Particle Measurement Methodology: Comparison of On-road and Lab Diesel Particle Size Distributions

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This work is part of the CRC E-43 Project, "Diesel Aerosol Sampling Methodology"

- Prime Contractor: University of Minnesota
- Subcontractors: West Virginia University, Paul Scherrer Institute, Carnegie Mellon University, Tampere University, University of California, Riverside, Dessert Research Institute, University of California, Davis

- Sponsors: Coordinating Research Council and the U.S. Office of Heavy Vehicle Technologies through NREL with co-sponsorship from the Engine Manufacturers Association, the Southcoast Air Quality Management District, the California Air Resources Board, Cummins, Caterpillar, and Volvo.

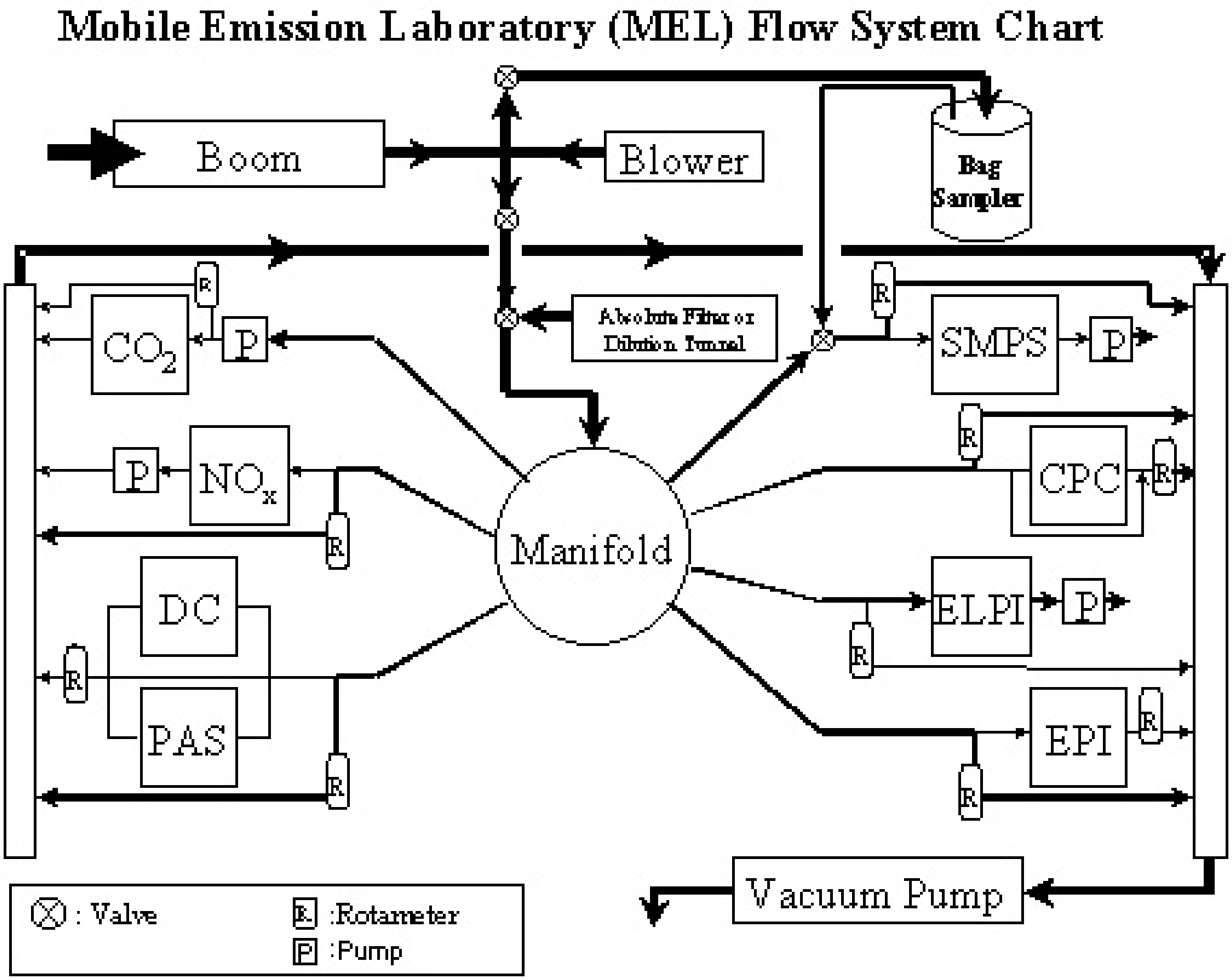
E-43 Questions

- Do modern Diesel engines produce nanoparticles under real world dilution conditions?
- Can we make laboratory measurements that mimic real world measurements?
- Do new low carbon emitters produce more nanoparticles than older designs?
- What is the composition of the nanoparticles?
- How long do they persist in the atmosphere?

