Ethanol Effects on Lean-Burn and Stoichiometric GDI Emissions

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DOE Sponsor – Vehicle Technologies

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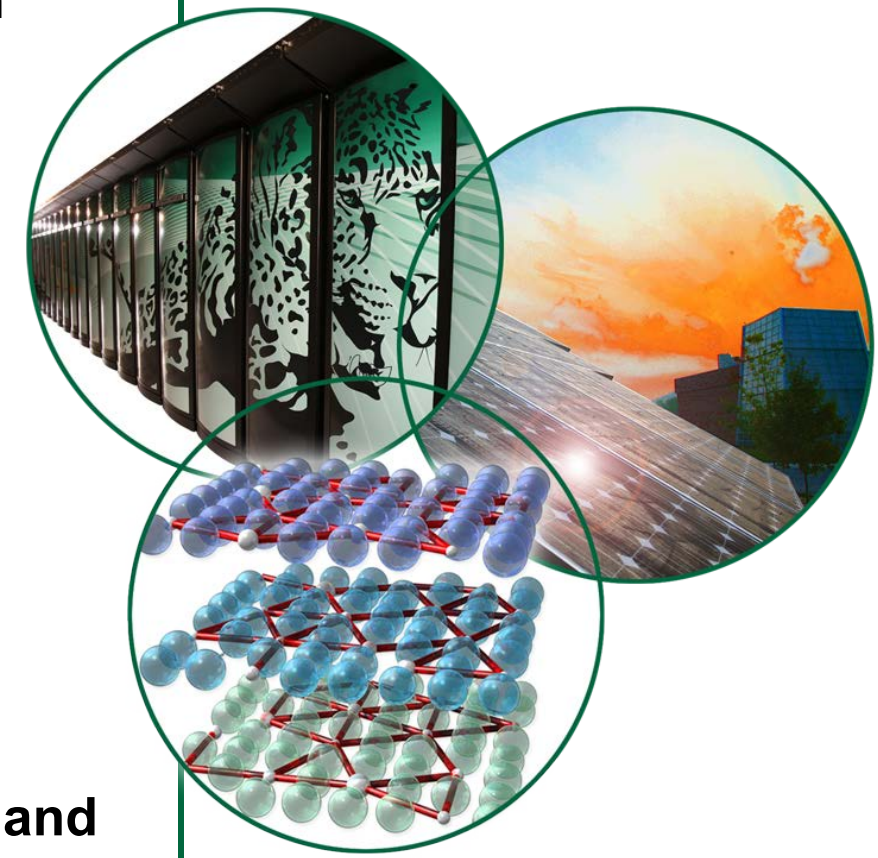
Gurpeet Singh & Ken Howden: Catalysts



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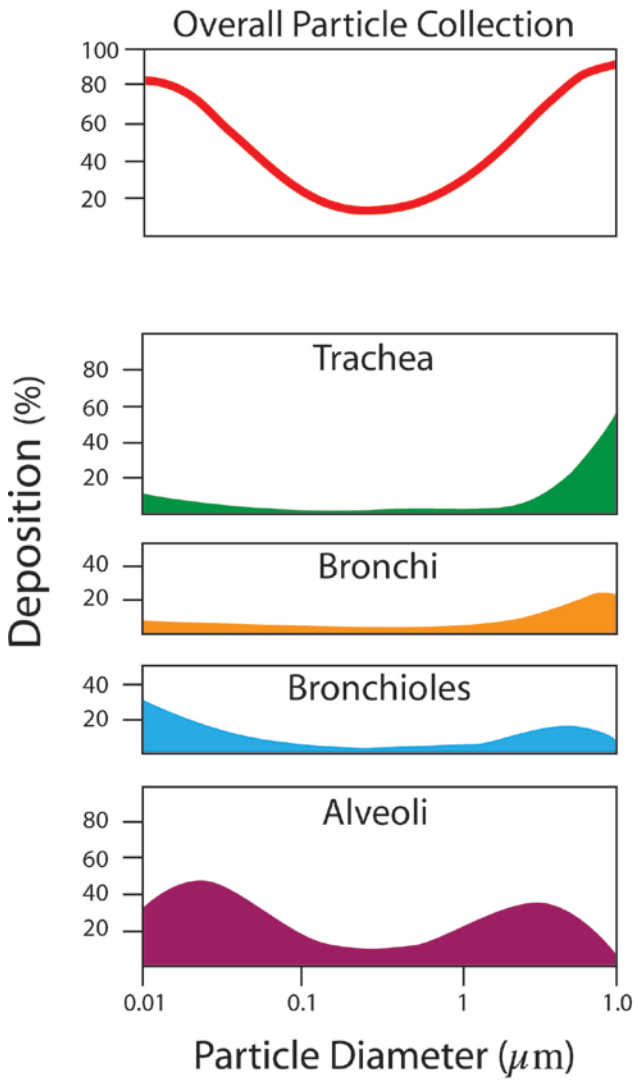
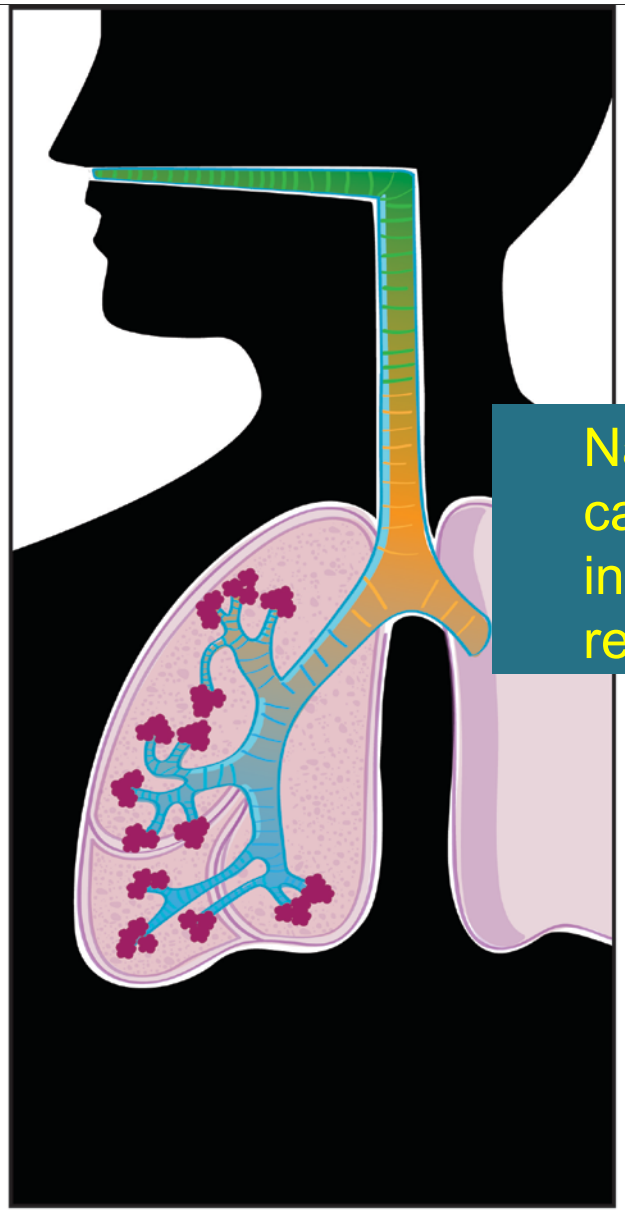
Particle Size Influences Location of Deposition in Respiratory System





Nanoparticles can penetrate into alveolar region

Data Source: Heyder (2004)

Comparison of Stoichiometric and Lean GDI Emissions

Stoichiometric GDI Vehicle
Pontiac Solstice
"wall-guided"

Lean GDI Vehicle
BMW 120i – Euro spec
"spray guided"

- **Motivation:** 1. Understand potential fuel effects on GDI PM emissions.
  2. Health implications and ambient air quality issues

