PALAS®

PALASCOUNTS

Ambient UFP Measurements

– Options & Limitations of current measurement techniques -

Frederik Weis

Palas serves aerosoltechnology since 1983…

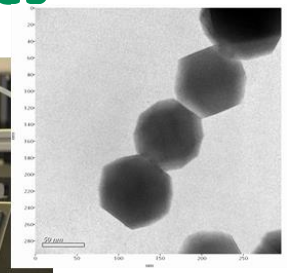
based in Karlsruhe, Germany
R&D and Manufacturing 100% inhouse

certified according to DIN EN ISO 9001:2015

Core competencies:

- Filter test systems
- Aerosol spectrometer systems
- Fine dust monitoring systems
- Nanoparticle measurement technology
- Particle generation systems
- Dilution systems
- Clean room particle technology
- Special developments
- Calibration systems
- Services
- Training courses and seminars

Product lines



Nano Particles Monitoring

Aerosol Spectrometer

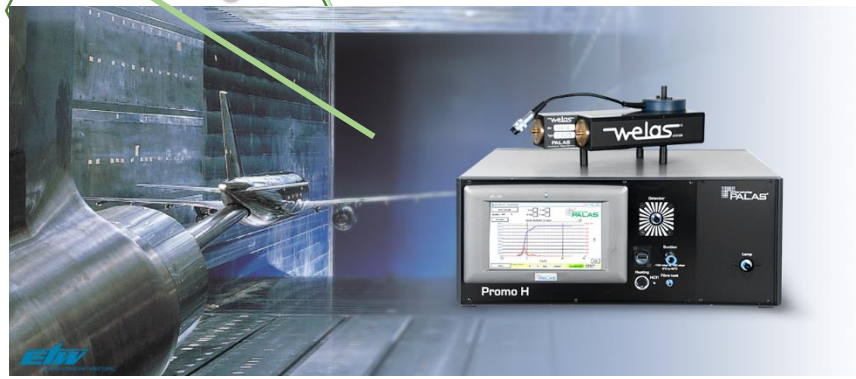
Fine Dust Monitoring

Aerosol Generation

Aerosol Dilution

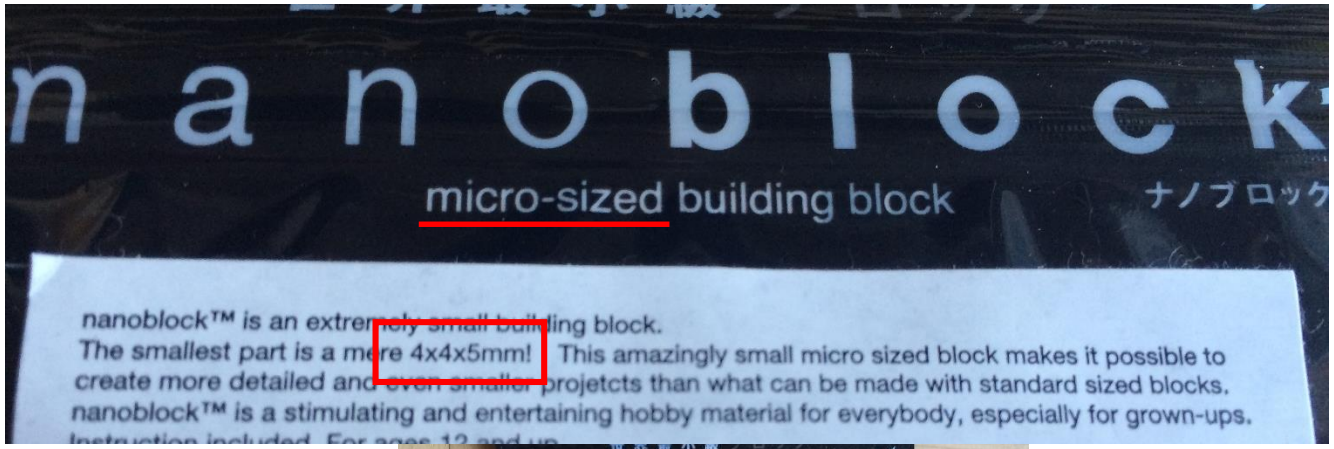
Filter test rigs & filter media

Product lines



Overview of Nanoparticle Measurement Systems

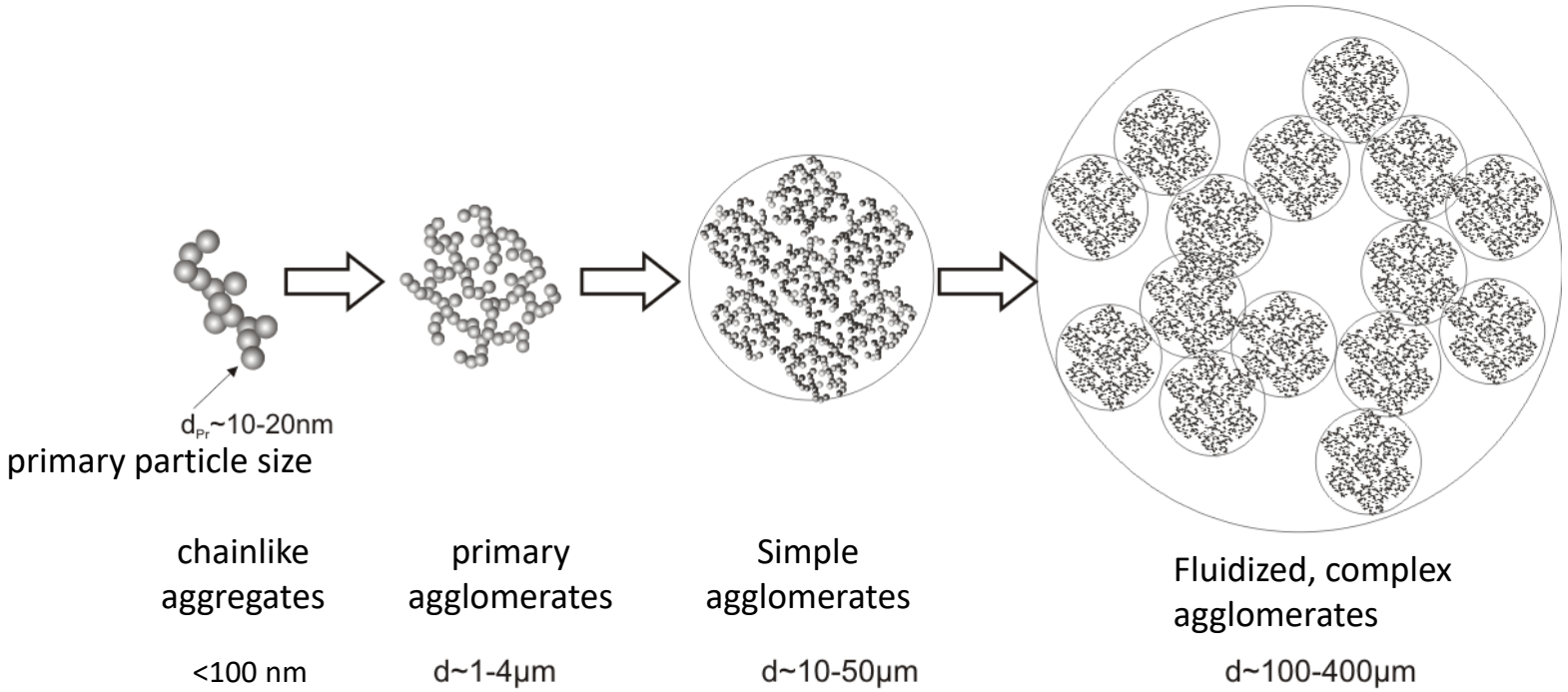
„Nano“ is trendy in everyday life….and marketing



Talking about the correct dimension

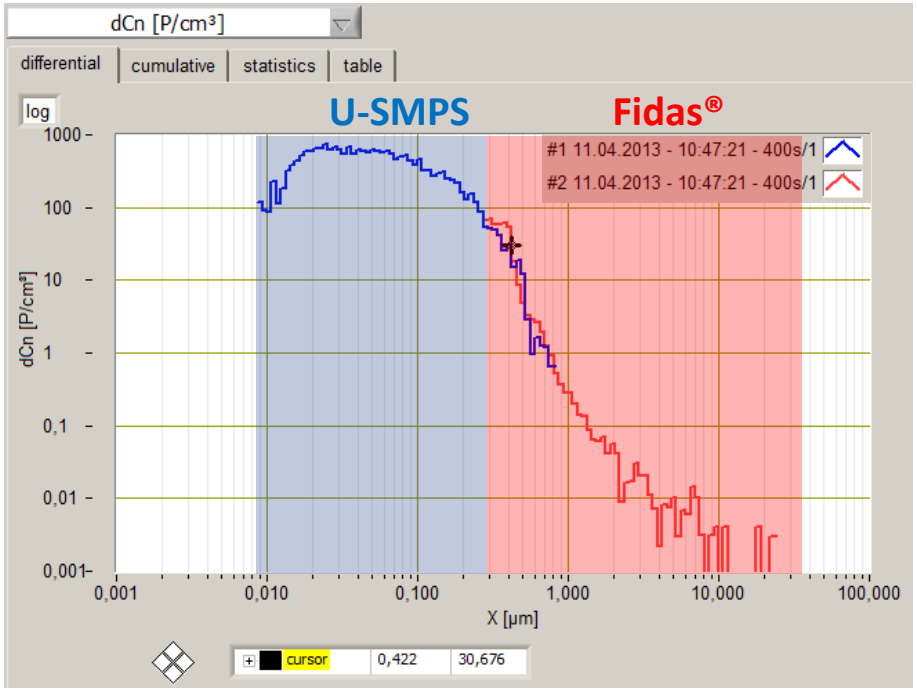
It´s not only marketing….also in real world, dimensions can be mixed.

Example: Fluidization of nanoparticles and nanopowders like Aerosil® in a fluidized bed reactor.

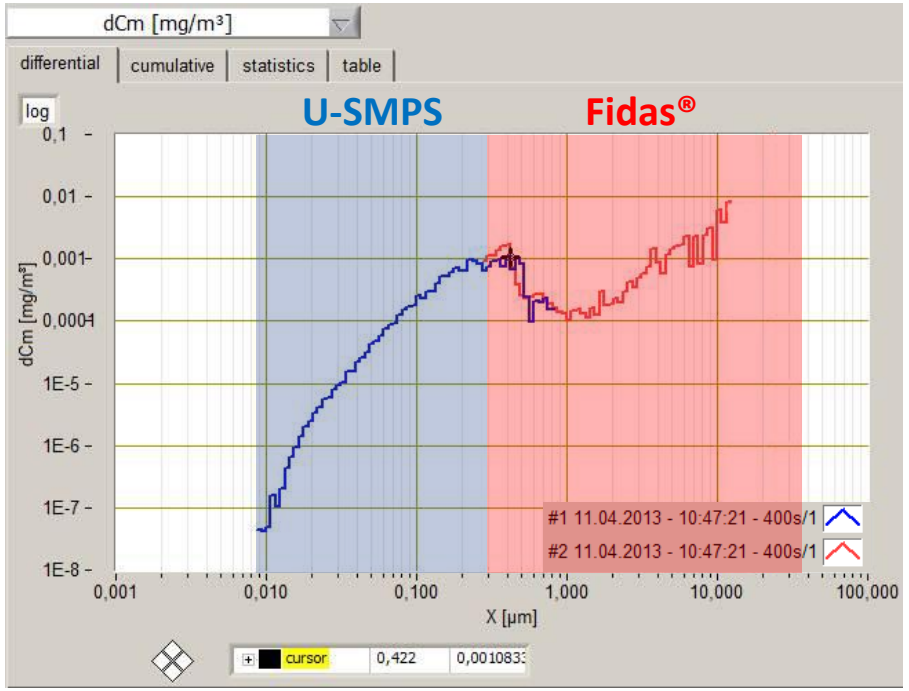


U-RANGE measurement for ambient air

Number concentration



Mass concentration



416 particles/cm³

19767 particles/cm³

67.9 µg/m³

6.1 µg/m³

Down to...

"There's Plenty of Room at the Bottom"

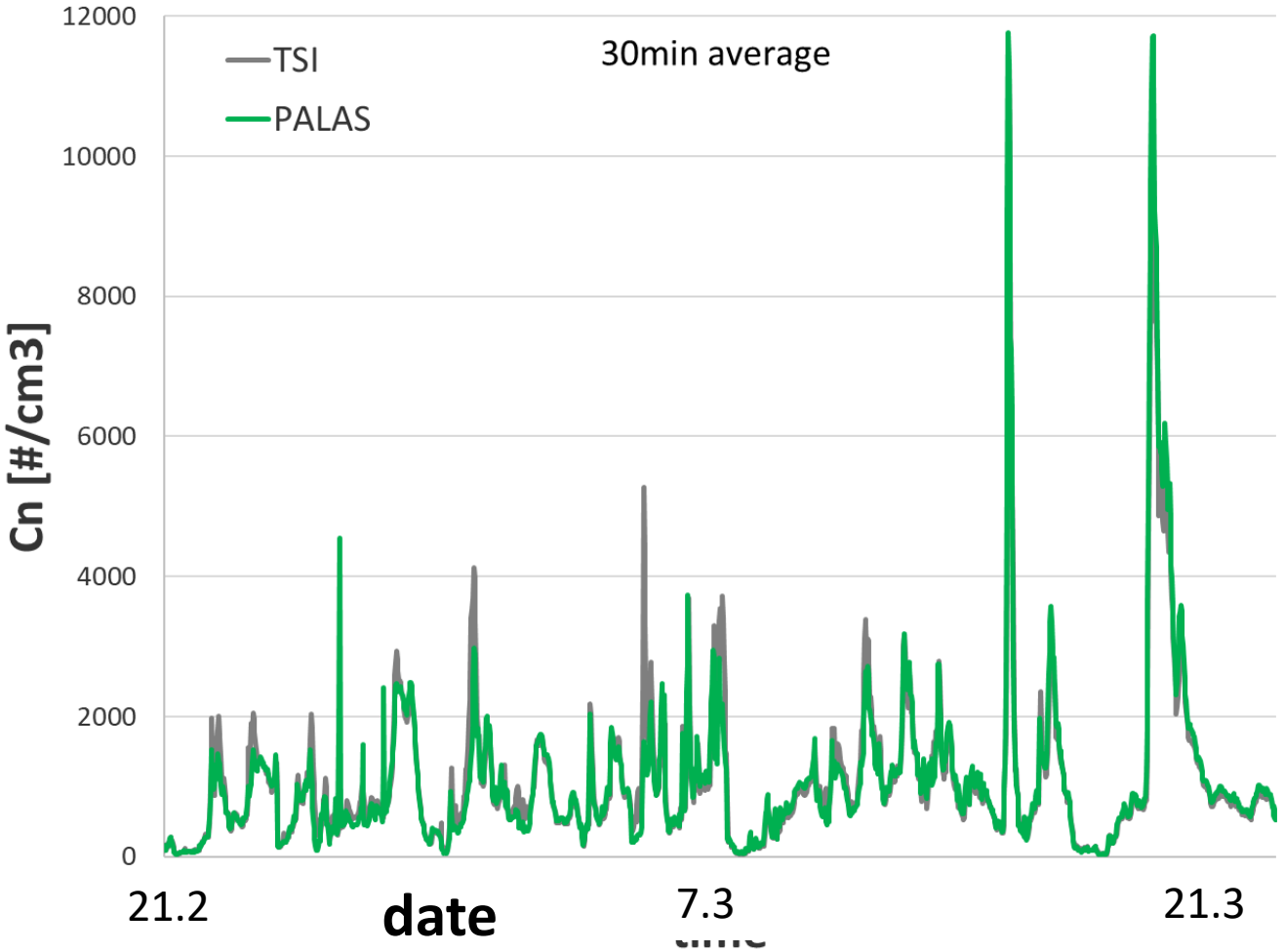
(Richard Feynman,1959)