E-43 Experiments

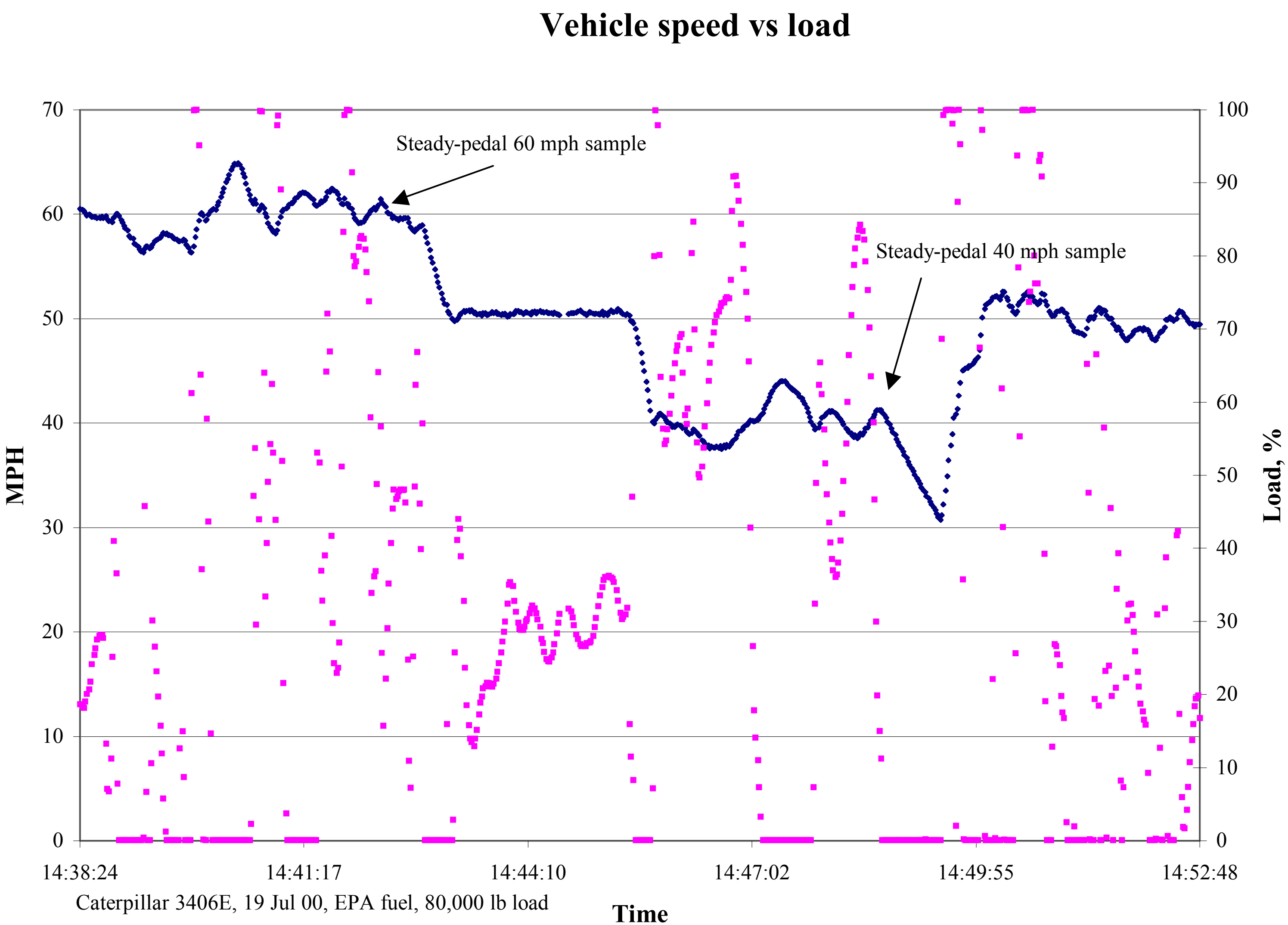
- Cummins engines
  - Chase experiments
    - ISM engine CA and EPA fuels
    - L10 engine EPA fuel
  - Wind tunnel – ISM engine CA fuel
  - Chassis dyno
    - ISM engine CA and EPA fuels
    - L10 engine EPA fuel
  - Engine dyno
    - ISM engine CA and EPA fuels
    - L10 engine EPA fuel
  - Tests of ISM engine at U of M
    - TDPBMS
    - Tandem DMA
- Caterpillar engines
  - Chase experiments
    - 3406E (C15) engine CA and EPA fuels
    - 3406C engine EPA fuel
  - Chassis dyno
    - 3406E (C15) engine CA and EPA fuels
    - 3406C engine EPA fuel
  - Engine dyno Caterpillar
    - 3406E (C15) in CVS cell
    - 2 additional 3406E in performance cell
  - Tests of C12 engine at U of M
    - Dilution system development
    - TDPBMS

Instrument and Sampling Arrangement in Mobile Emission Laboratory



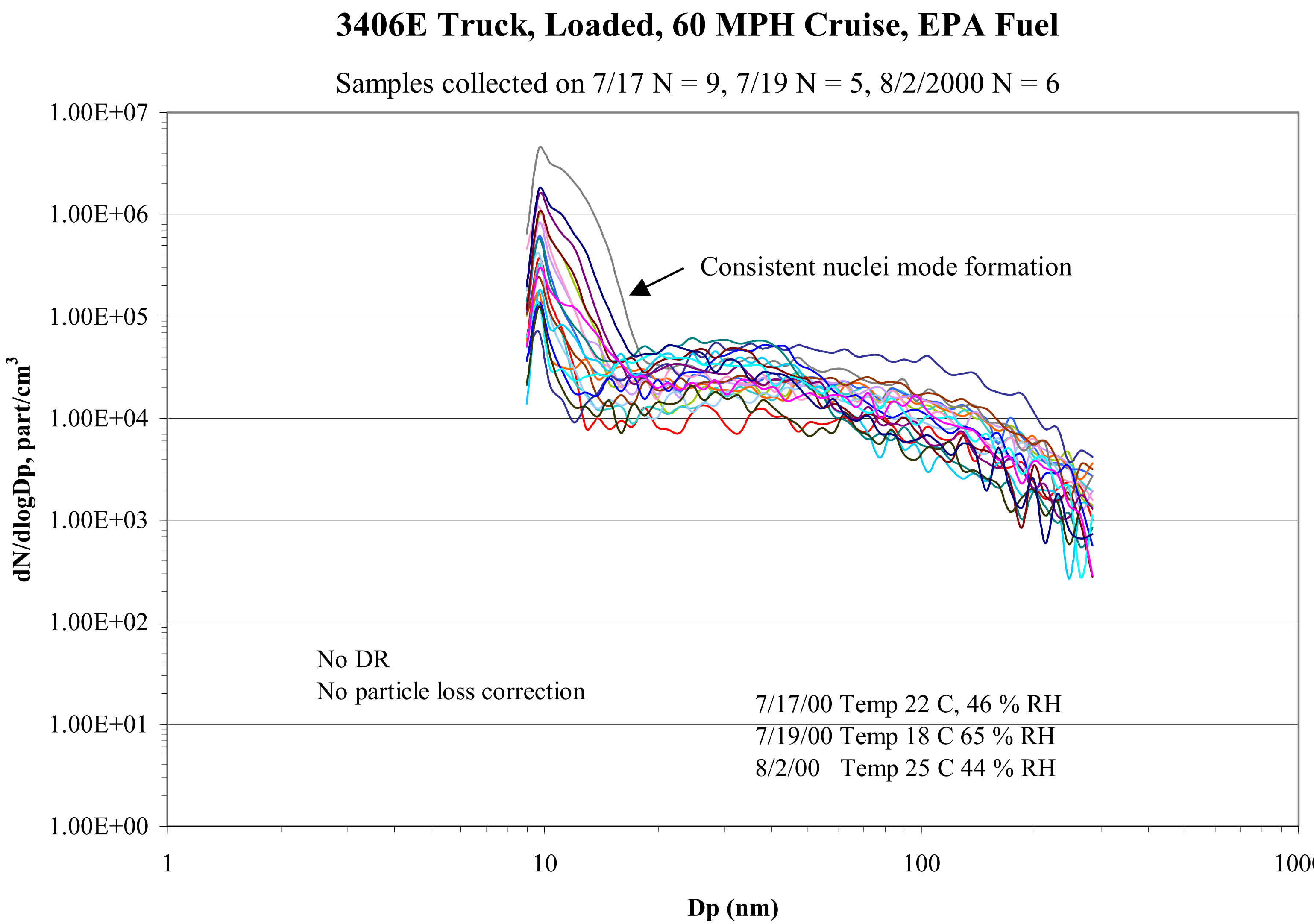
University of Minnesota, E-43, Mobile Aerosol Laboratory during a Roadway Chase Experiment