- **Approach**
- Test cycles: FTP and US06, transient accelerations plus steady state
- Fuels: Gasoline and intermediate ethanol blends (E0, E10, E20)
- Measurements:
  - **Particle mass**: collection on Teflon-coated quartz-fiber filters and gravimetric analysis
  -- **Particle composition:** organic carbon/elemental carbon (OC/EC)
  - **Particle number concentration and size distributions**: analysis by SMPS

Particle Emissions Analysis

Dilution Systems

Full-flow CVS

Partial Flow BG-3

Microtunnel

European PMP

Catalyst

Number-Size Distributions

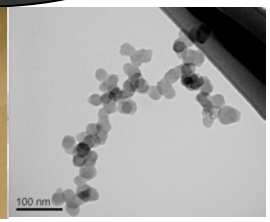
Steady-State

Scanning Mobility Particle Sizer

Transient

EEPS

Morphology



Transmission Electron Microscopy;TEM-Sampler

Organic Fraction

Organic to Elemental Carbon Ratio

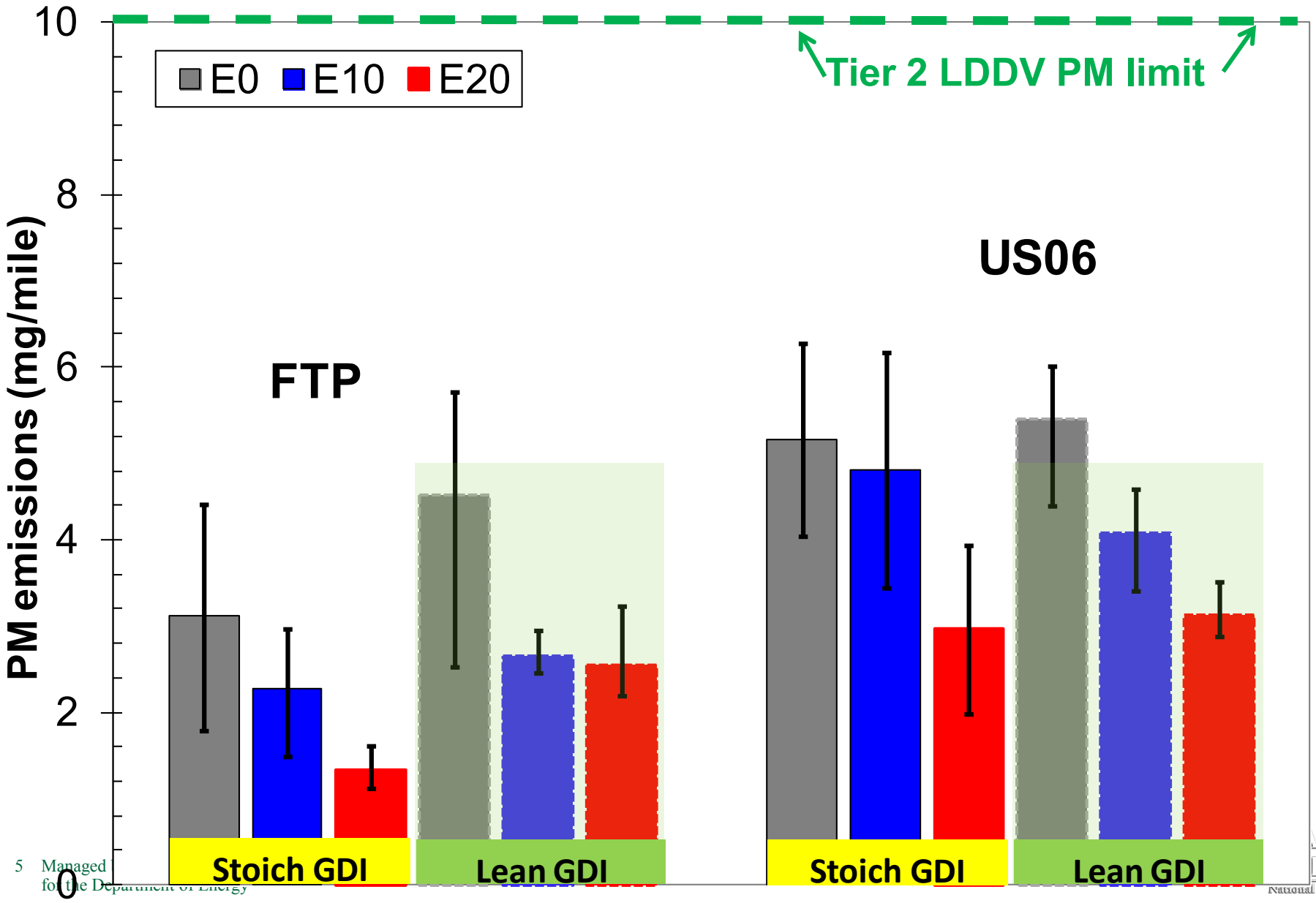
Microwave Reactor Extraction Organic Speciation