PALASCOUNTS

Application examples and related questions

Ambient Air monitoring for UFP

measure total concentration of UFPs by Condensation Particle Counters

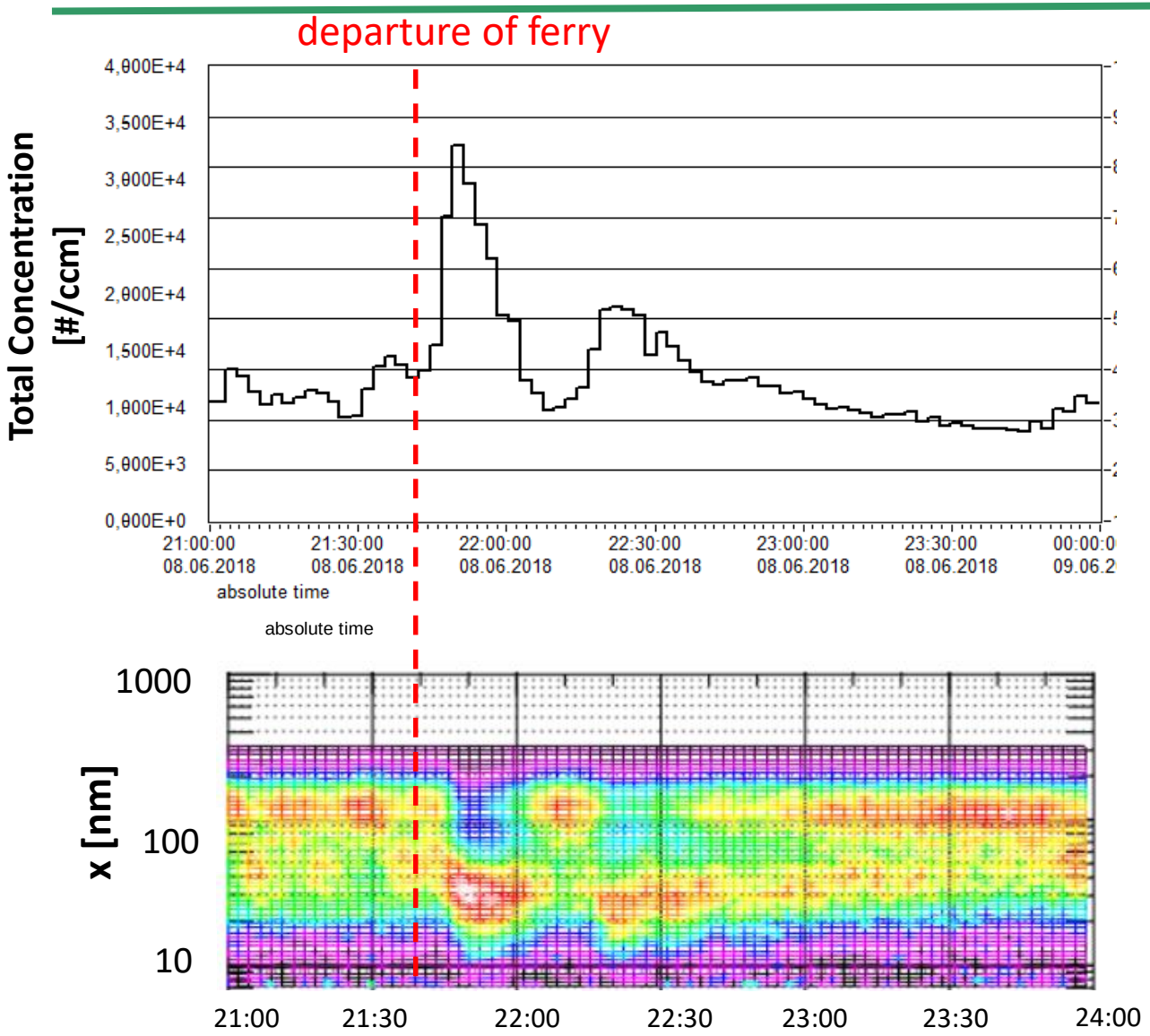


Monitoring station at 3000m

UFP monitoring at harbours

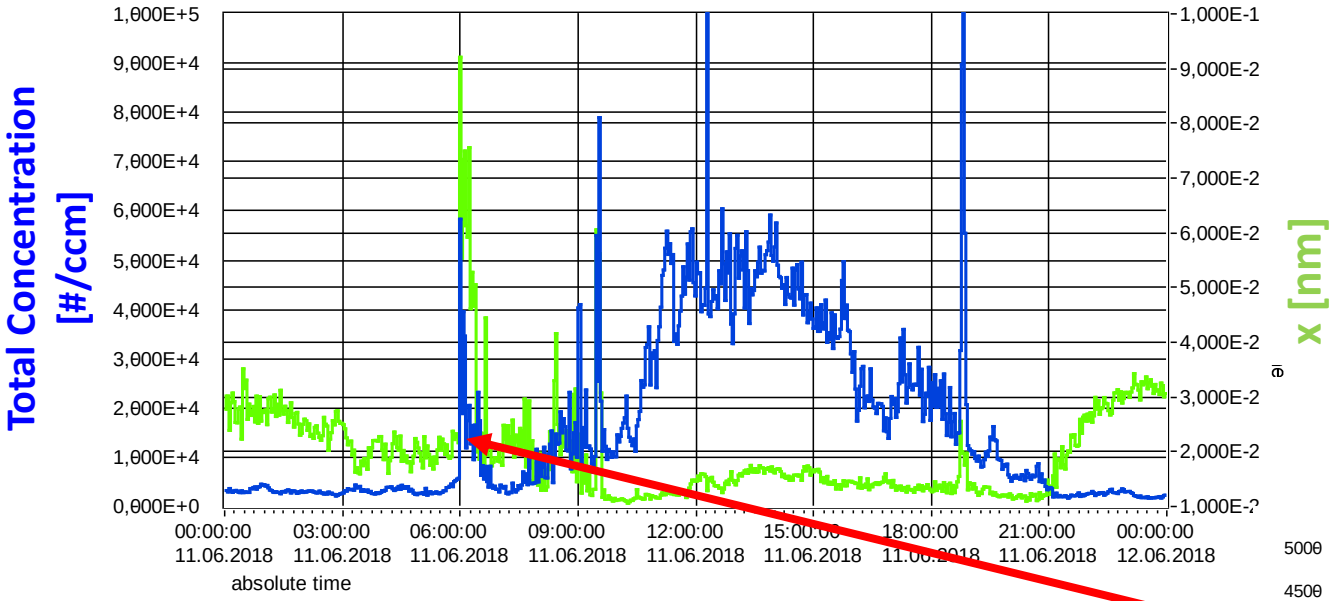
Scope: identify ship emissions

UFP monitoring at harbour

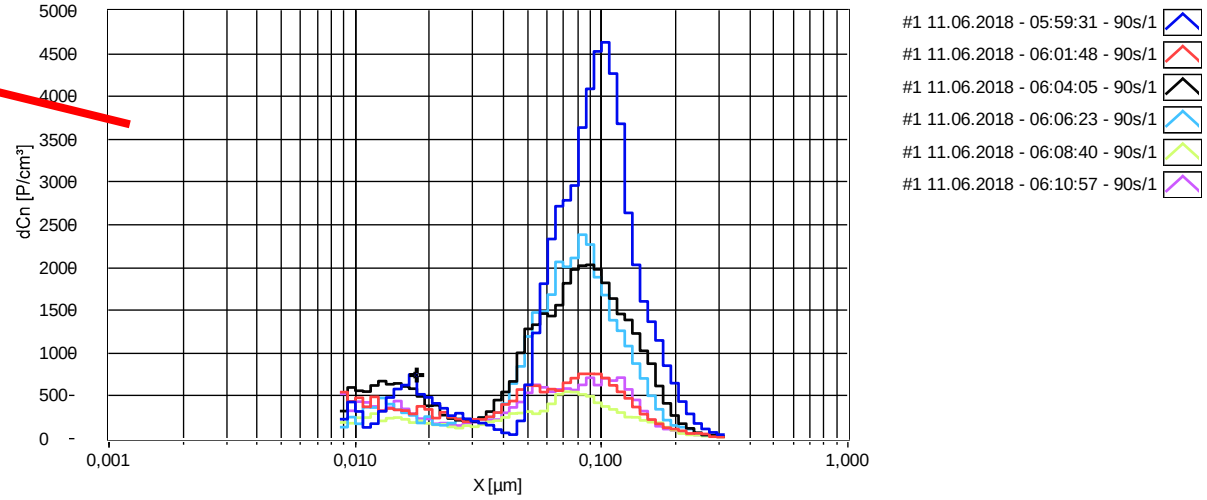


data: measured by Palas® U-SMPS 2100 X
graphs by Palas® PDAnalyze

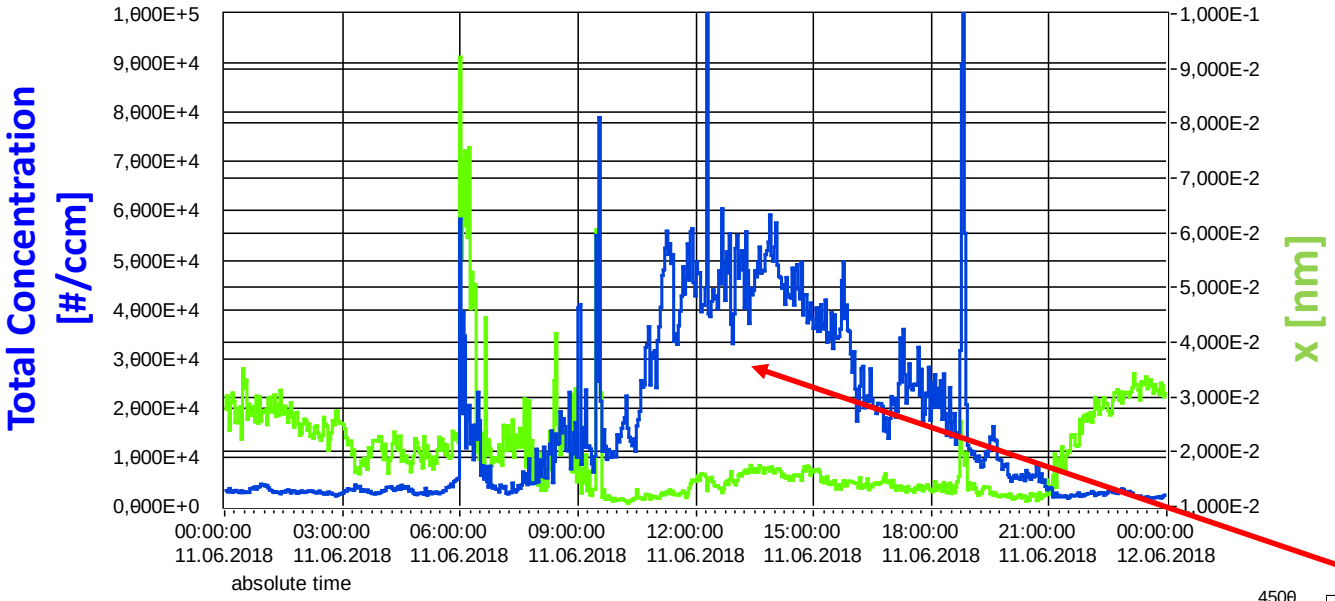
UFP monitoring at harbour

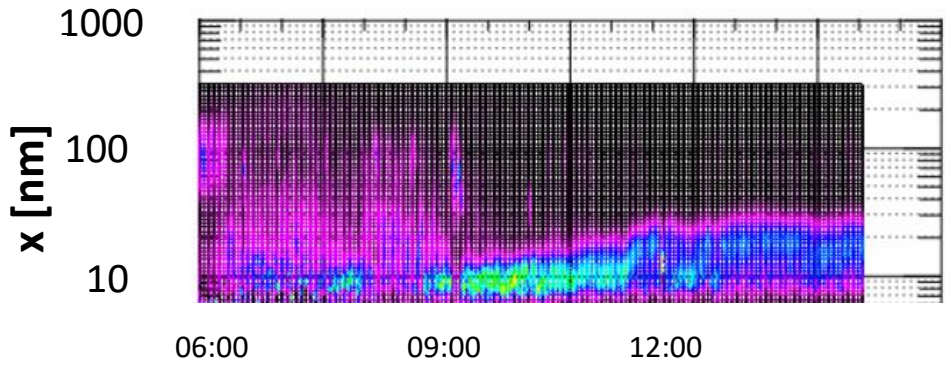


Arrival of ferry scheduled at 6:00 Uhr

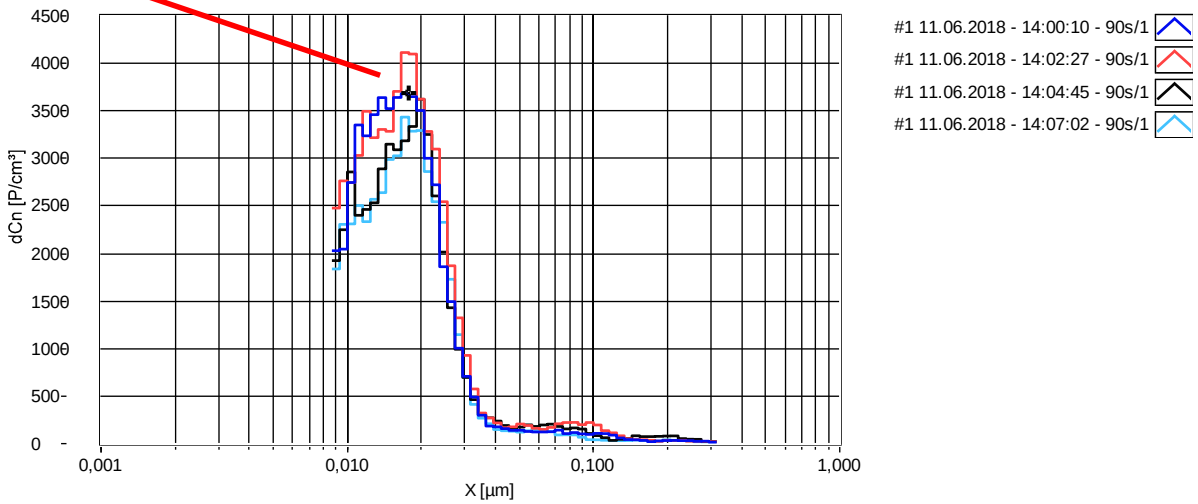


UFP monitoring at harbour – identifying the sources

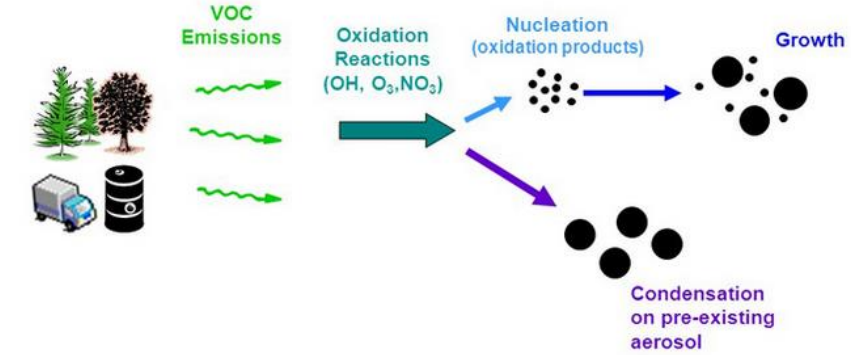




Ultra fine particle formation event

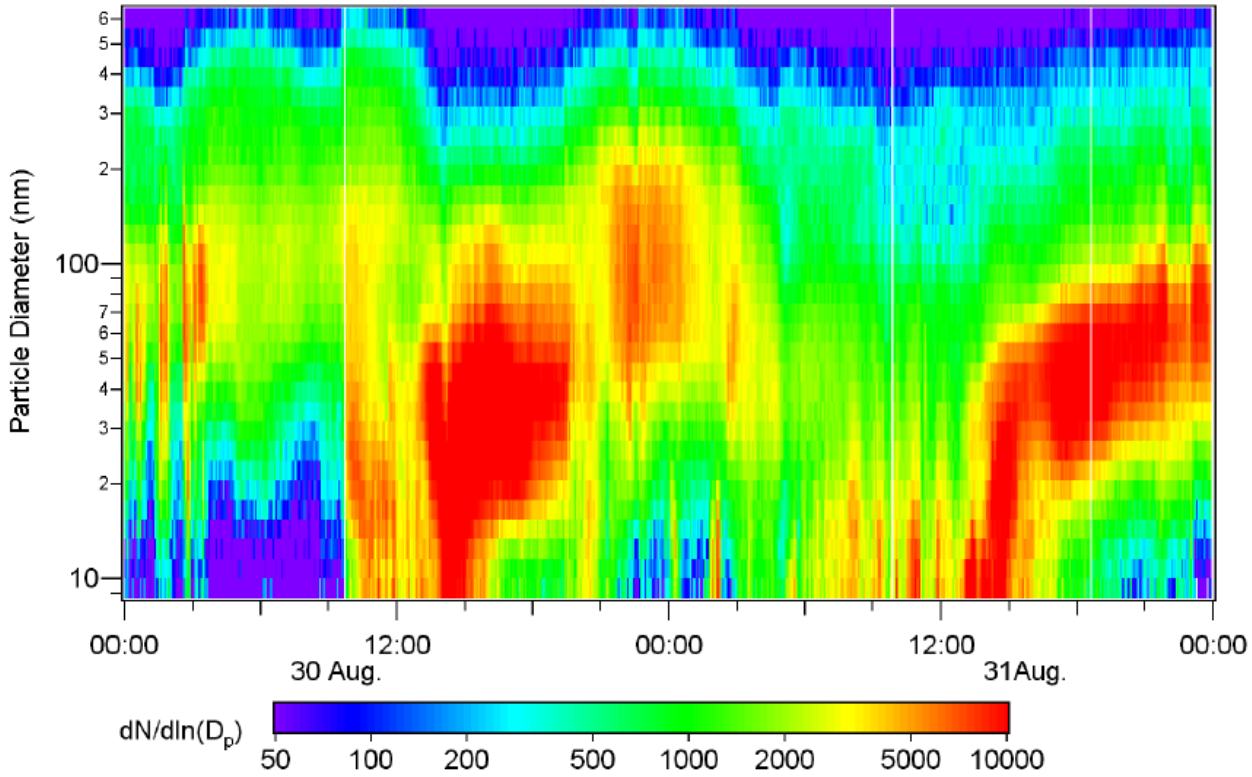


SECONDARY ORGANIC AEROSOL PRODUCTION



Over 500 reactions to describe the formation of SOA precursors, ozone, and other photochemical pollutants [Griffin et al., 2002; Griffin et al., 2005; Chen and Griffin, 2005]

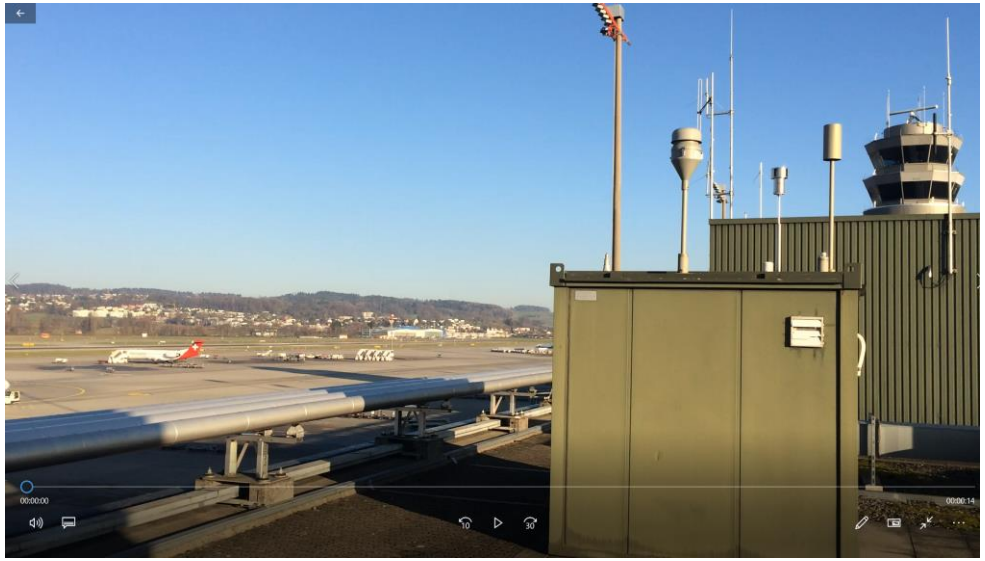
M. Mozurkewich et al.: Particle nucleation and growth i



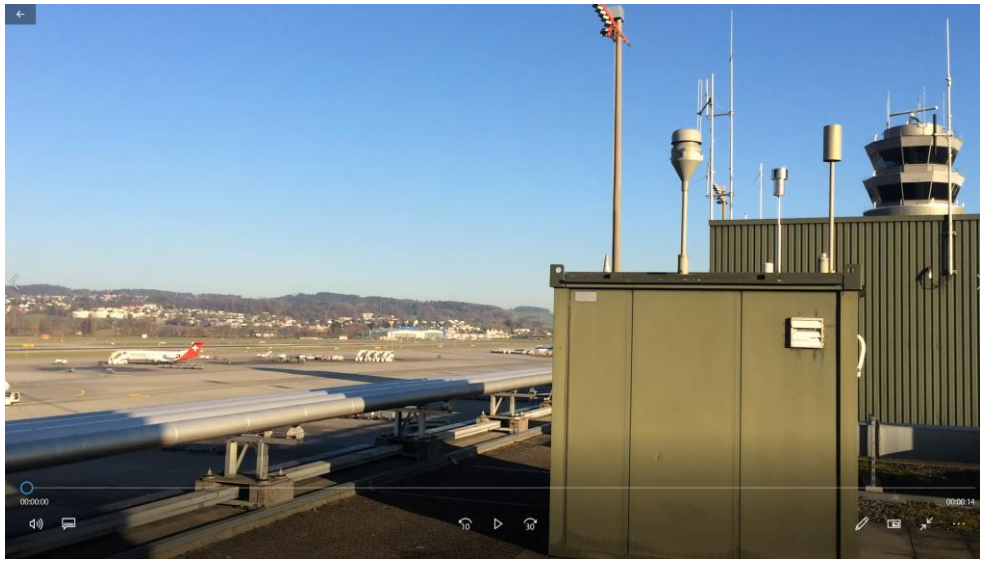
growth rates were approximately 5 to 10 nm hr^{-1}. The nucleation events seem to have been triggered when the UV flux reached about 25 W m^{-2}. We can not identify the nucleating species, but the growth appears to have been driven by the photochemical oxidation of biogenic organic compounds.

Fig. 10. DMA number size distributions for 30 and 31 August 2001 at Eagle Ridge showing the particle growth event on the 30th and the nucleation event on the 31st.

UFP monitoring at airports



Example A

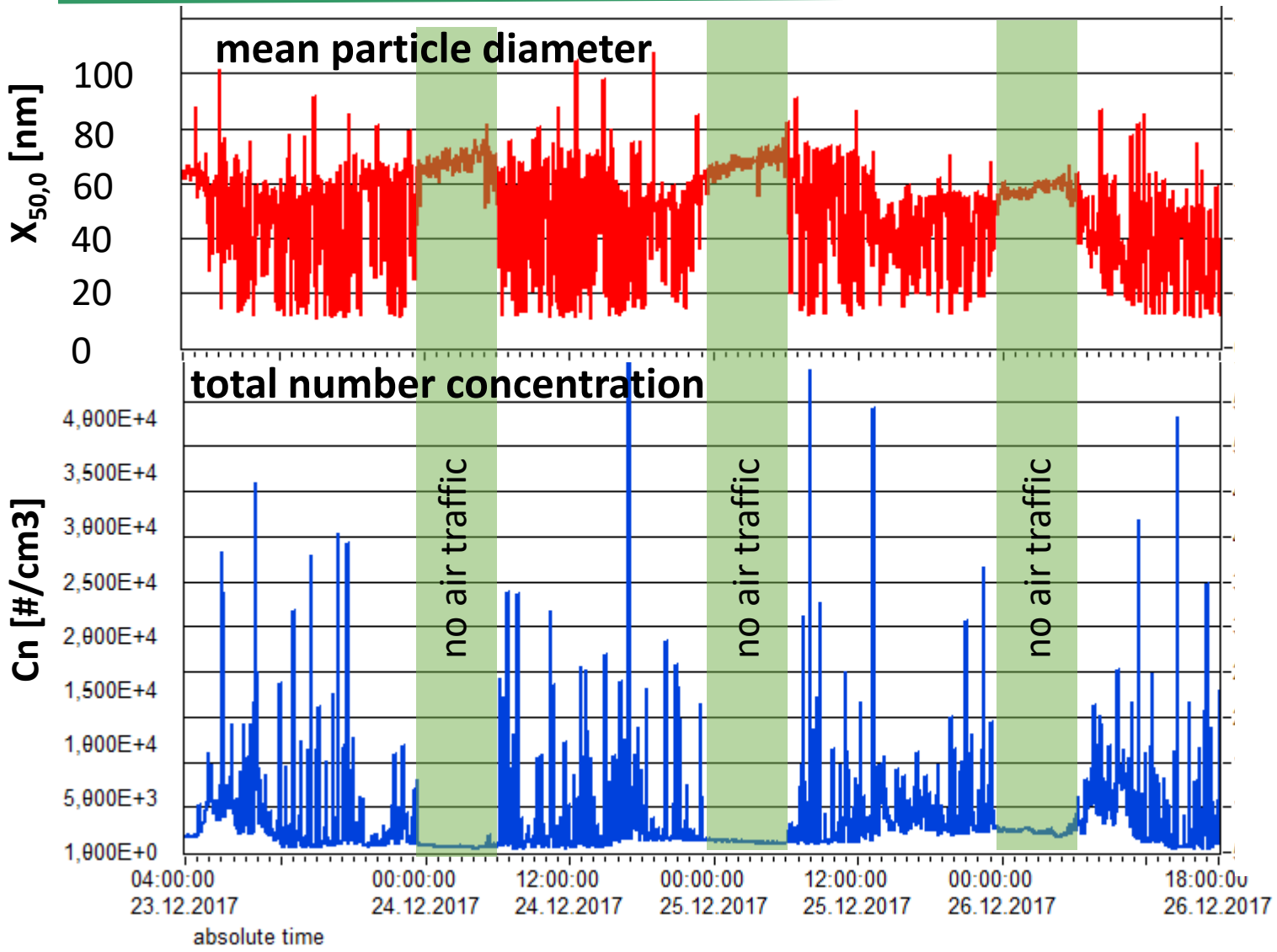


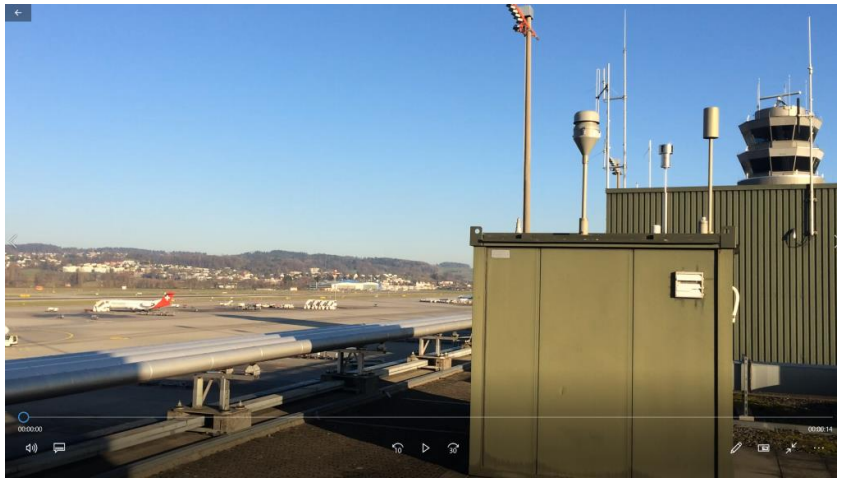
Station at terminal (400 m to runway for landings / departure)

scope: general monitoring, air traffic visible ?

data: measured by Palas ® U-SMPS 2100 X
graphs by Palas® PDAnalyze

UFP monitoring at airport





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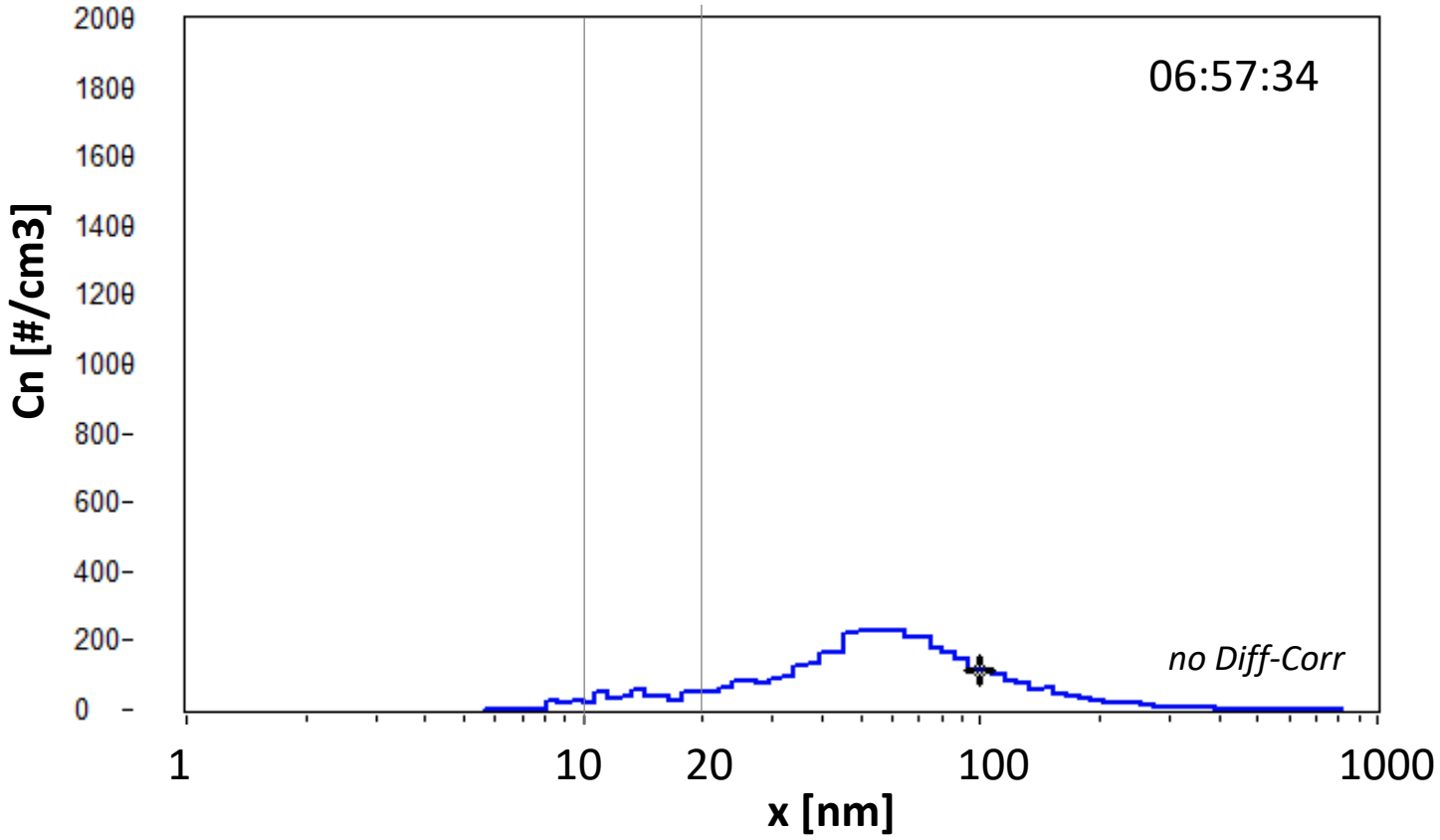


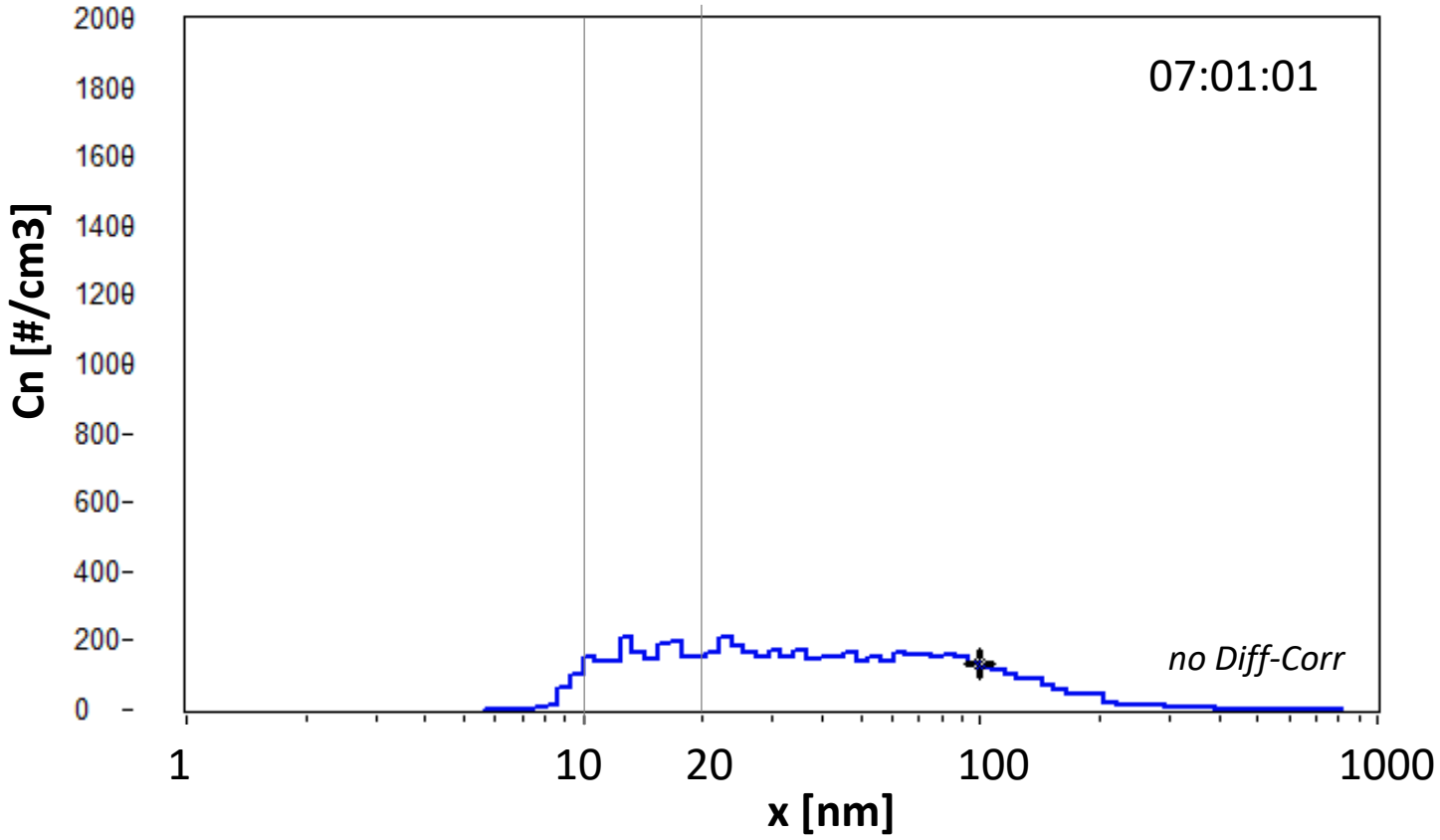
Example 1

time-resolved particle size distributions

- Scans from 7 – 800 nm every 150 seconds

data: measured by U-SMPS 2100 X
graphs by PDAnalyze

UFP monitoring at airport



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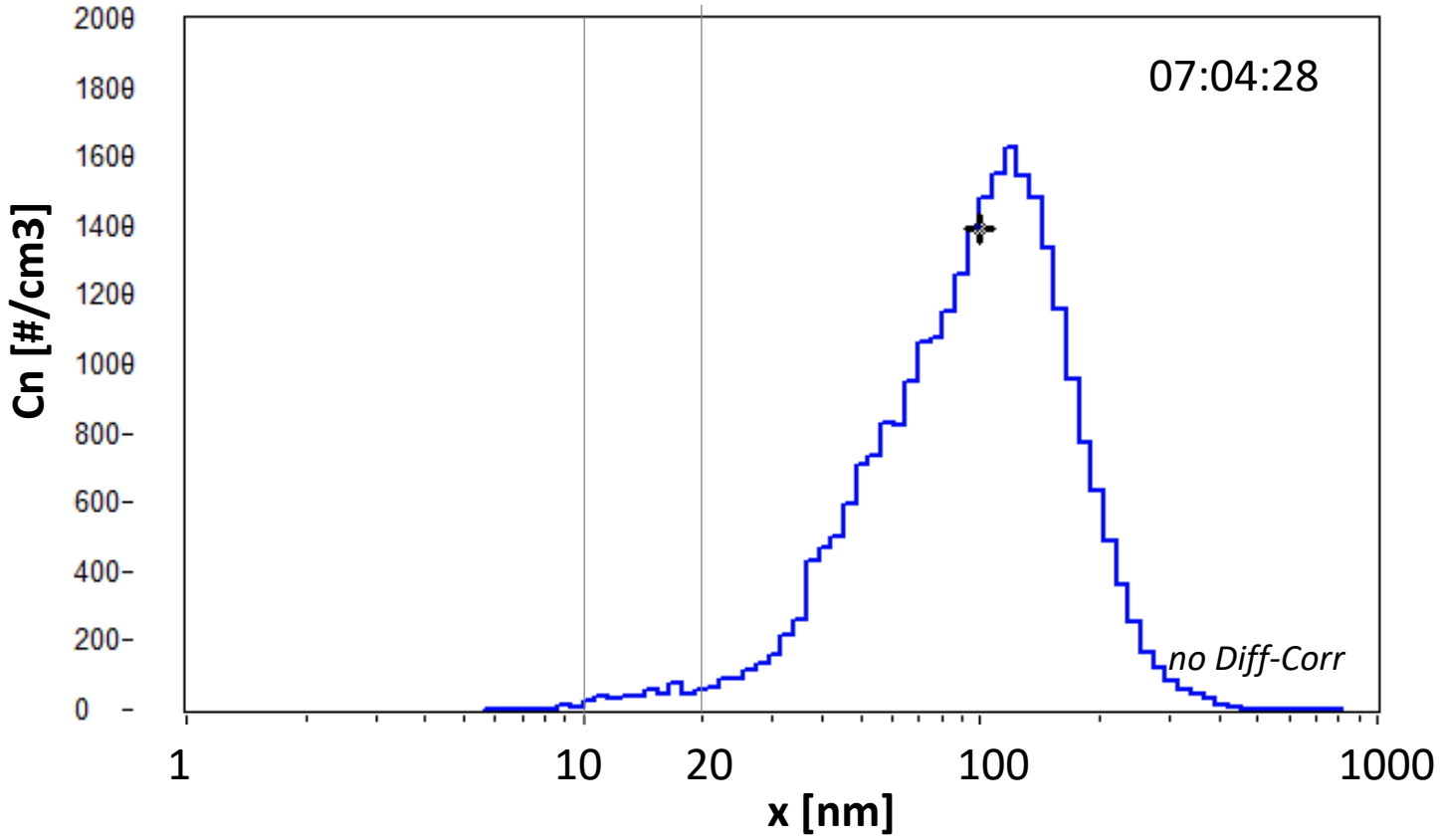

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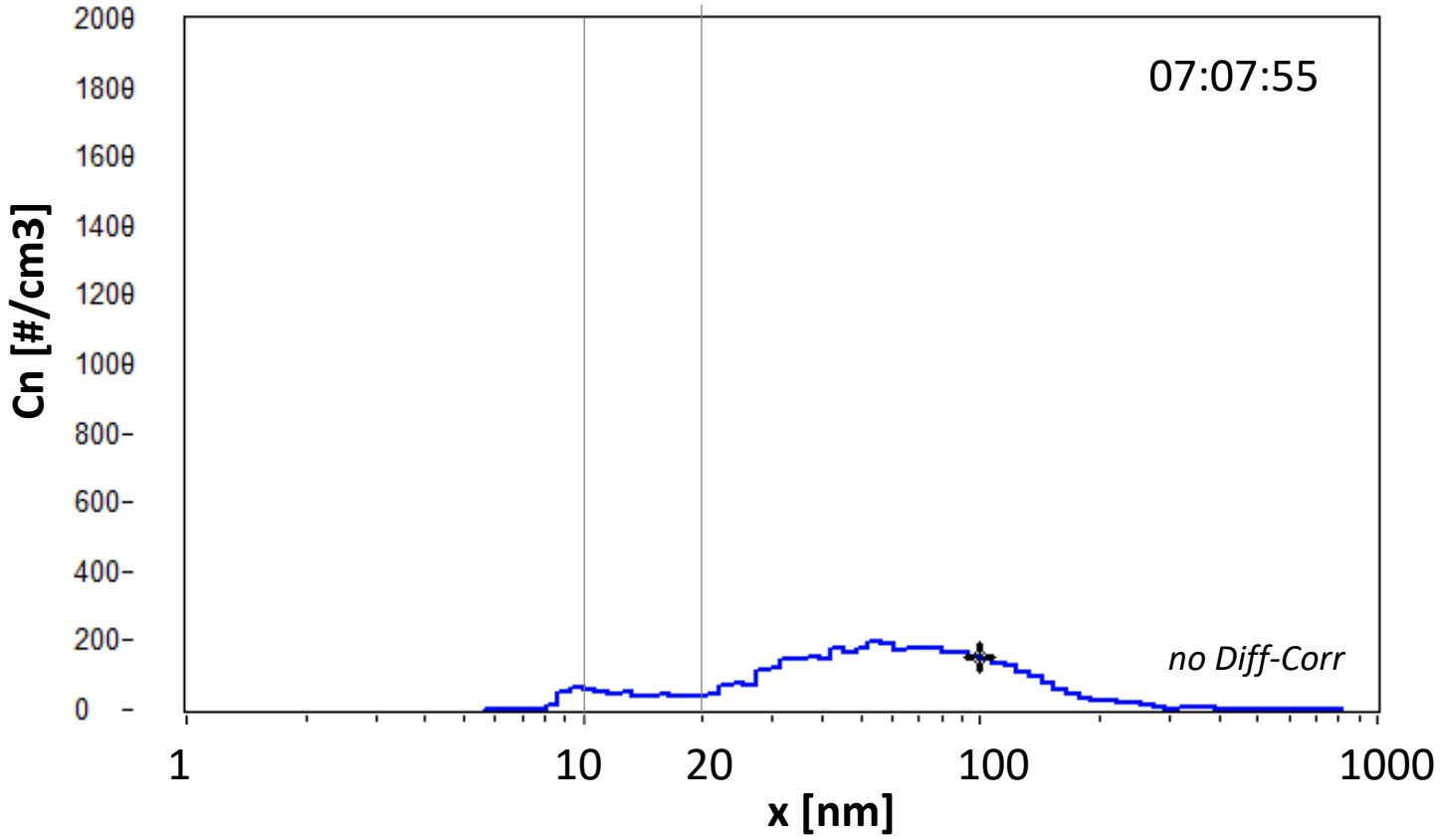

