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Natural Gas Transit Bus Ultrafine Particle Emissions: Laboratory Dilution & Number Distributions

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* The statements and opinions expressed in this paper are solely the authors' and do not represent the official position of the California Air Resources Board. The mention of trade names, products, and organizations does not constitute endorsement or recommendation for use.

Overview

- LA Transit Bus Emissions Study
  - ARB + multiple investigators dyno. testing
  - Late-model, in-use transit buses
  - Diesel, Trap-diesel and CNG* (Phase 1)
  - Evaluate effect of CNG oxidation catalyst (Phase 2)

- SMPS Particle Size Distributions Focus
  - Idle and Steady-State full scans
  - preliminary single-diameter transient cycle (CBD)

* No after-treatment

Motivation

- Ultrafine (UF) particle health effects
- Diesel vehicle exhaust = toxic air contaminant
- Transit buses = significant urban UF sources
- Changing HDV regulations
  - CAAA "Fleet" alternative fuel vehicle requirements
  - Tailpipe emissions limits (PM, NOx)
  - Fuel regulations (June 2006 – reduced diesel S)

- In-use "clean"/ "green" alternatives to HD diesels
  - Compressed natural gas (CNG)
  - Diesel + diesel particulate filters (DPF)

Transit Bus Emissions Project

Overall Research Objectives:

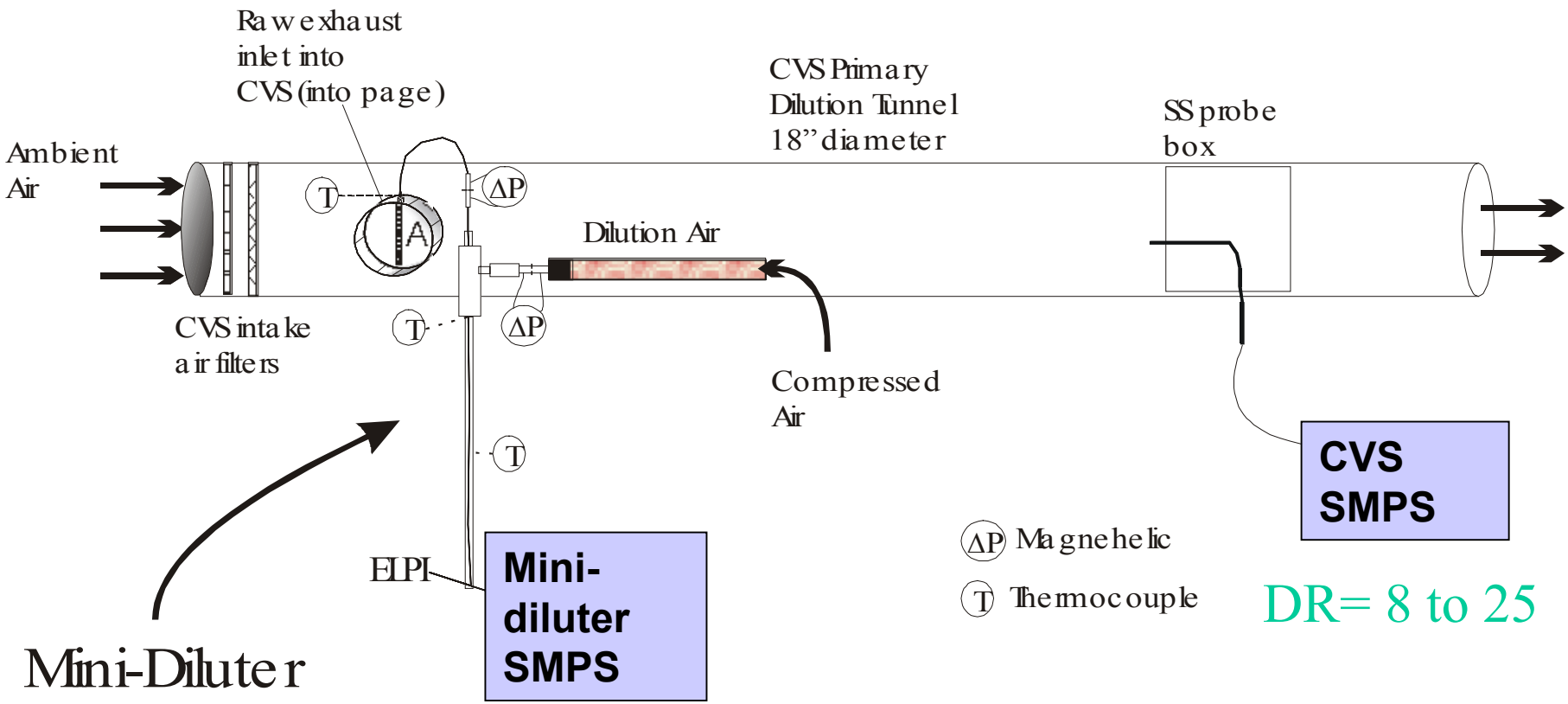
Compare 3 different transit bus configurations in 'single vehicle' 'snap-shot' testing:

- Exhaust "toxicity"
- Total PM and ultrafine emissions
- Driving cycle effects

Scanning Mobility Particle Sizer

- TSI 3080 Classifier, 3025A CPC
- 1.45 Lpm aerosol flow rate (14.5 Lpm sheath)
- 2-min up-scans &
  30-sec retrace
- 6 – 225 nm
- dN/dlogDp (AIM ver4.3)
- TB and DR-corrected

Dual Dilution Setup



Dilution Ratio = 64 or 18

5 Test Vehicle Configurations

Diesel in 2 configurations

- DDC **baseline** diesel "OEM" (Oxi. Cat.)
- DDC diesel + **CRT** particulate filter

Diesels operated on ECD-1 ULSF (11 ppm S)

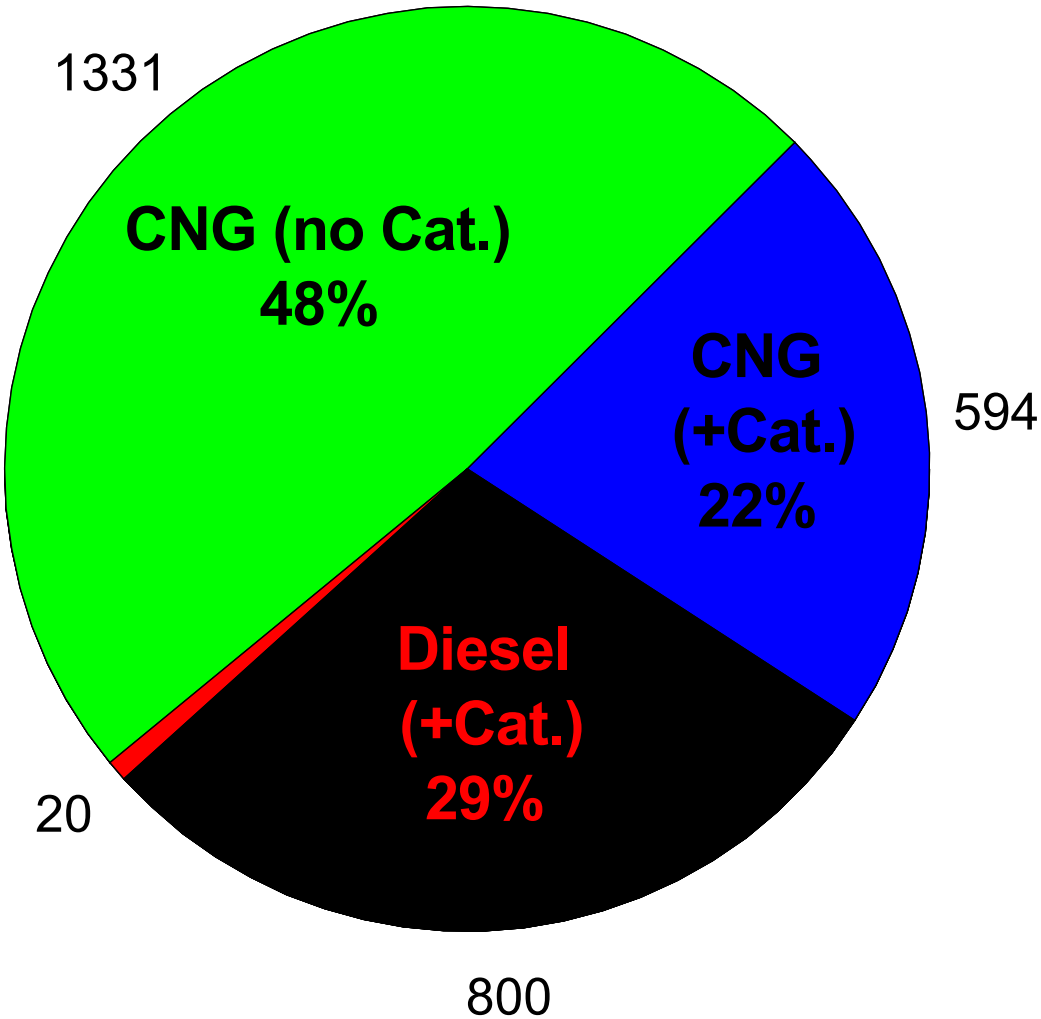
CNG in 3 configurations:

- DDC engine, **no Oxi. Cat.** (tested 2x)
- DDC engine + Oxi. Cat.
- Cummins engine + Oxi. Cat. "state-of-art"

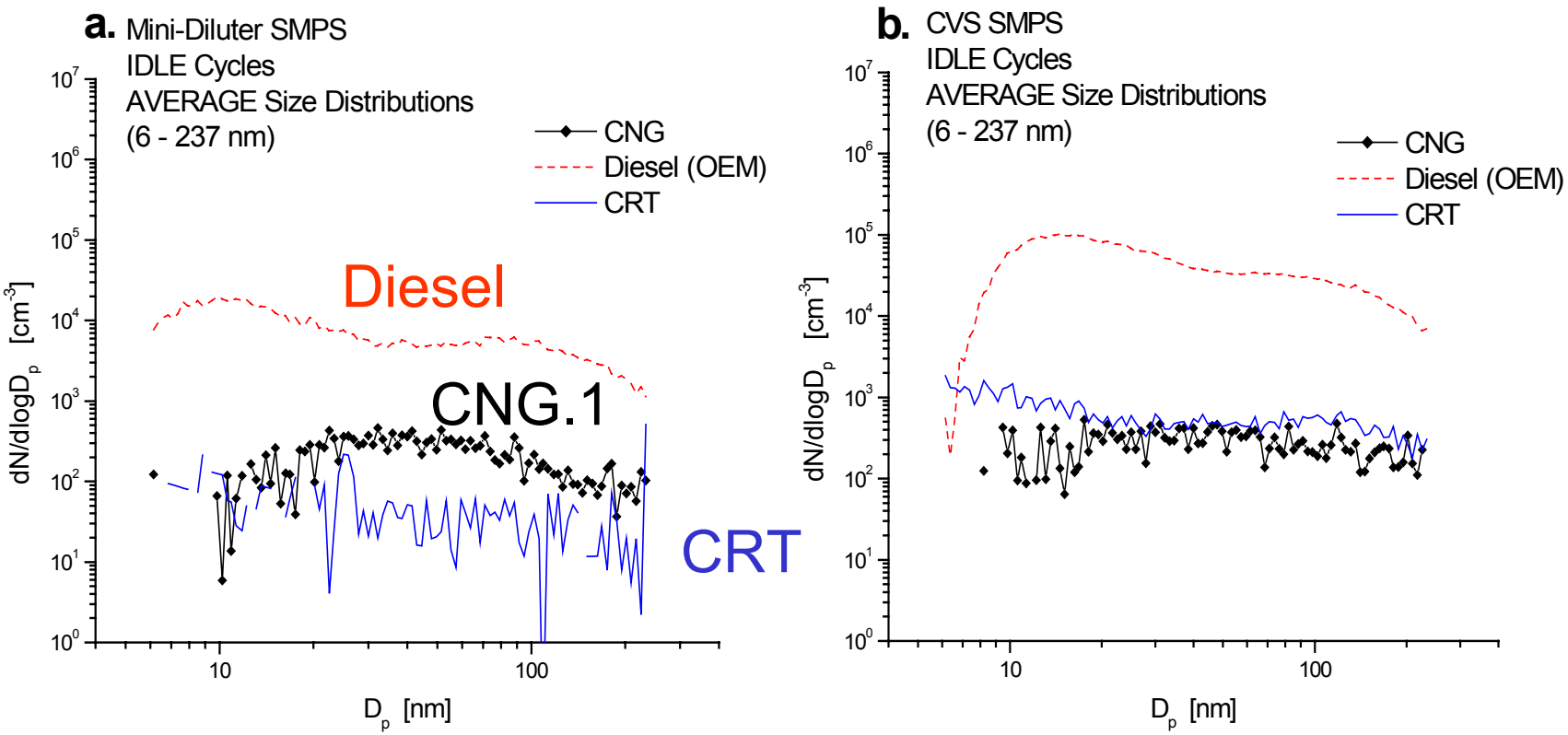
DDC = Detroit Diesel Corp.