Mass

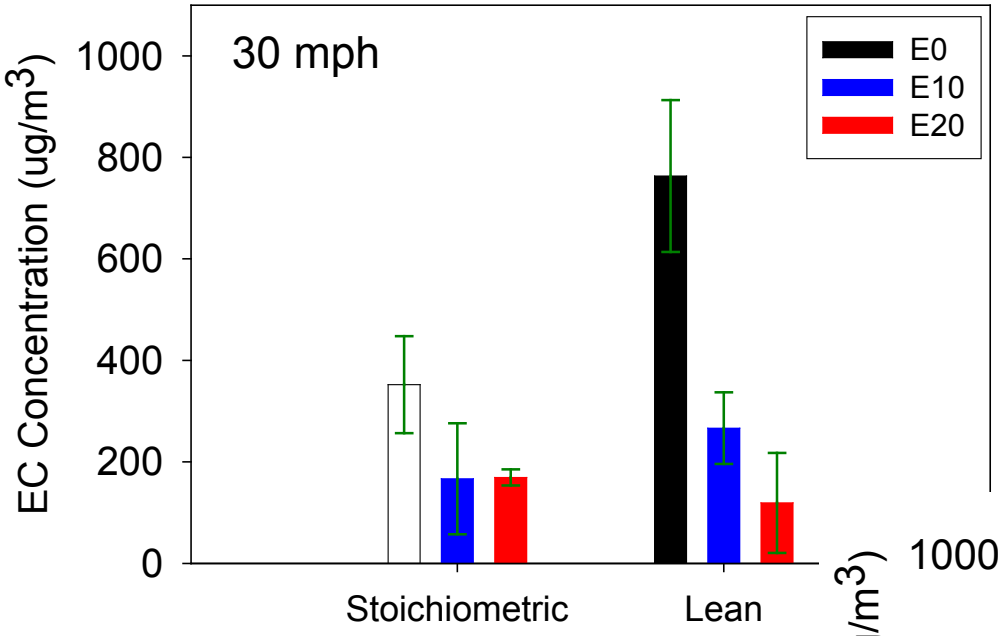
AVL Micro Soot Sensor

Mettler Microbalance

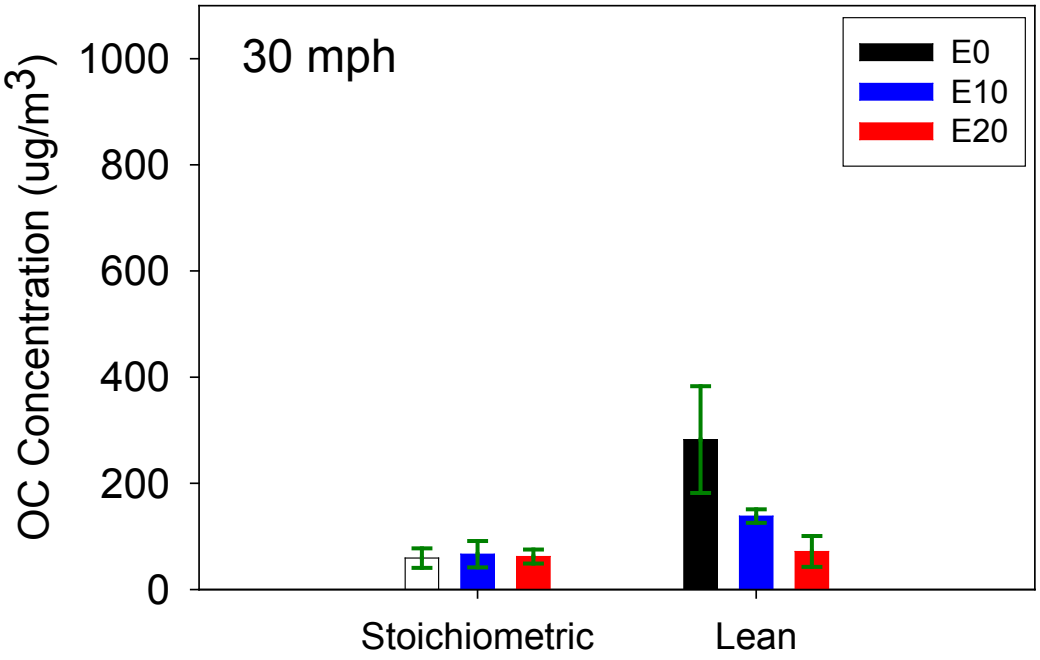
Stoichiometric GDI Vehicle PM emissions more sensitive to fuel and cycle than lean GDI



Ethanol leads to lower elemental carbon concentrations in the tailpipe



- Less EC implies less soot formation for E10, E20
  - Catalyst temperature too low to oxidize soot

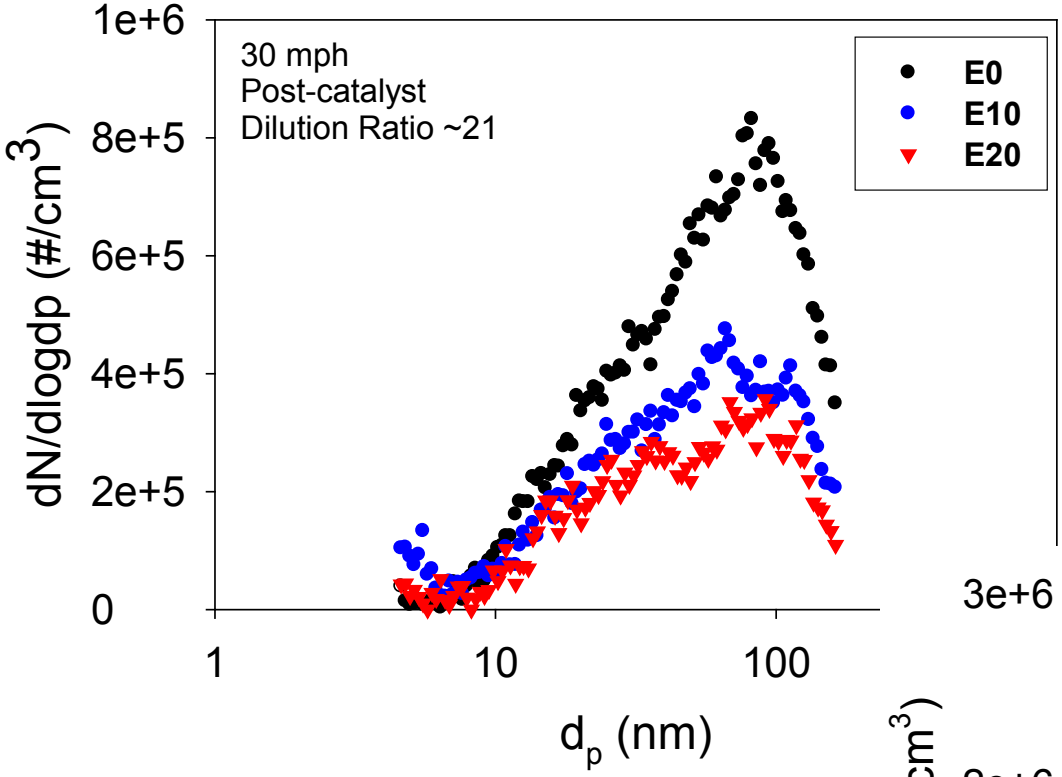


- OC higher for lean burn
- Survives the catalyst
- OC/EC ratios 0.2 – 0.7
- Diesel OC/EC > 5 typically

Results – Particle size and number

- Used scanning mobility particle sizer (SMPS) ~ 1 -2 minutes for size distributions – steady state only
- Particle counter (CPC3025) can be used independently
  - particle concentration too high! Required 1000:1 dilution
- Investigated three separate sizes for accels: 10, 50, 100 nm

Size distributions consistent at both steady-state points (stoich GDI)

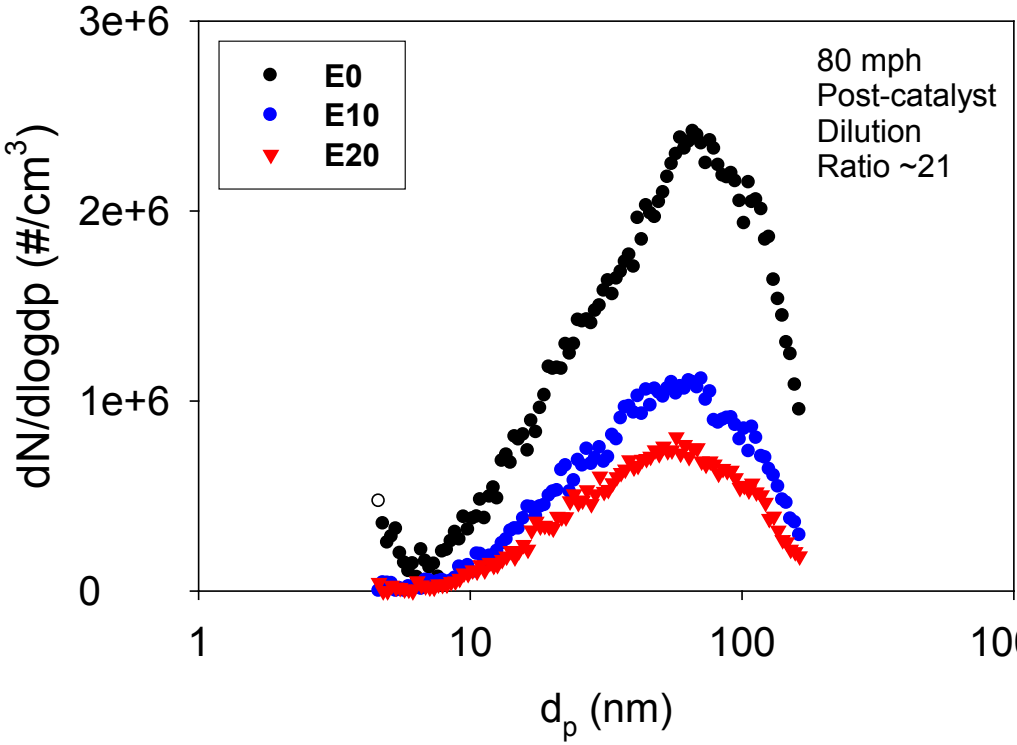


Ethanol content does not change general shape.

