Exploring Advanced Combustion Regimes for Efficiency and Emissions

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Overview

- Motivation
- Experimental Platform
- Results
  - Approach
  - HC and PM characterization
  - Single particle characterization (BNL)
  - Other possible approaches
- Summary / Observations
- Future Work

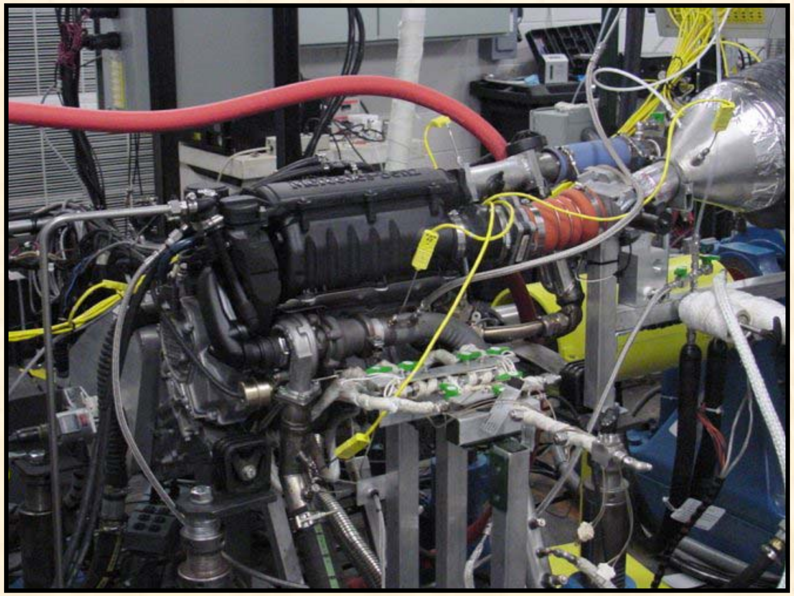
Motivation: Improving system efficiency by lowering performance requirements for post-combustion emissions controls

Objectives:

- **Detailed emissions characterization for improved understanding of combustion regimes and environmental impact.**
  - **Hydrocarbon speciation**
  - **PM characterization**
- **Extend load/speed envelope.**
- **Are these regimes useful for NOx adsorber and DPF regeneration?**

Approach - Experimental Platform

- Conducted engine-based experiments using a Mercedes 1.7L engine equipped with RPECS-based controls.

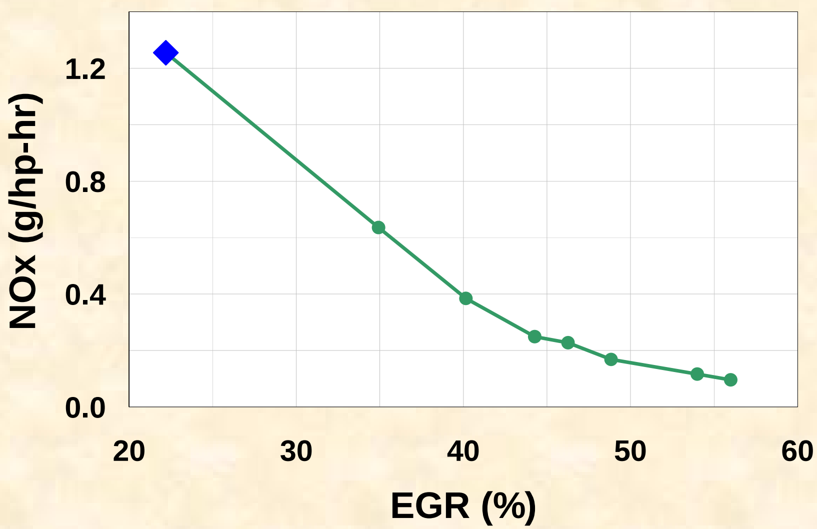


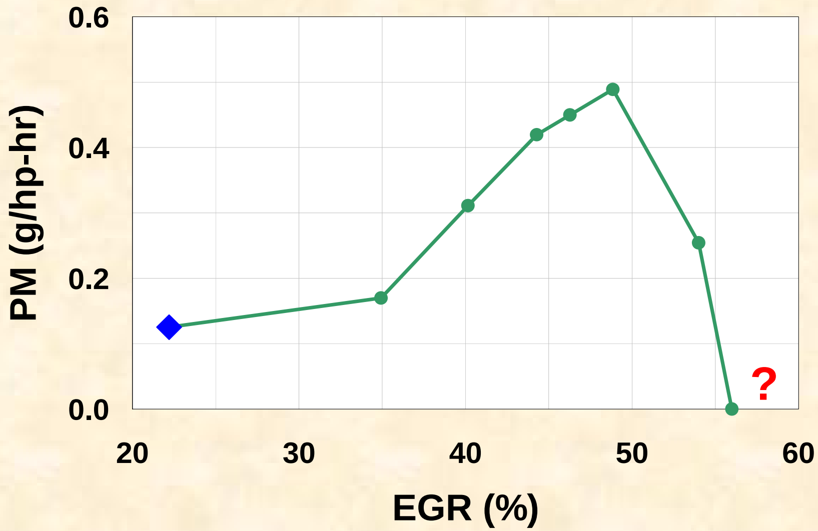
- Extensive instrumentation for characterizing gaseous emissions, particulate matter, and combustion.