LA Transit Bus Fleet

Cat. = Oxidation Catalyst
DPF = Diesel Particulate Filter

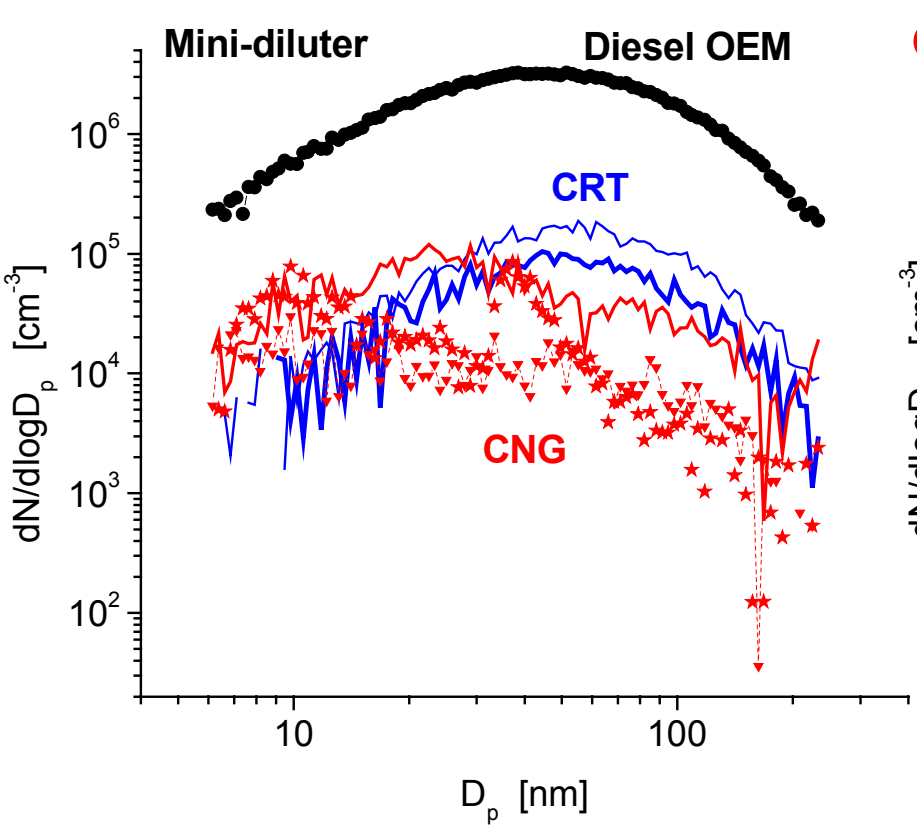


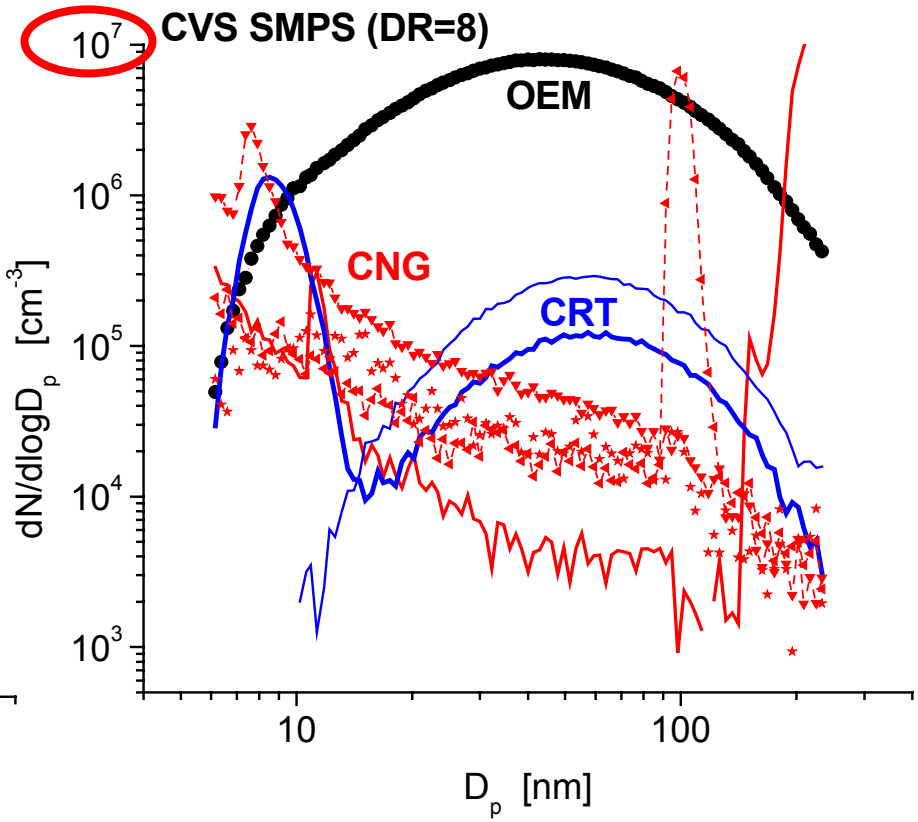
Idle Phase 1 Results



- Bimodal diesel OEM distributions @ idle
- CNG ~ CRT << Diesel

Steady-State 55 MPH

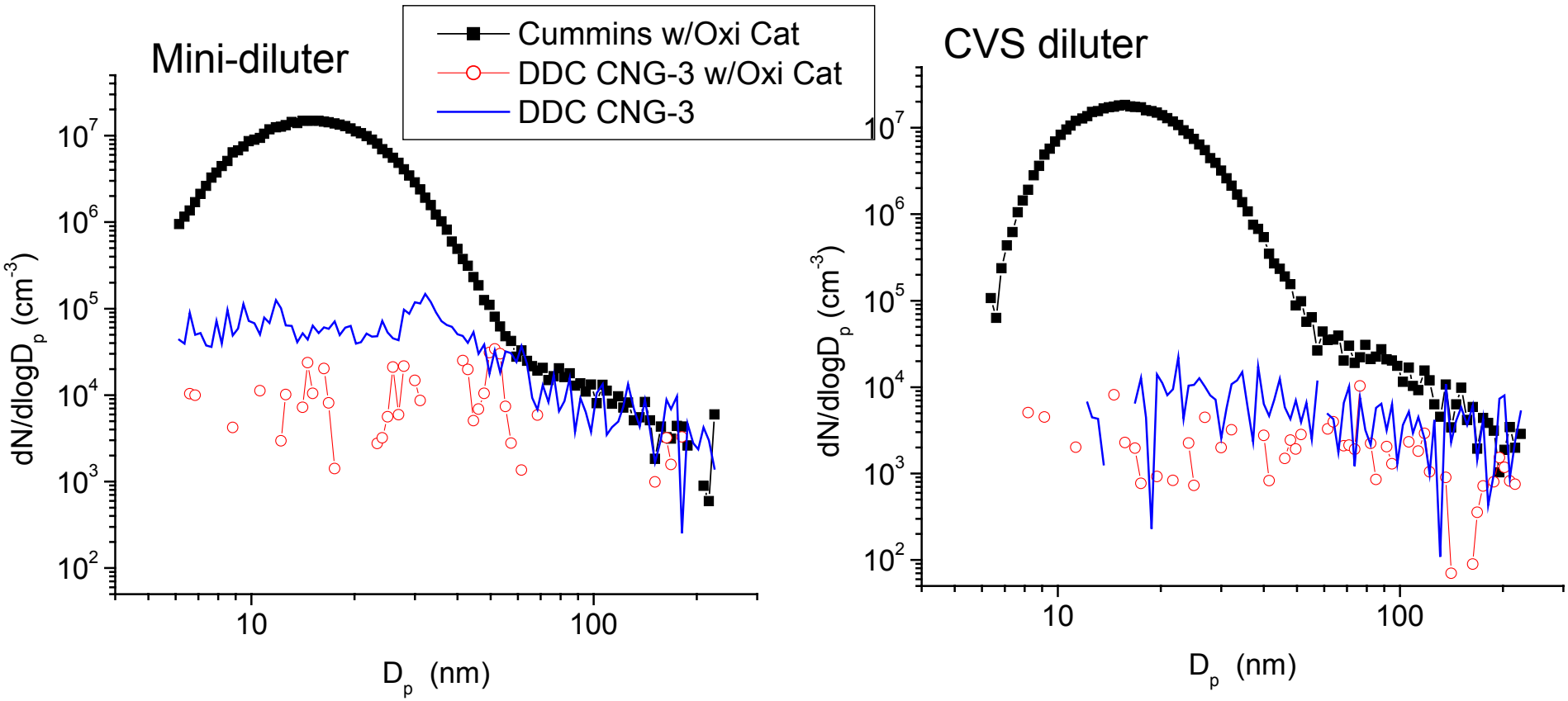