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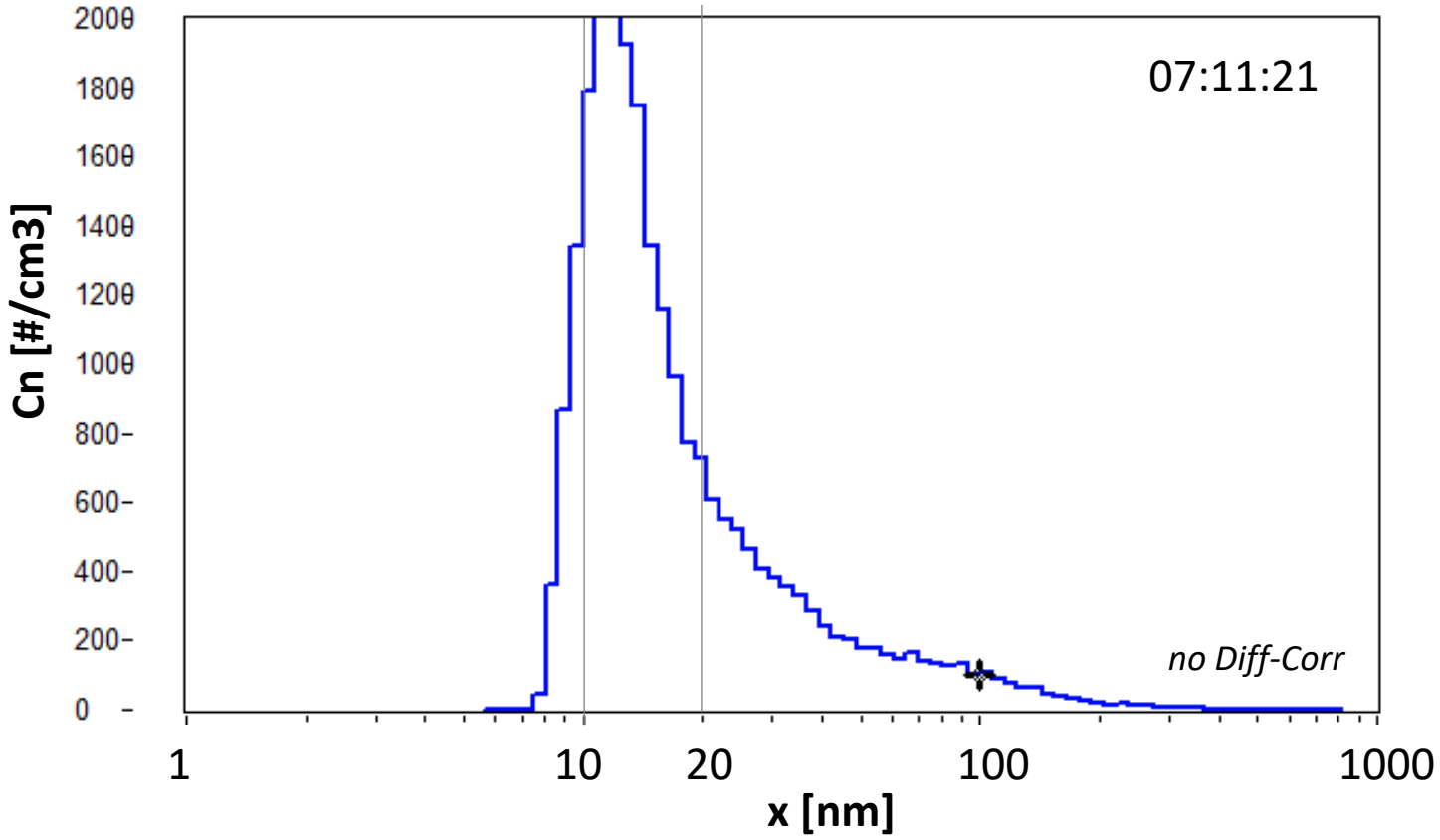

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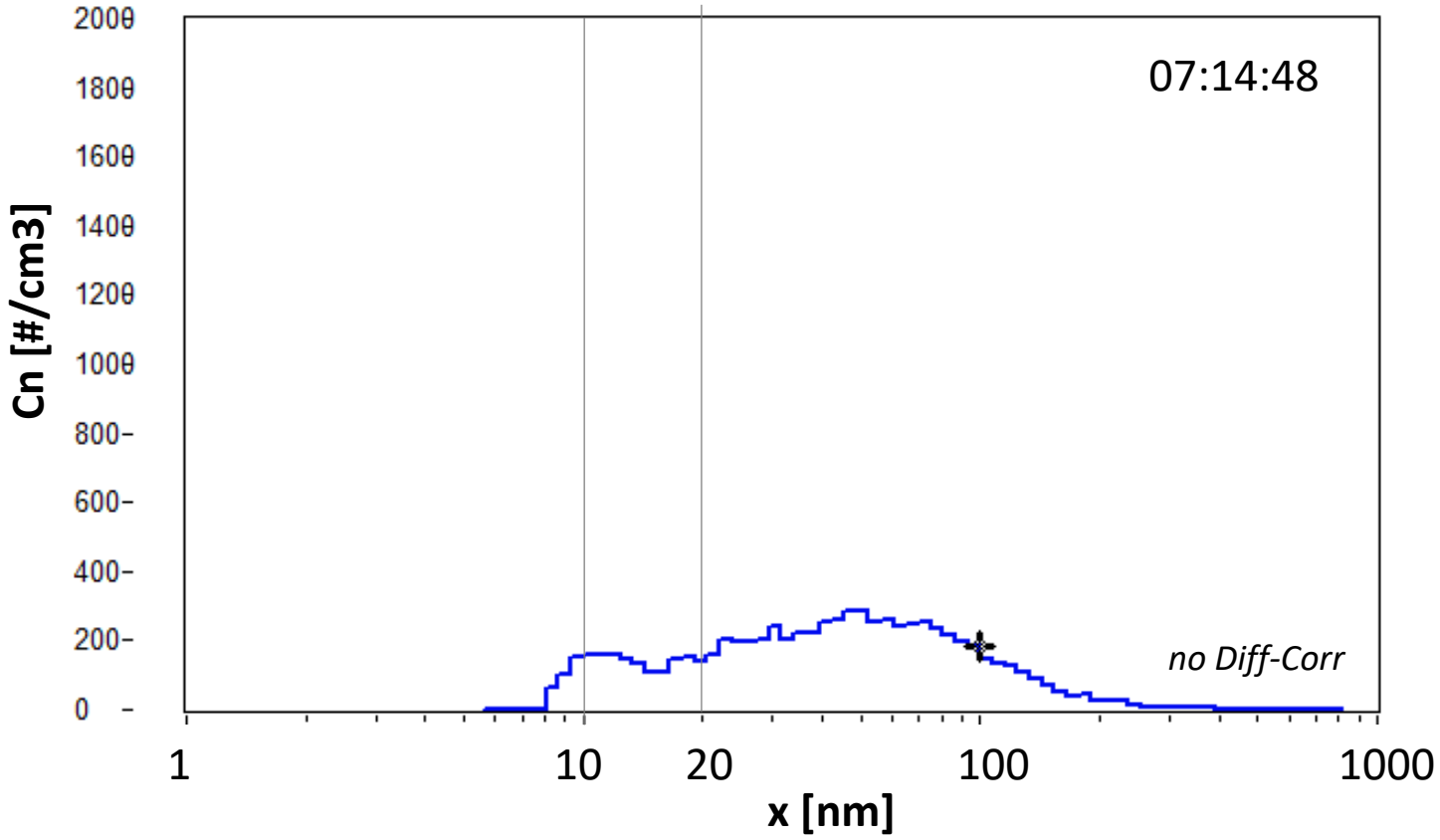

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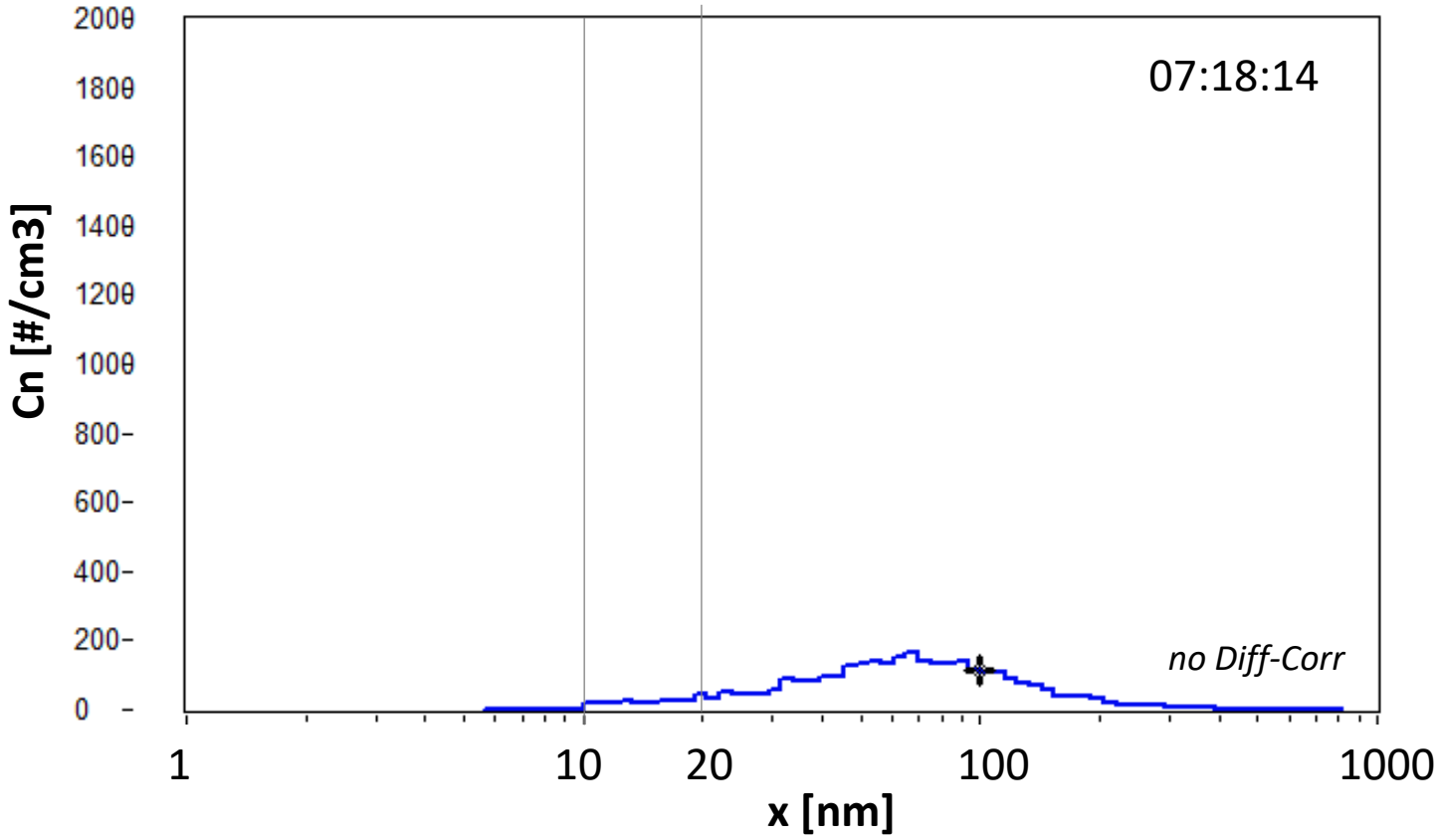

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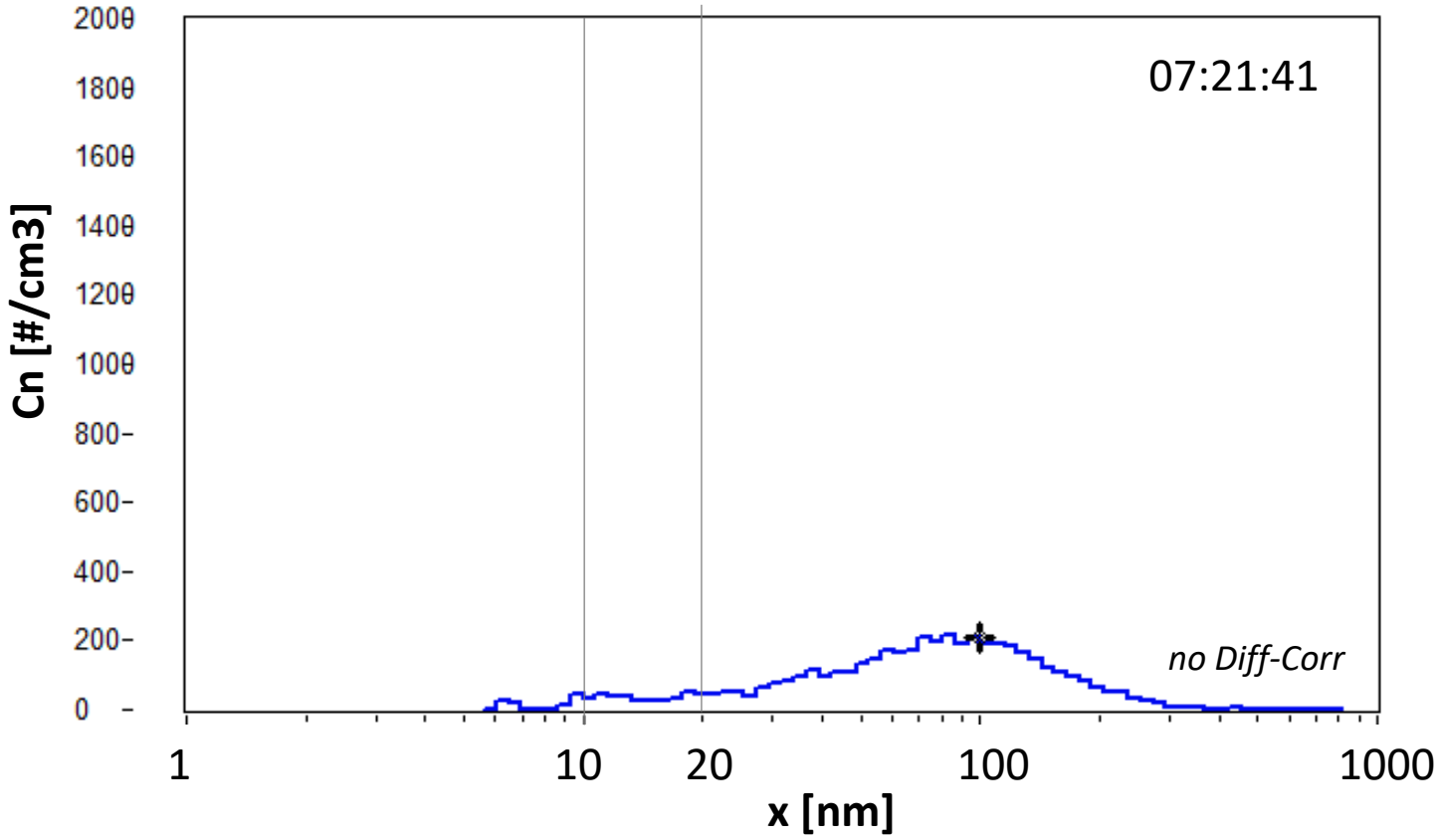

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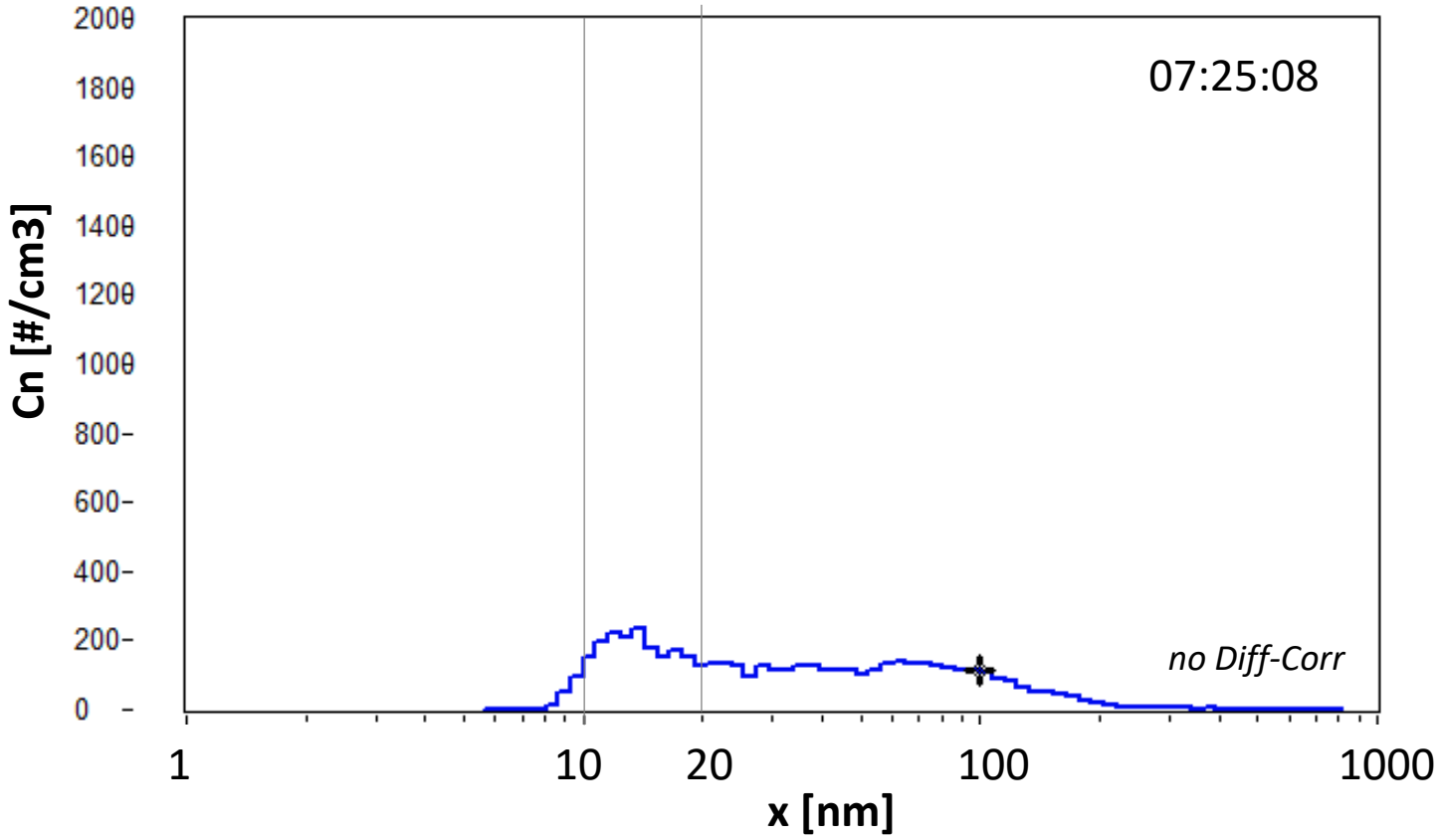

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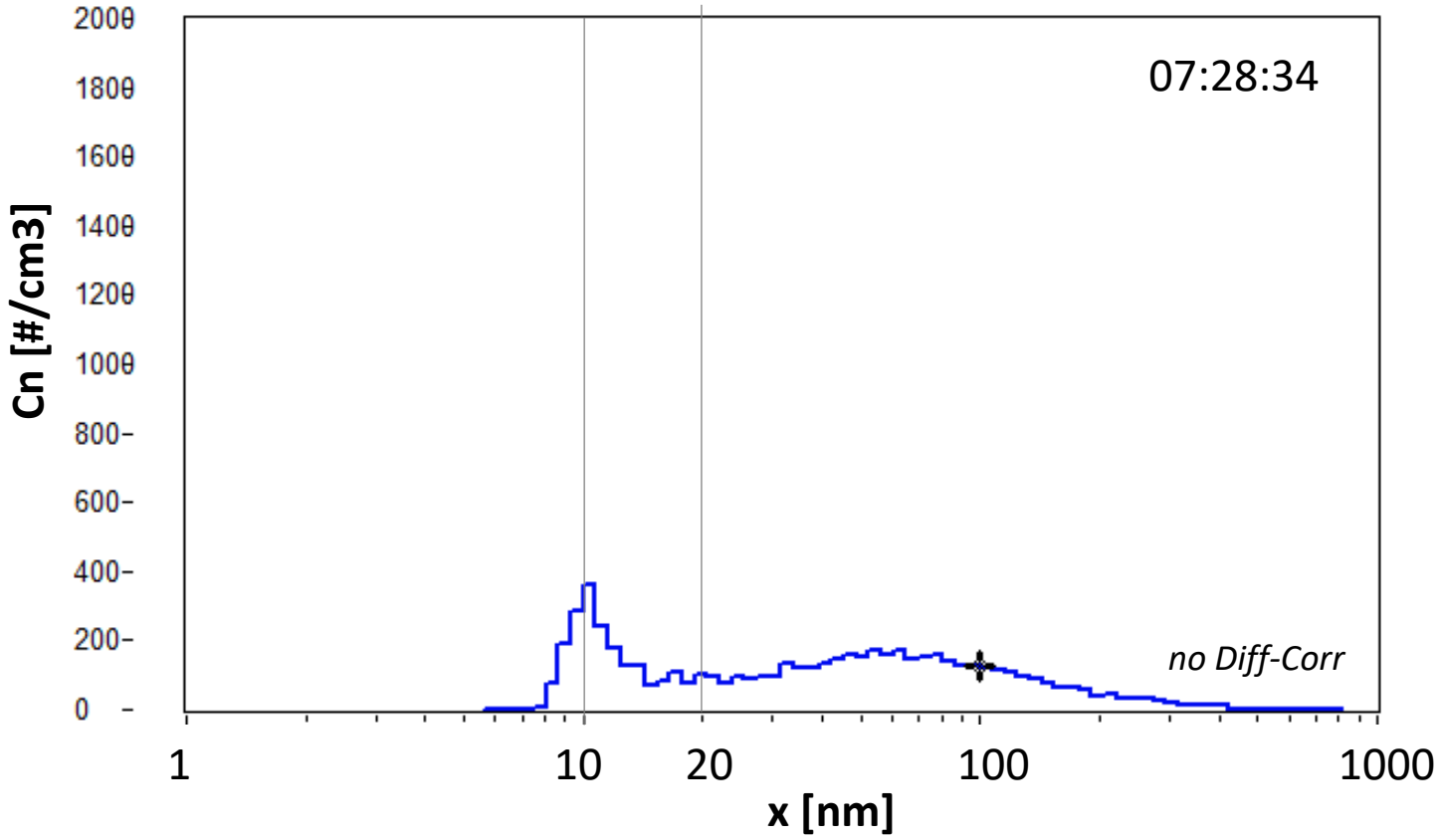


Example 1

time-resolved particle size distributions

- Scans from 7 – 800 nm every 150 seconds

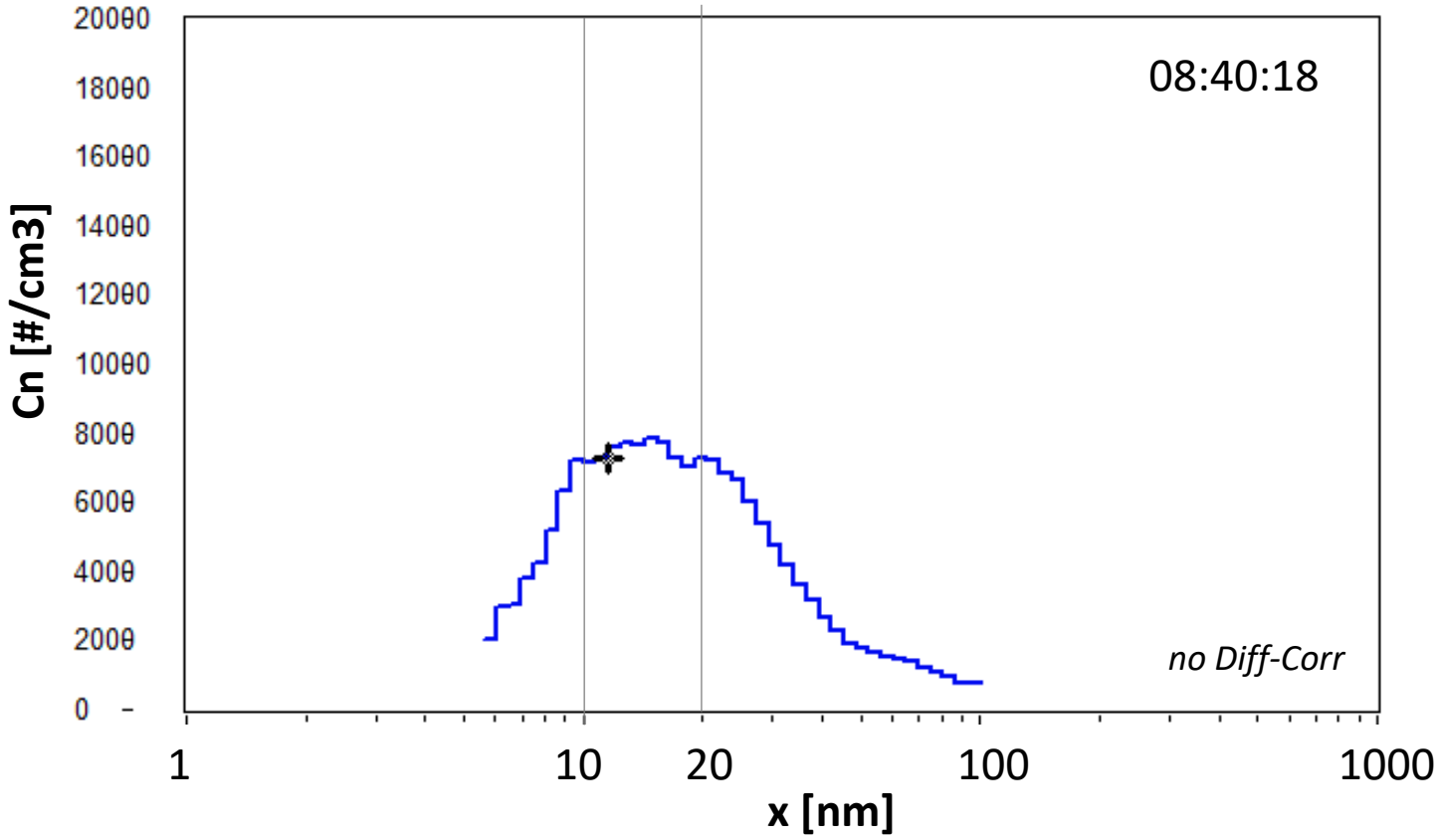
data: measured by U-SMPS 2100 X
graphs by PDAnalyze