On-road test conditions were very unsteady even under “steady state” conditions

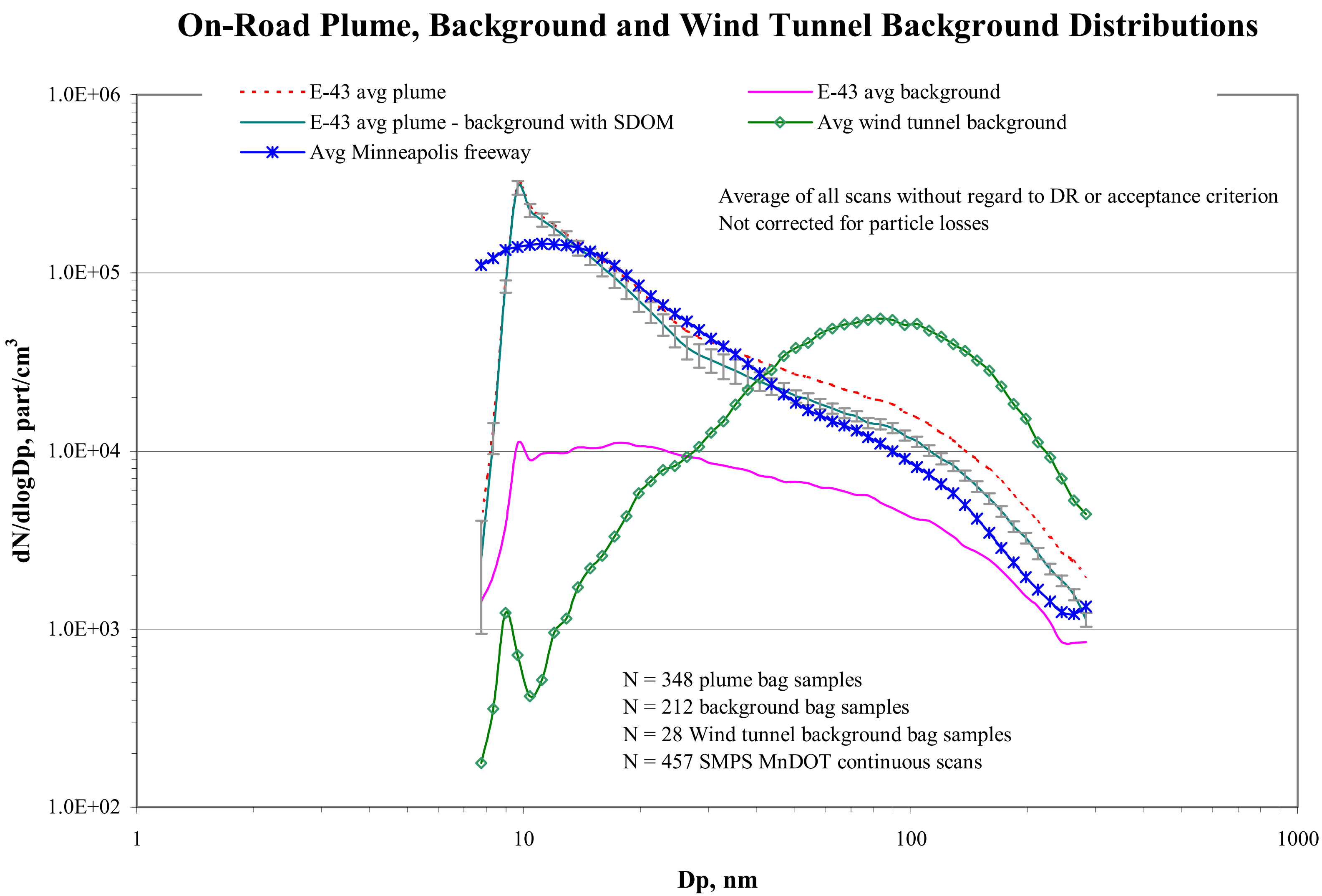


Caterpillar 3406E, 19 Jul 00, EPA fuel, 80,000 lb load

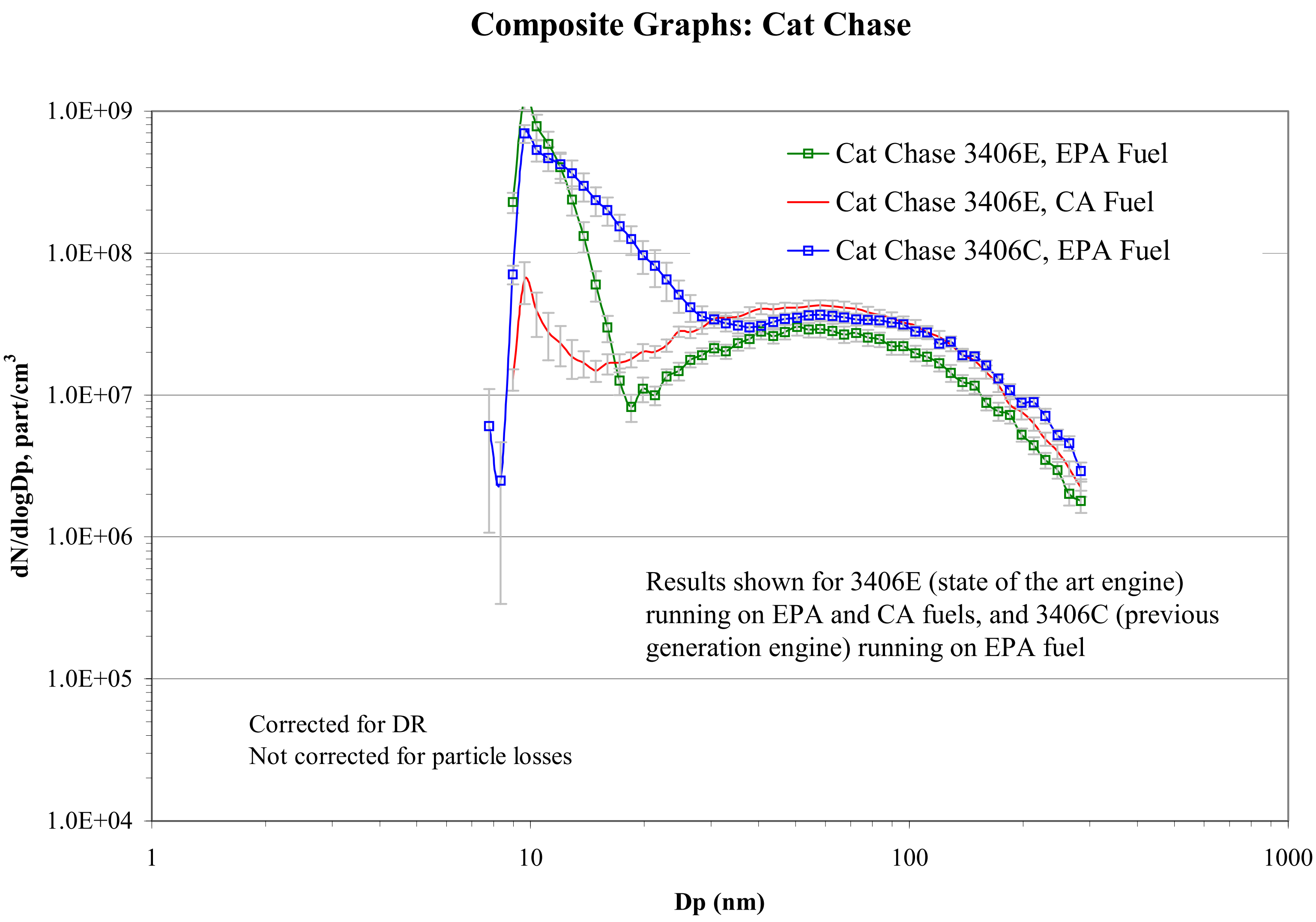
