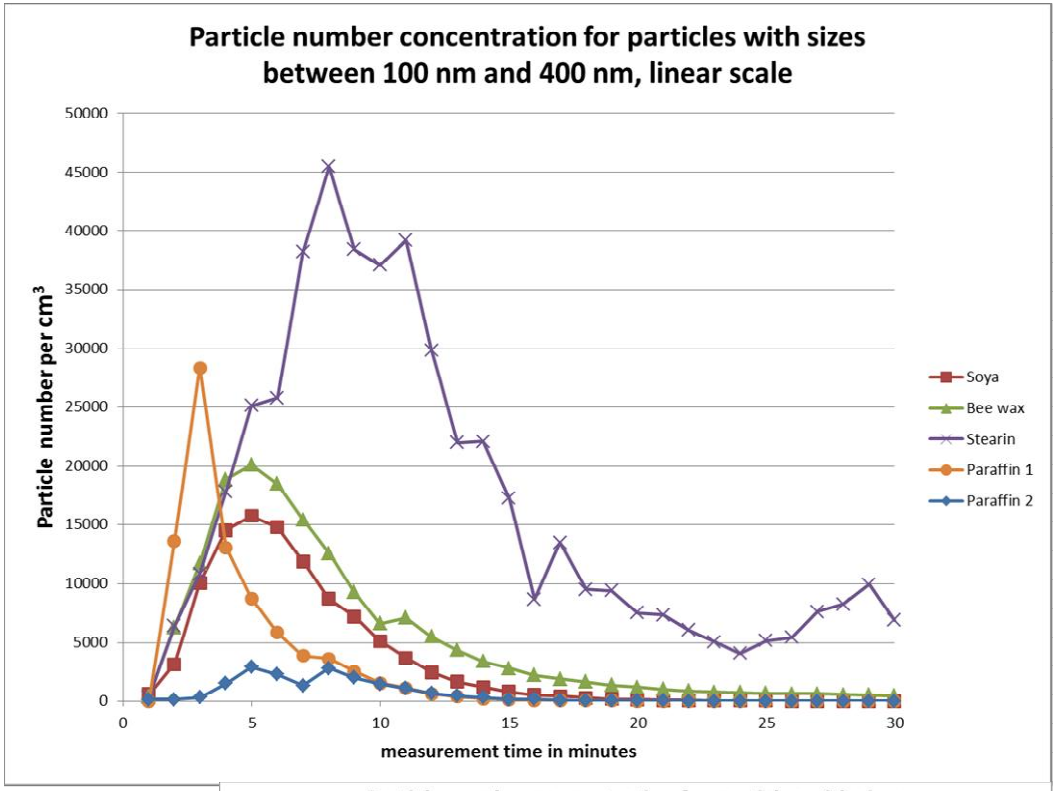


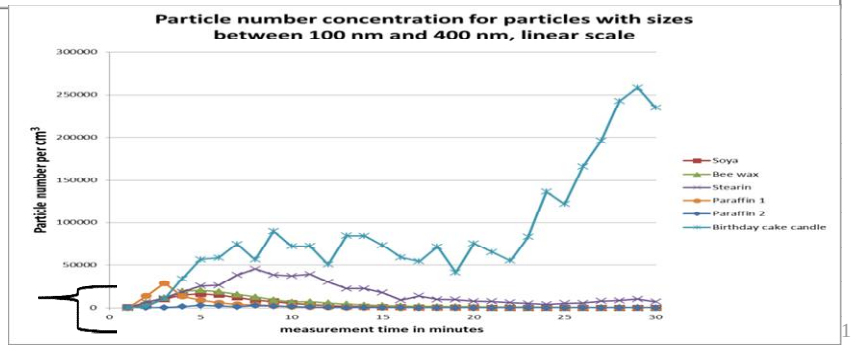
Innovationskonsortium NaKIM (2010-2013)

Lækage i HEPA-filtre
(viste målinger: Teknologisk Institut)