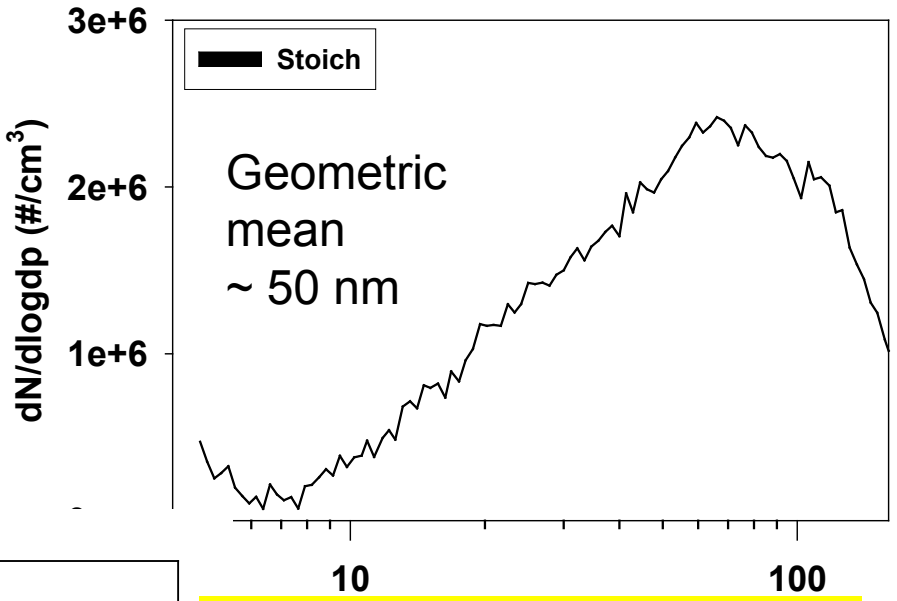
E20 reduces total number concentration by about 50% at 30 mph and 70% at 80 mph

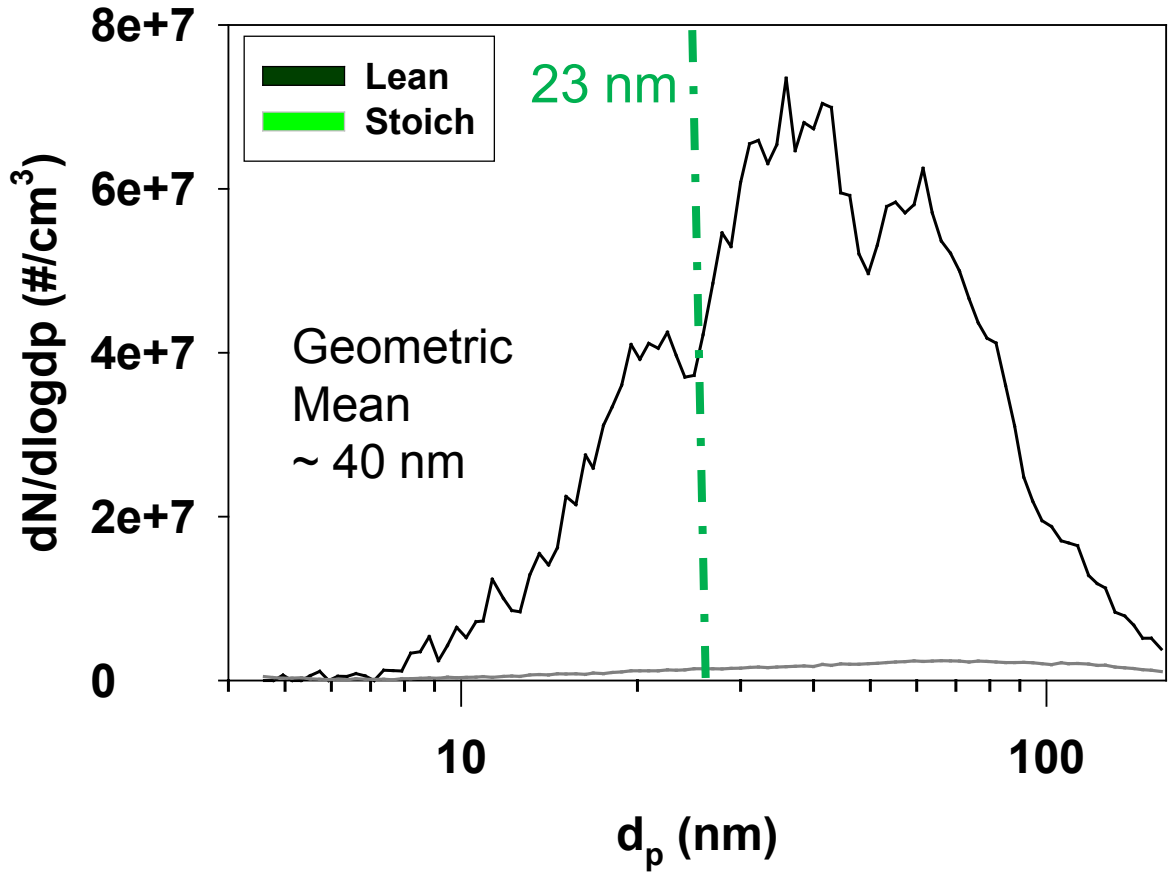
Geometric mean diameter for all distributions ~ **50 nm**

Distribution broader than diesel exhaust particles



Lean GDI Vehicle Particle Size Distribution for 80 mph (E0 fuel)