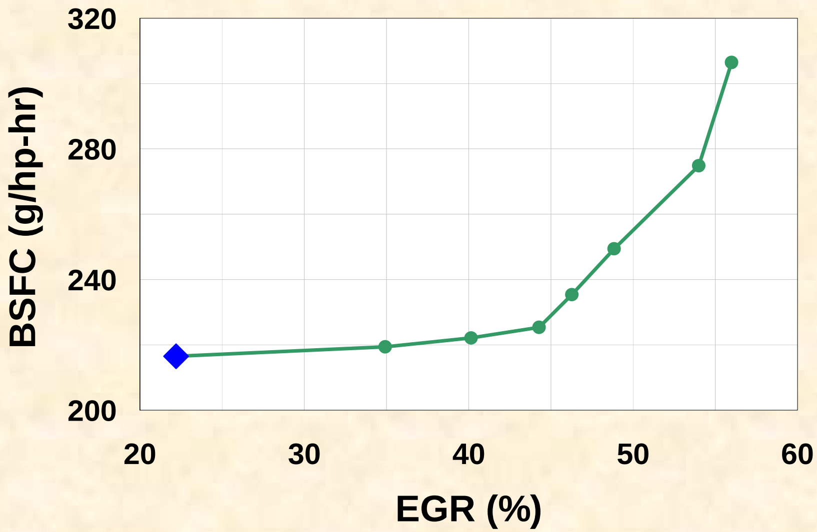
Injection parameters and EGR were used to explore low emission regimes

- **Approach One**
  - **EGR used to enter low emissions regimes.**
  - **Throttle assist to increase EGR rate used when necessary.**
- **Approach Two**
  - **Combination injection timing and EGR used to enter low emissions regimes.**
  - **Throttle not typically used with approach two.**
- **Recovery**
  - **Any means necessary to recover or maintain efficiency in low emissions regimes (e.g. typically injection parameters).**