Example B

very close to runway for landings / departure (~50m)

scope: identify individual airplanes, high-time resolution

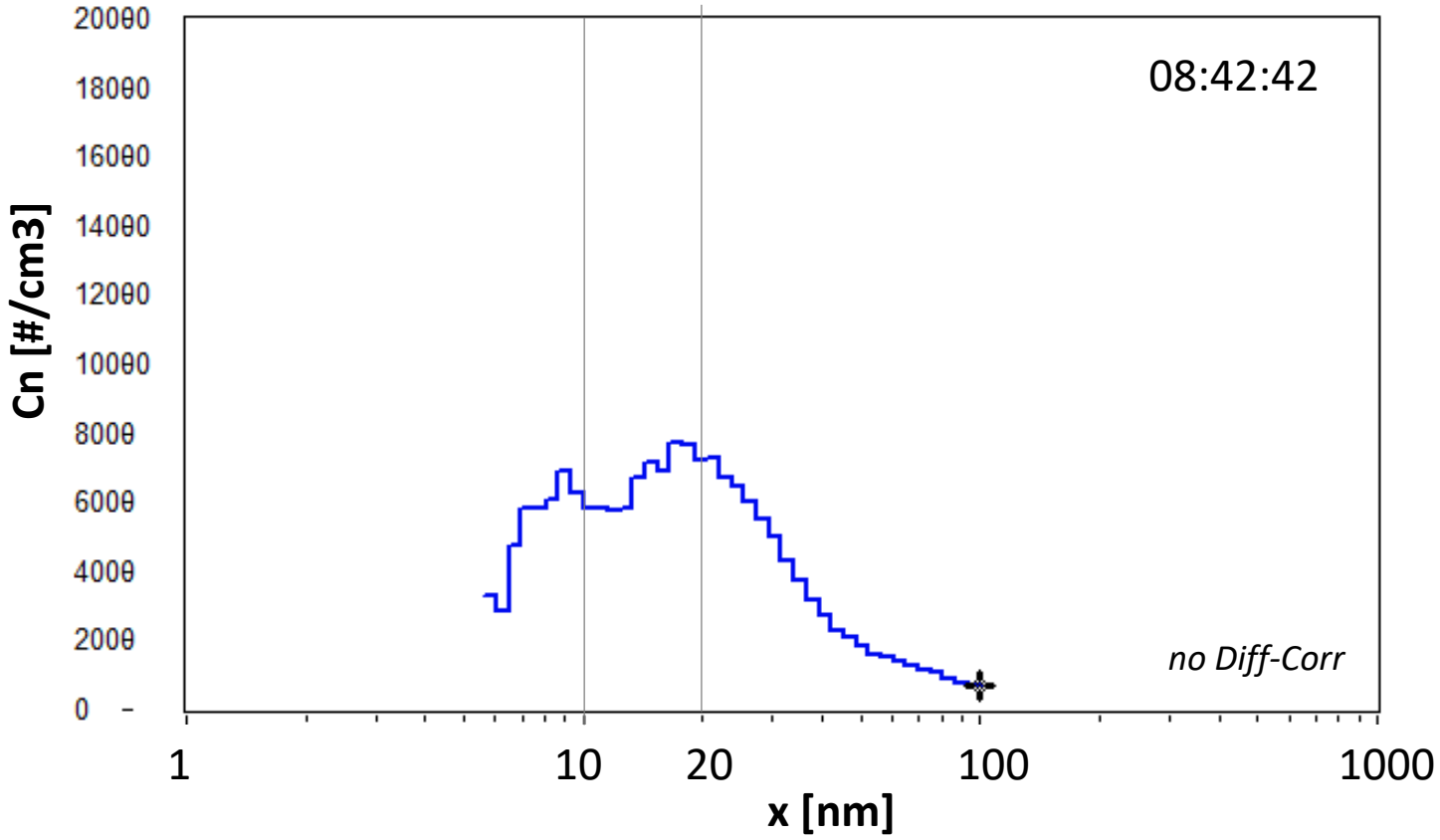
UFP monitoring at airport



Scenario B

- Close to departure/arrival runway
- Fast scans 7 – 100 nm in 40 seconds

UFP monitoring at airport



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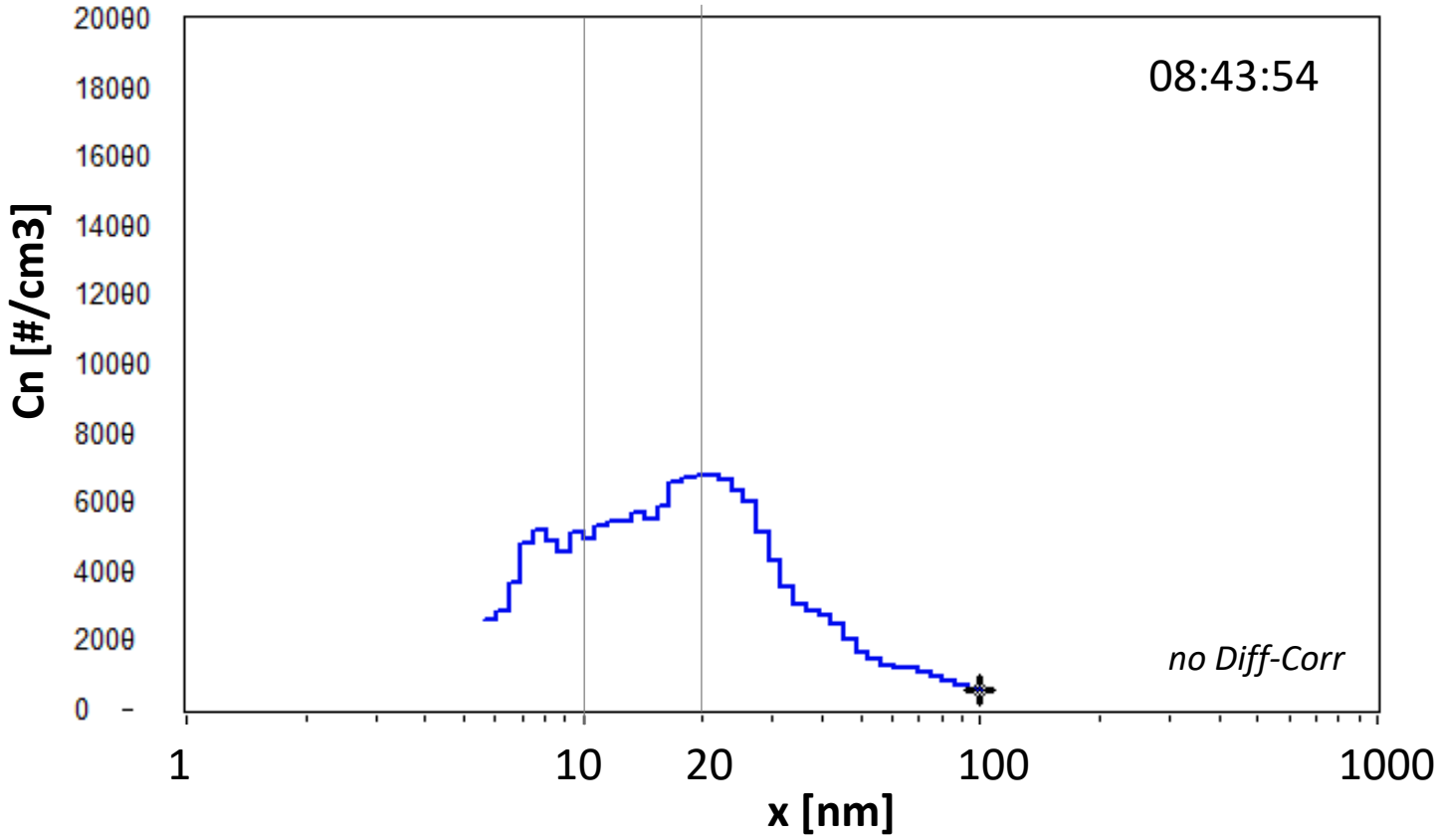

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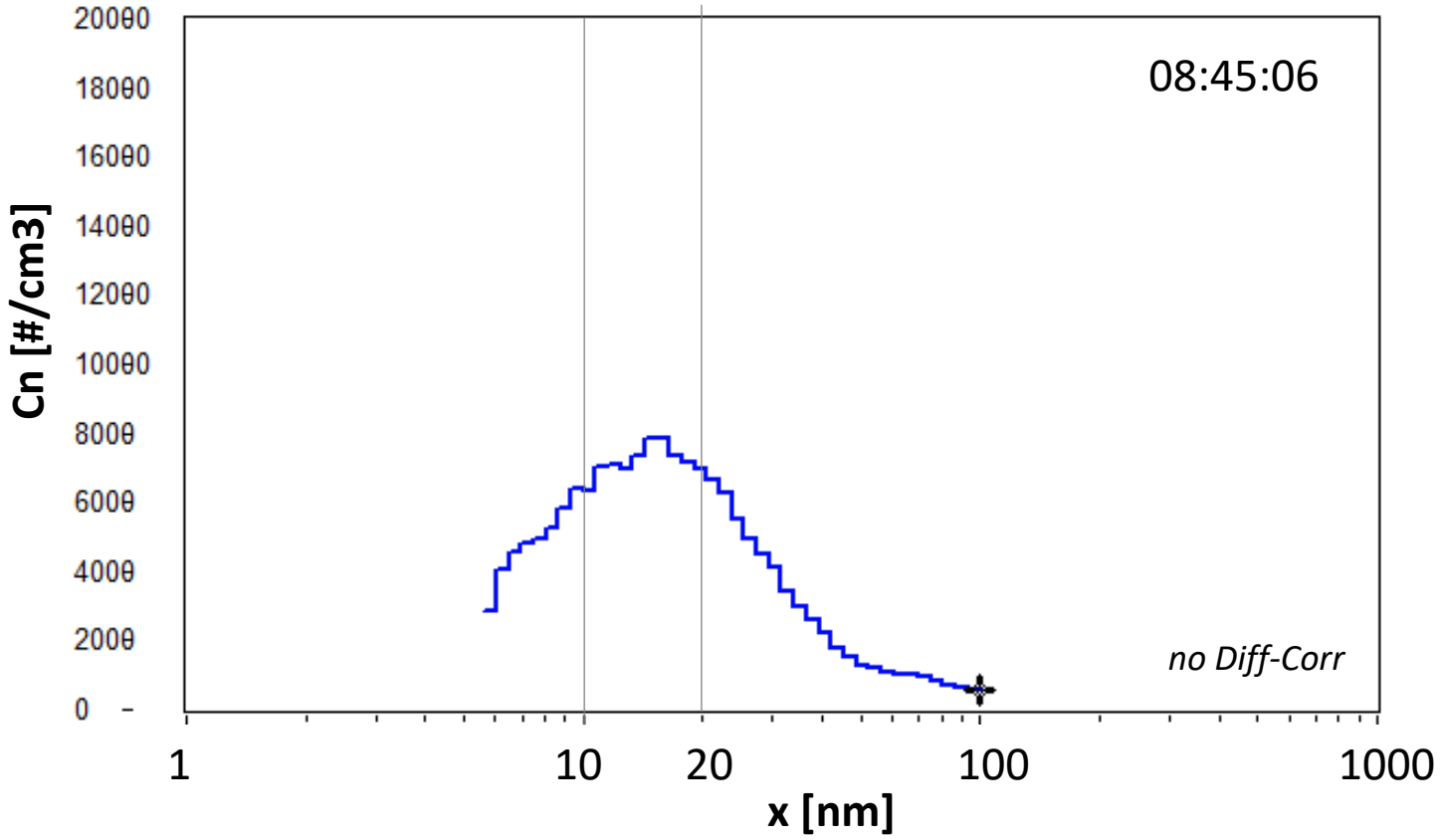

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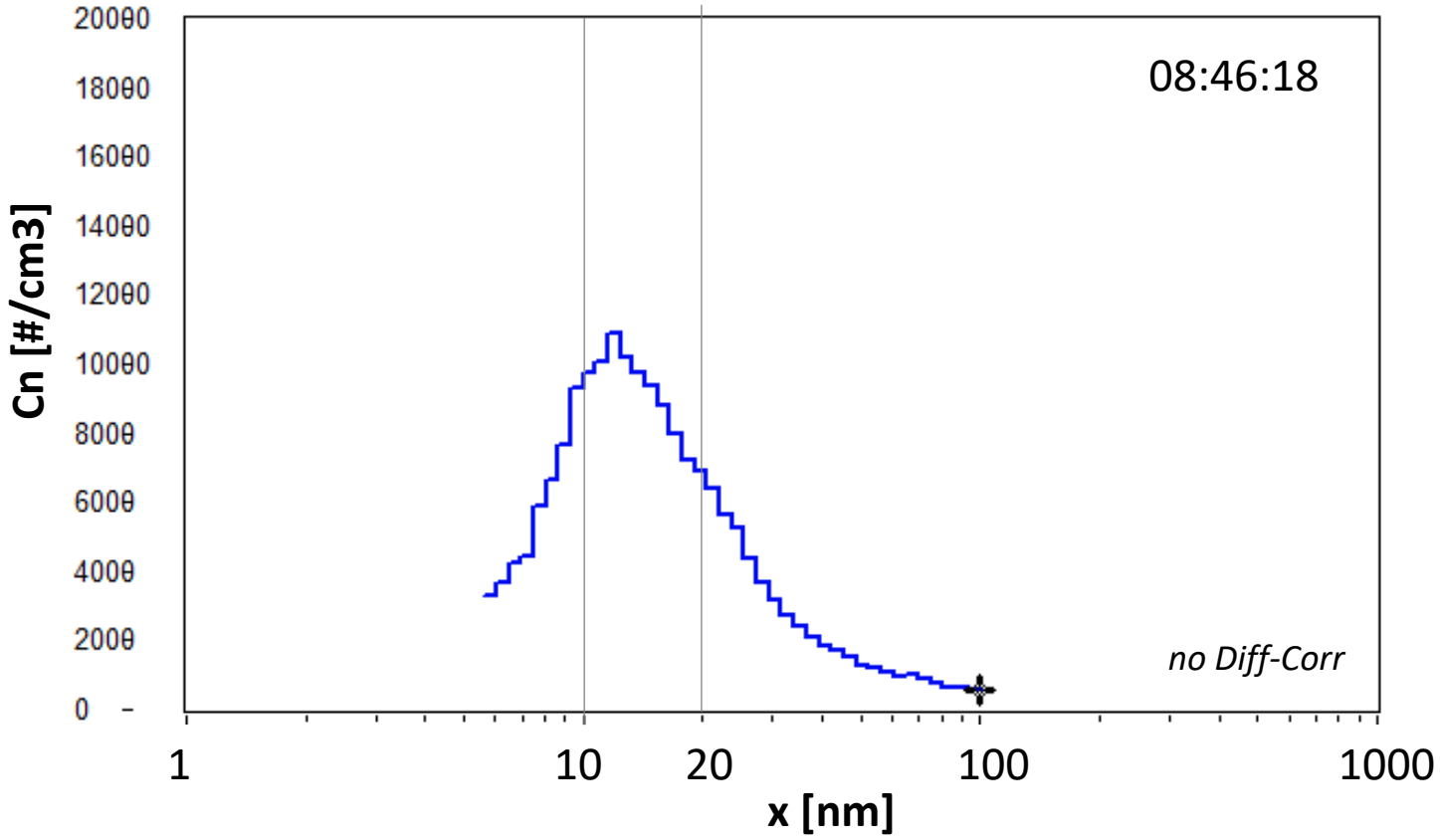

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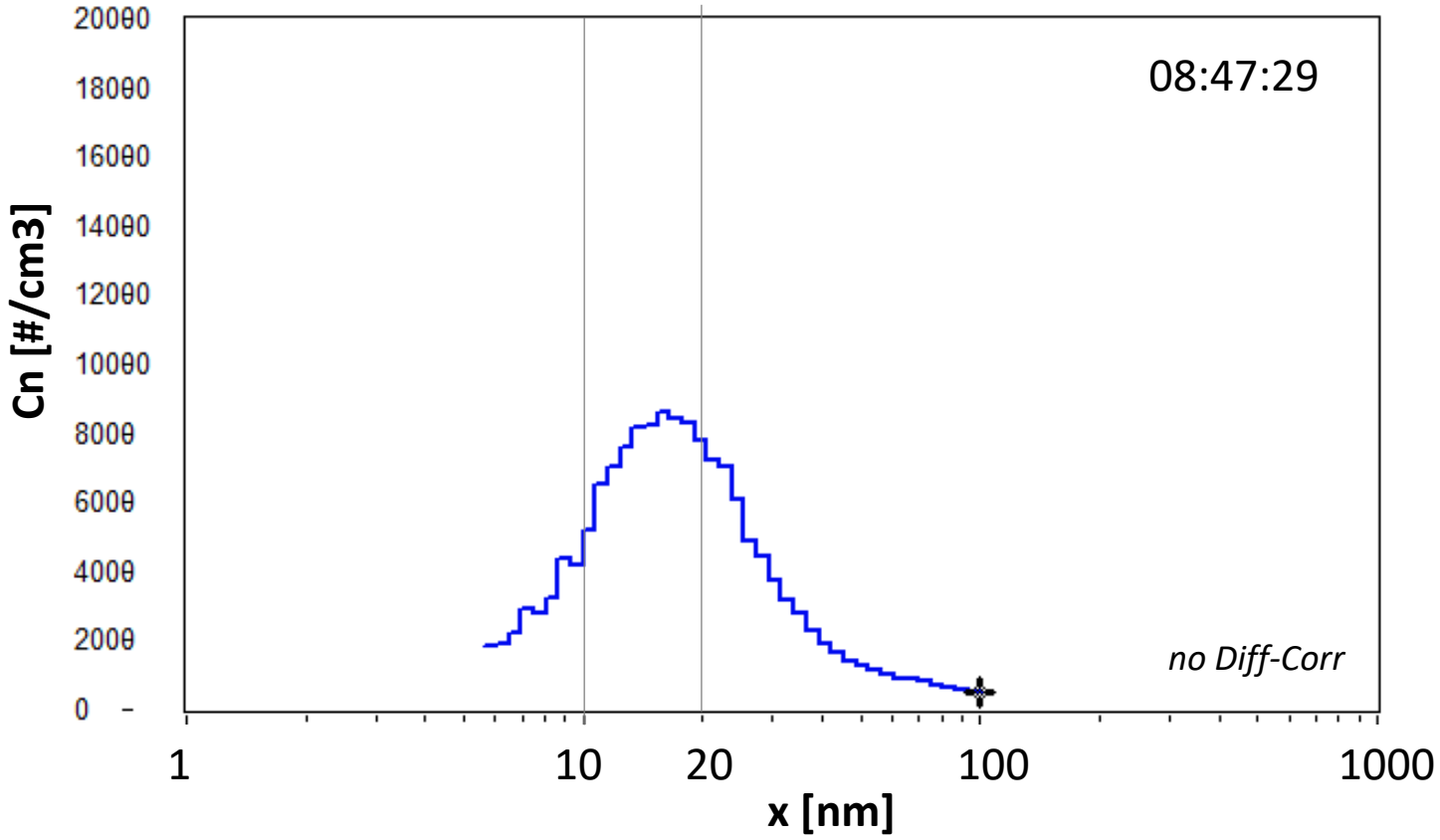

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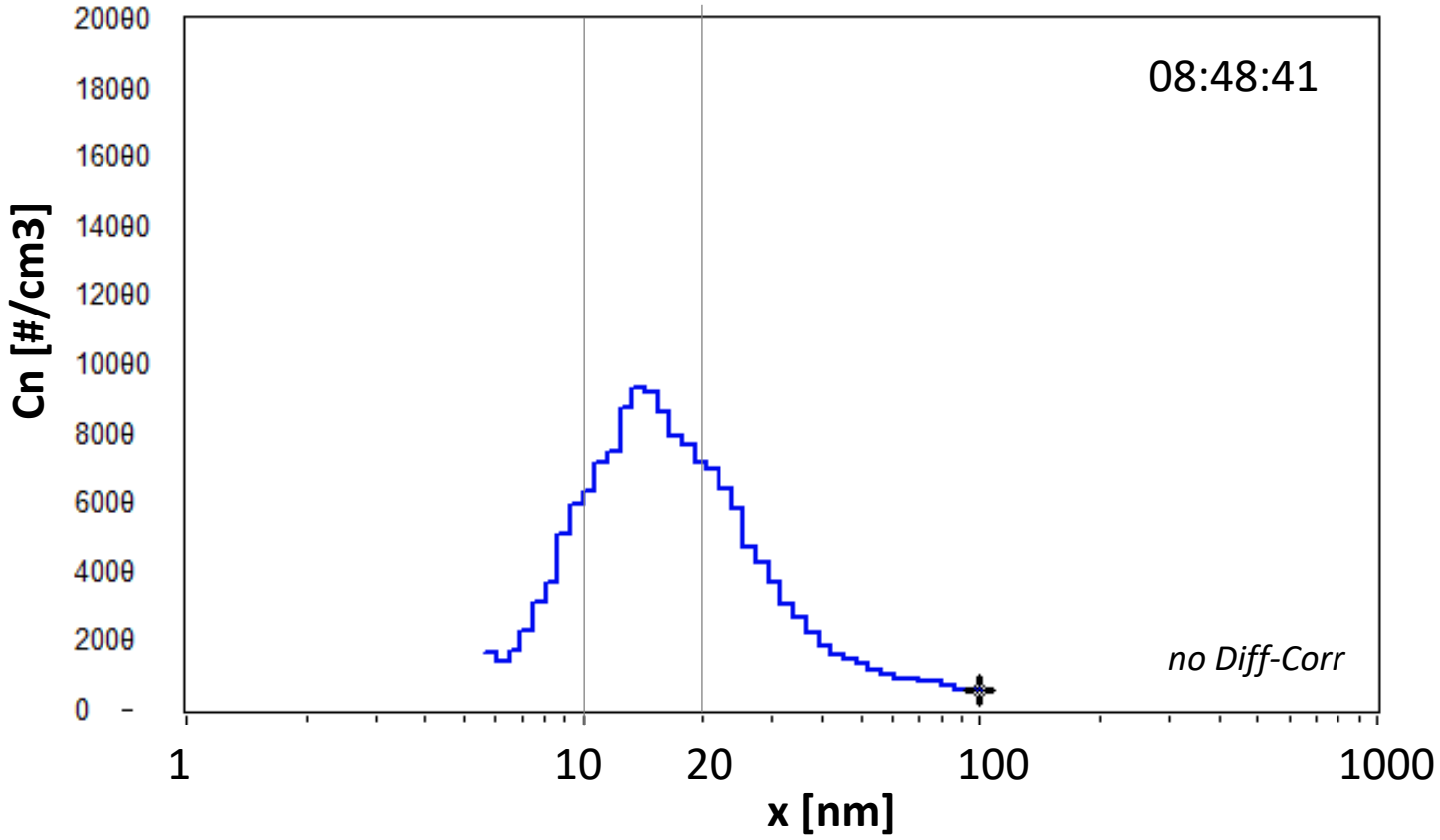

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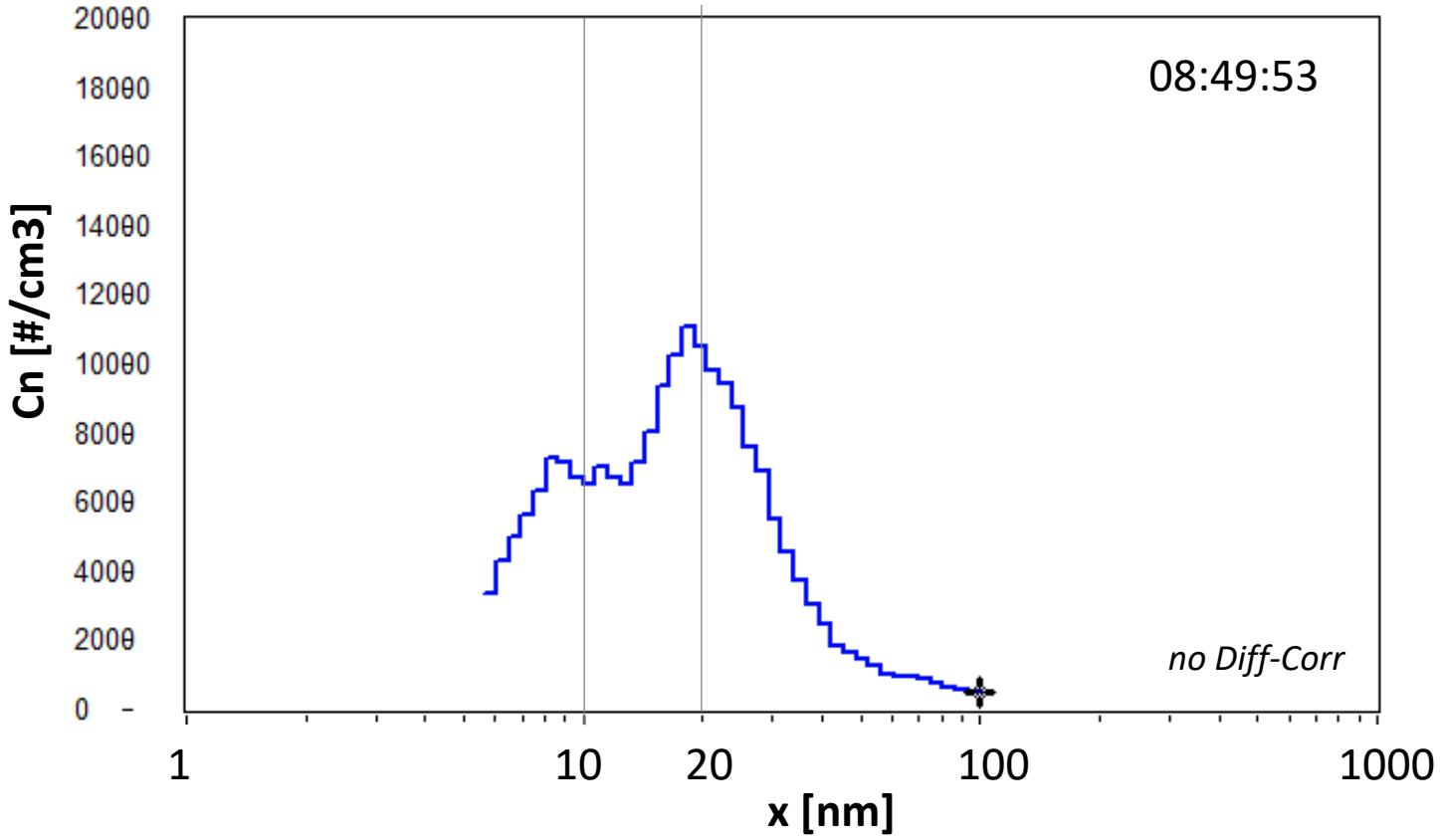

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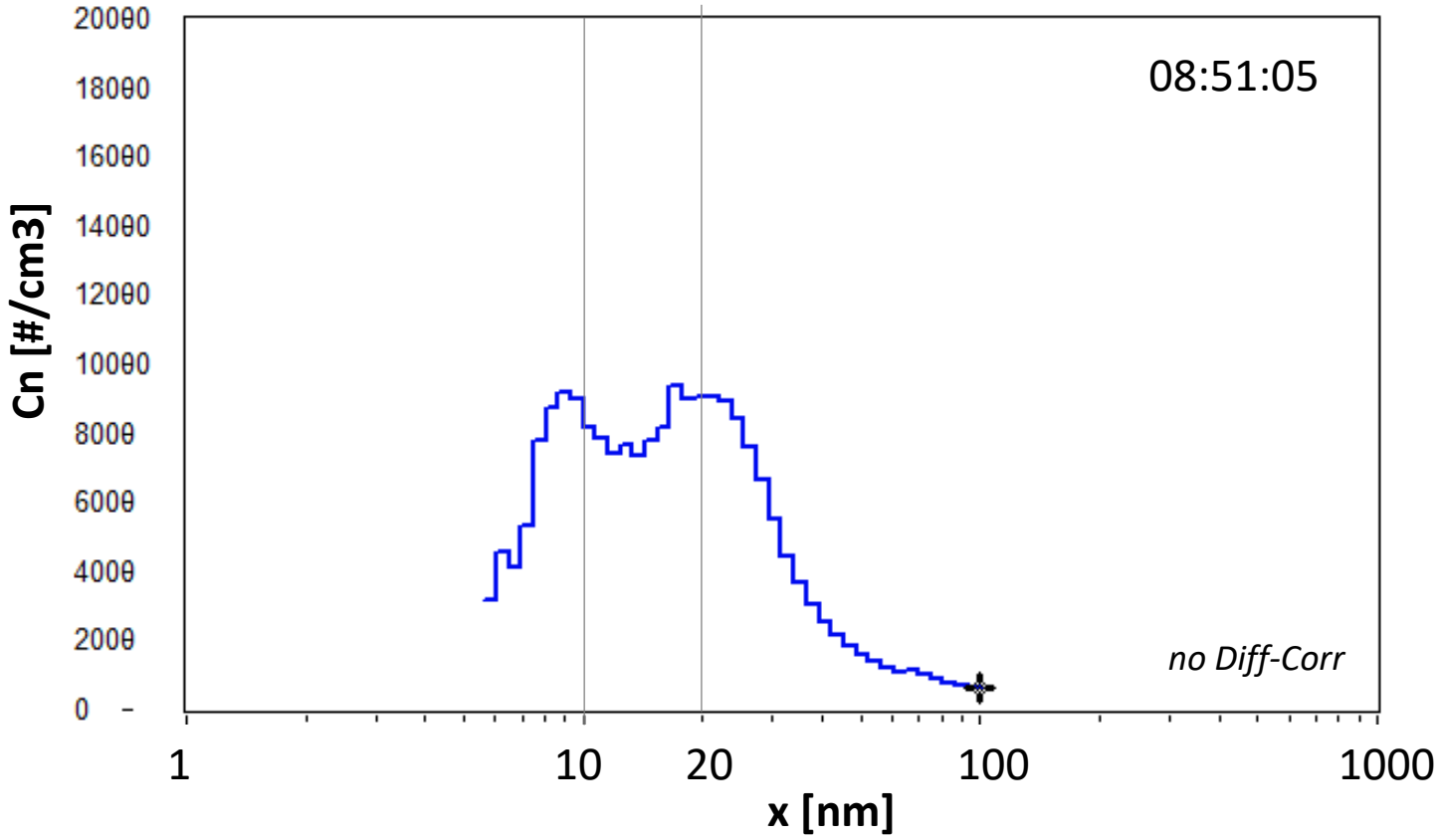

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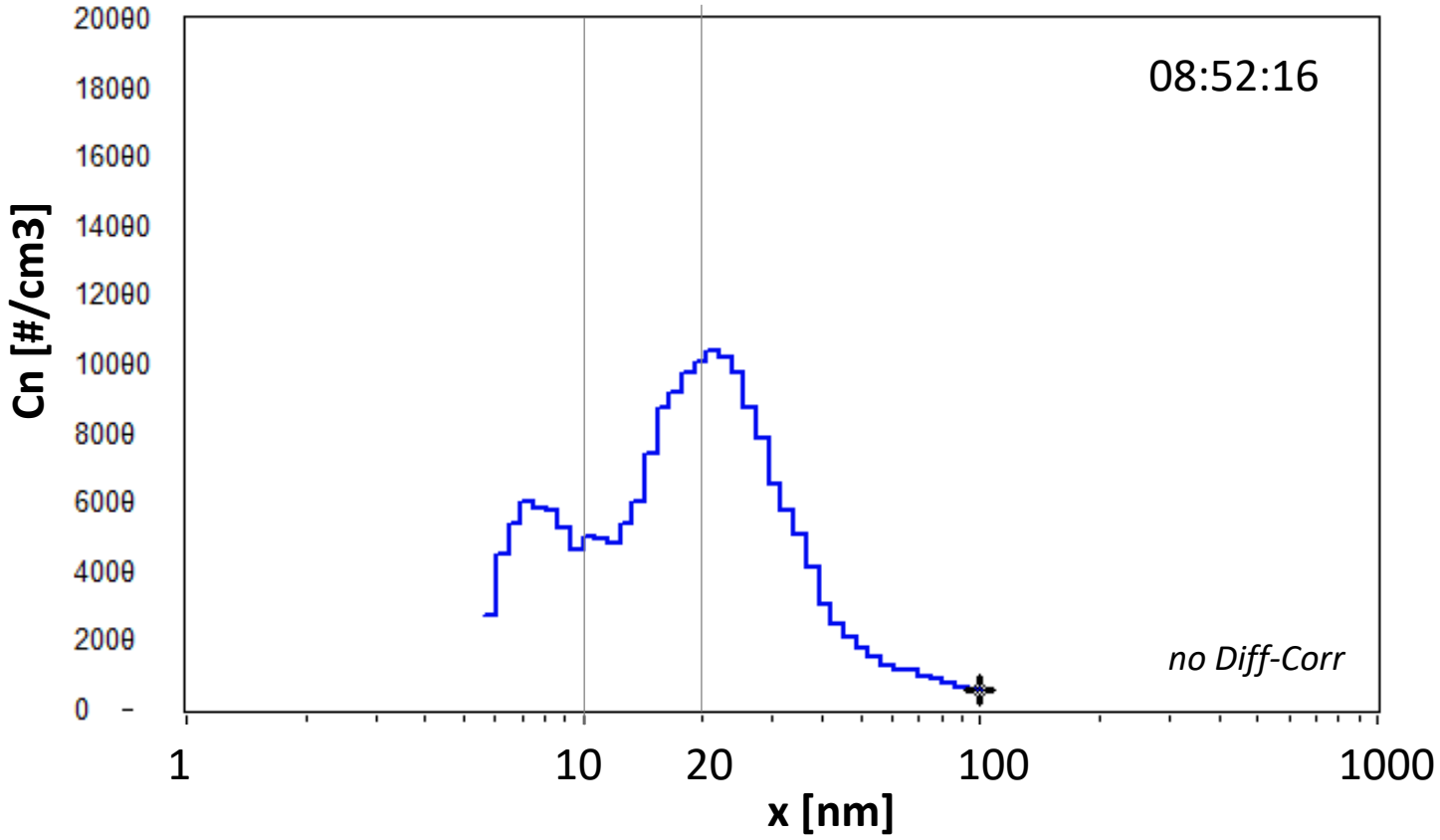