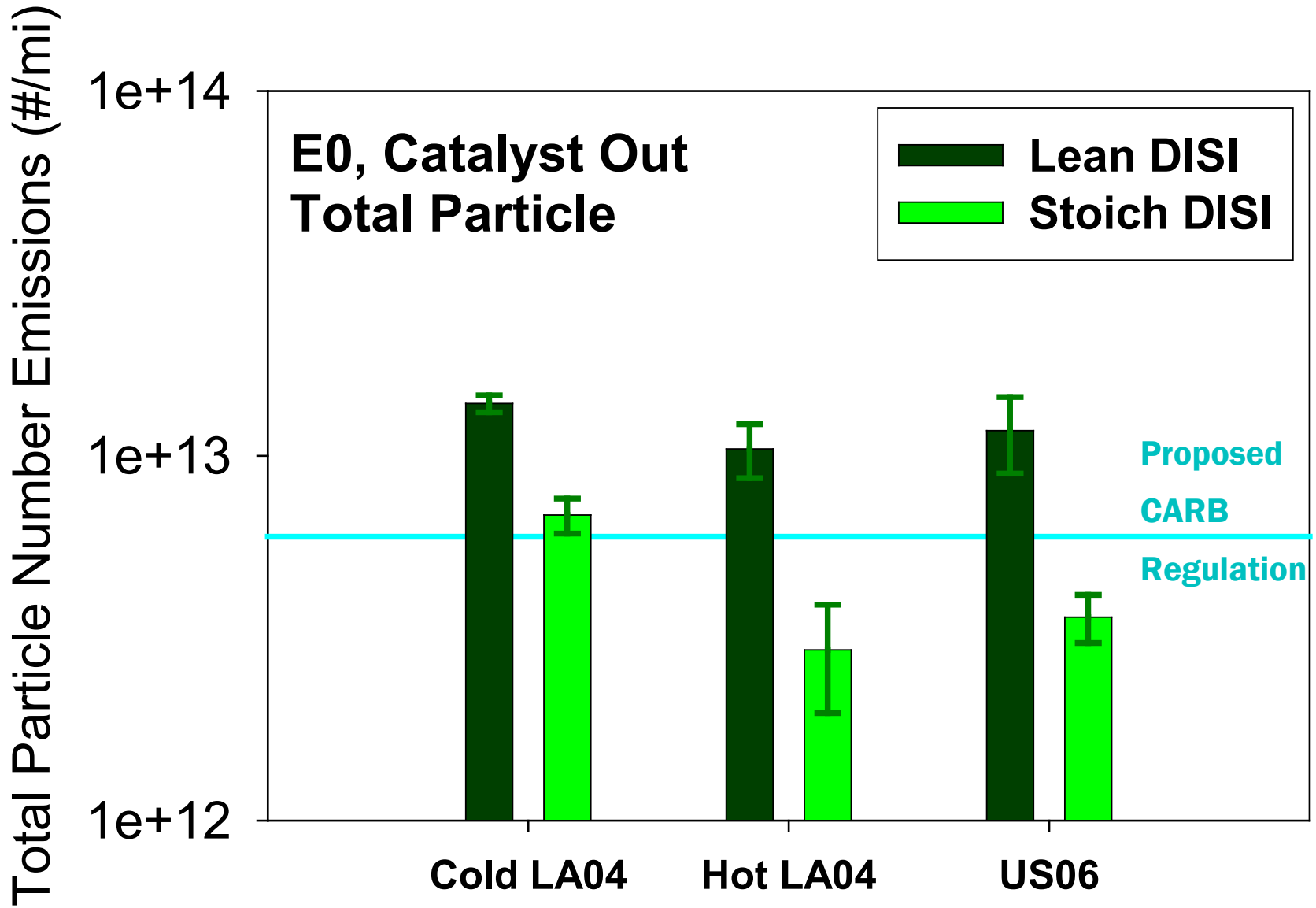




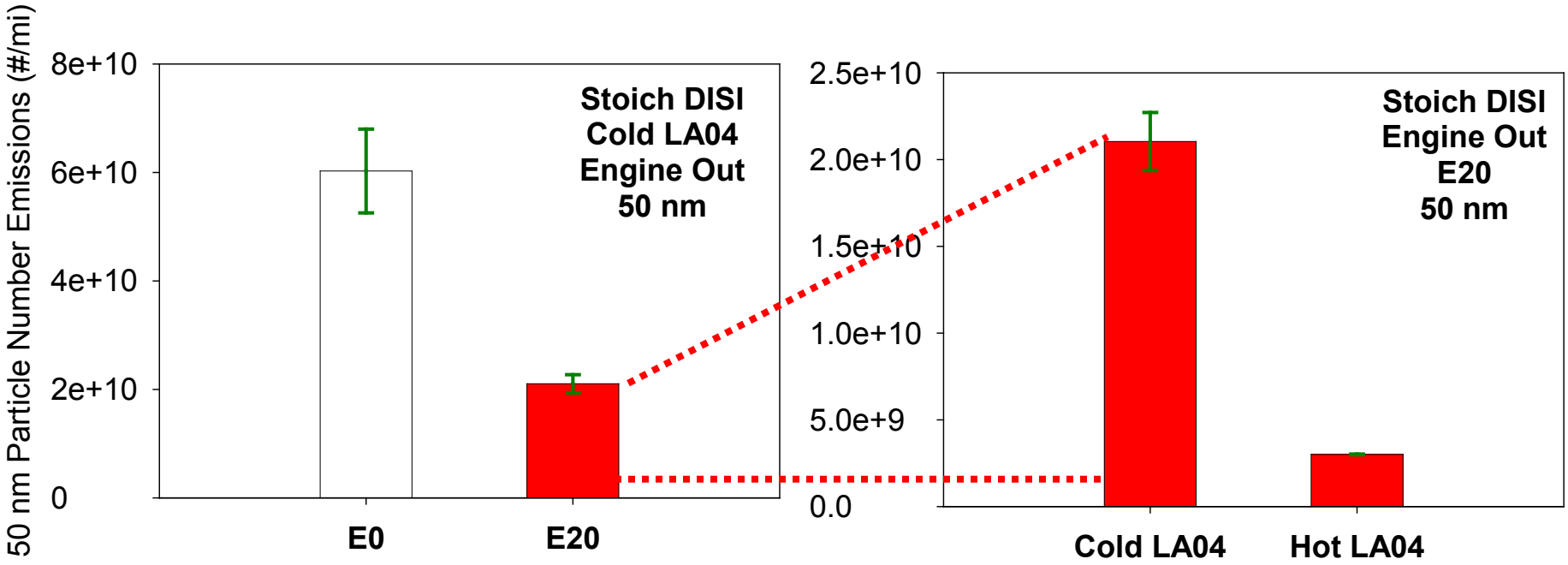
European PMP (Particulate Measurement Protocol) counts particles above 23 nm

Stoich GDI particles biased larger but less abundant than lean particles

Lean GDI total number emissions also higher than stoich GDI – comparable to potential regulation