Forbrændingspartikler fra lyse







Renrum klasser – global kvalitetssikring igennem standardisering

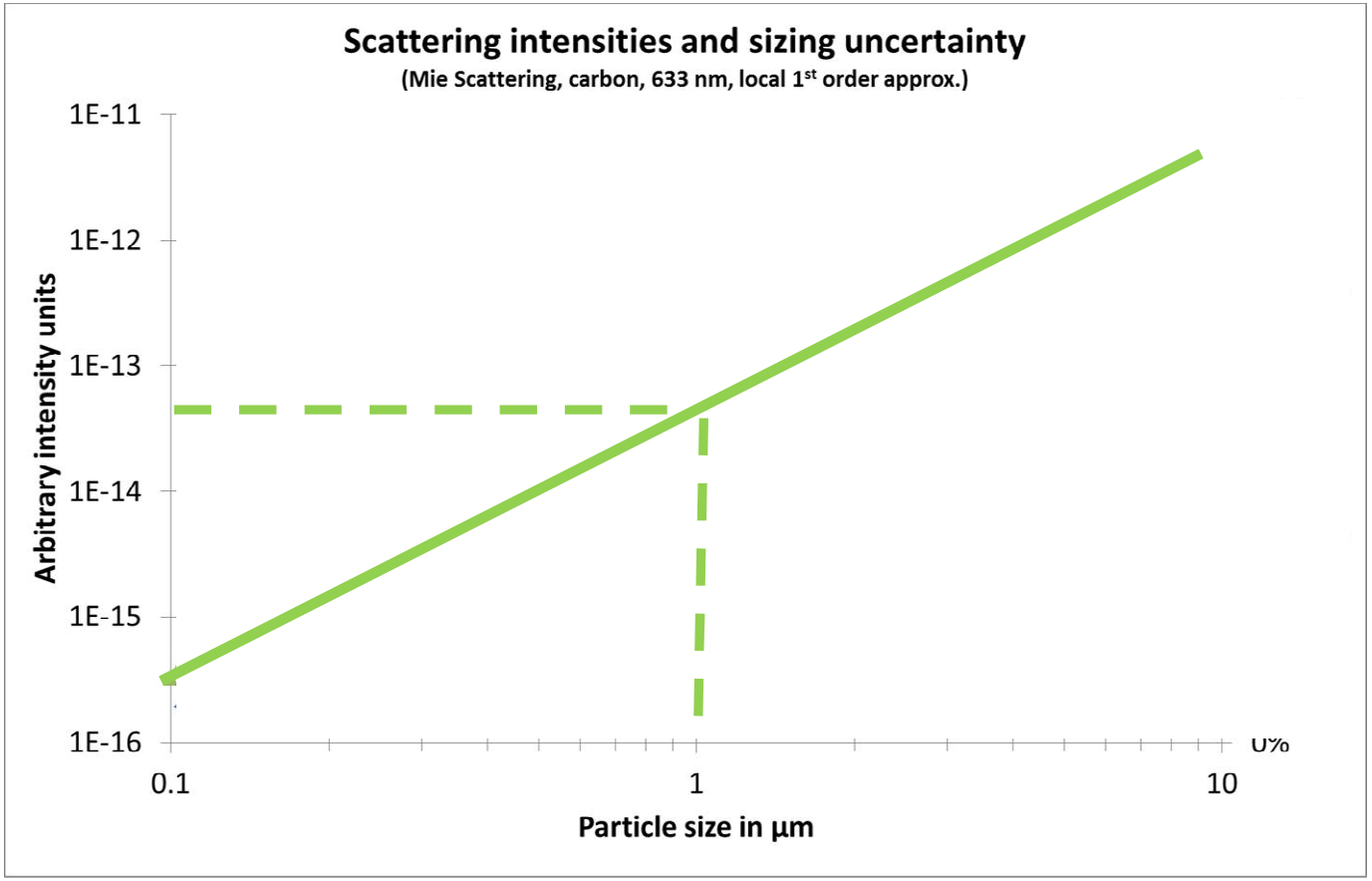
Class	maximum particles/m^3					
	≥0.1 µm	≥0.2 µm	≥0.3 µm	≥0.5 µm	≥1 µm	≥5 µm
ISO 1	10	2.37	1.02	0.35	0.083	0.0029
ISO 2	100	23.7	10.2	3.5	0.83	0.029
ISO 3	1,000	237	102	35	8.3	0.29
ISO 4	10,000	2,370	1,020	352	83	2.9
ISO 5	100,000	23,700	10,200	3,520	832	29
ISO 6	1.0×10^6	237,000	102,000	35,200	8,320	293
ISO 7	1.0×10^7	2.37×10^6	1,020,000	352,000	83,200	2,930
ISO 8	1.0×10^8	2.37×10^7	1.02×10^7	3,520,000	832,000	29,300
ISO 9	1.0×10^9	2.37×10^8	1.02×10^8	35,200,000	8,320,000	293,000