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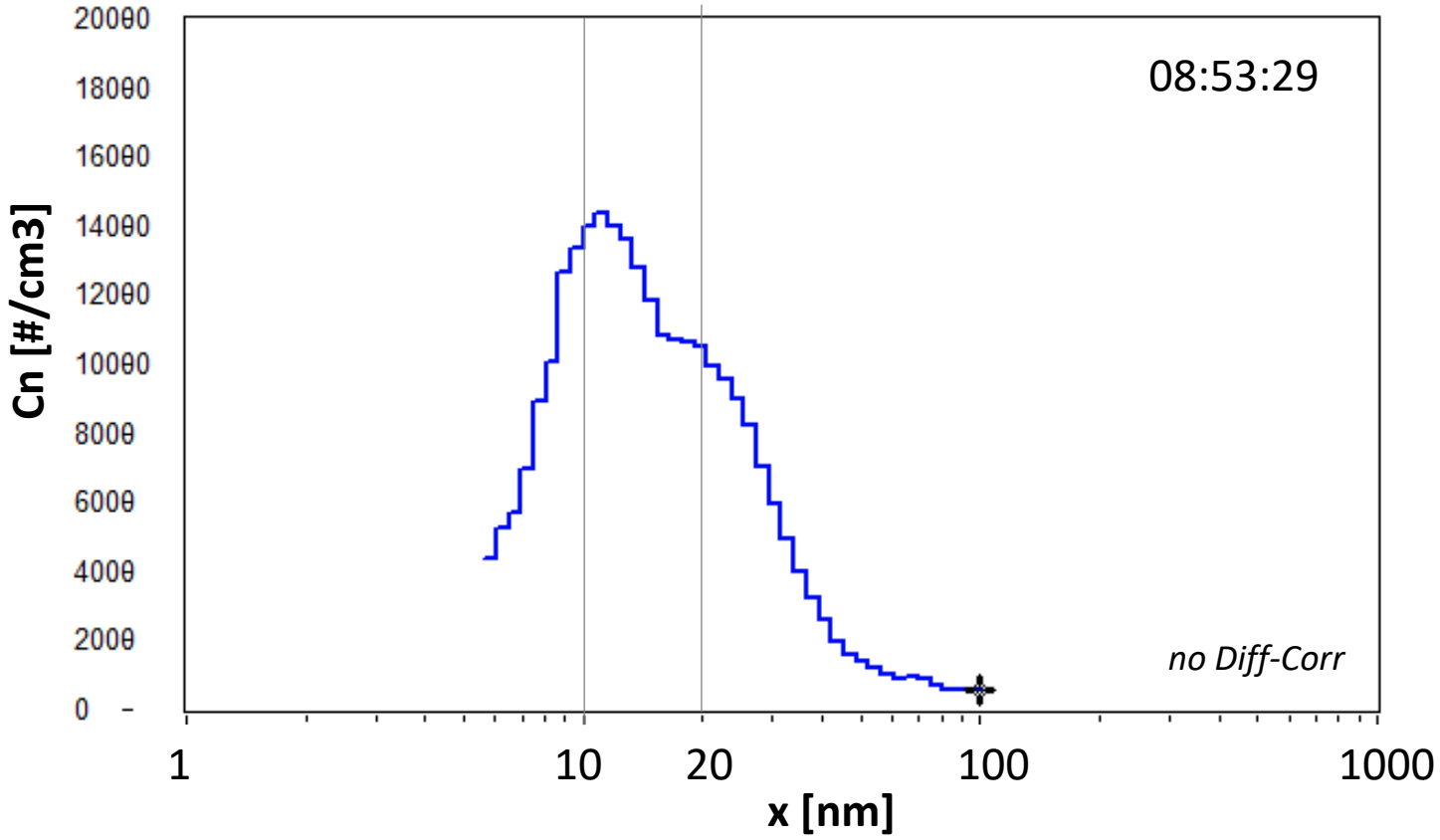

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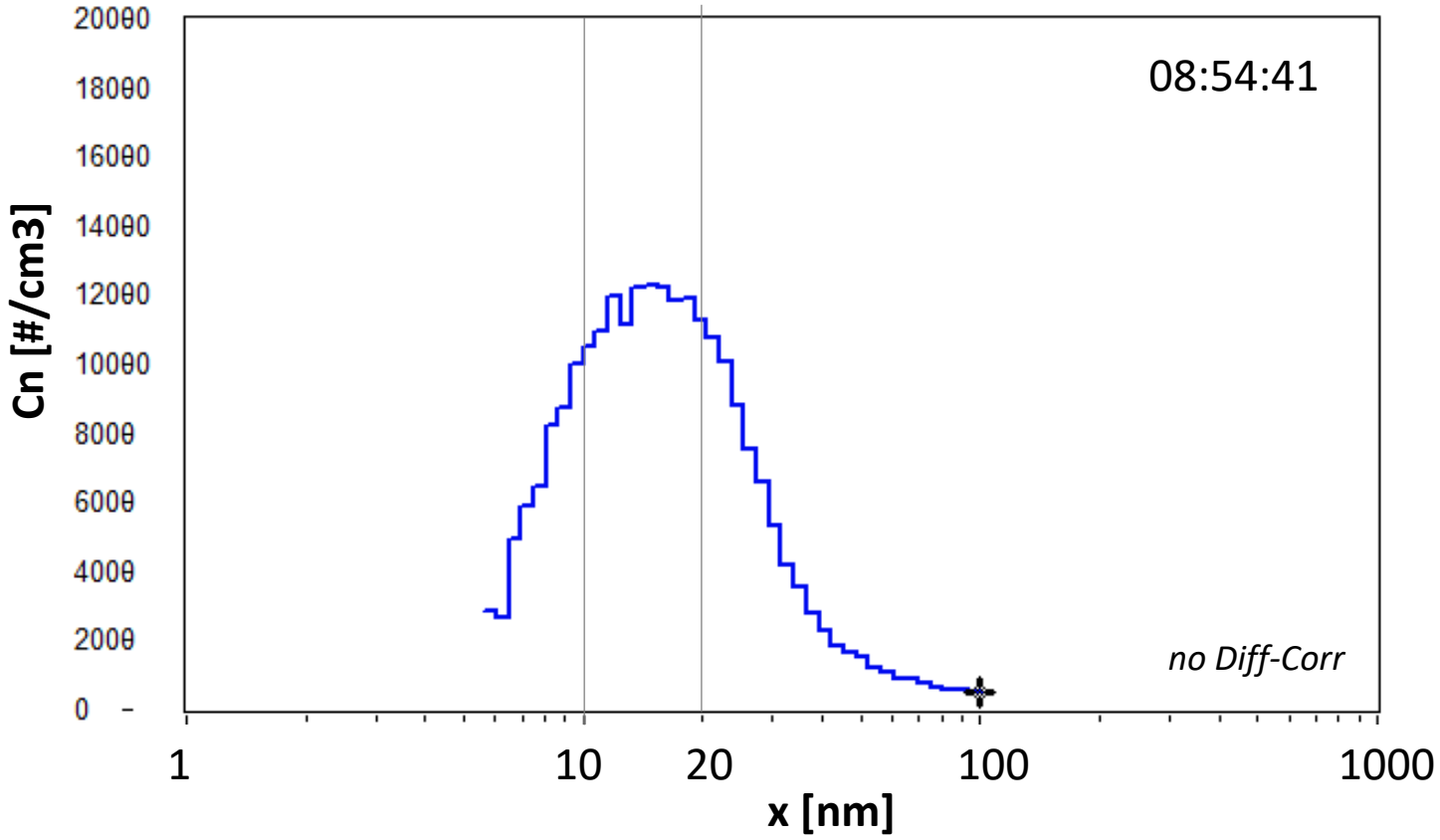

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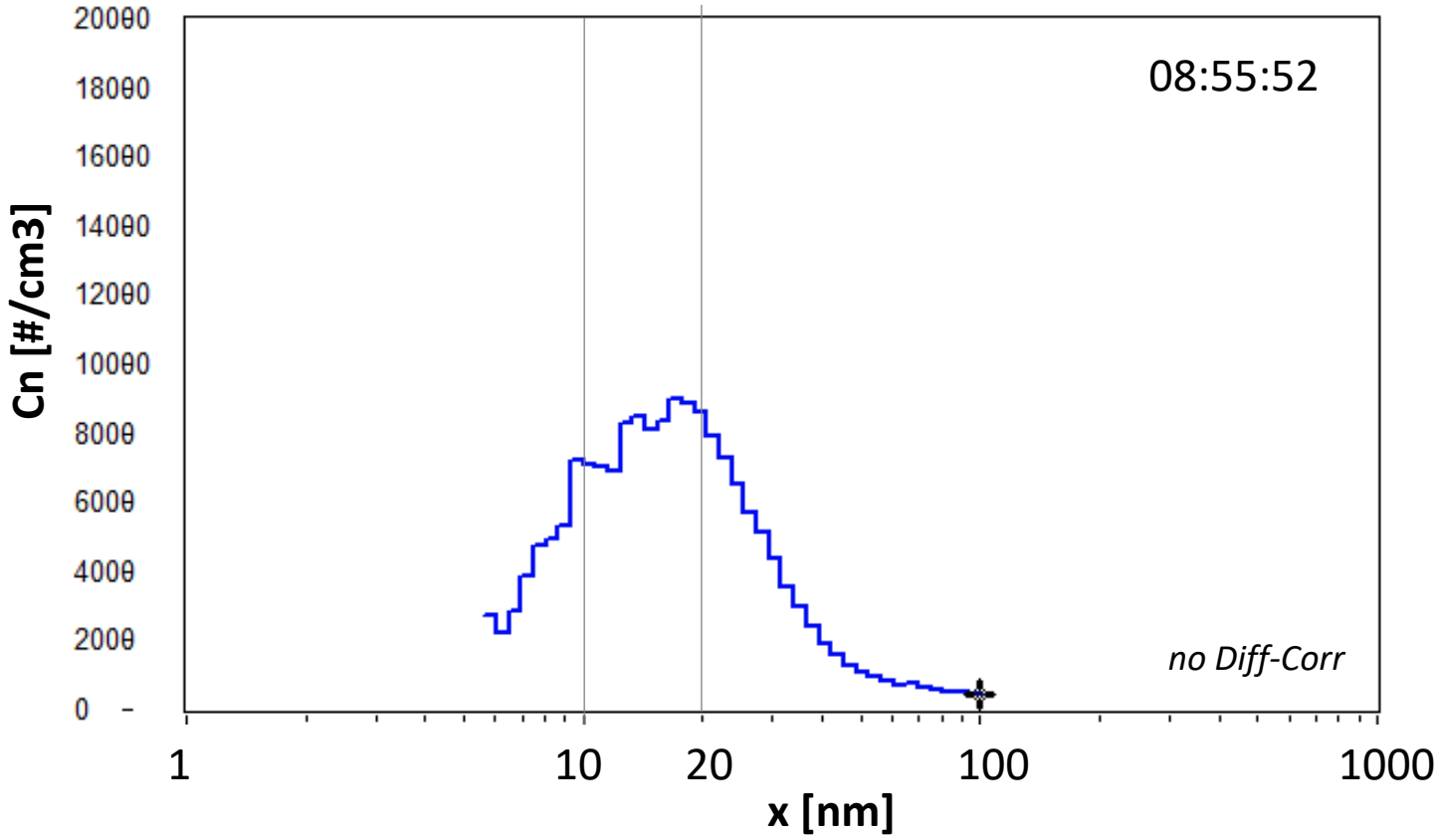

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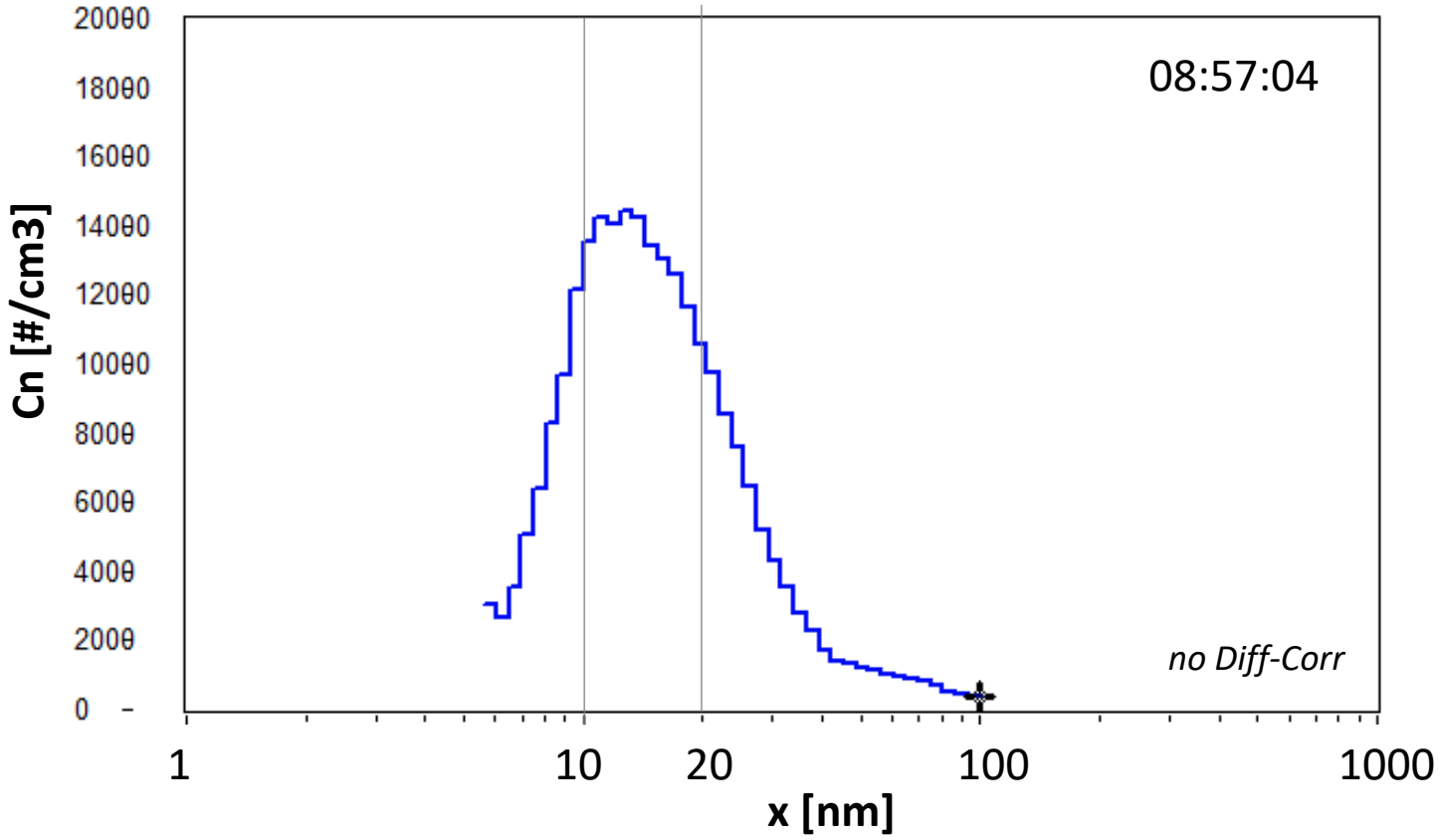

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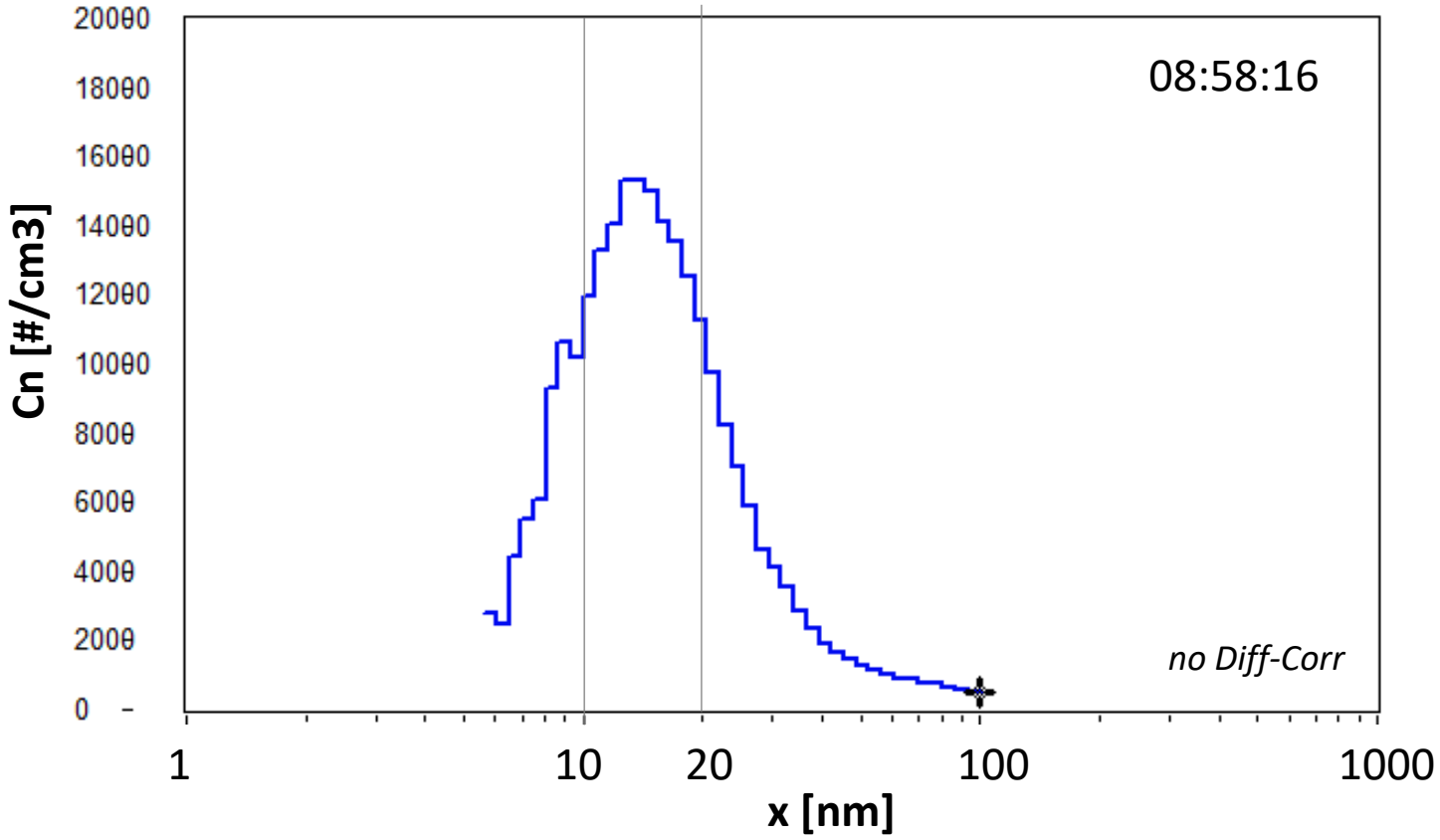

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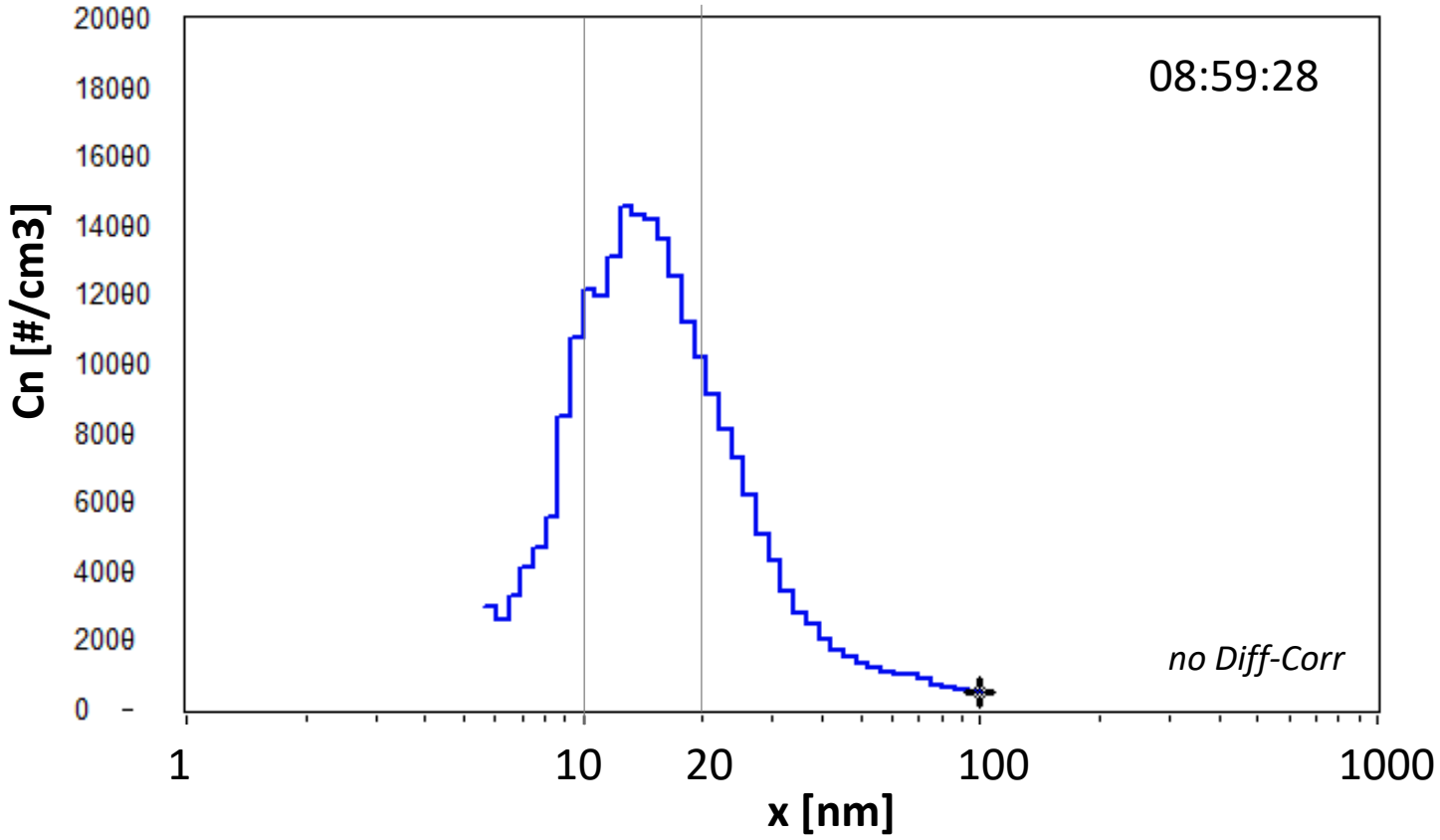

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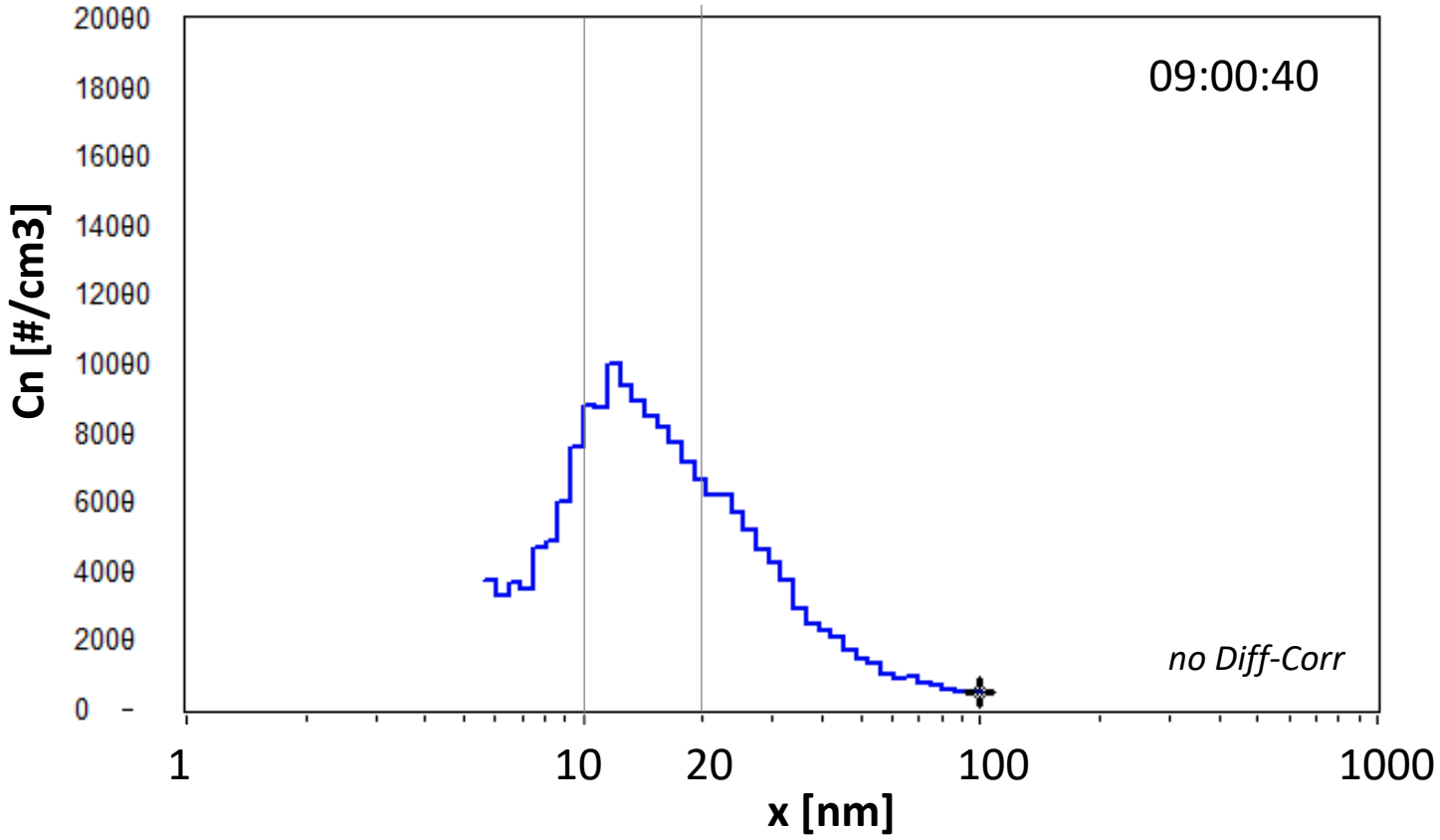

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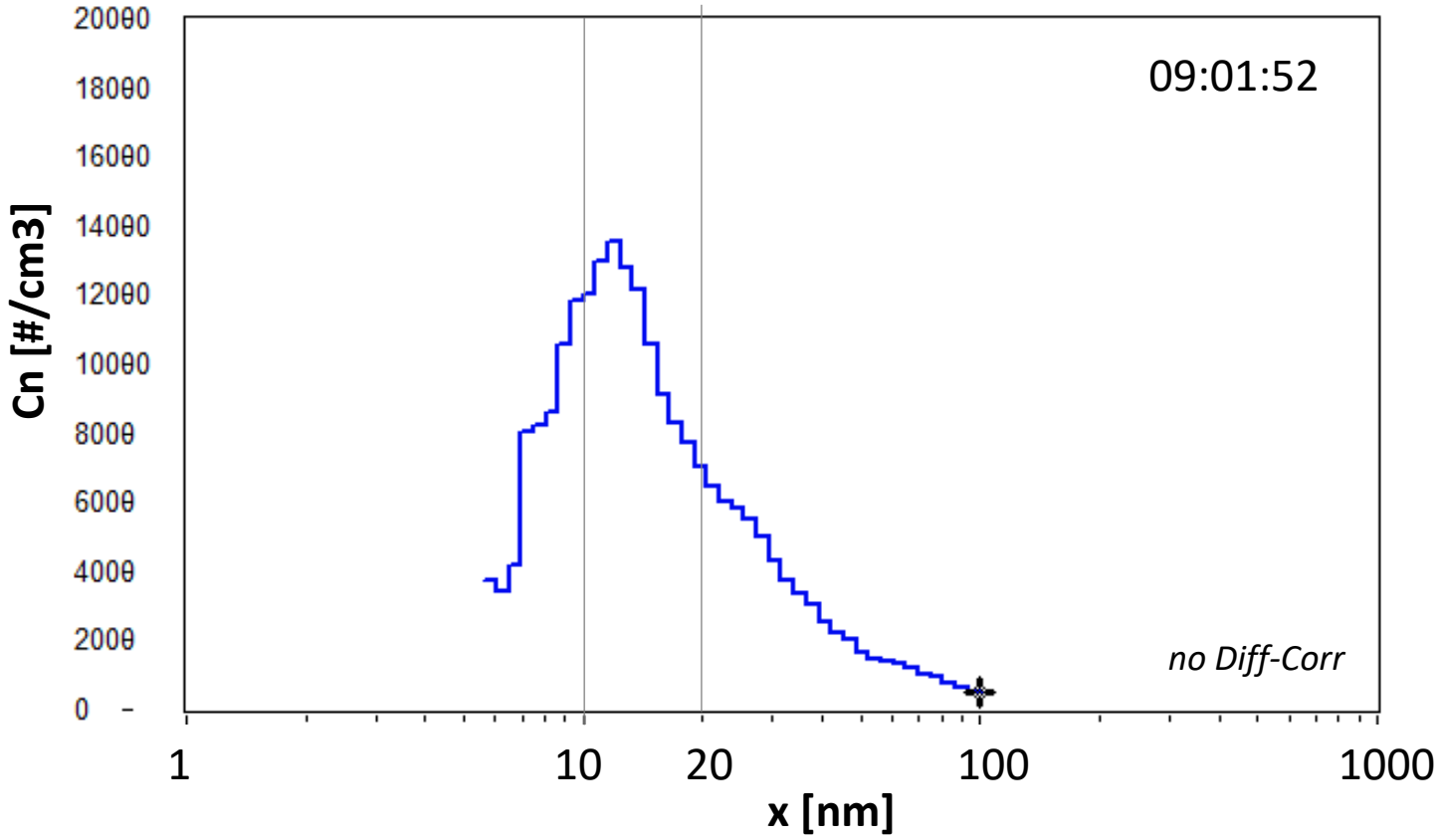