On-road test conditions were very unsteady even under “steady state” conditions



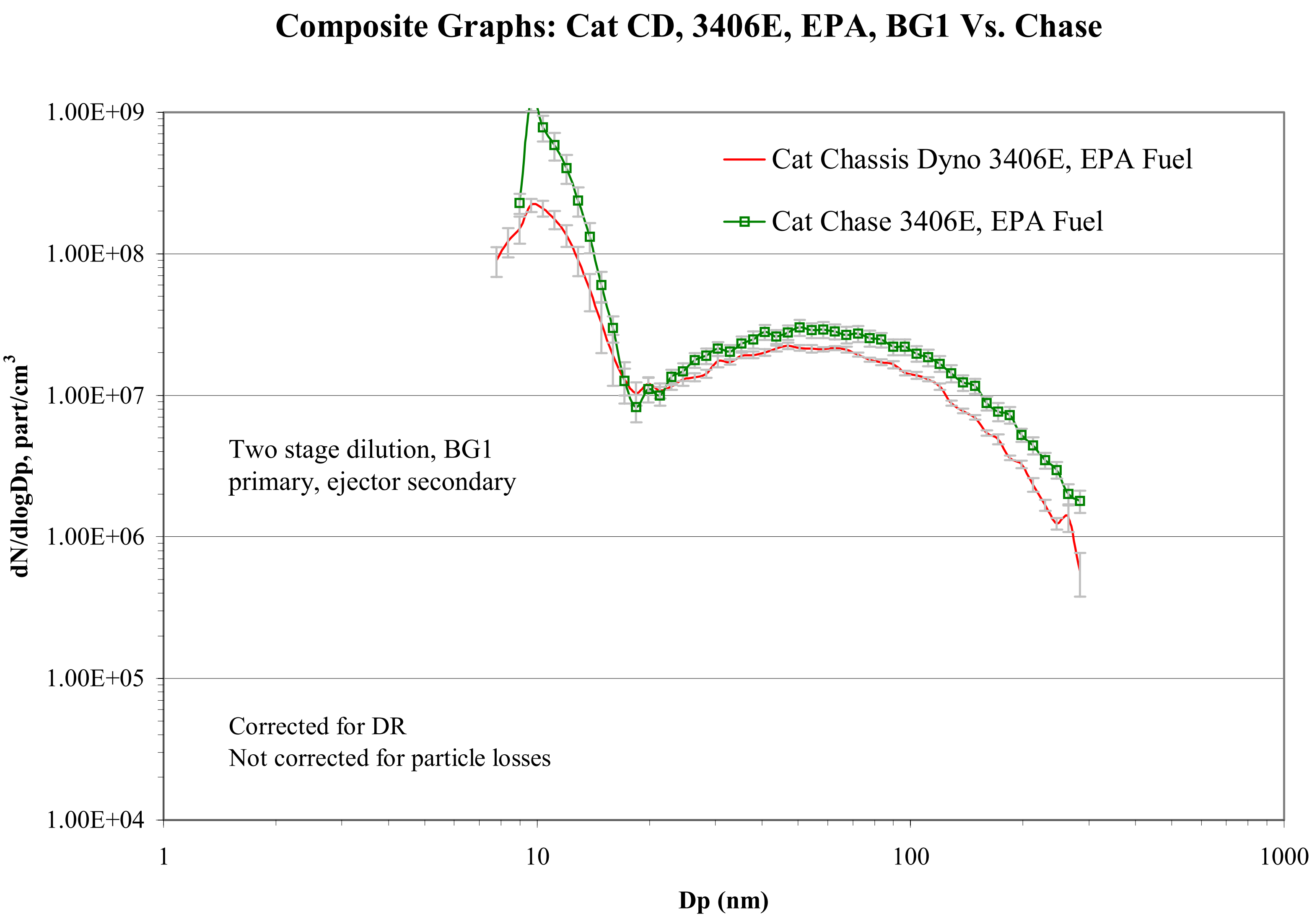
A clear pattern showing a significant on-road nuclei mode emerged for overall averages