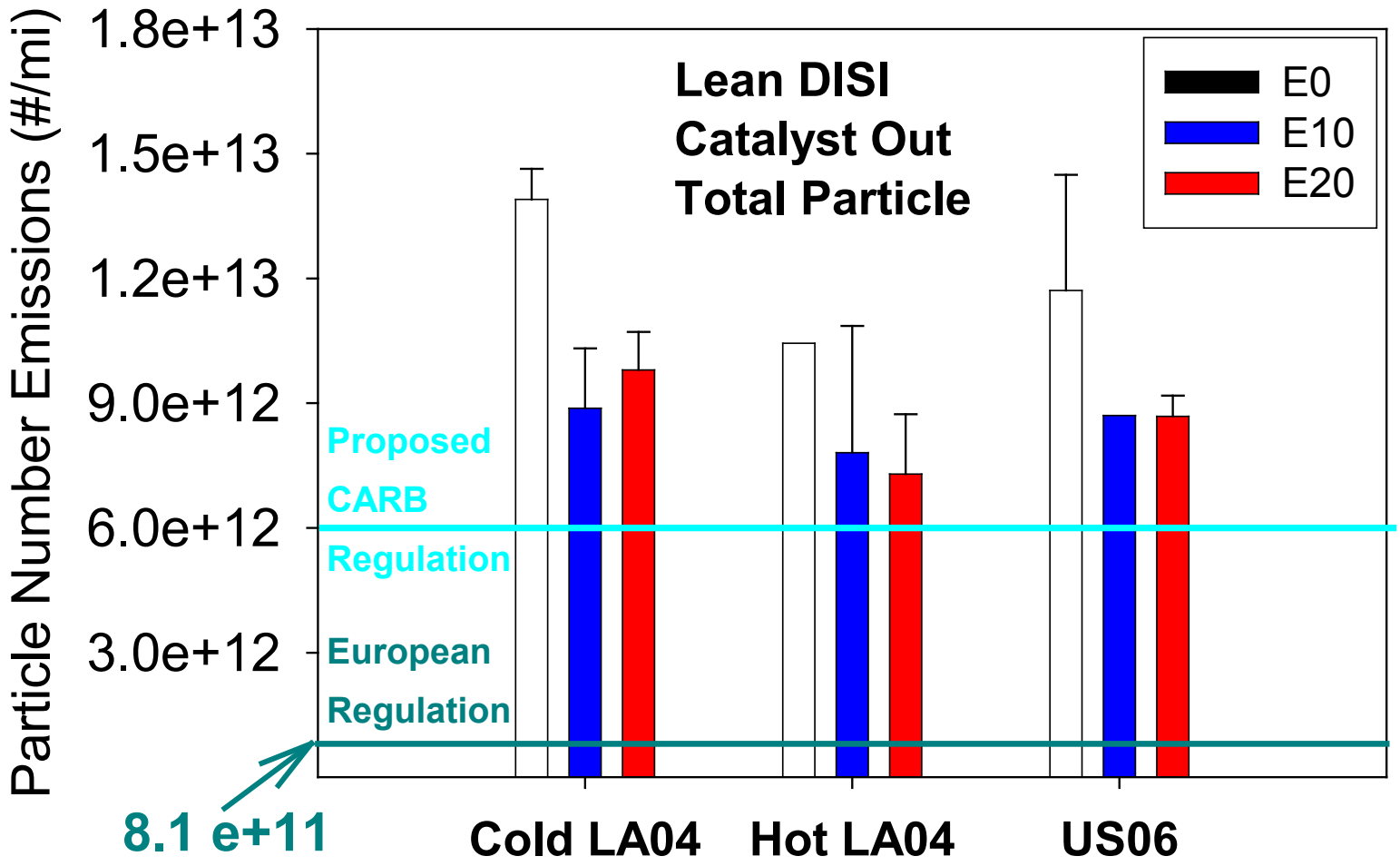


Particles per mile decrease with ethanol content and hot cycles



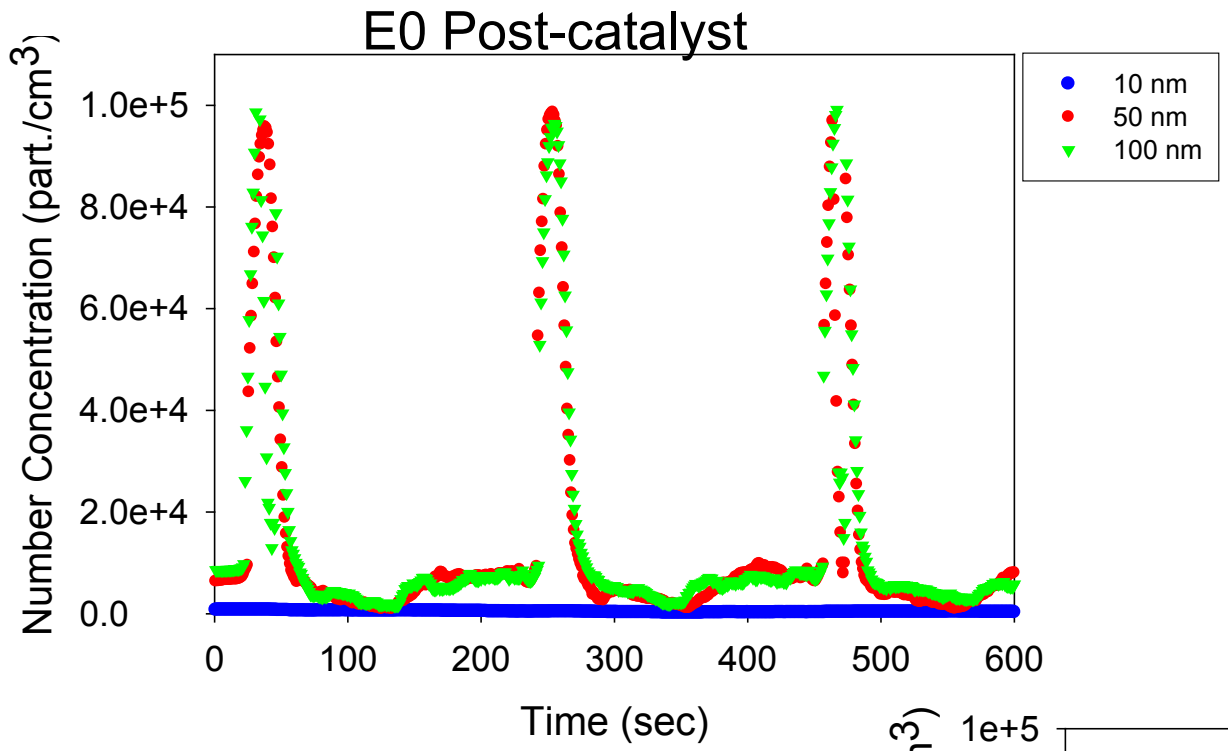
- All fuels show majority of particles from cold start
- Ethanol reduces overall particle count

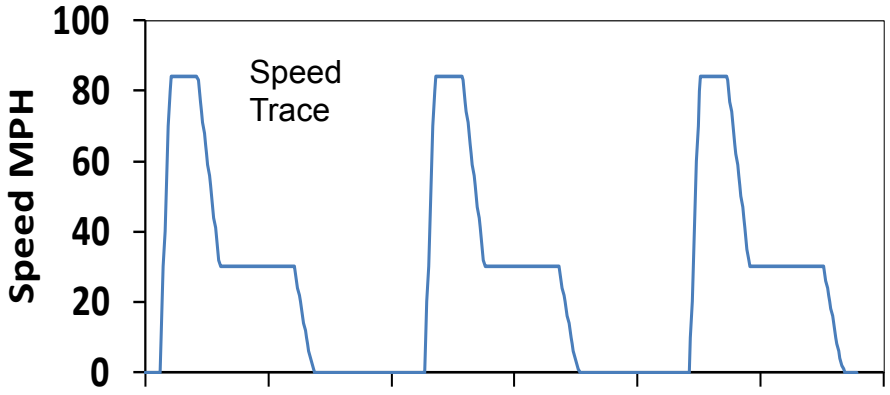
Reduction by E-blends E10 & E20 Similar for lean DI vehicle