Monomodal diesel OEM distributions

CVS diluter Nanoparticles >> OEM

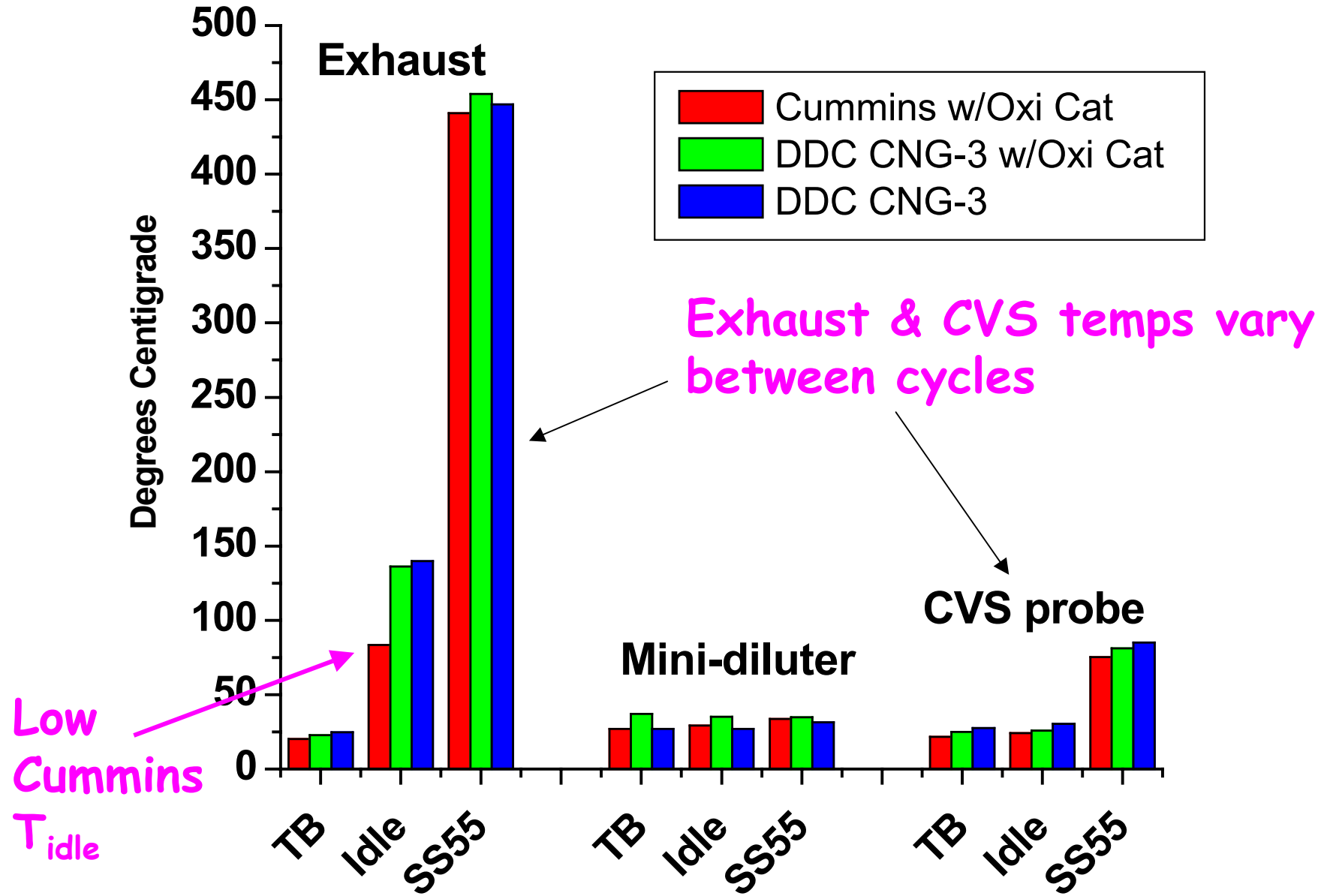
CNG buses: Idle



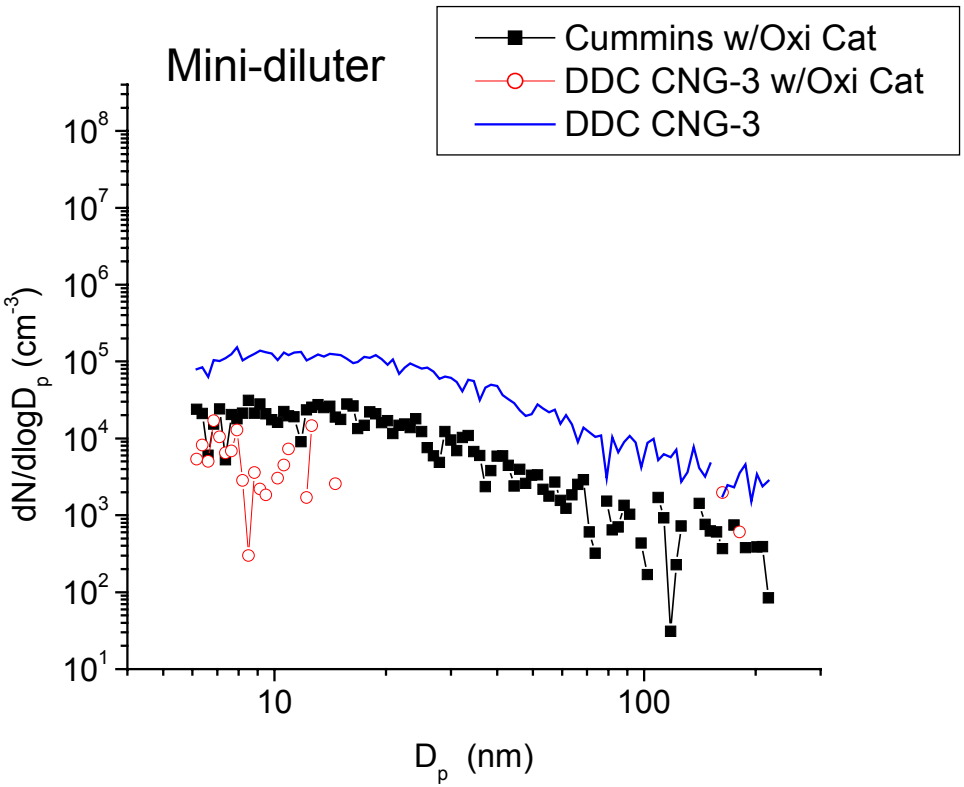
@ Low Load: Cummins >> NoCat > DDC+OxiCat

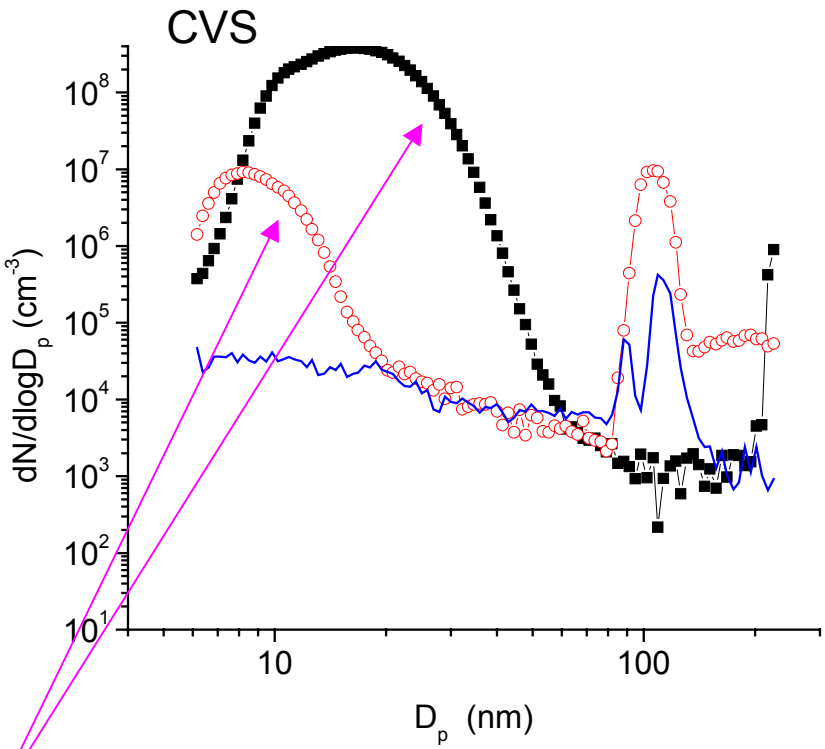
Cummins high nanoparticle concentrations independent of dilution method