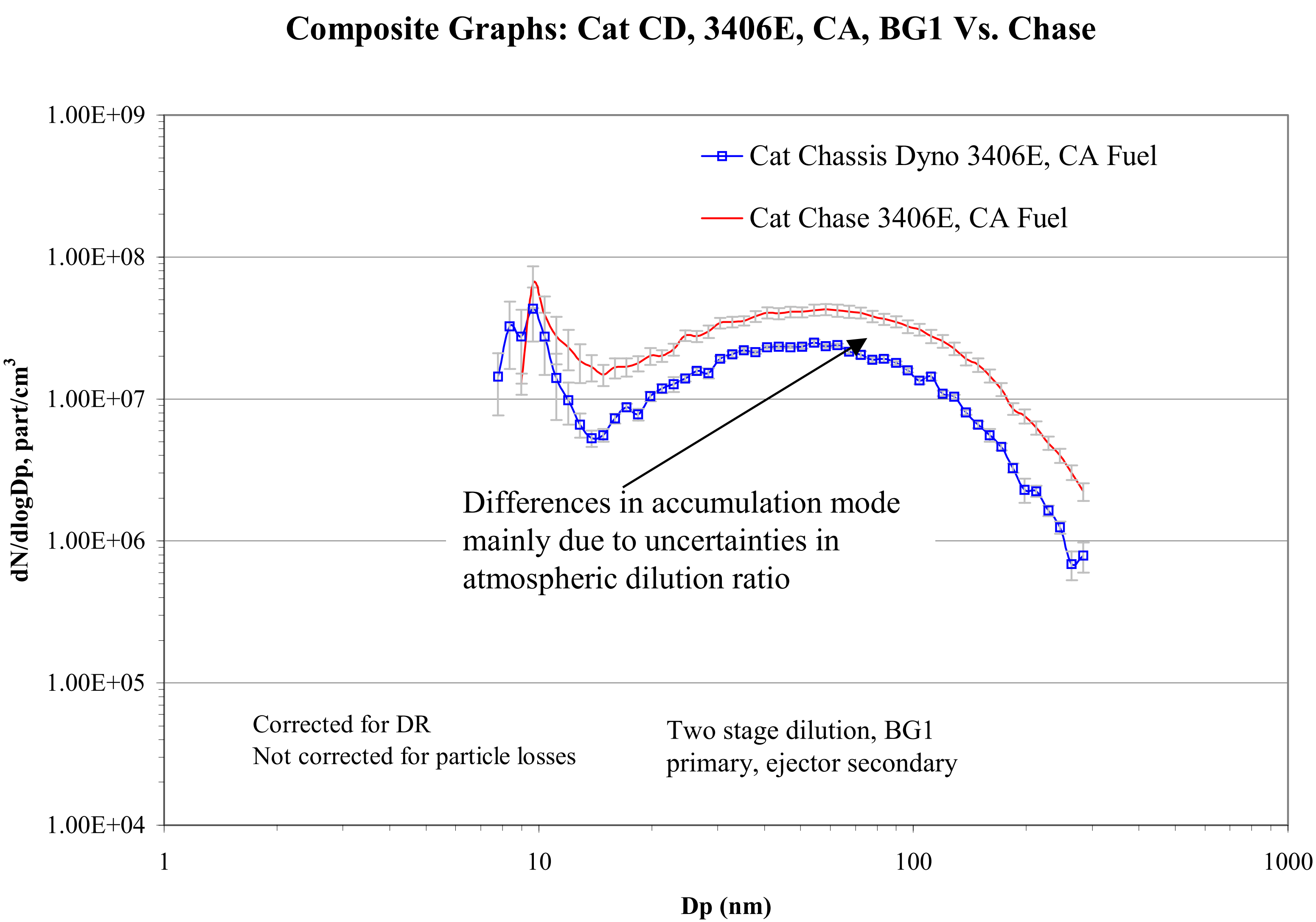
Composite on-road chase results show much less scatter. Character of size distribution from current and older technology similar.