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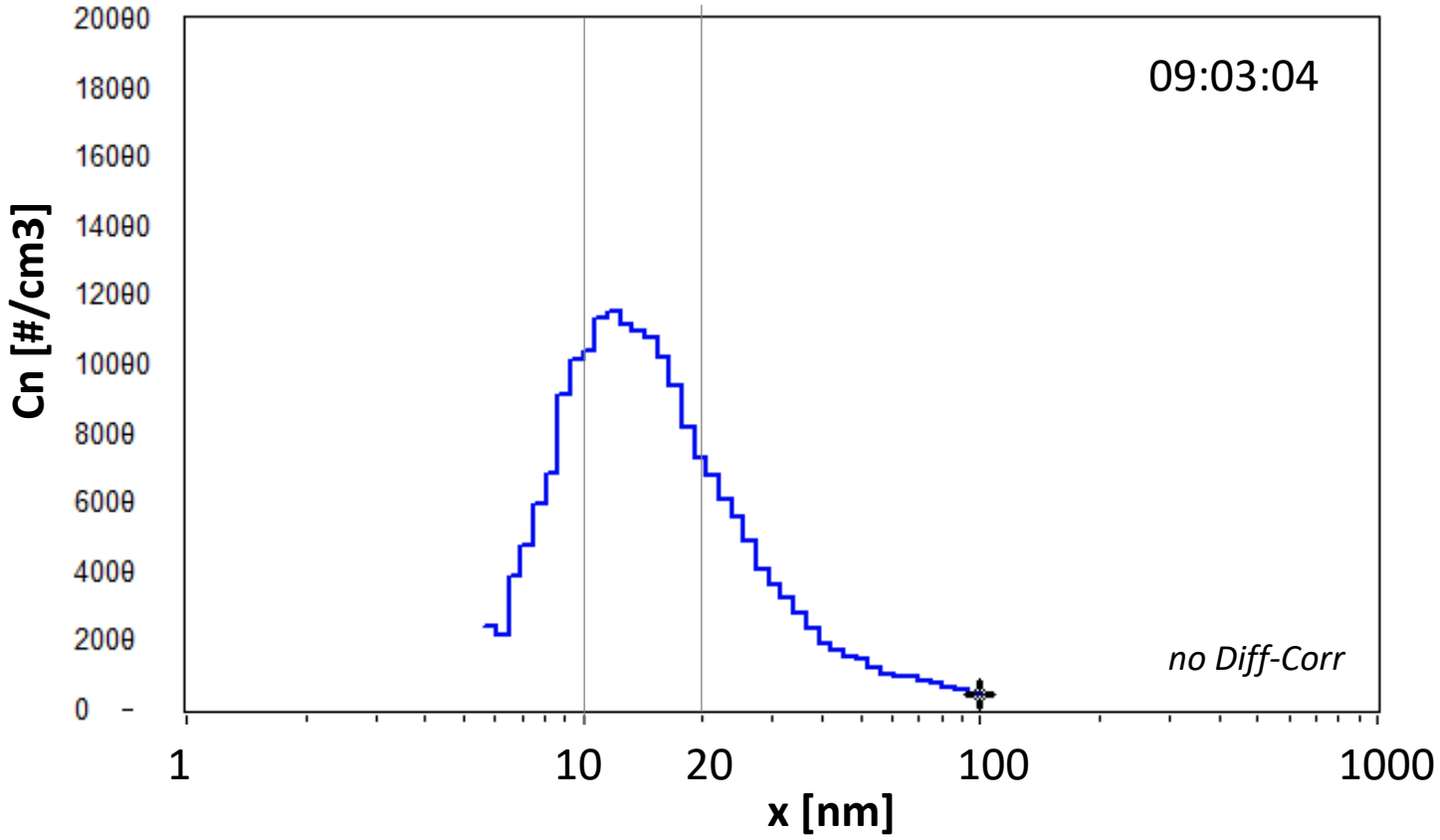
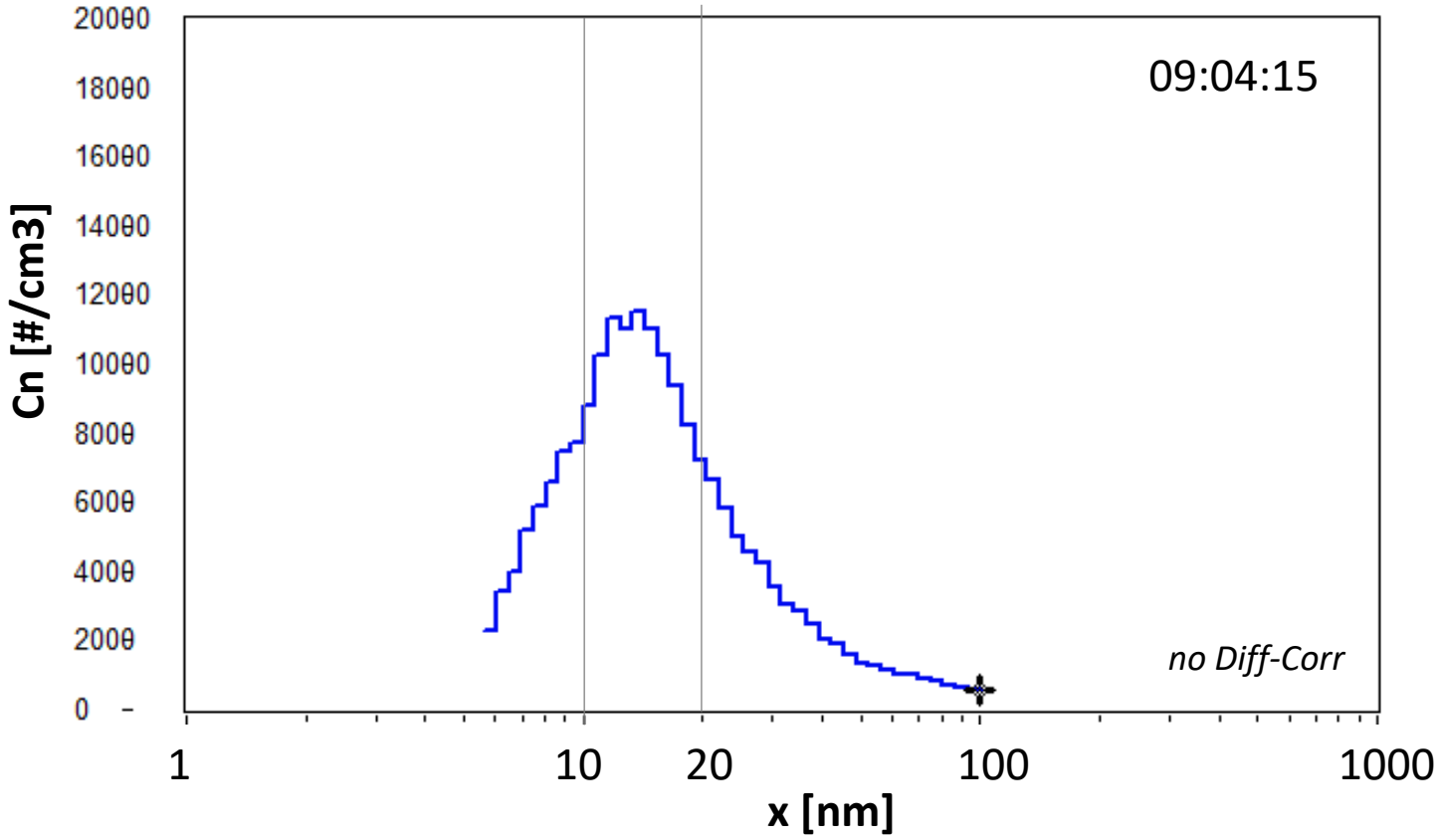
UFP monitoring at airport



Scenario B

- Close to departure/arrival runway
- Fast scans 7 – 100 nm in 40 seconds

UFP monitoring at airport



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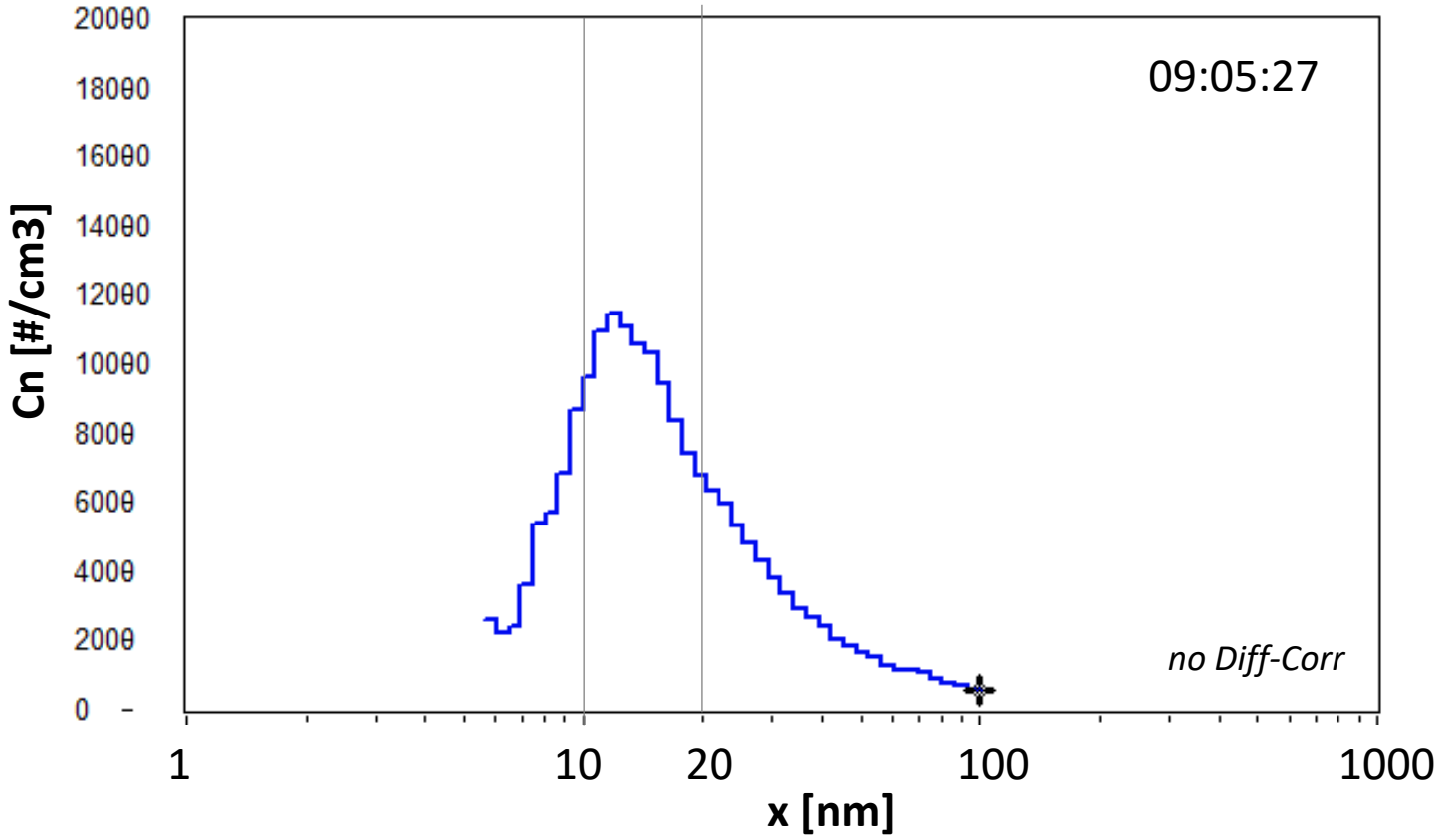


Scenario B

- Close to departure/arrival runway
- Fast scans 7 – 100 nm in 40 seconds

UFP monitoring at airport

Example data interpretation for one data set:

- Air traffic is clearly visible
- high UFP-fraction < 20 nm → very small particles directly from jet combustion

but

daily average

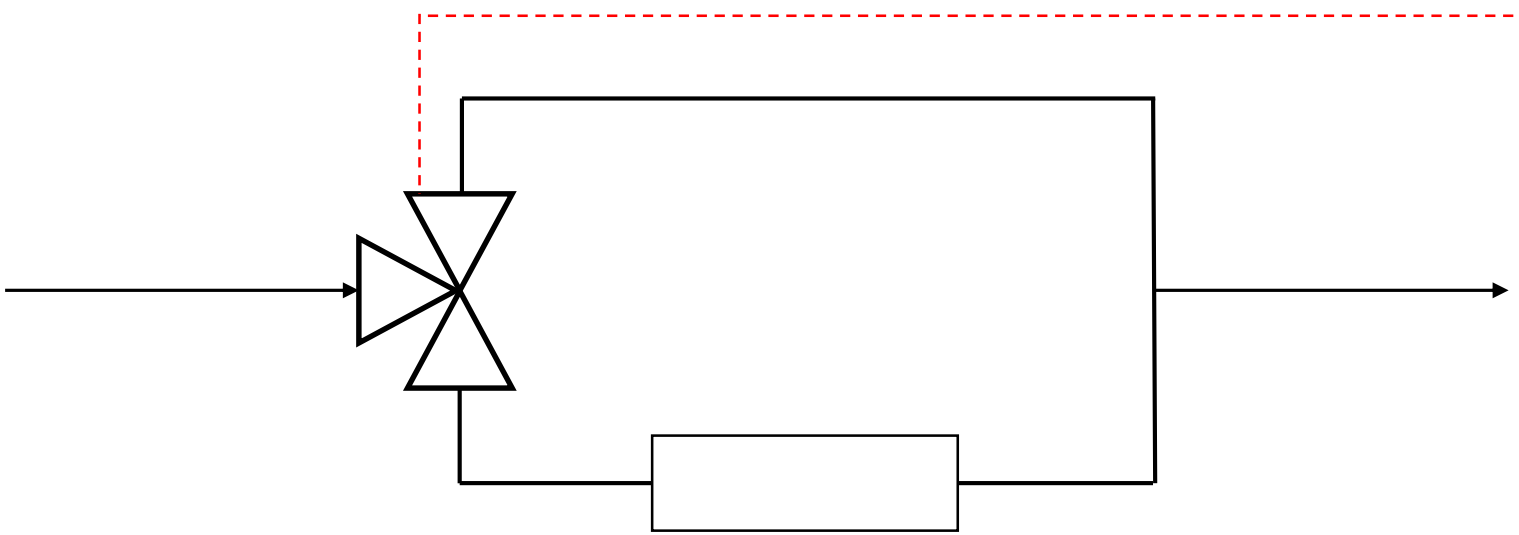
	Cn_total [#/ccm] > 7 nm	Cn_total [#/ccm] > 23 nm	
no Diff-Correction	281 000	63 000	4,5x higher
with Diff-Correction	811 000	81 000	10x higher

Quantitative conclusions and comparisons among different sites are criticial!
(especially for different measurement systems and different Cutoffs)

Going one step further…

Going one step further

+ use of built-in AUX port for valve switching



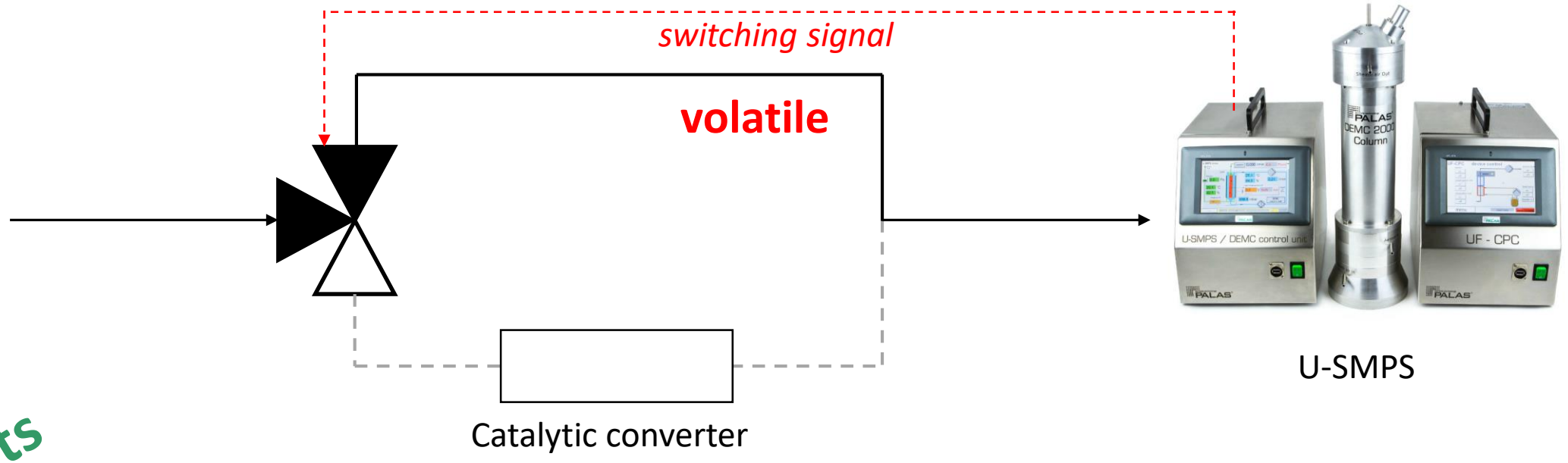
U-SMPS

Benefits

- differentiate between volatile and semi-volatile compounds

Unique features of Palas® U-SMPS

+ built-in AUX port for valve switching (digital or analog)



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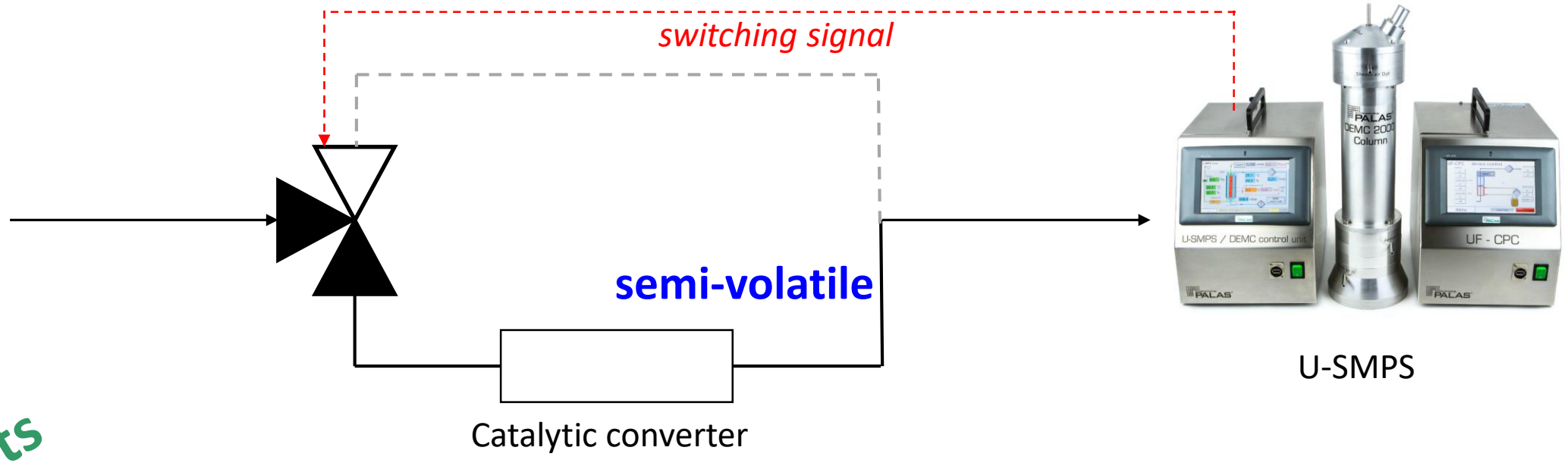

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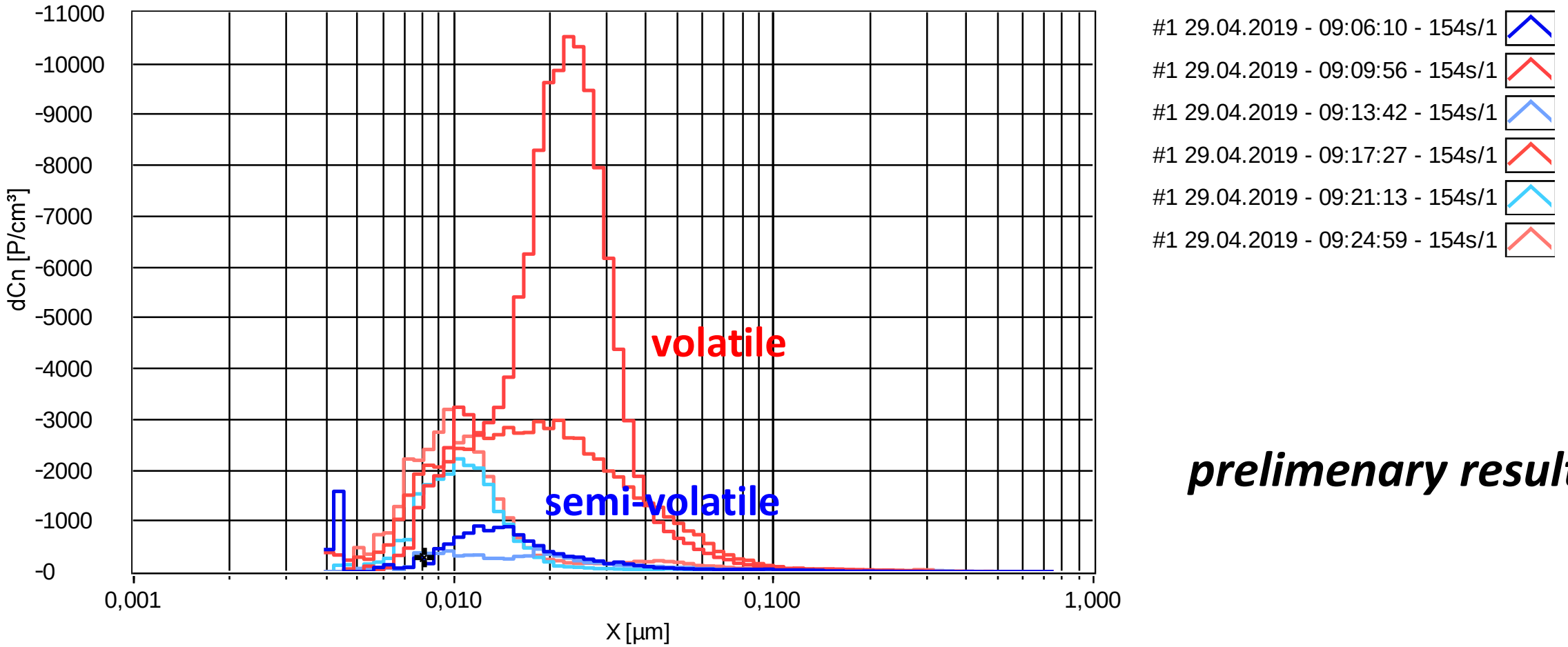
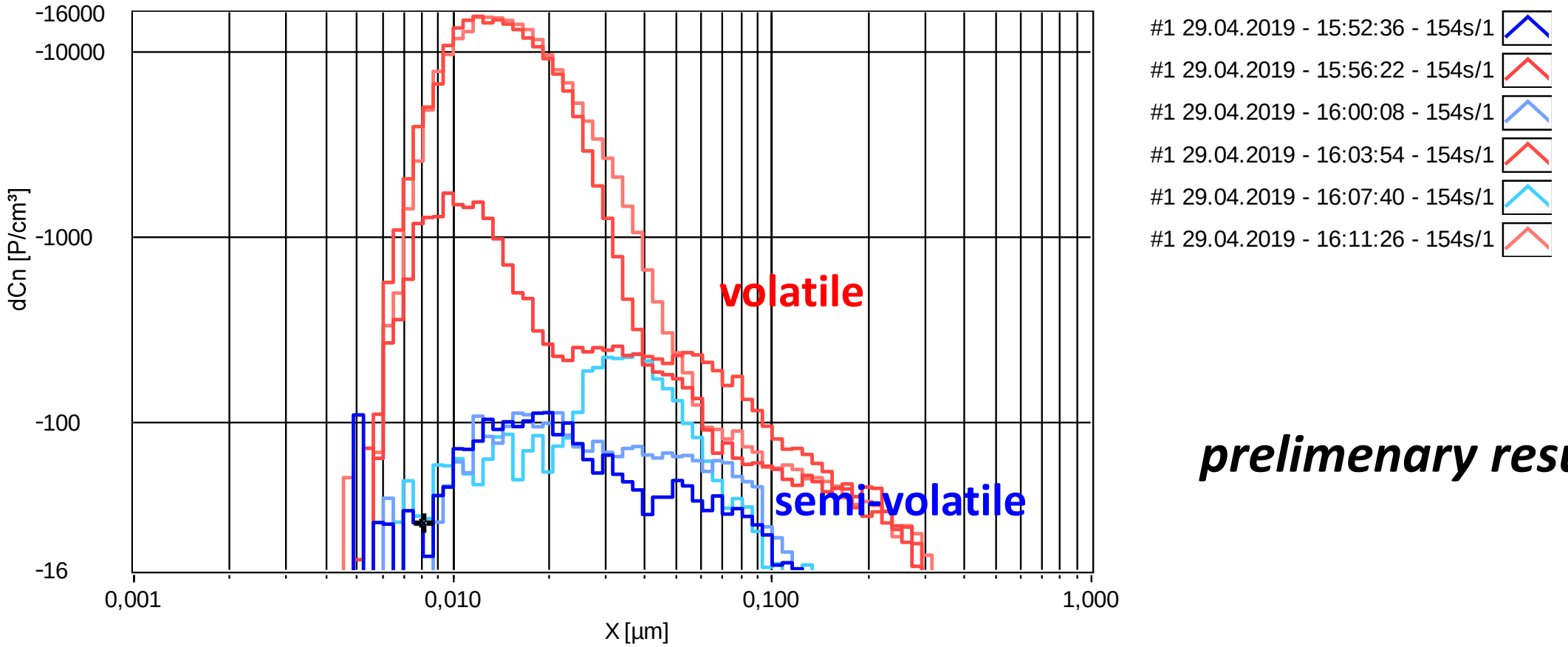


prelimenary results

size range <30nm is dominated by volatile particles



prelimenary results

size range <30nm is dominated by volatile particles

Down to... pushing the limits

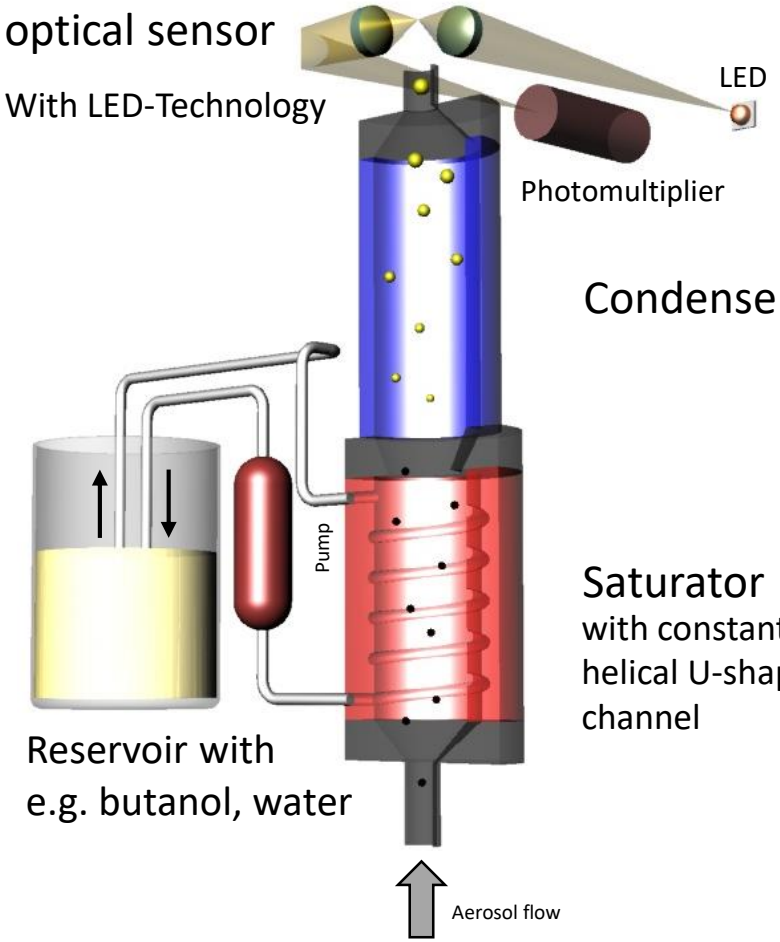
“There’s Plenty of Room at the Bottom”