Temperatures °C



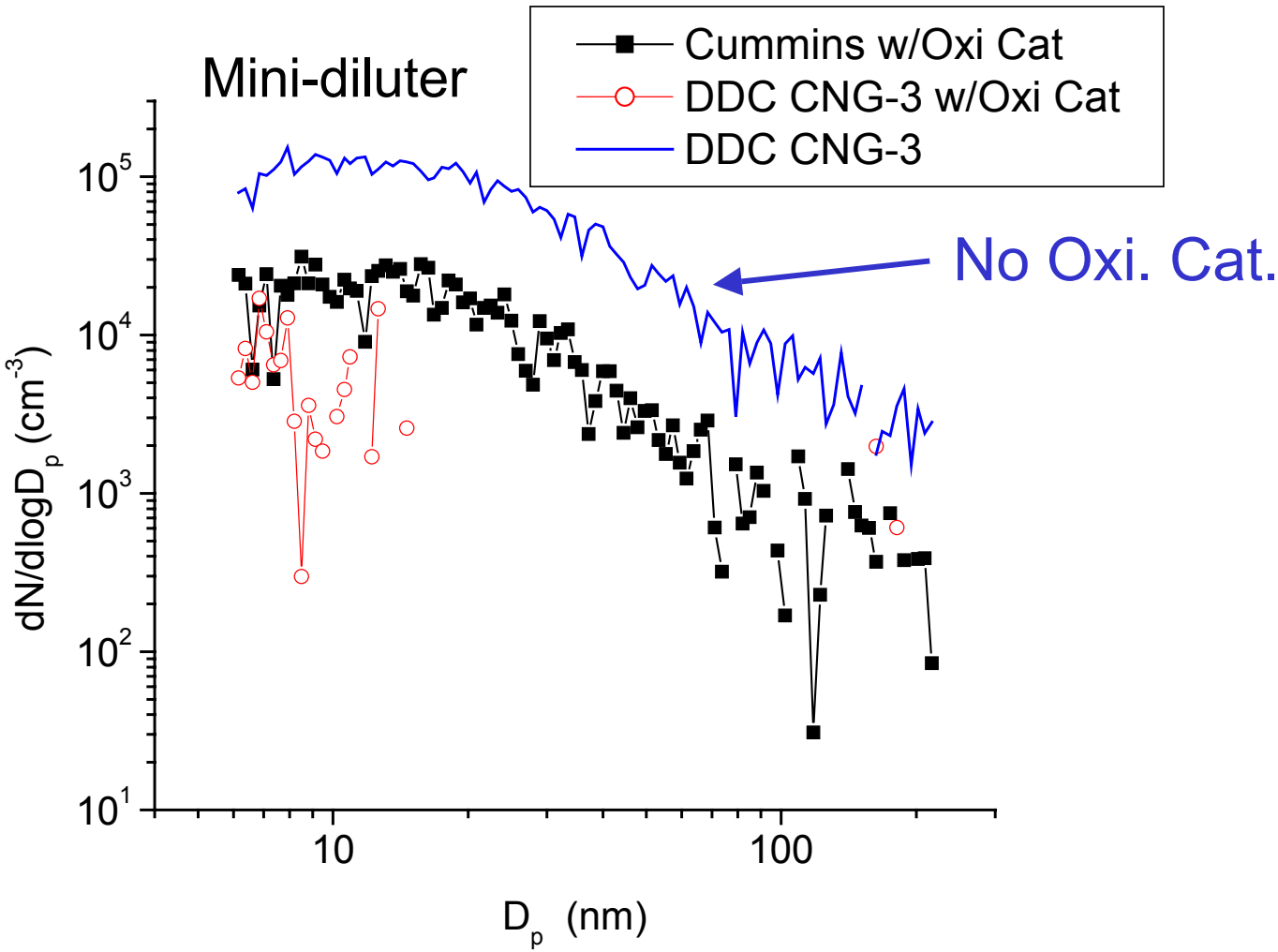
CNG buses: Steady-State 55



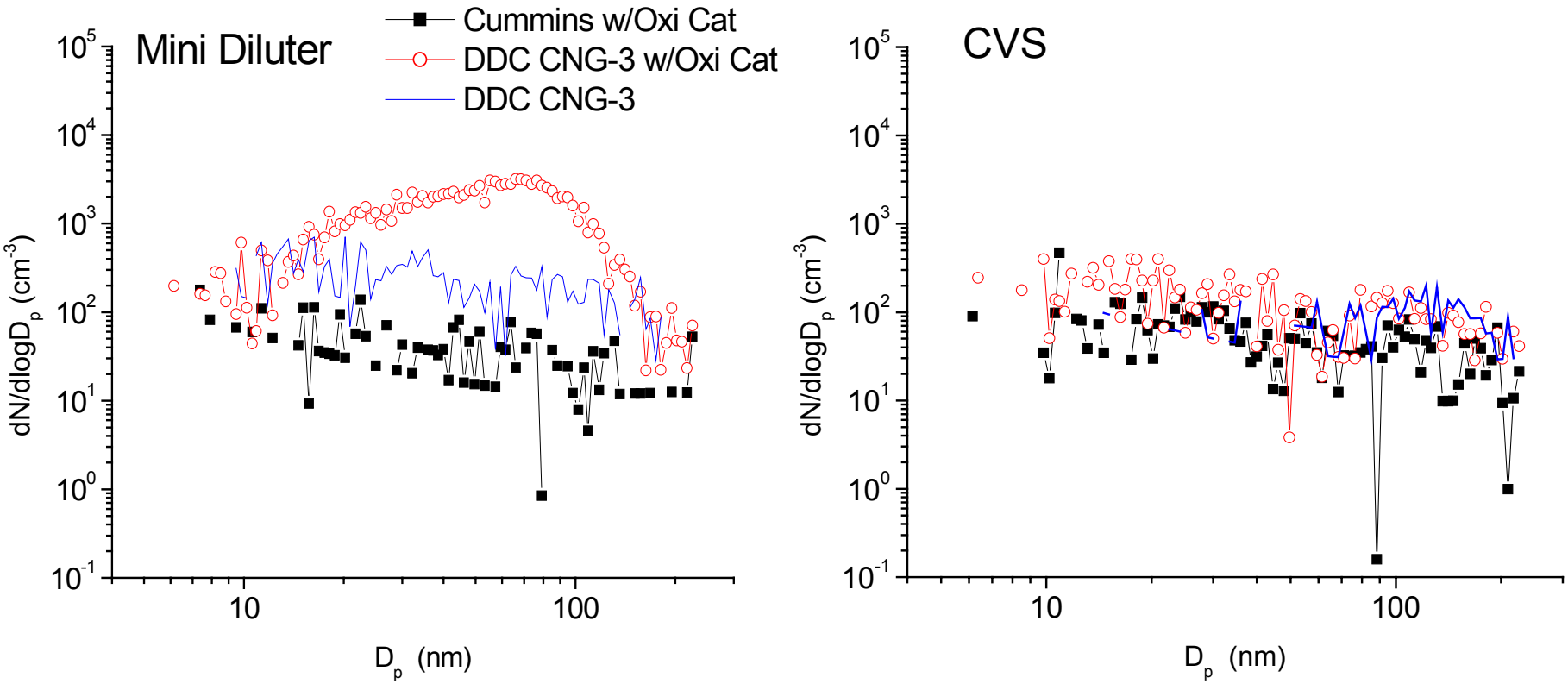


CVS nanoparticles only for both CNG's with Oxi. Cats

CNG buses: Steady-State 55