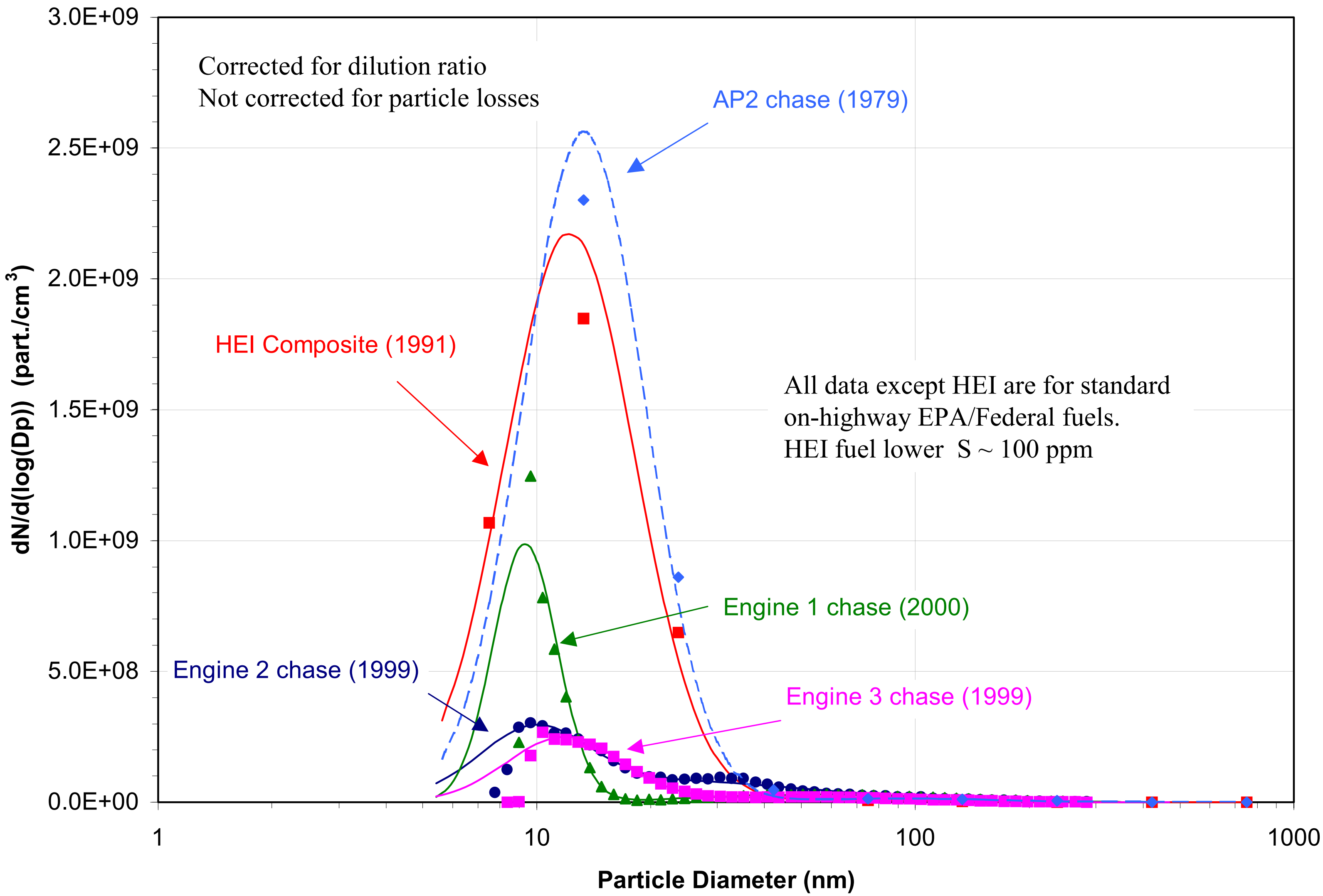
Comparison of lab and chase measurements – EPA fuel – larger nuclei mode on-road



Comparison of lab and chase measurements – CA fuel - larger nuclei mode in lab



Comparison with previous studies: Nanoparticles from newer engines are at lower concentrations and somewhat smaller



E-43 Questions and answers

- Can we make laboratory size distribution measurements that mimic real world measurements?
  - *On-road results are very dependent upon dilution conditions like ambient temperature and previous operating history – what condition are we trying to mimic?*
  - *However, we found that although laboratory results are also extremely sensitive to sampling and dilution conditions, we could design systems that give results similar to on-road composite highway cruise and acceleration conditions measured under moderate summer conditions (20-30 C).*
- Do modern Diesel engines produce nanoparticles under real world dilution conditions?
  - *Yes and so do mixed on-road fleets, even in the absence of significant Diesel traffic.*
  - *Nuclei mode formation strongly dependent on ambient temperature and traffic conditions.*
- Do new low carbon emitters produce more nanoparticles than older designs?
  - *No substantial difference has been observed for engines tested in E-43.*
  - ***Nuclei mode formation linked to volatile precursor (hydrocarbon and sulfuric acid) concentrations, especially under on-road conditions***