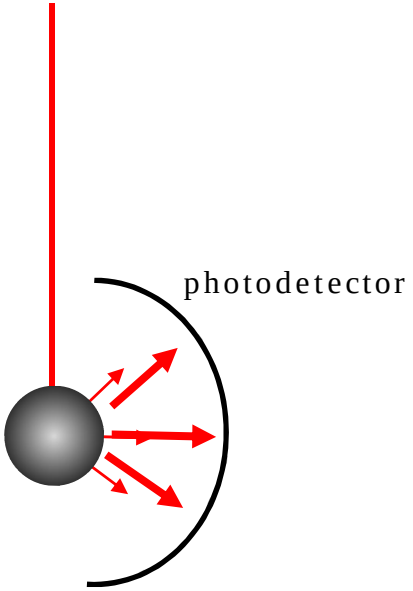
ISO 14644-1
ISO 21501-4

Danske eksperter bidrager aktivt i ISO udvalg

Physical limitations of optical particle counters

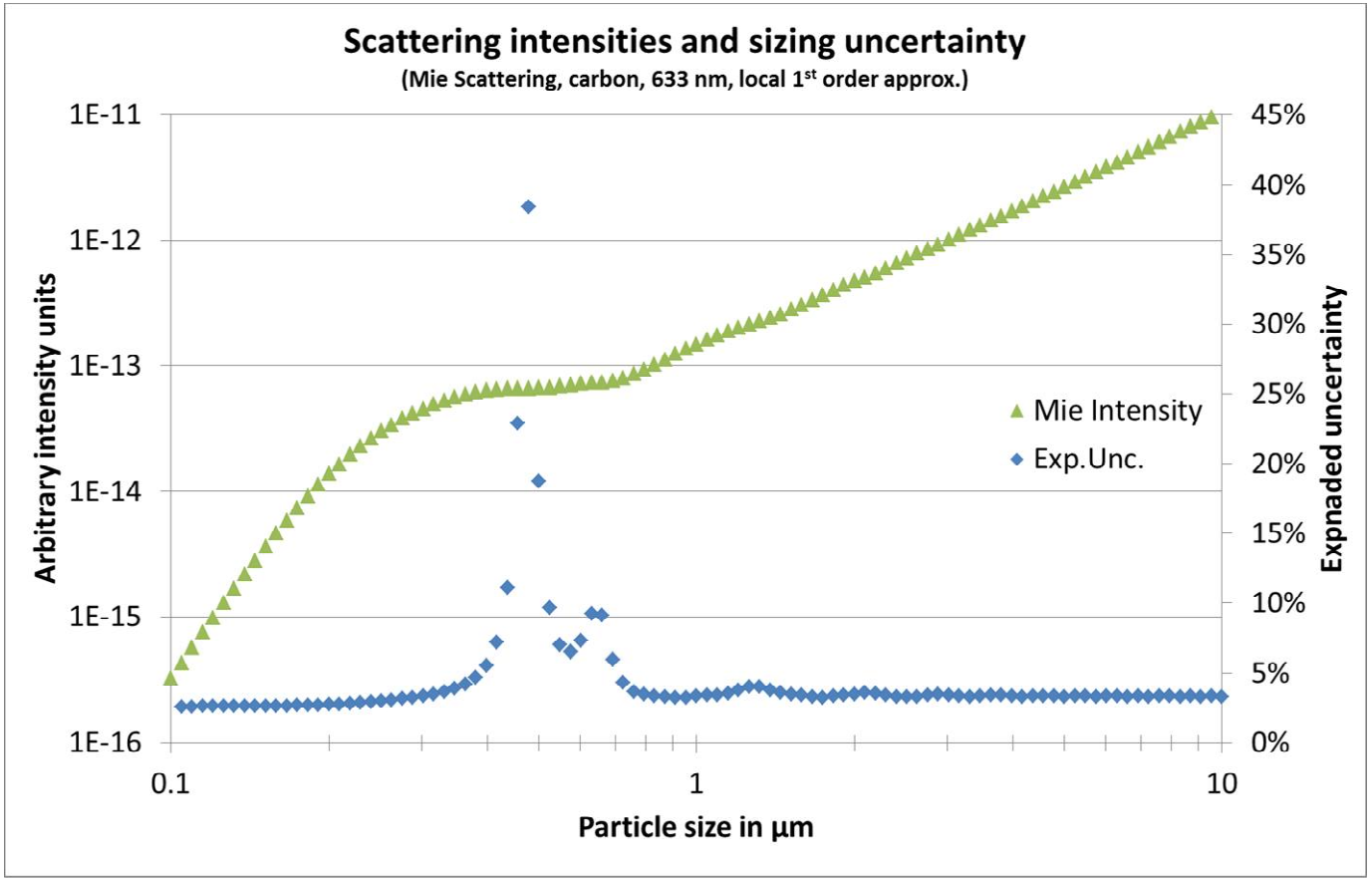
Light scattering particle counters a photodetector to measure the intensity of the light scattered from a particle.