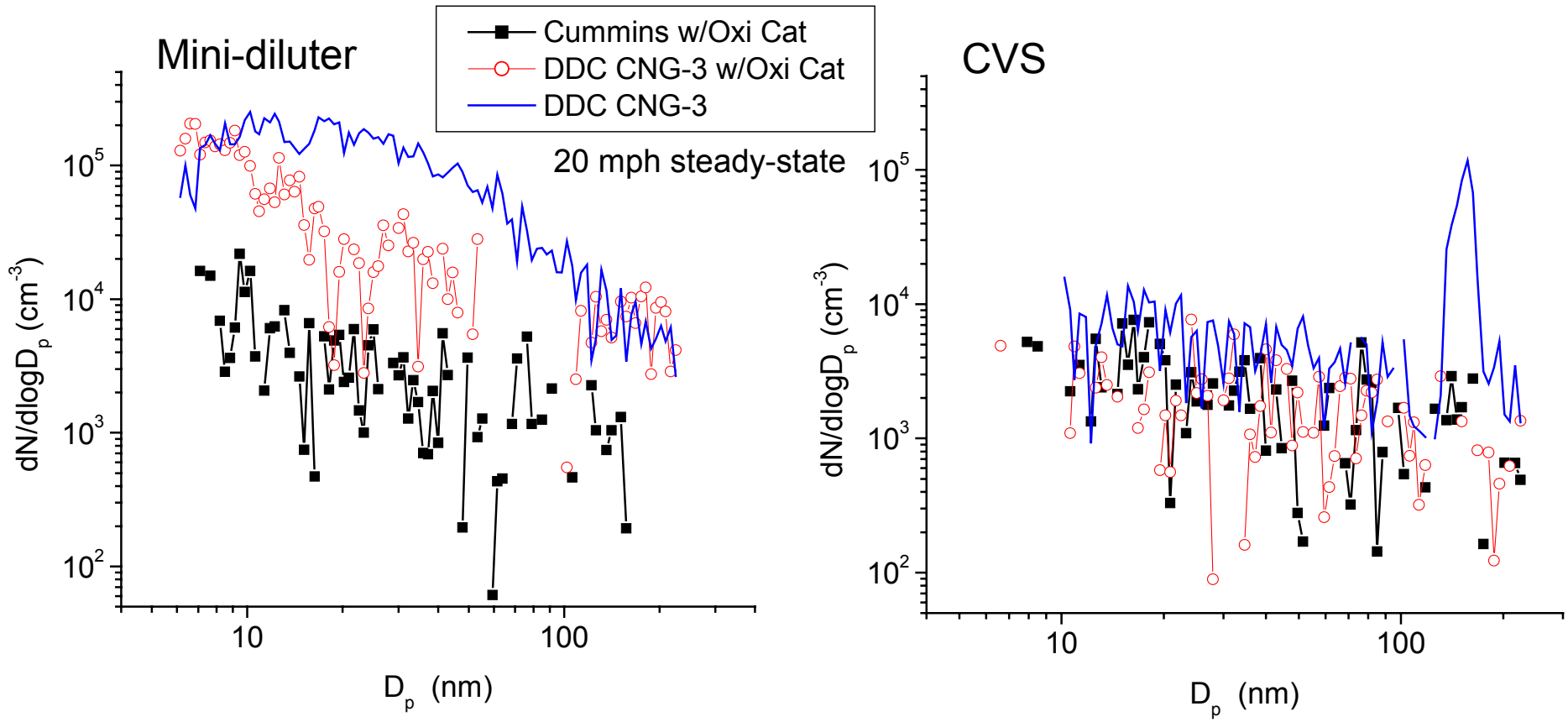
CNG buses: Tunnel Blanks



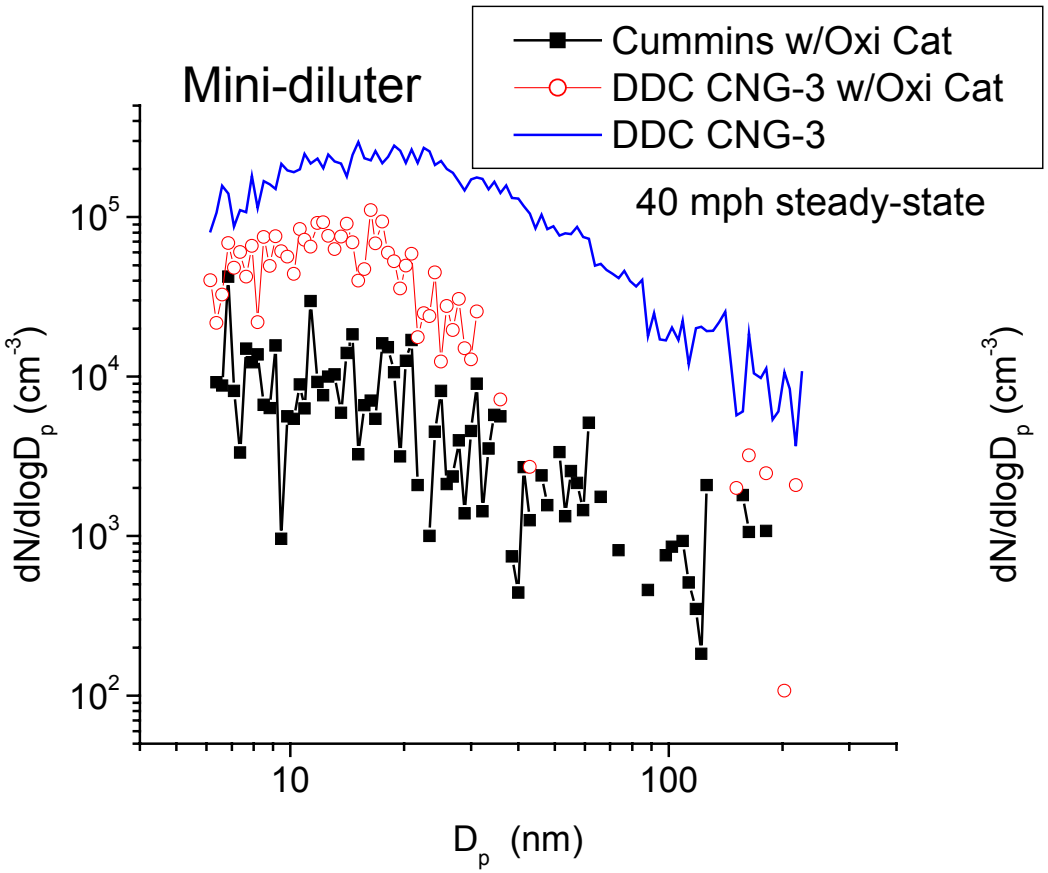
Mini-diluter tunnel blanks more variable than CVS

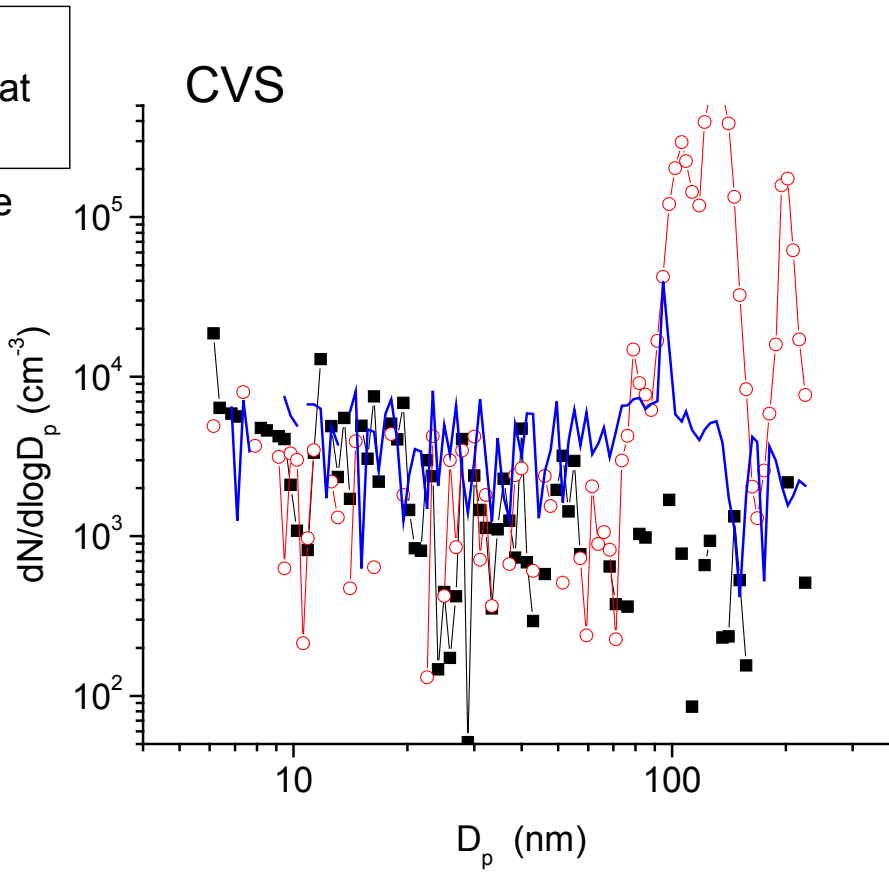
Opposite was seen in Phase 1.