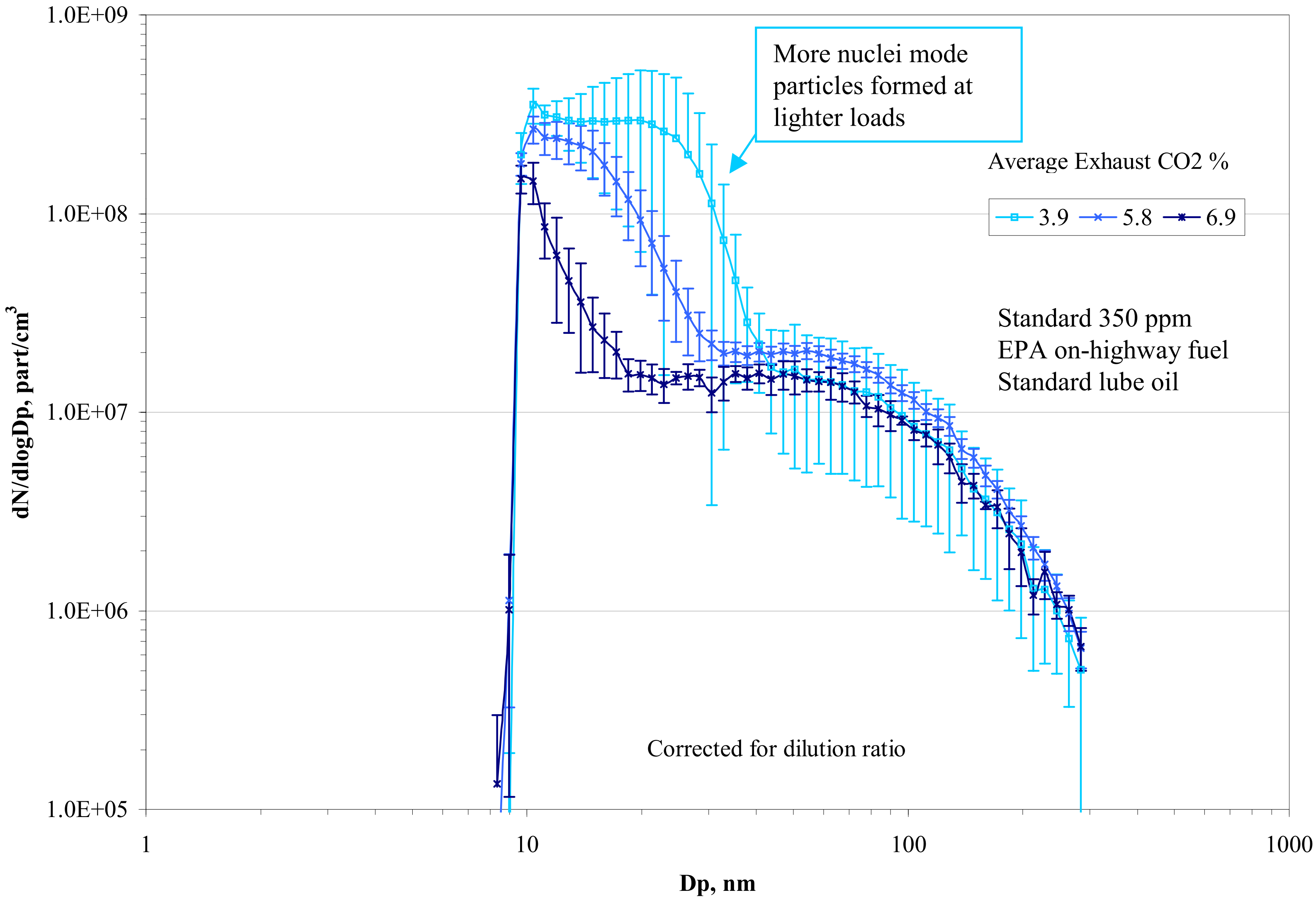
E-43 Questions and answers

- What the chemical and physical characteristics of the nanoparticles?
  - *Companion presentation shows that they consist mainly volatile materials like heavy hydrocarbons, sulfuric acid, and …*
  - *No evidence of **significant** solid fraction.*
- How long do they persist in the atmosphere?
  - *Modeling (Capaldo and Pandis, 2002) indicates that for typical urban conditions characteristic times and transit distances for 90% reduction of total number (mainly ultrafine) concentrations are on the order of a few minutes and 100-1000 m, respectively.*
  - *Thus high ultrafine and nanoparticle concentrations from engines are expected to be found mainly on and near roadways – a hotspot problem.*

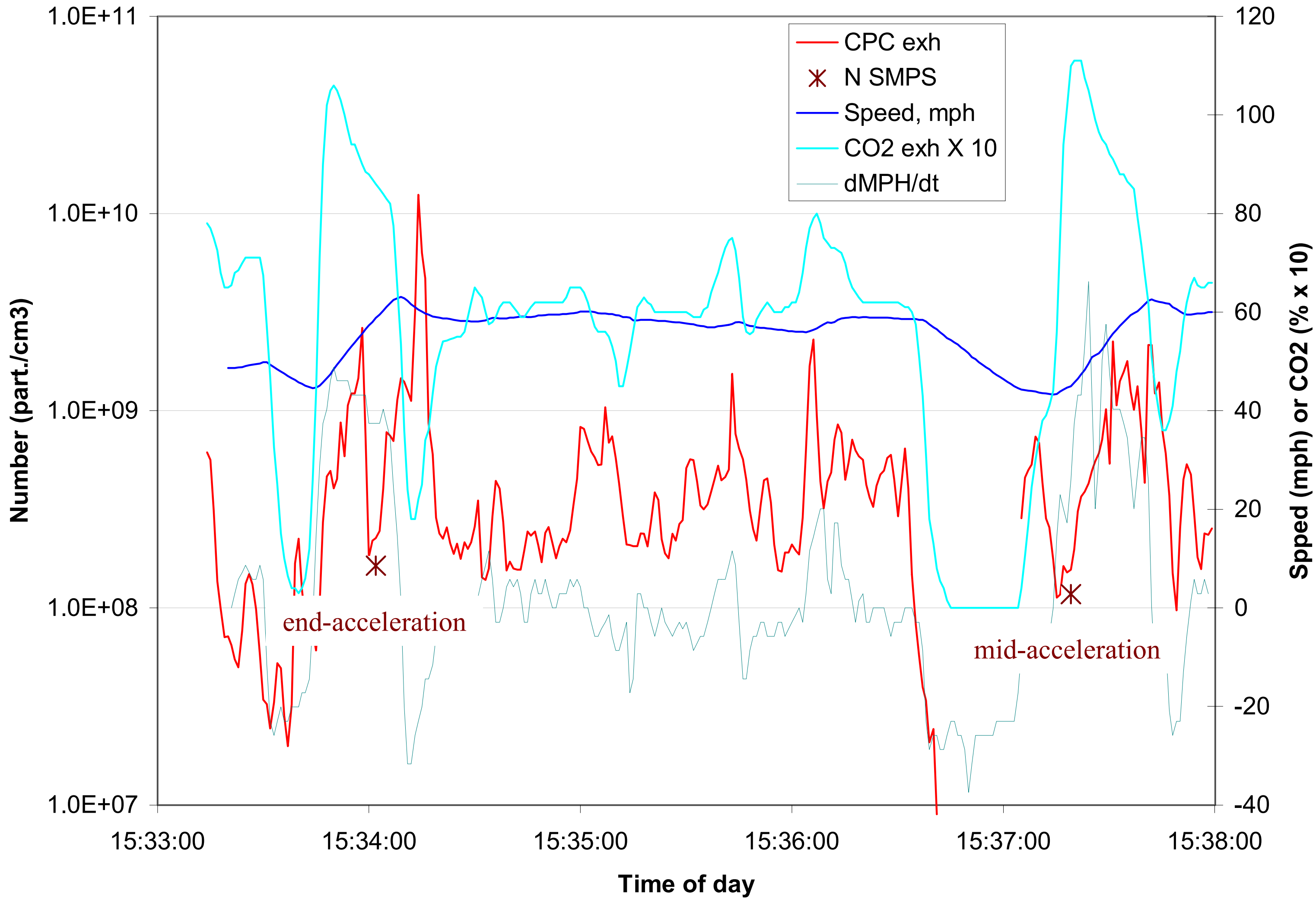
Sniffing our own exhaust – some new results