(Richard Feynman,1959)

Condensation Particle Counter

optical sensor

With LED-Technology

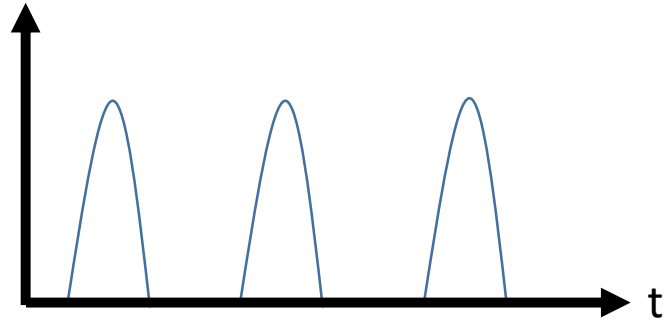


Condenser

Saturator
with constantly heated helical U-shaped channel

Reservoir with
e.g. butanol, water

droplet detection



CPC counts single light pulses
dN/dt

<u>Total</u> Number Concentration
c_N : Particles/cm^3

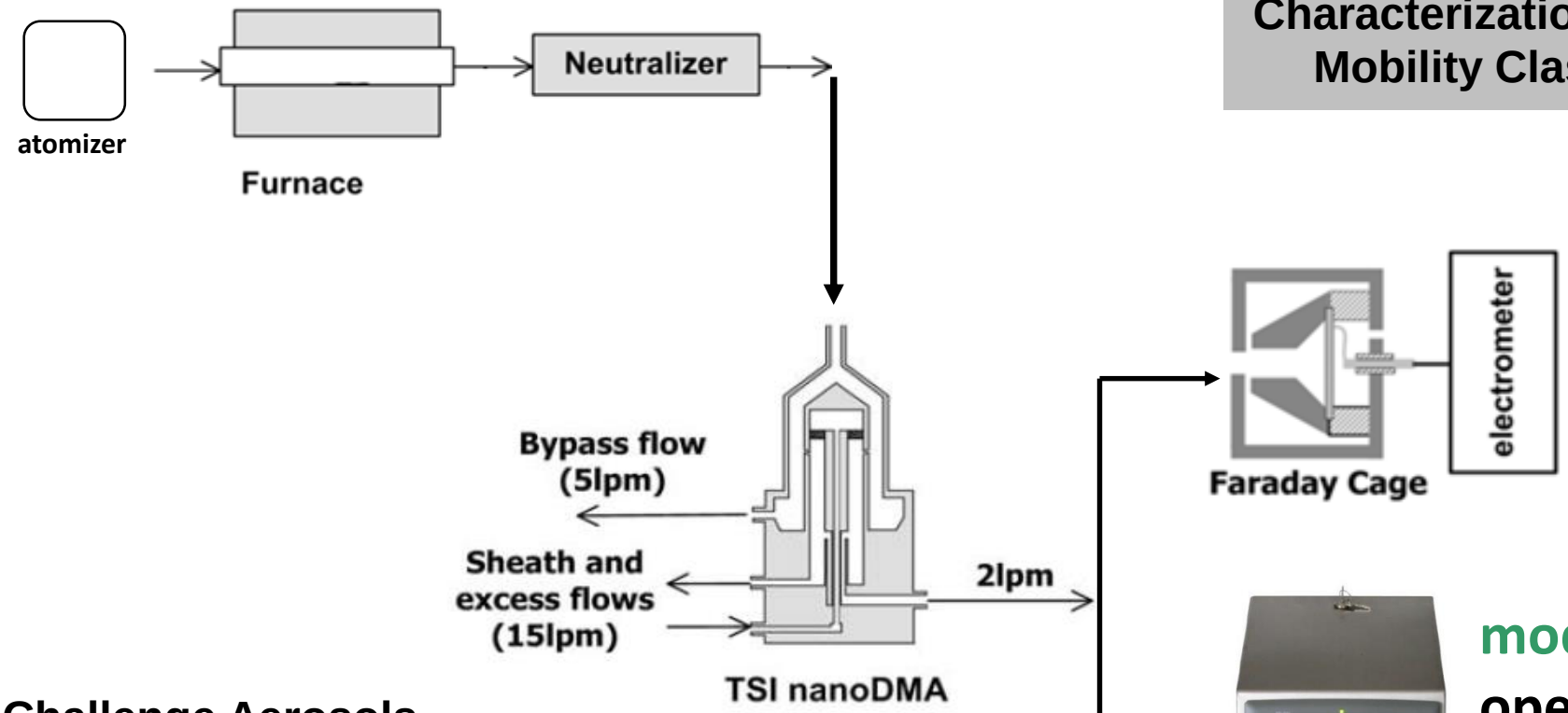
No particle size can be obtained !

• (nano)particle

Down to…10nm…1nm

Slides taken from: presentation C.Kuang, AAAR conference 2016 + 2017

Characterization Schematic with Mobility Classified Aerosol



Challenge Aerosols

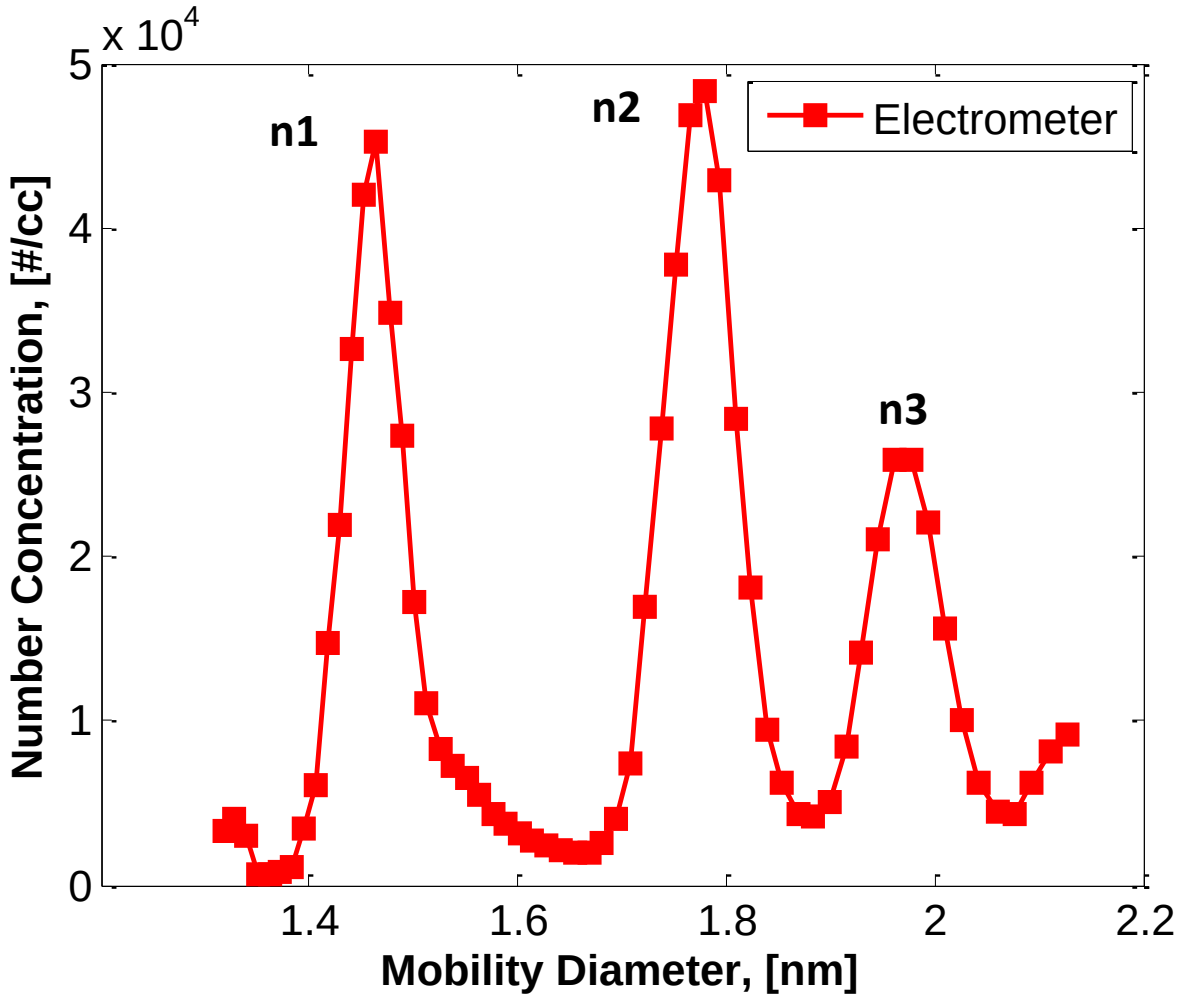
- ammonium sulfate (+, –)
- neutralizer ions (+, -)

modified Palas® UF-CPC operated with DEG Di-ethylene-glycol

*Adapted from Jiang, J., et al. (2011). Electrical Mobility Spectrometer Using a Diethylene Glycol Condensation Particle Counter for Measurement of Aerosol Size Distributions Down to 1 nm. *Aerosol Sci. Technol.* 45:510 - 5

Down to...

Slides taken from: presentation C.Kuang, AAAR conference 2016 + 2017



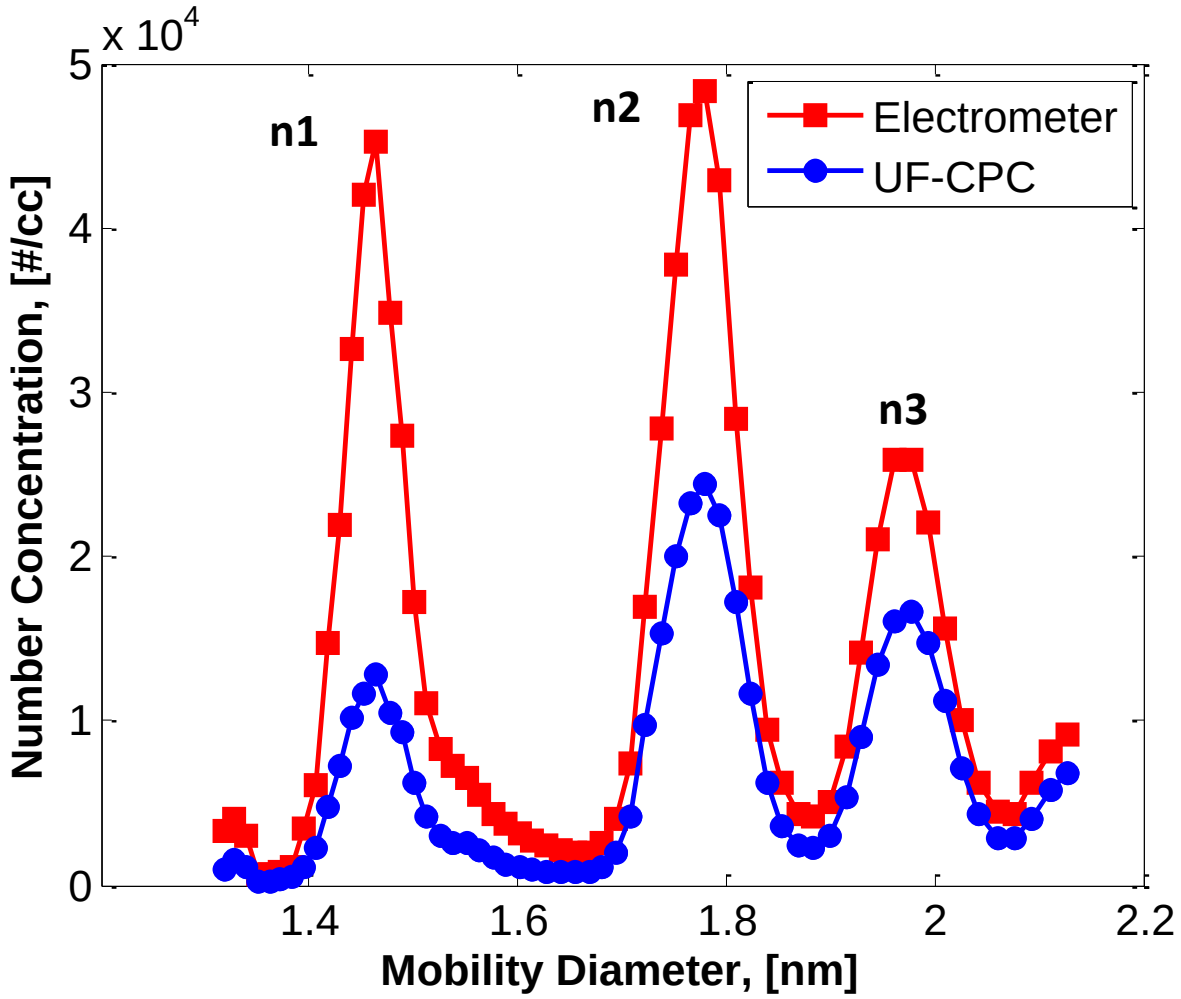
Ion Mobility Standard:
HRDMA Calibration

Tetra-heptyl ammonium bromide (THAB)

$[CH_3(CH_2)_6]_4N(Br)$

Down to...

Slides taken from: presentation C.Kuang, AAAR conference 2016 + 2017

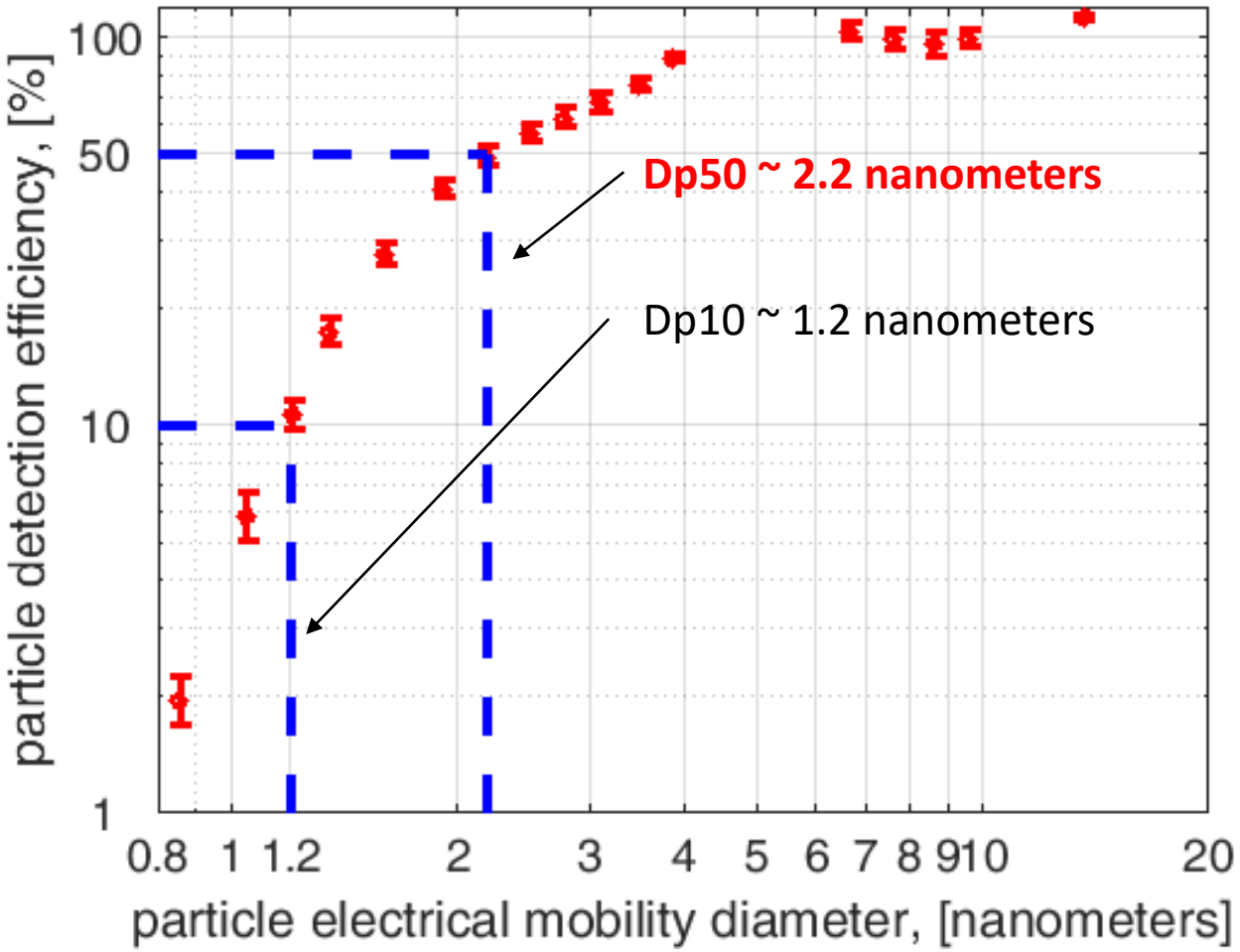


Ion Mobility Standard:
HRDMA Calibration

Tetra-heptyl ammonium bromide (THAB)
$[CH_3(CH_2)_6]_4N(Br)$

- **UF-CPC operated with DEG enables for Cluster detection down to 1.47 nm**

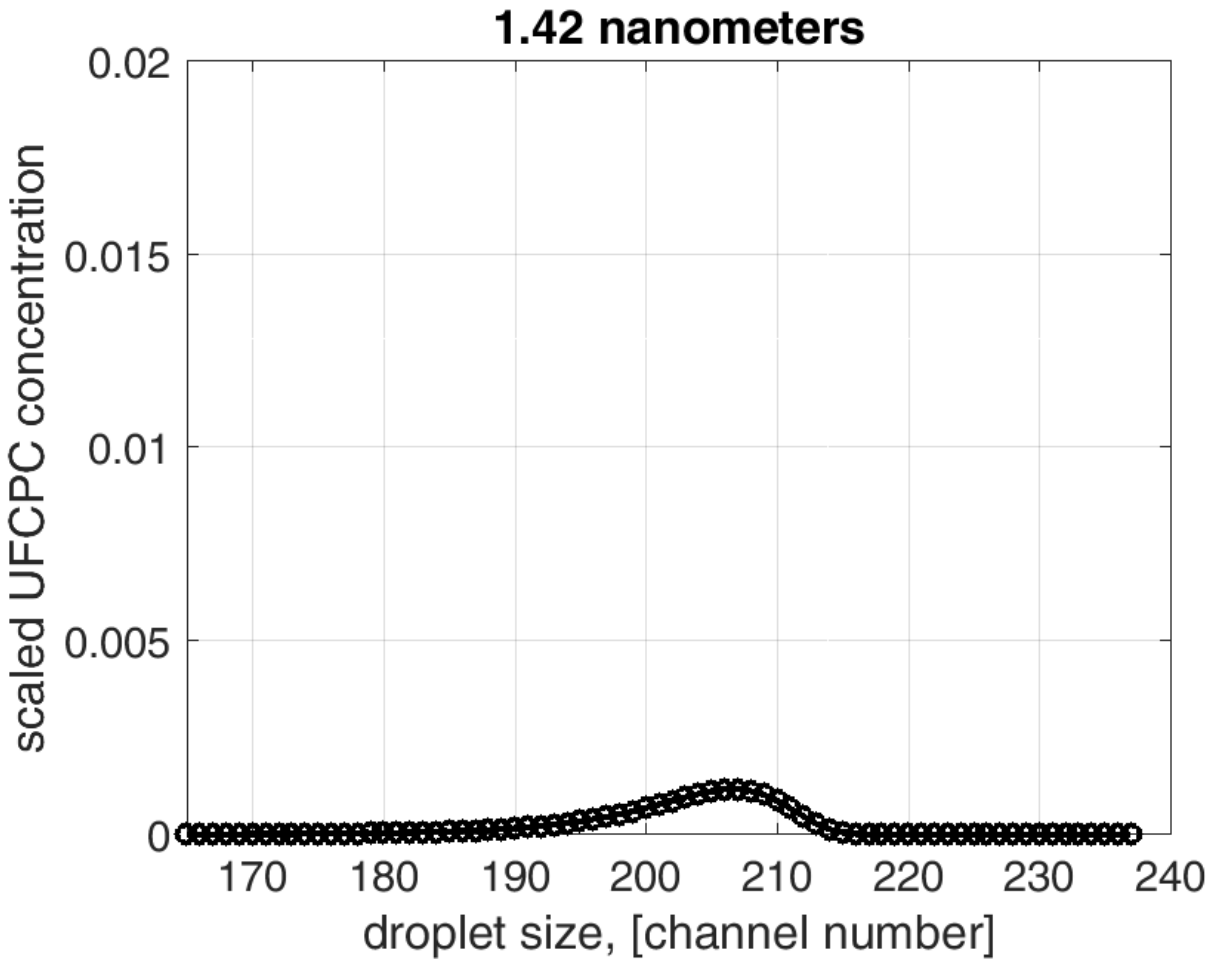
Down to...1nm



Ammonium Sulfate Calibration: Detection Efficiency

- Negatively charged ammonium sulfate
- UF-CPC operating temperatures: **55C/10C** (saturator/condenser)
- tuned optics

Down to...



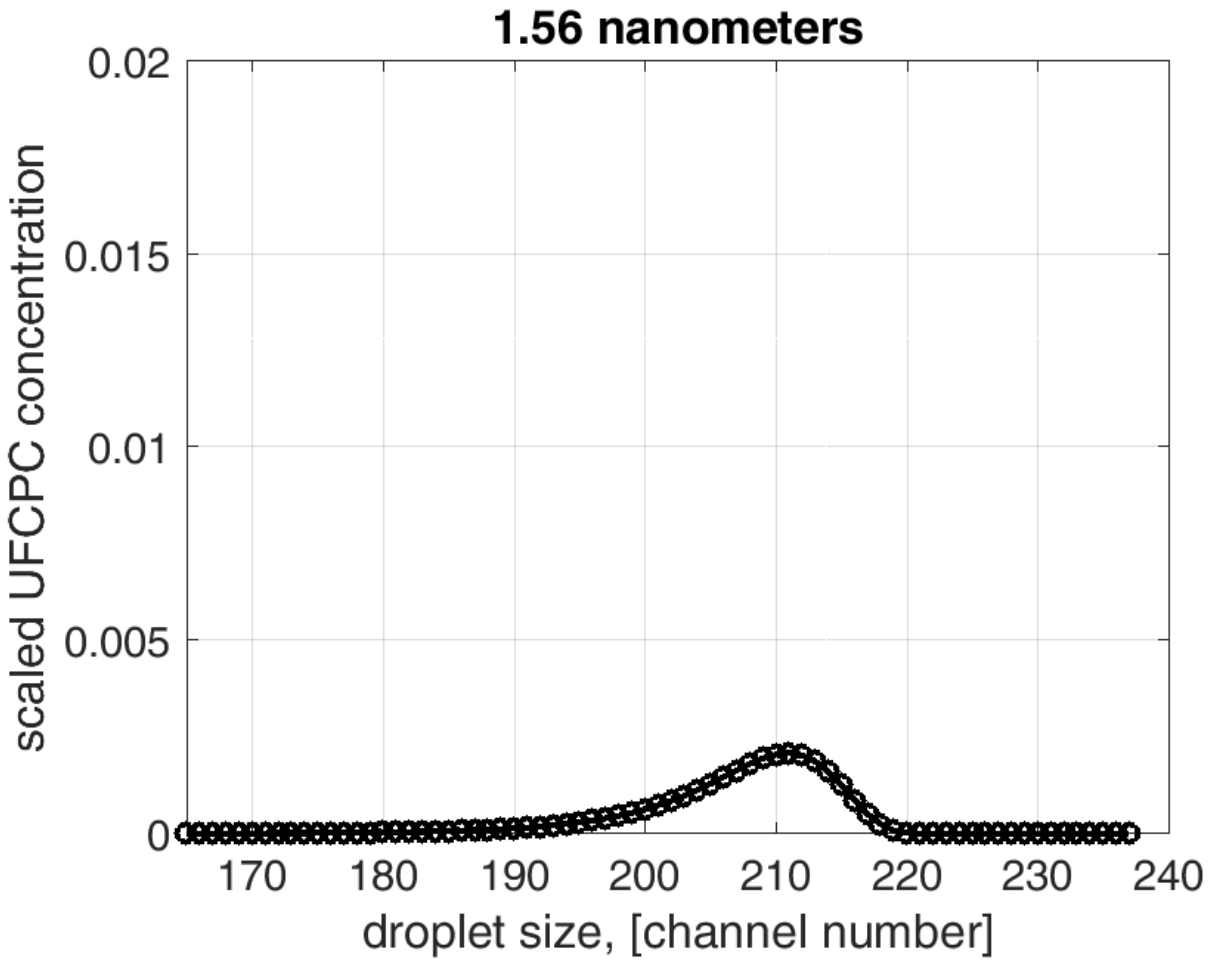
Ammonium Sulfate Calibration:
Droplet Size As a Function of Initial Size

Tuned optics: setup 2

Use of tuned photomultiplier settings and optic setup to detect droplet size distribution

- Chongai Kuang (2018): A Diethylene Glycol Condensation Particle Counter for Rapid Sizing of sub-3 nm Atmospheric Clusters, Aerosol Science and Technology, DOI:10.1080/02786826.2018.1481279

Down to...