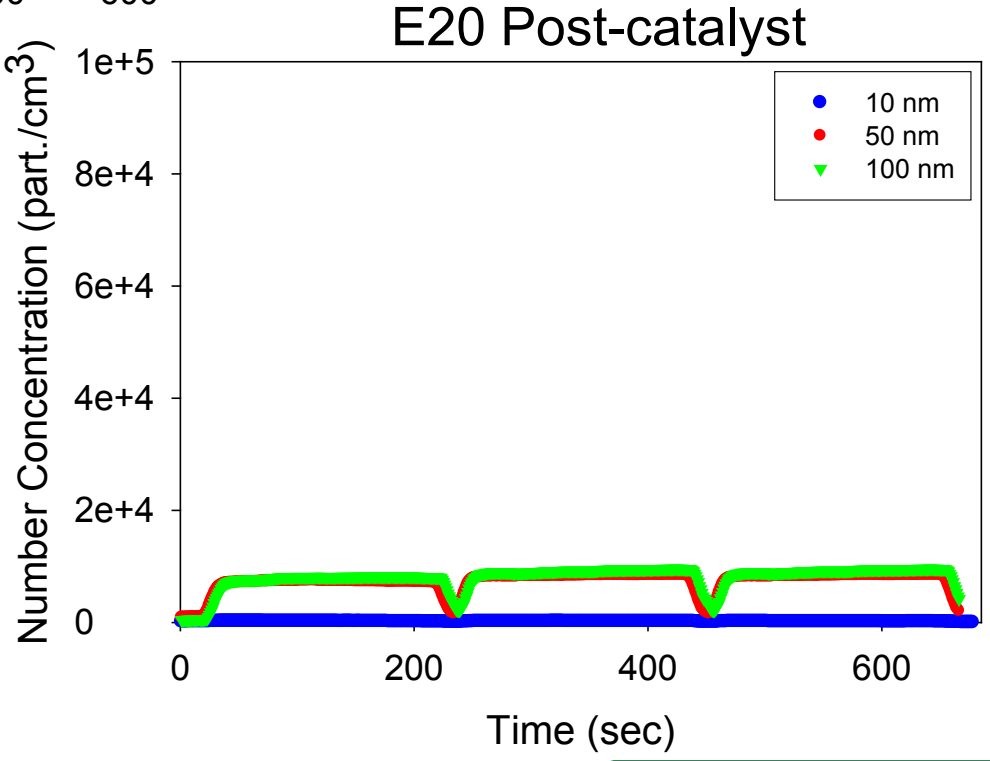


< 23 nm particles included in our measurements

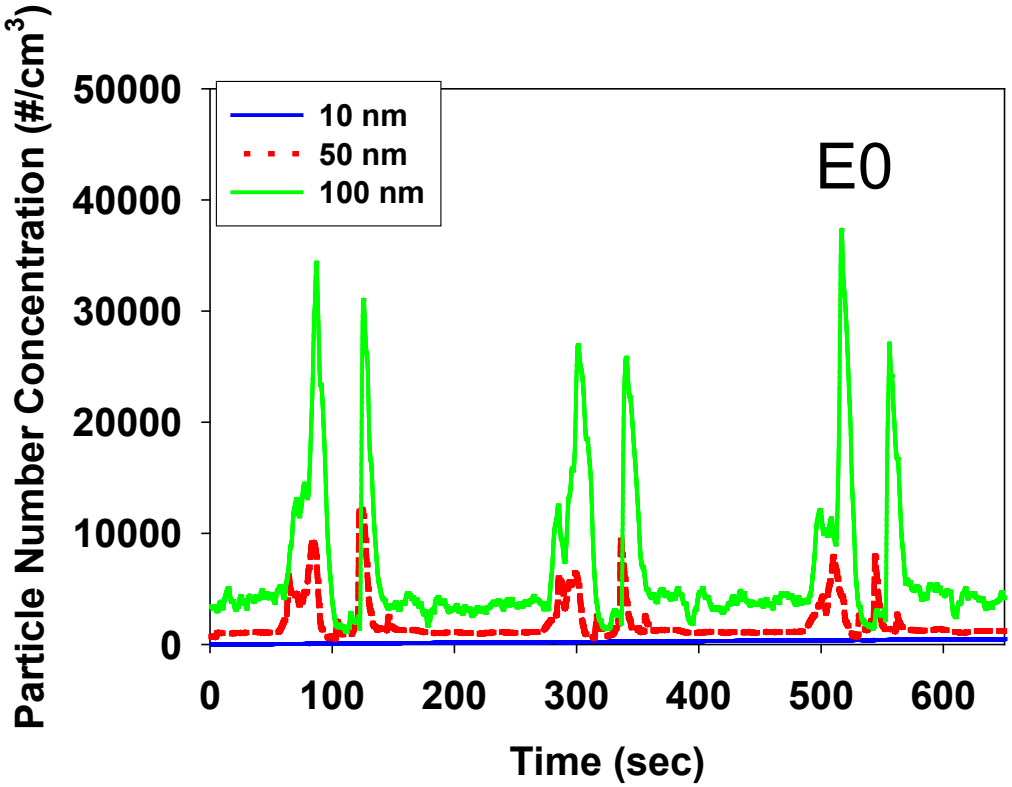
Stoich GDI Wide Open Throttle 0 – 80 mph



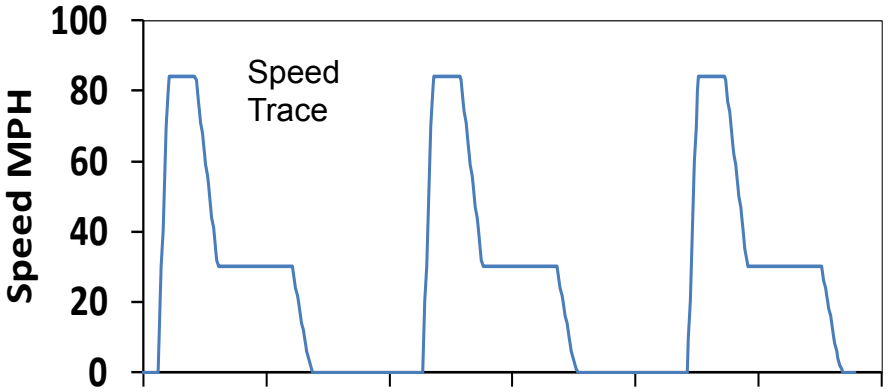


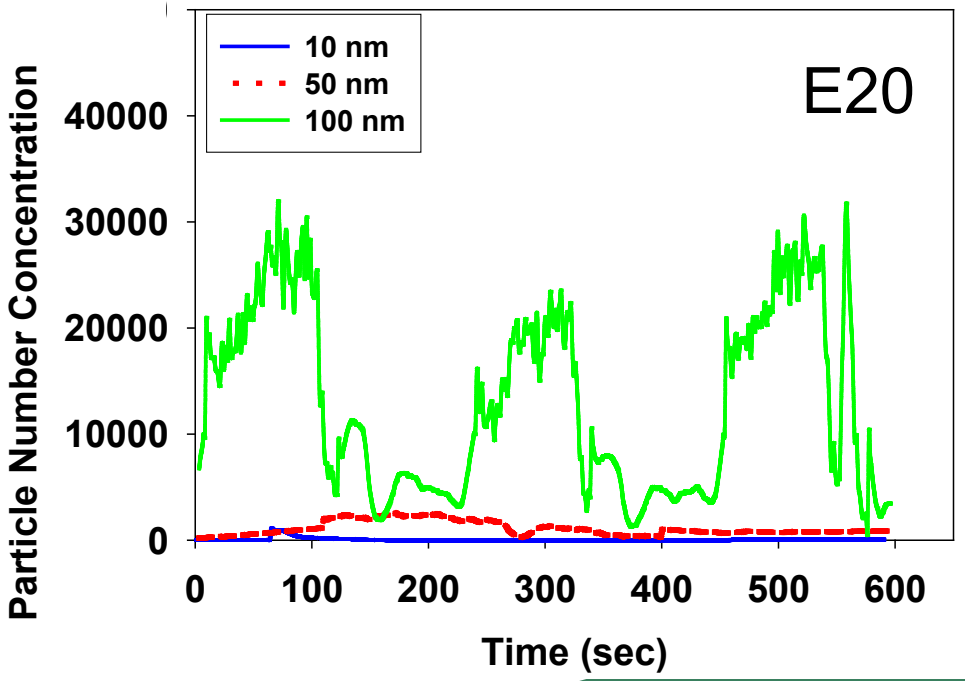


Lean GDI vehicle Wide Open Throttle 0 – 80 mph



Distinct spikes disappear for E20; not much reduction in 100 nm particles





Conclusions:
Fuel Effects for the stoich GDI Vehicle

- Use of E20 resulted in a 40 to 60% reduction in PM mass emissions
- >50% reduction in total particle number concentration for 30 and 80 mph; no change in size distribution
- Reduction of 50 and 100 nm particle emissions during acceleration
- Cold start significant contributor to overall PM number

Fuel Effects for the lean GDI Vehicle

- E20 resulted in 30-40% drop in cycle-based PM mass emissions
- Lean vehicle had smaller mean size, larger number of particles
- Ethanol slightly reduced number based emissions
  - Implies fewer larger particles
- Less difference between cold start and warm cycles.

Implications for GDI PM control

- Need for exhaust particulate filter (GPF) depends on success of in-cylinder control
  - Cold start worse for wall-guided injectors
  - Oil entrainment?
  - Avoidance of sooting conditions
- Particulate filter issues for GDI
  - High EC content implies refractory particles
  - High temperatures will help
  - Ash content would have to be addressed