Sponsored by Johnson-Matthey, BP/Amoco, Castrol, Corning, Volvo

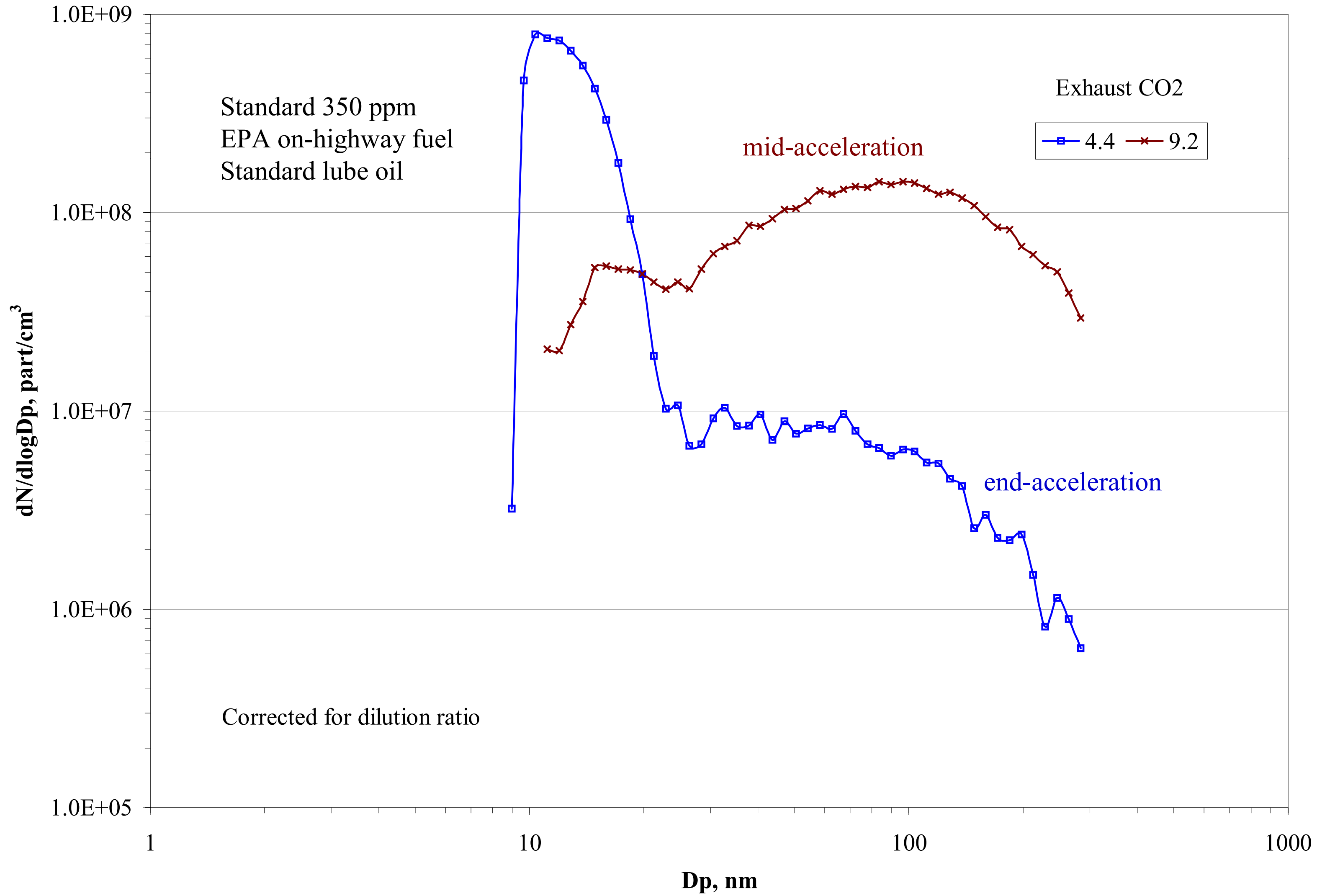
Volvo on-road cruise, variable load as indicated by CO2



Continuous instruments show additional structure



Mid-acceleration, heavy load produces large accumulation mode, end acceleration hot overrun a large nuclei mode



Ongoing plume sniffing work with mobile lab

- 15 ppm S fuel, reduced S lube oil, no aftertreatment
- 15 ppm S fuel, reduced S lube oil, CRT (CSF)
- 50 ppm S fuel, reduced S lube oil, CRT (CSF)
- 50 ppm S fuel. Standard S lube oil, CRT (CSF)
- 50 ppm S fuel. Standard S lube oil, no aftertreatment
- NOx aftertreatment??

Related References

- Kittelson, David, Winthrop Watts, and Jason Johnson, 2002 “Diesel Aerosol Sampling Methodology - CRC E-43: Final Report, submitted to Coordinating Research Council, September 2002
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- Capaldo, Kevin and Spyros Pandis, 2002. “Lifetimes of Ultrafine Diesel Aerosol,” submitted to Coordinating Research Council, September 2002
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- Kittelson, D., J. Johnson, W. Watts, Q. Wei, M. Drayton, and D. Paulsen, and N. Bukowiecki. 2000. "Diesel Aerosol Sampling in the Atmosphere," SAE Transactions Journal of Fuels and Lubricants, SAE Paper No. 2000-01-2212.