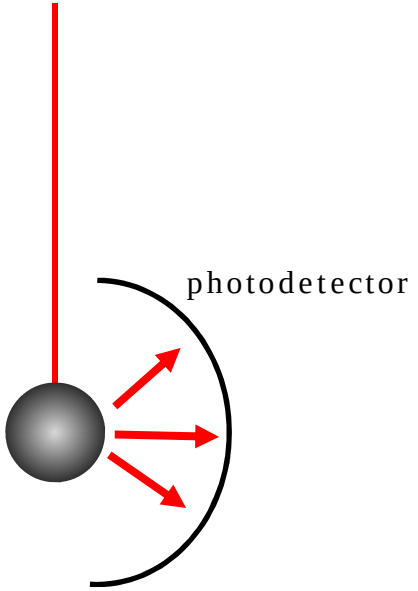




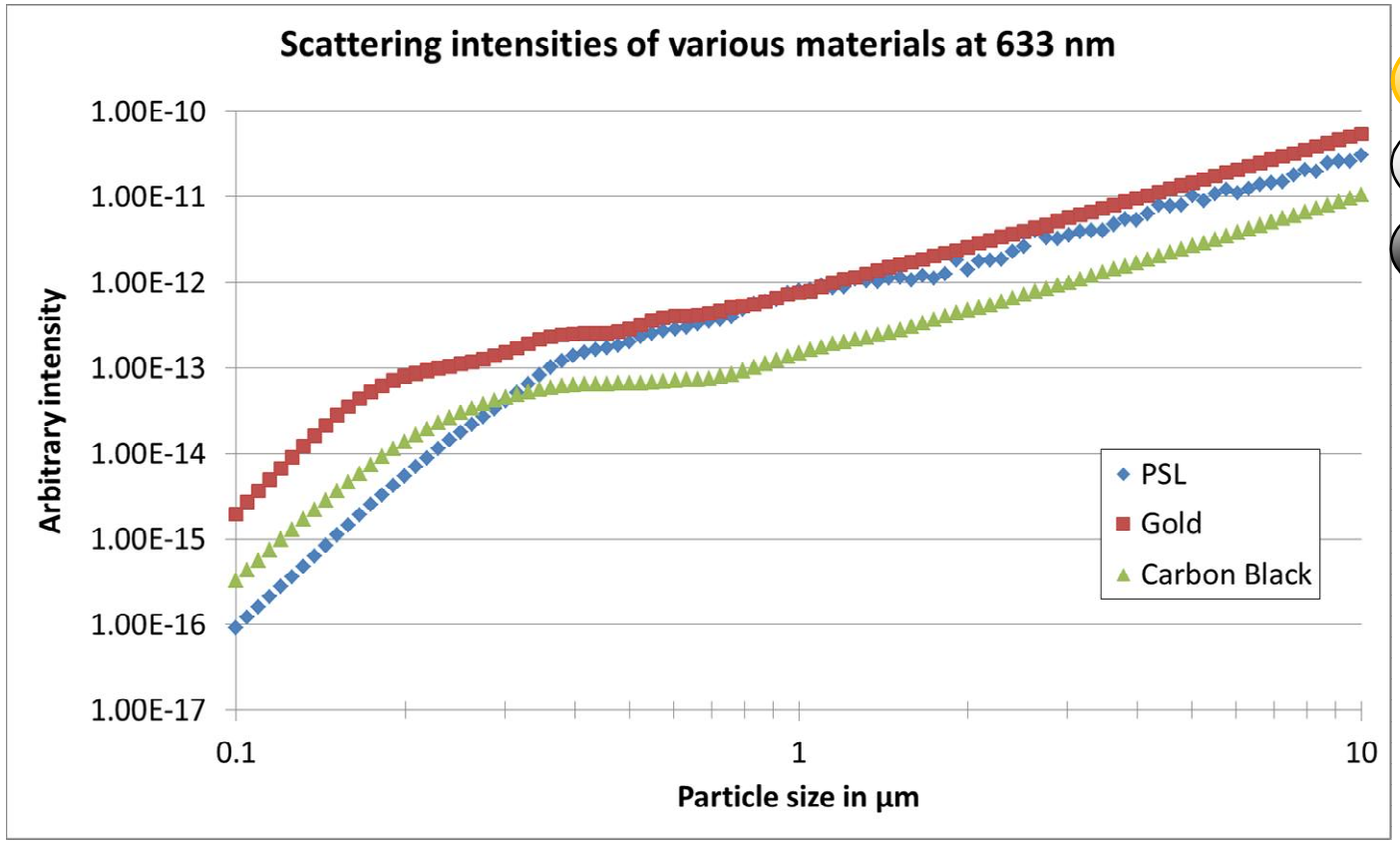
Physical limitations of optical particle counters

Light scattering particle counters a photodetector to measure the intensity of the light scattered from a particle.