Extra slides

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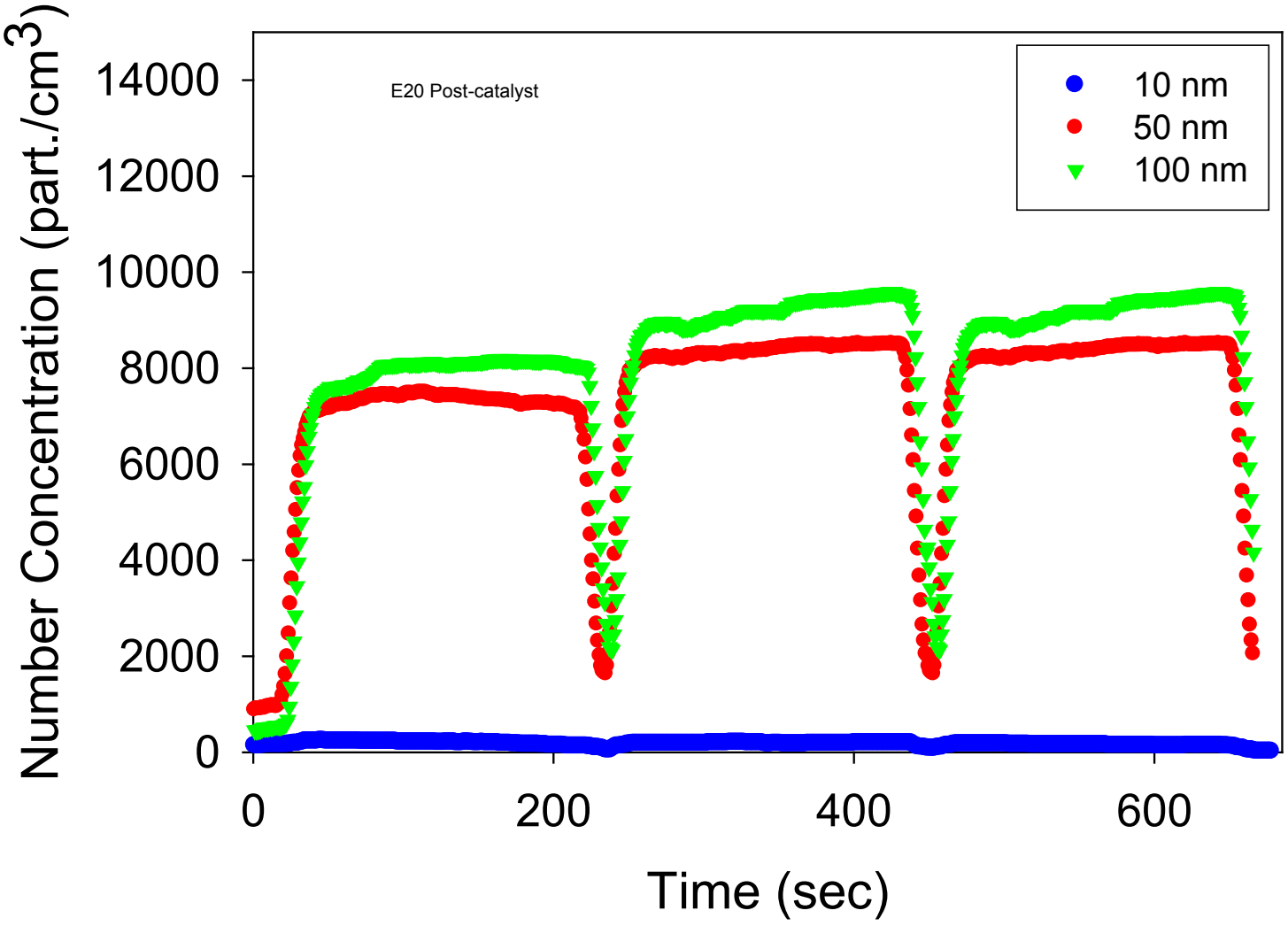
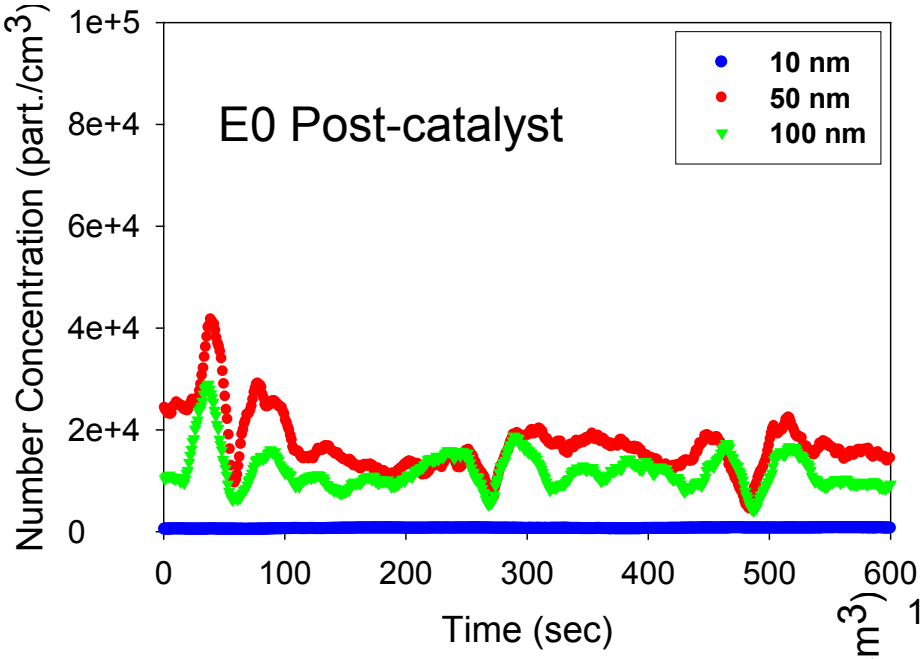
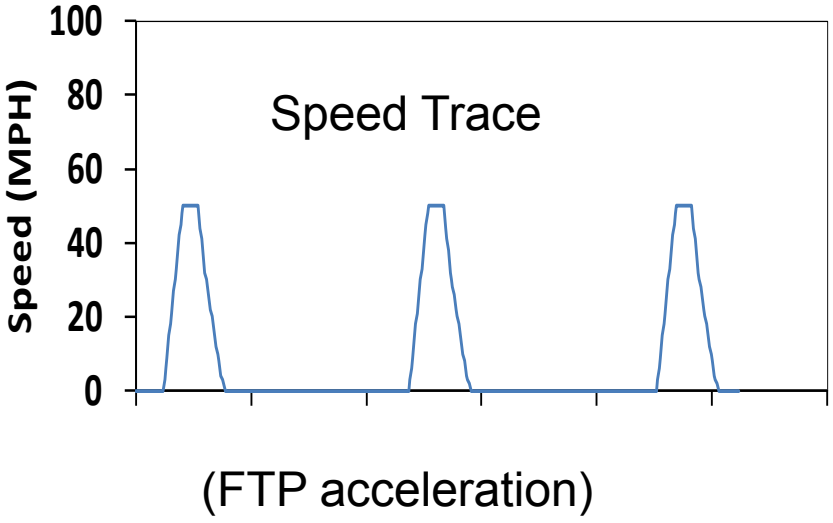
Stoich Wide Open Throttle 0 – 80 mph (E20 detail)



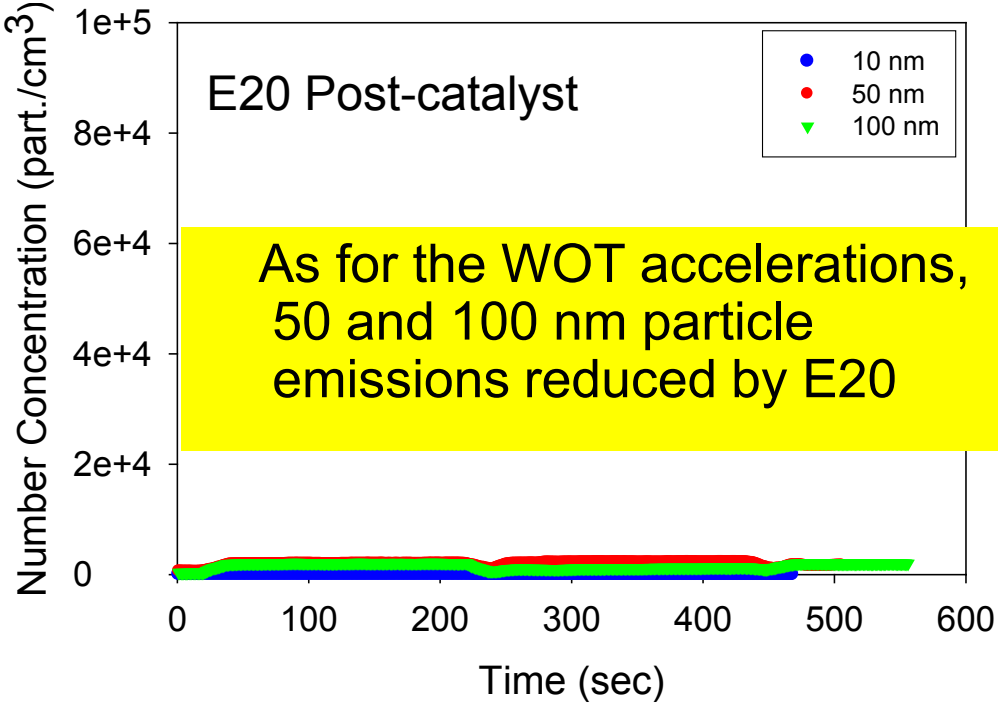
Stoich vehicle moderate acceleration - 0 to 50 mph



- Particles may be generated in in-cylinder fuel rich zones
- Ethanol may reduces amount of carbon available for soot formation through CO formation pathway (Wu et. al, 2006)



(FTP acceleration)



As for the WOT accelerations, 50 and 100 nm particle emissions reduced by E20

The cycling behavior of the lean GDI vehicle results in a variety of PM size distributions