CNG buses: Steady-State 20 MPH

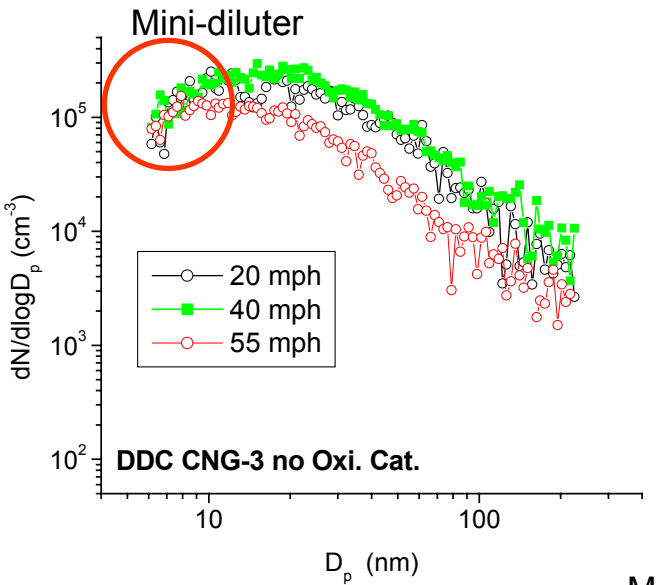


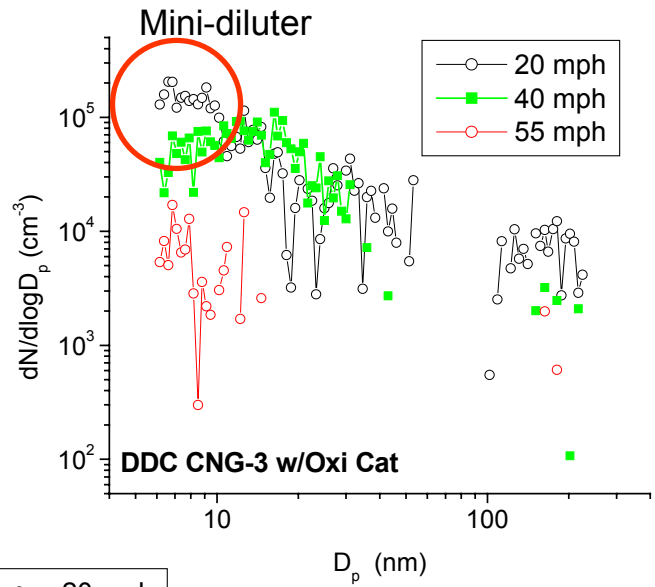
CNG buses: Steady-State 40 MPH

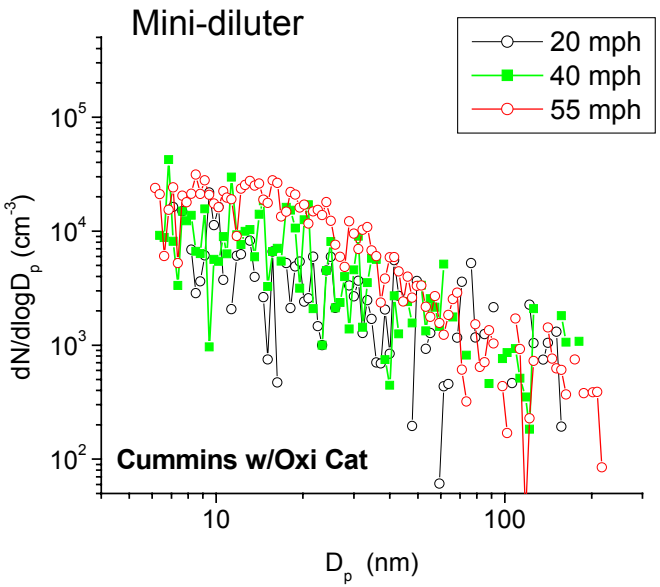




20 to 55 MPH Steady-State

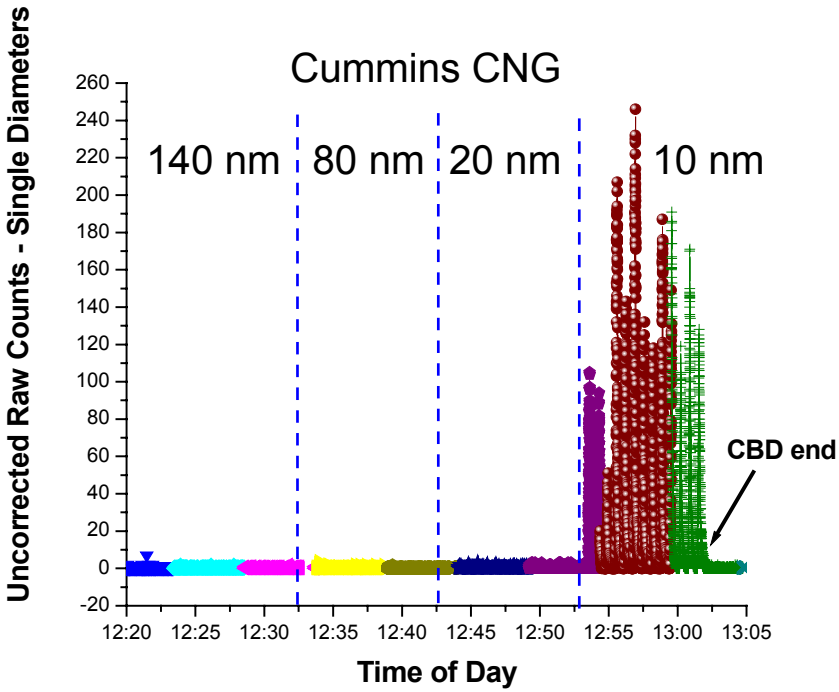




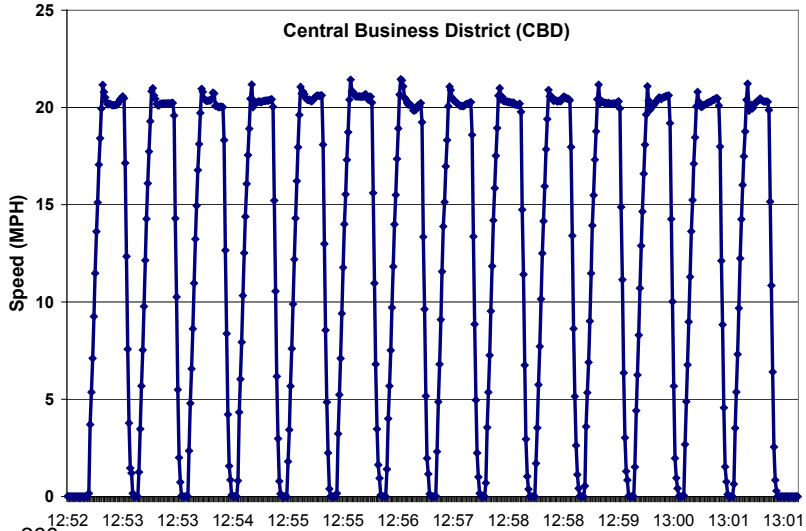


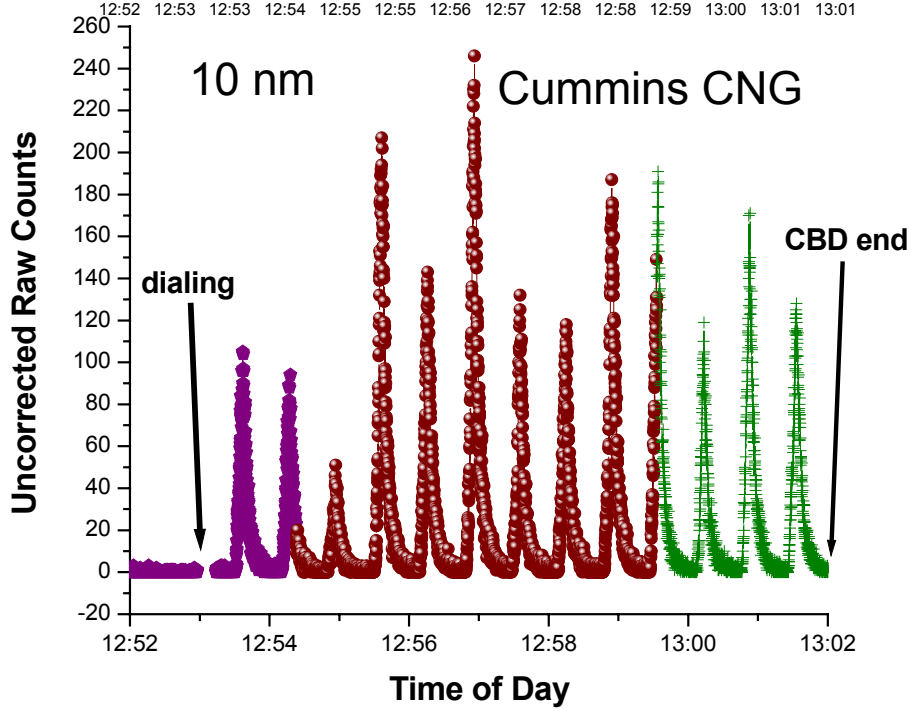
TB and DR corrected

Single Diameter CBD Cycles



Cummins CNG





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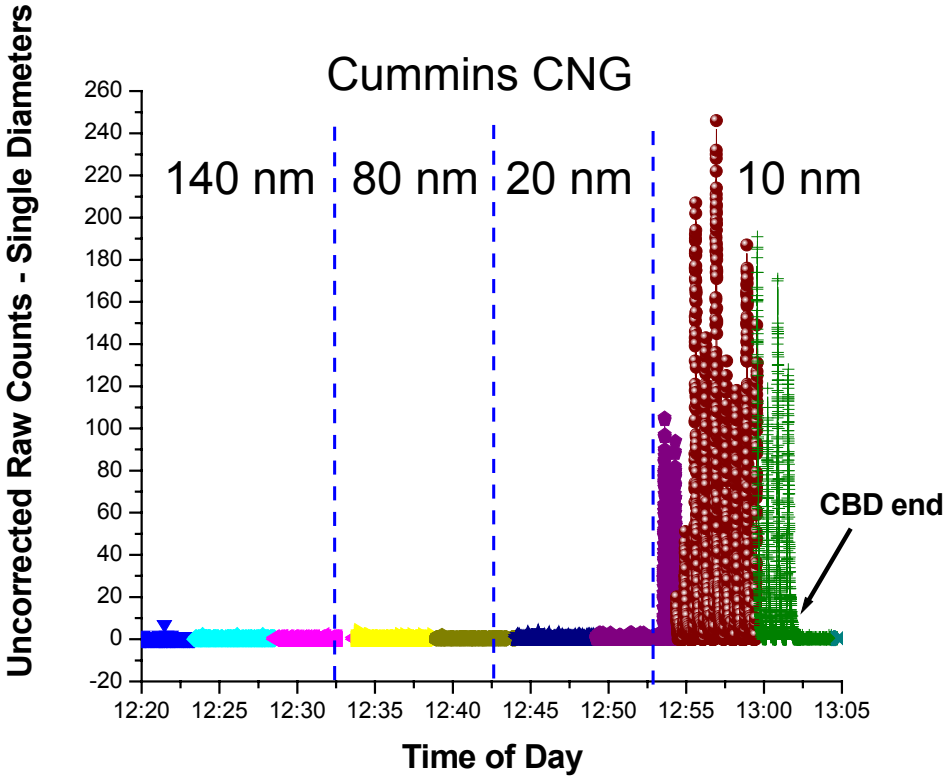
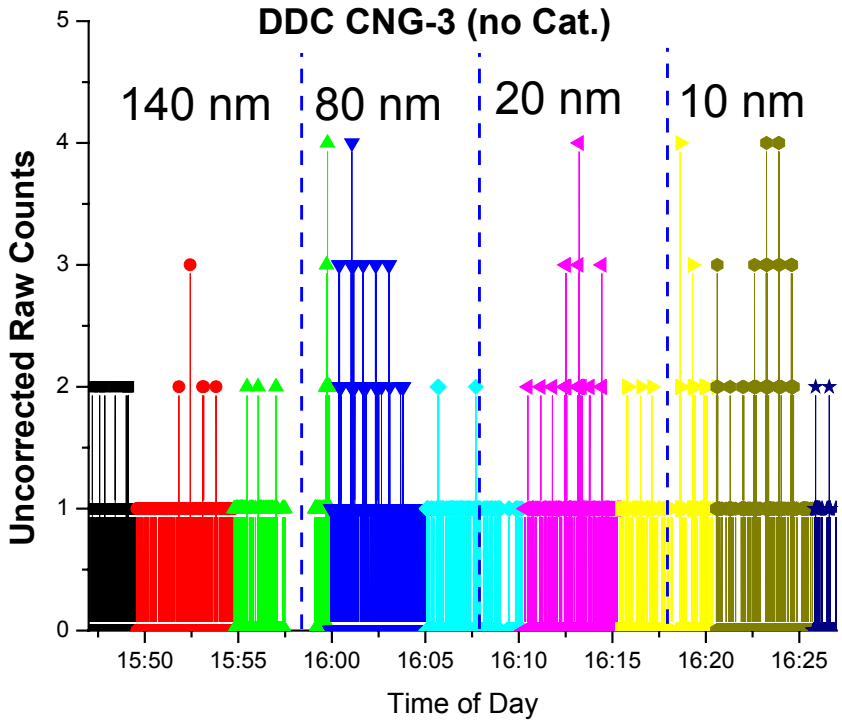


Cummins CNG



DDC No CAT

Summary 1

CNG v. CRT v. OEM

- Both "green" bus configurations reduced N by 10 –100x compared to OEM diesel.
- Ultrafine particles in **CNG** exhaust appear to be smaller than ultrafine particles in **diesel** exhaust.
- CVS dilution artifacts hinder interpretation of ultrafine distributions.

CNG Catalysts:

- Reduce UF number for some operating conditions
- CNG bus load and engine design trends not clear-cut
  - UF distributions more variable with Oxi. Cat.

Summary 2

- At low-load (IDLE), Cummins CNG emits very high nanoparticle concentrations, independent of dilution conditions. Why?
  - –? Catalyst temperature effect
  - –? Lubrication oil release
- "Clean" CNG and CRT vehicles challenge current sampling/analytical methods.
  - –Tunnel blank role/subtraction very important
    - Temperature effects on TB vs. cycle must be addressed

Thank you!

California Air Resources Board

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ARB's Emissions Project Web Site:

http://www.arb.ca.gov/research/cng-diesel/cng-diesel.htm