Physical limitations of optical particle counters



guld

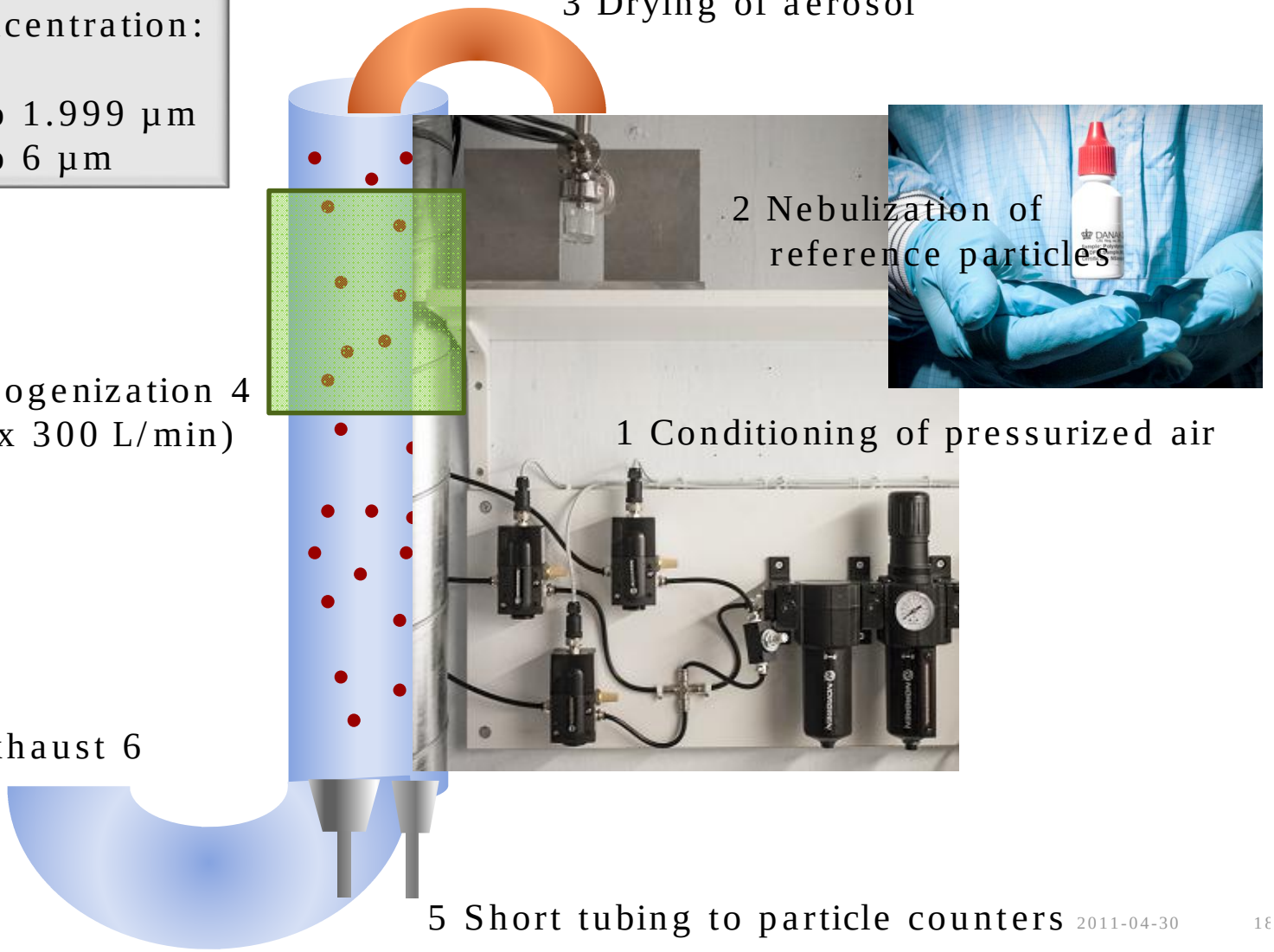
Polystyren (flamingo)