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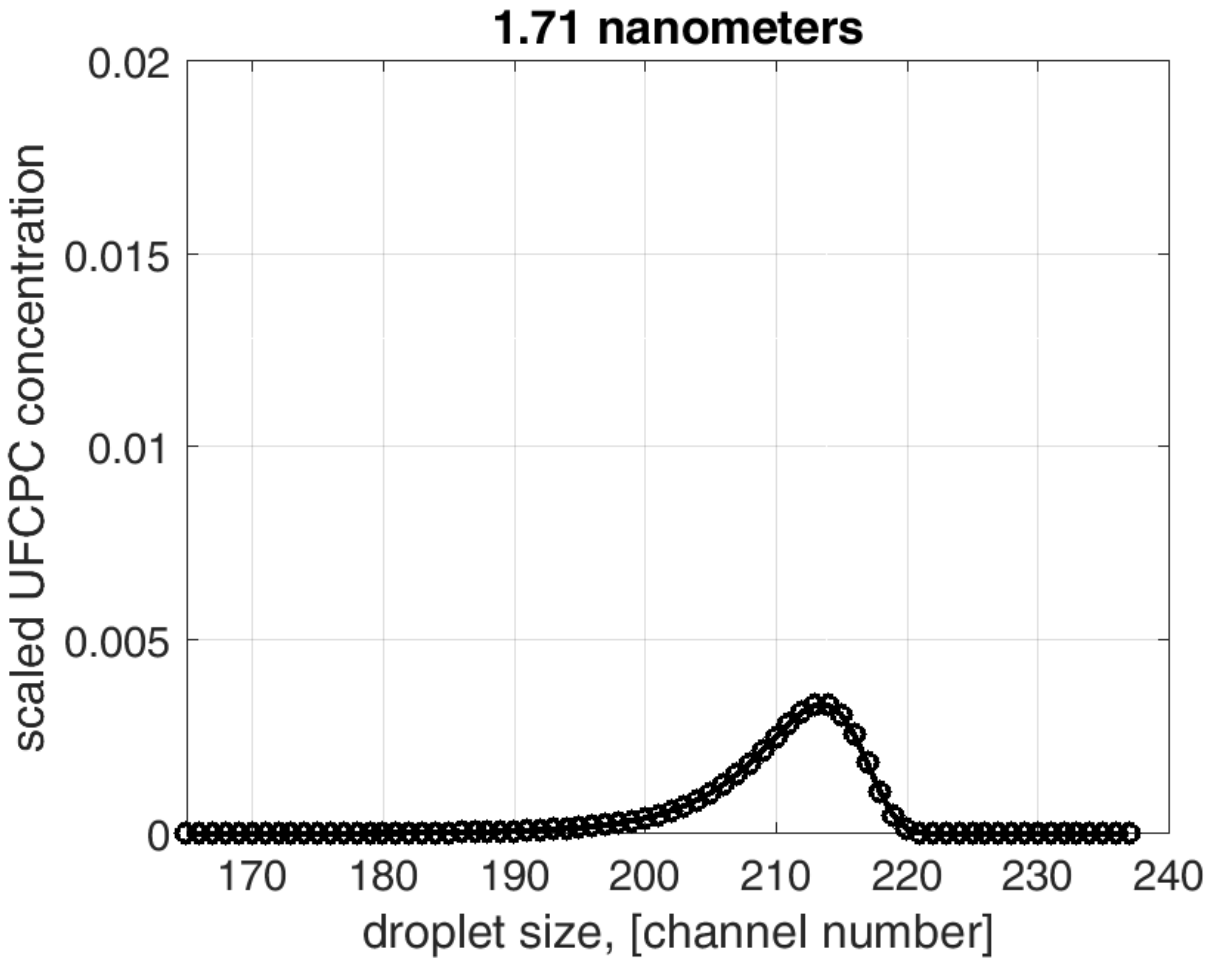

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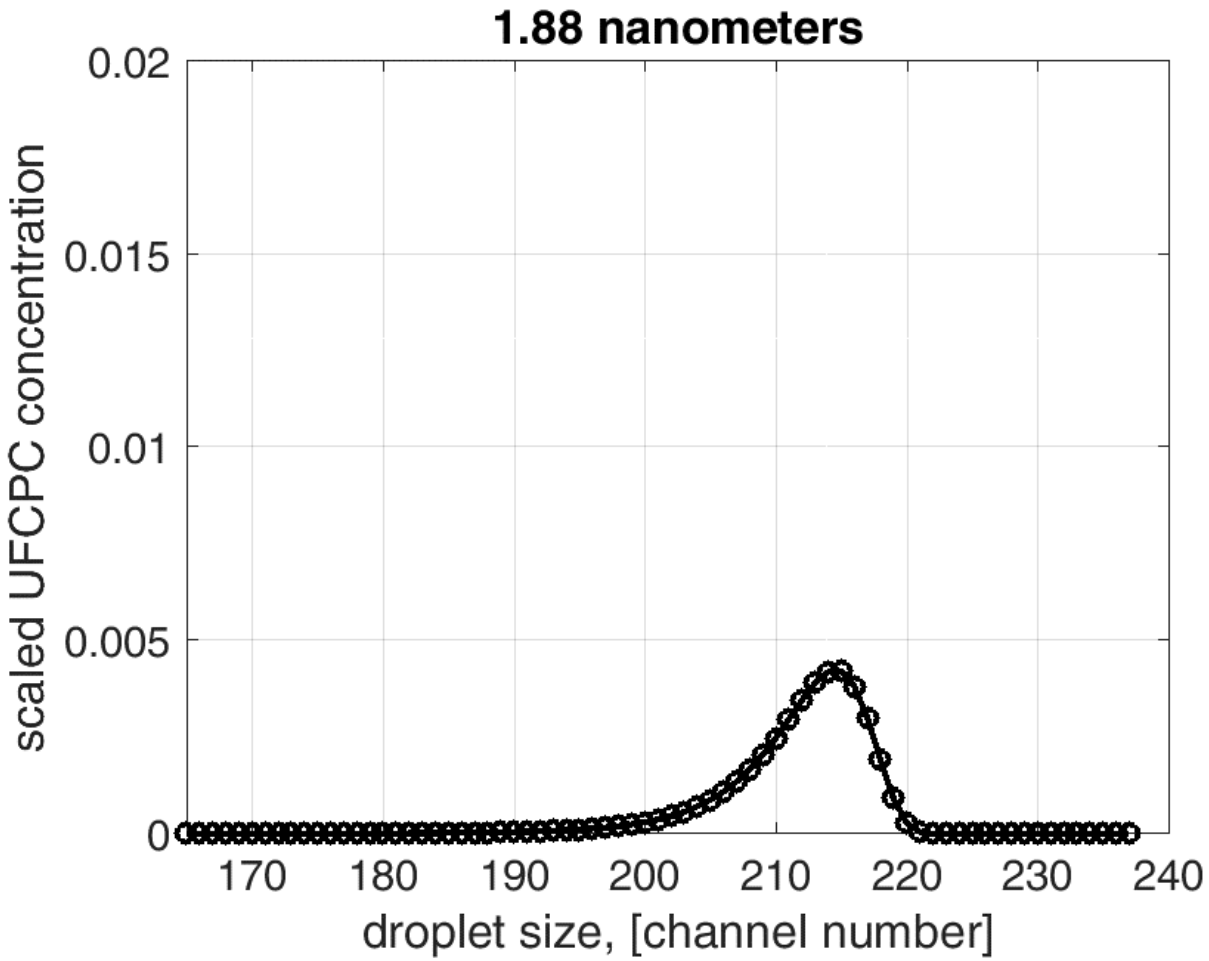

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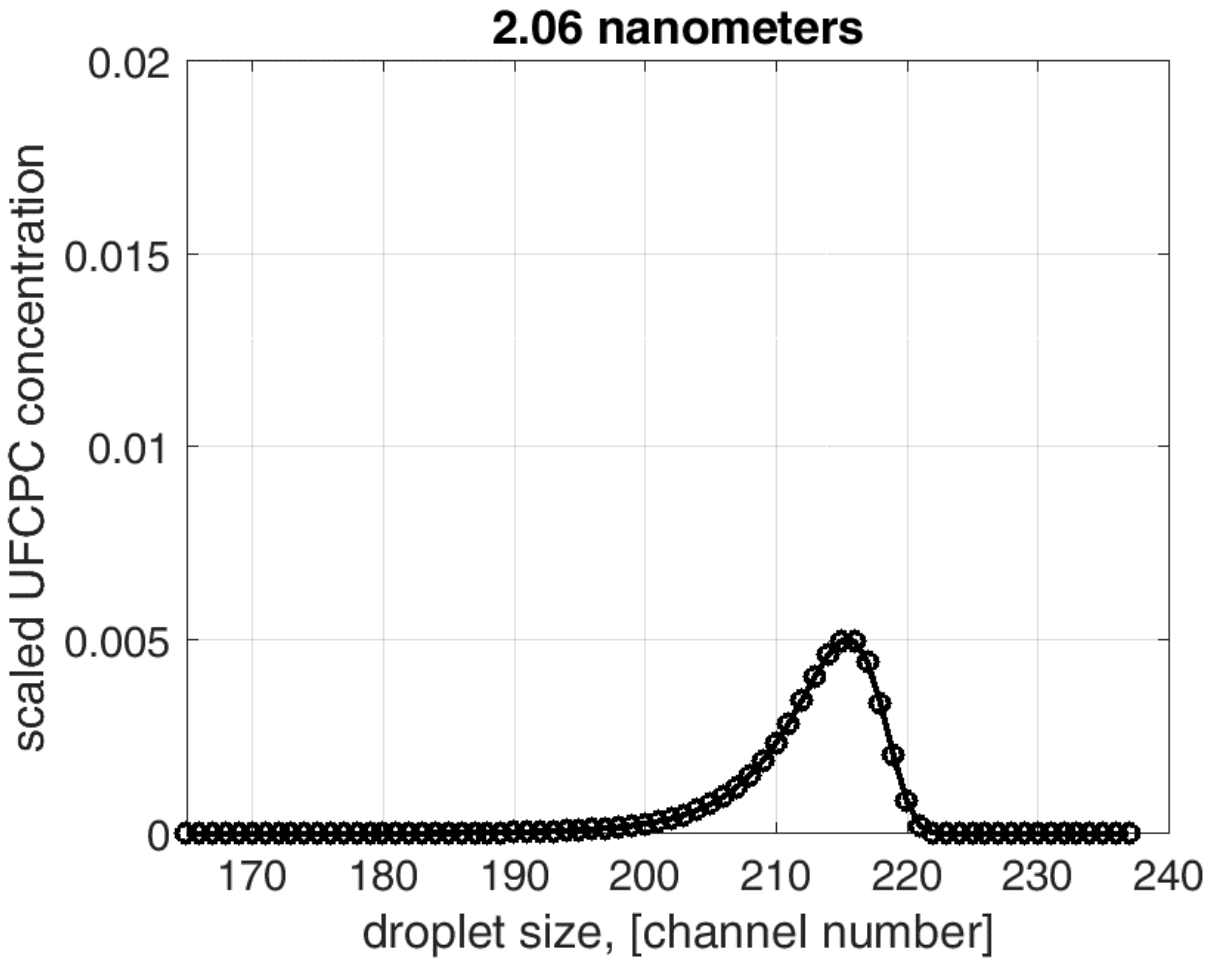

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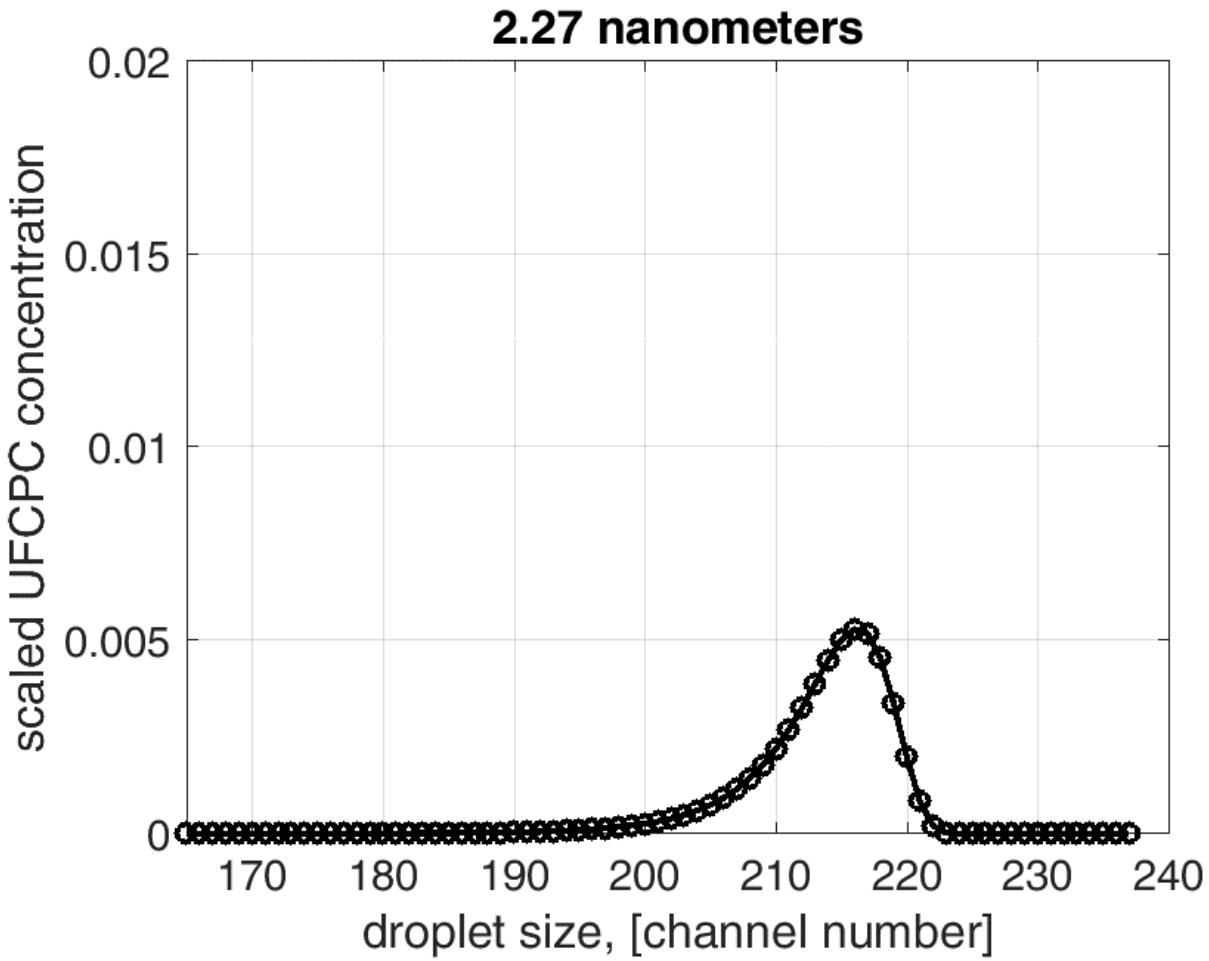

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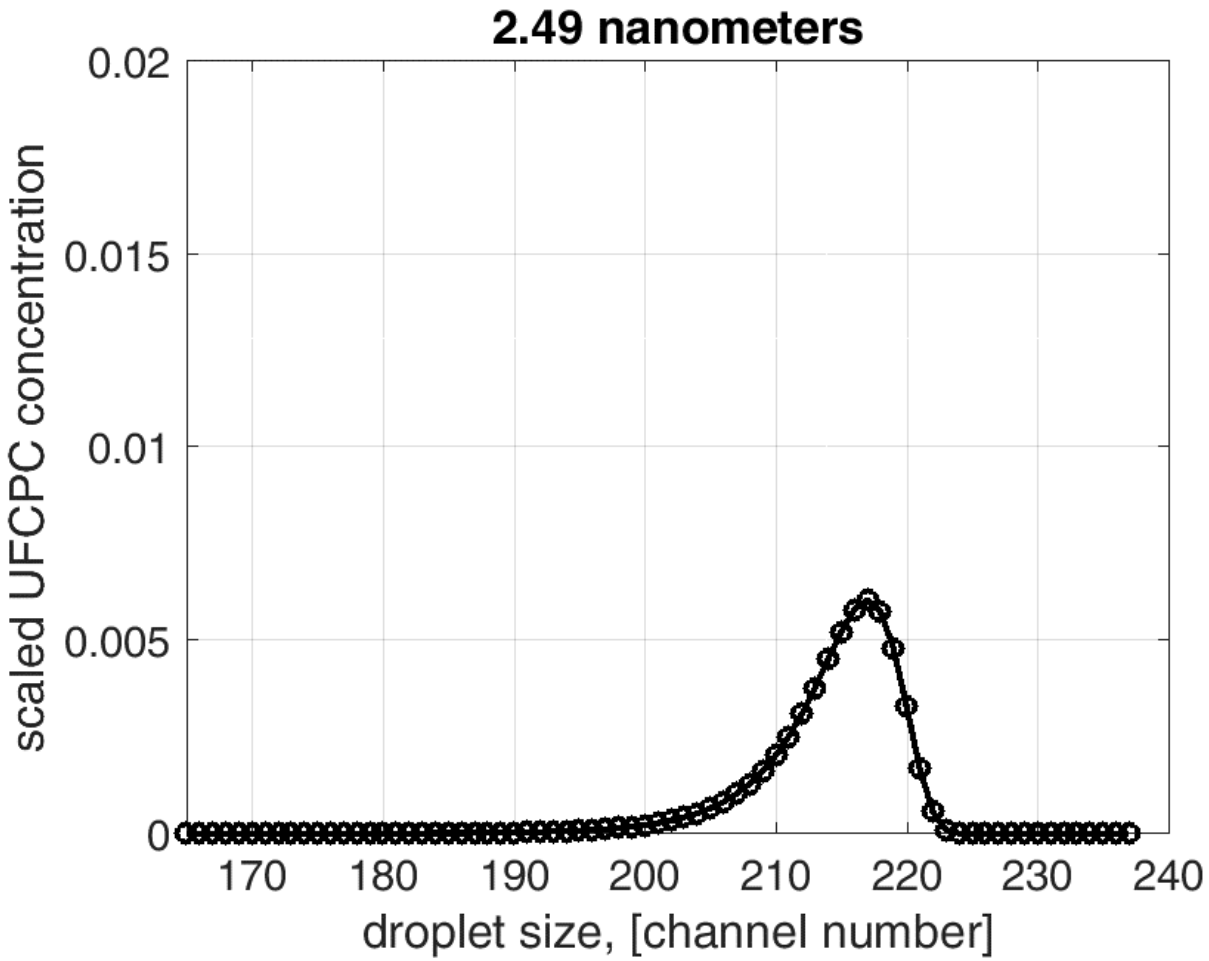

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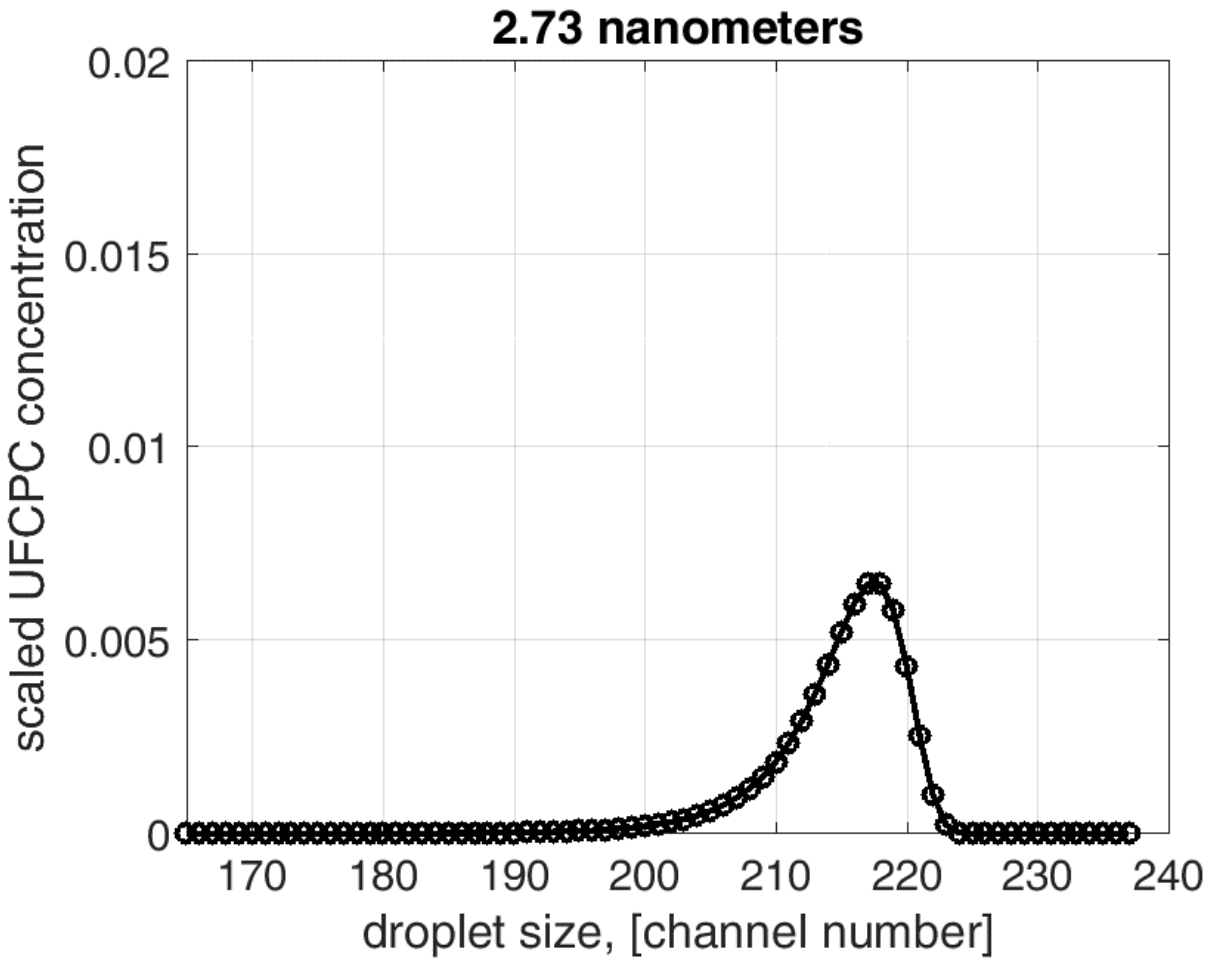

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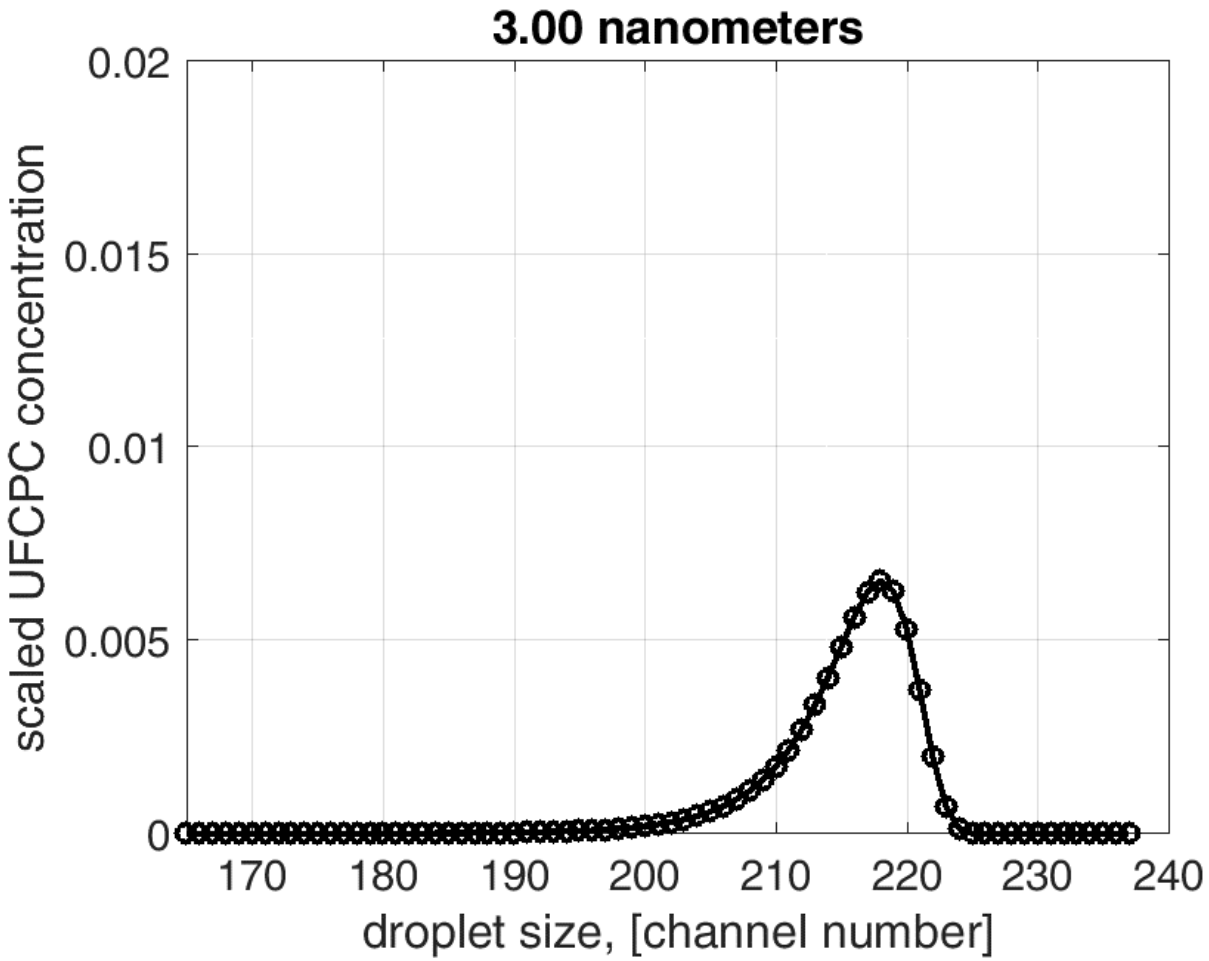

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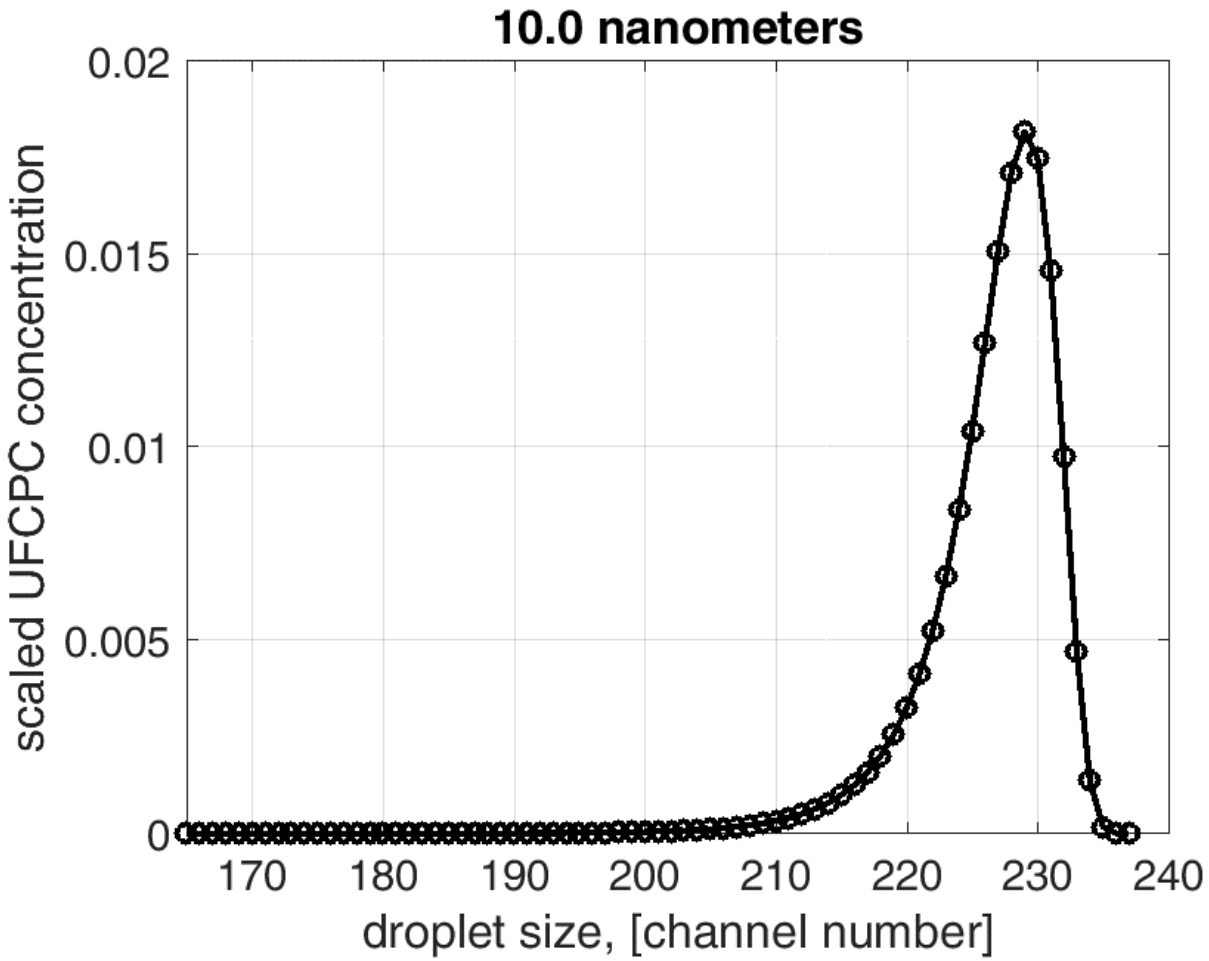

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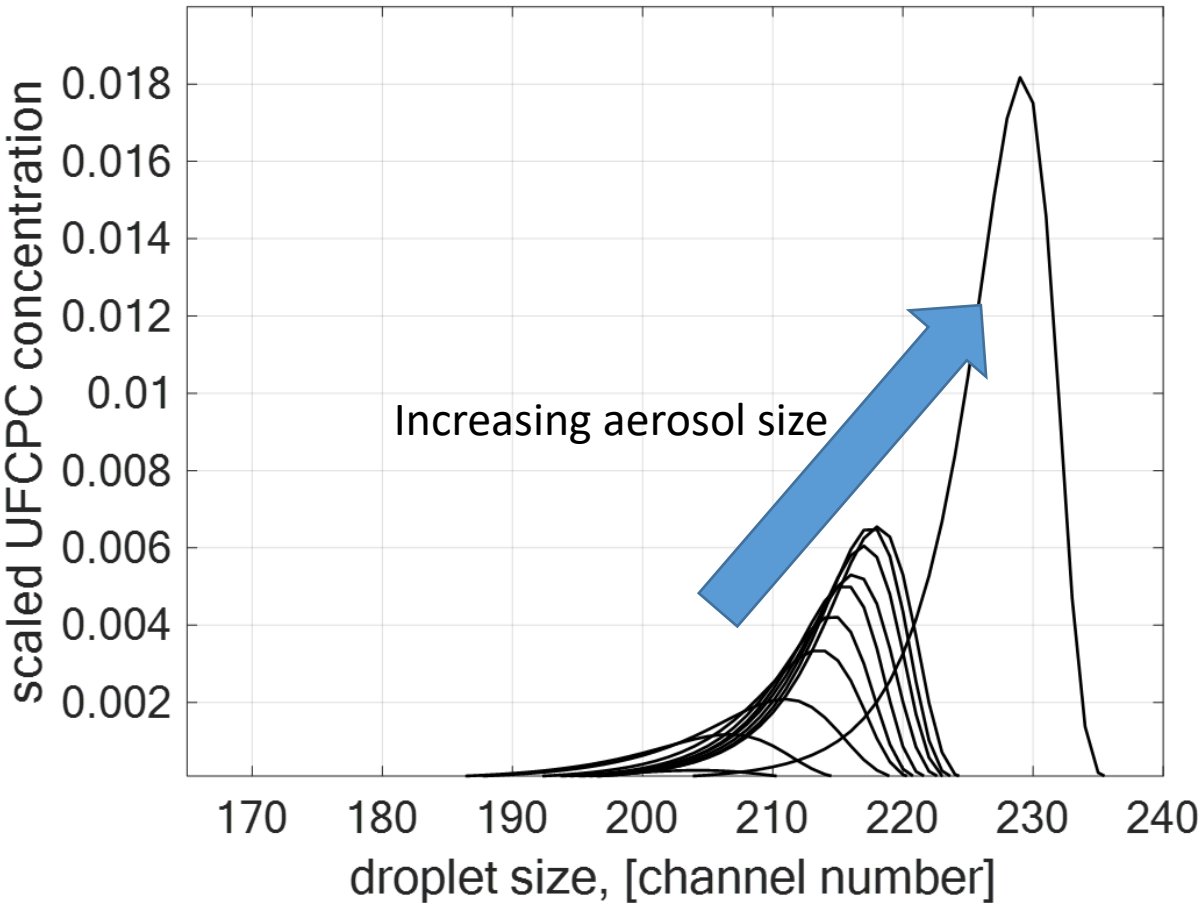

Ammonium Sulfate Calibration:
Droplet Size As a Function of Initial Size

Outlook:

Is detection of initial particle size with a single-stage CPC possible ?
based on droplet size distribution

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urther questions?

Contact:

Dr. Ing Frederik Weis

frederik.weis@palas.de

Palas GmbH

www.palas.de

Thank you for your attention !