kul

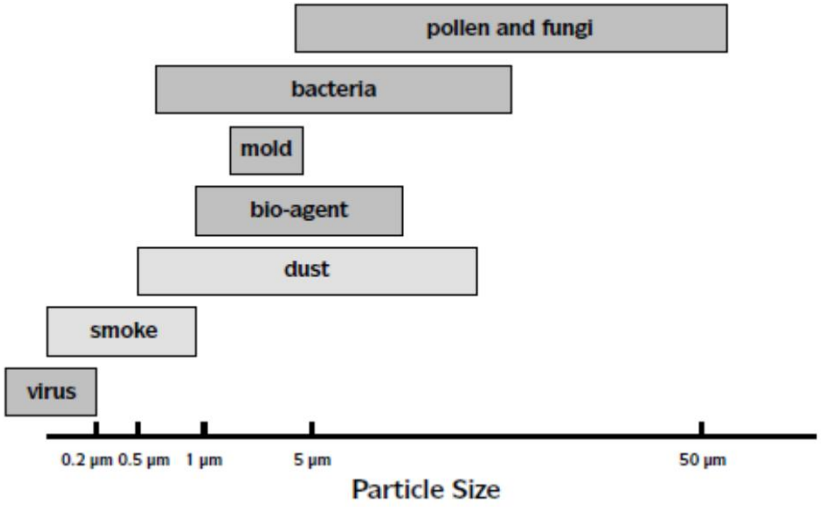
Akkrediteret ydelse til kalibrering af partikeltæller i rene rum

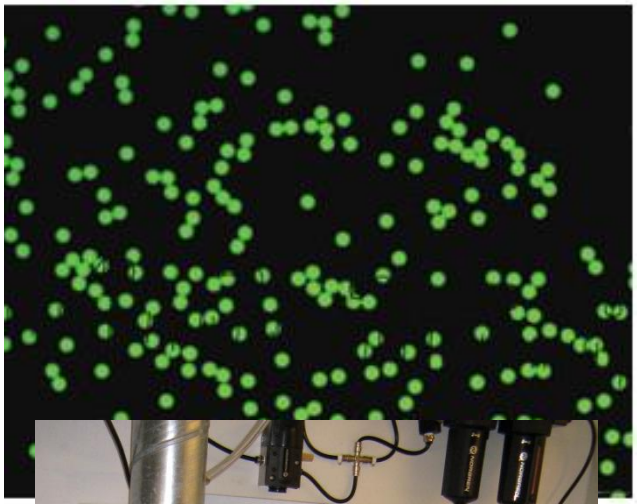
Expanded uncertainties on particle number concentration:

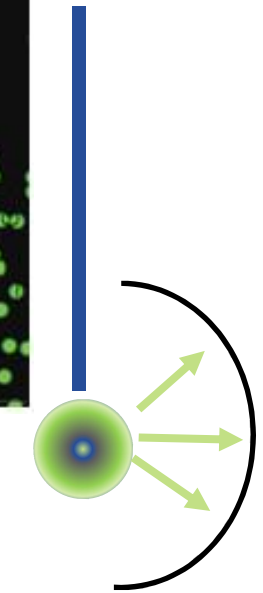
5% sizes 0.1 µm to 1.999 µm
8% sizes 2.0 µm to 6 µm

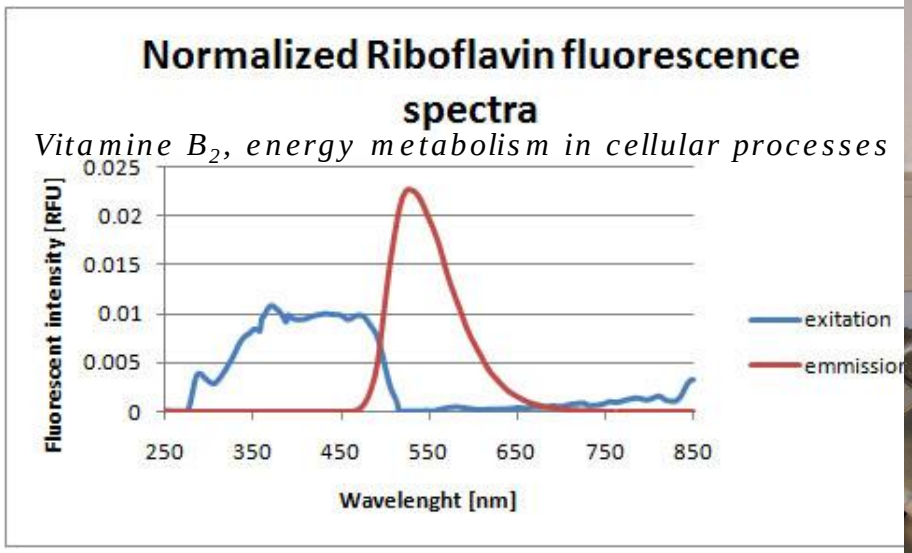


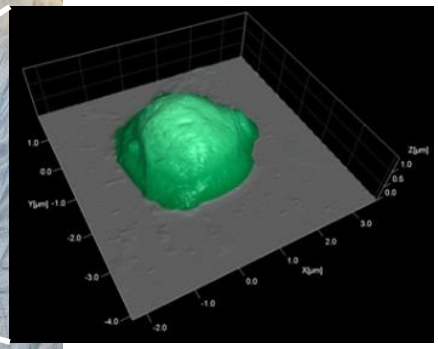
Fremtidige udfordringer – detektering af levedygtige partikler











Fungi spores penicillium chrysogenum

Image: PD

Opsummering – Dansk partikel metrologi 2014

- Danmark bidrager succesrig i internationale partikel aktiviteter (forskning, sammenligninger, standardisering)
- Videnhjemtagning er essentielt for at fortsætte opbyggelsen af ekspertise og opretholde konkurrencedygtighed
- Danske serviceydelser (i GTS fællesskab) inkluderer myndighedsbetjening, aerosolanalyse og –udmåling, akkrediterede kalibreringsydelser
- I tæt samarbejde med industrielle partner motiveres og initieres videregående og relevant state-of-the-art forskning