Lower engine-out emissions observed under low load with Approach One

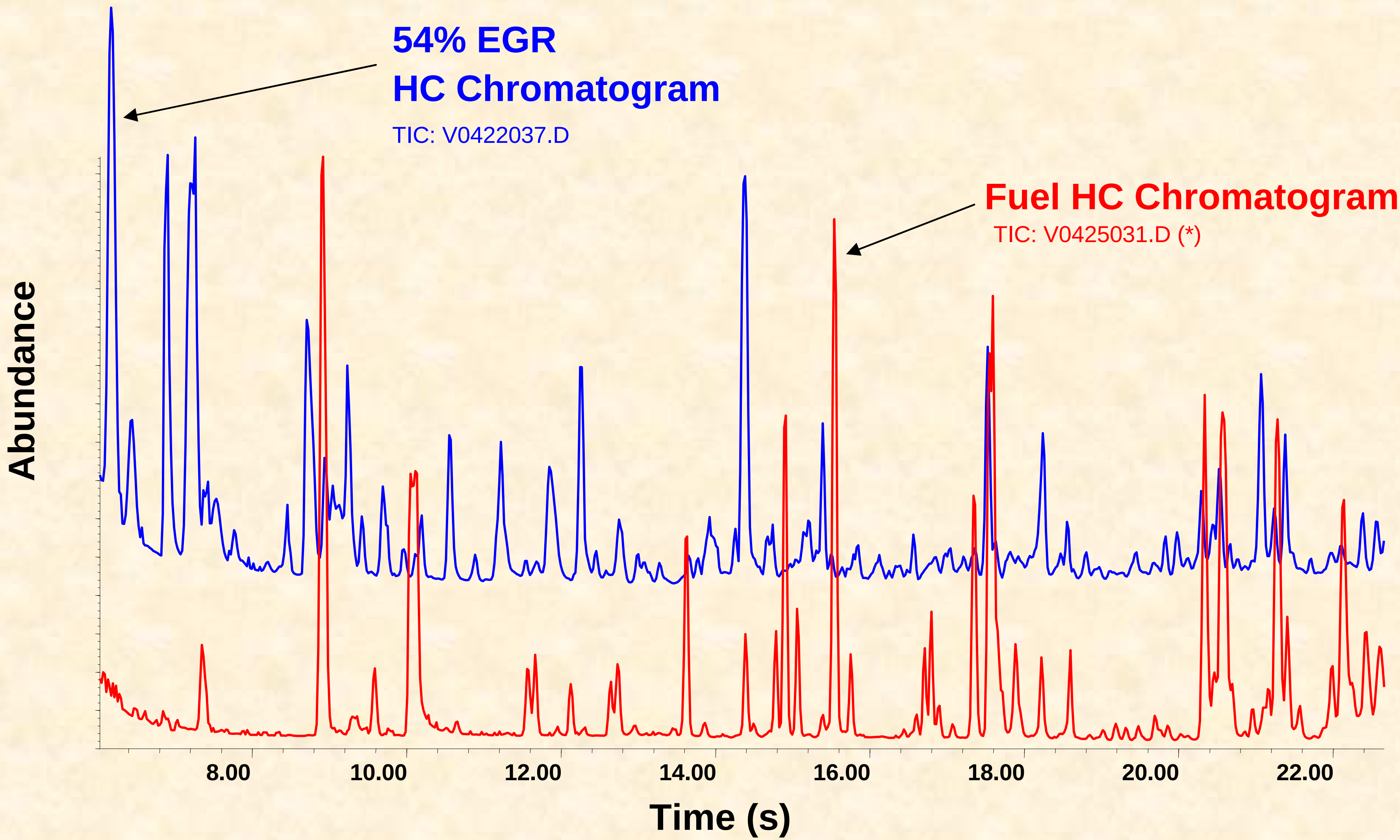




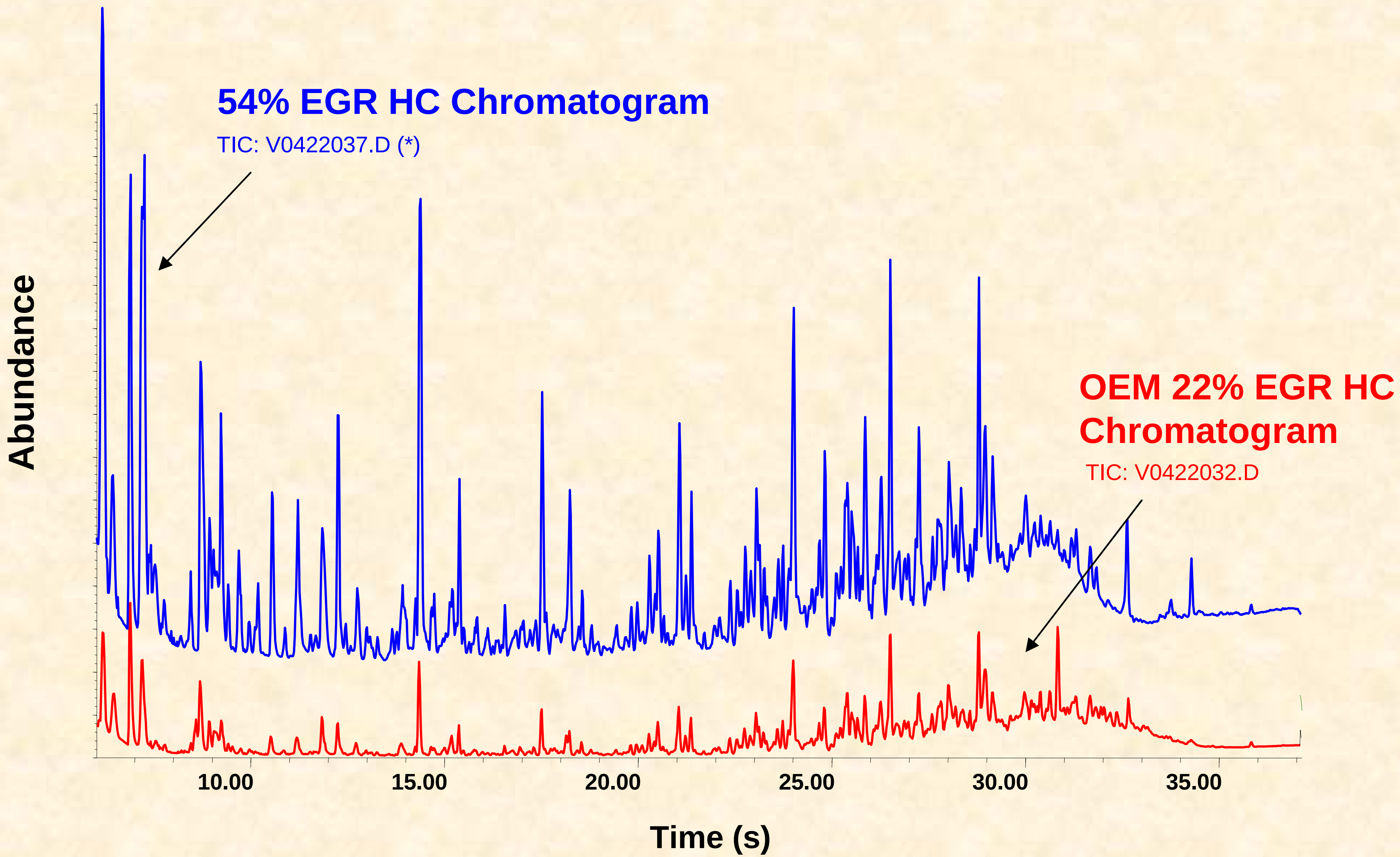


- 1500 rpm, 2.6 bar BMEP
- OEM EGR 22% (blue).
- "Road load" type condition
- PM unmeasurable with TEOM at 56% EGR

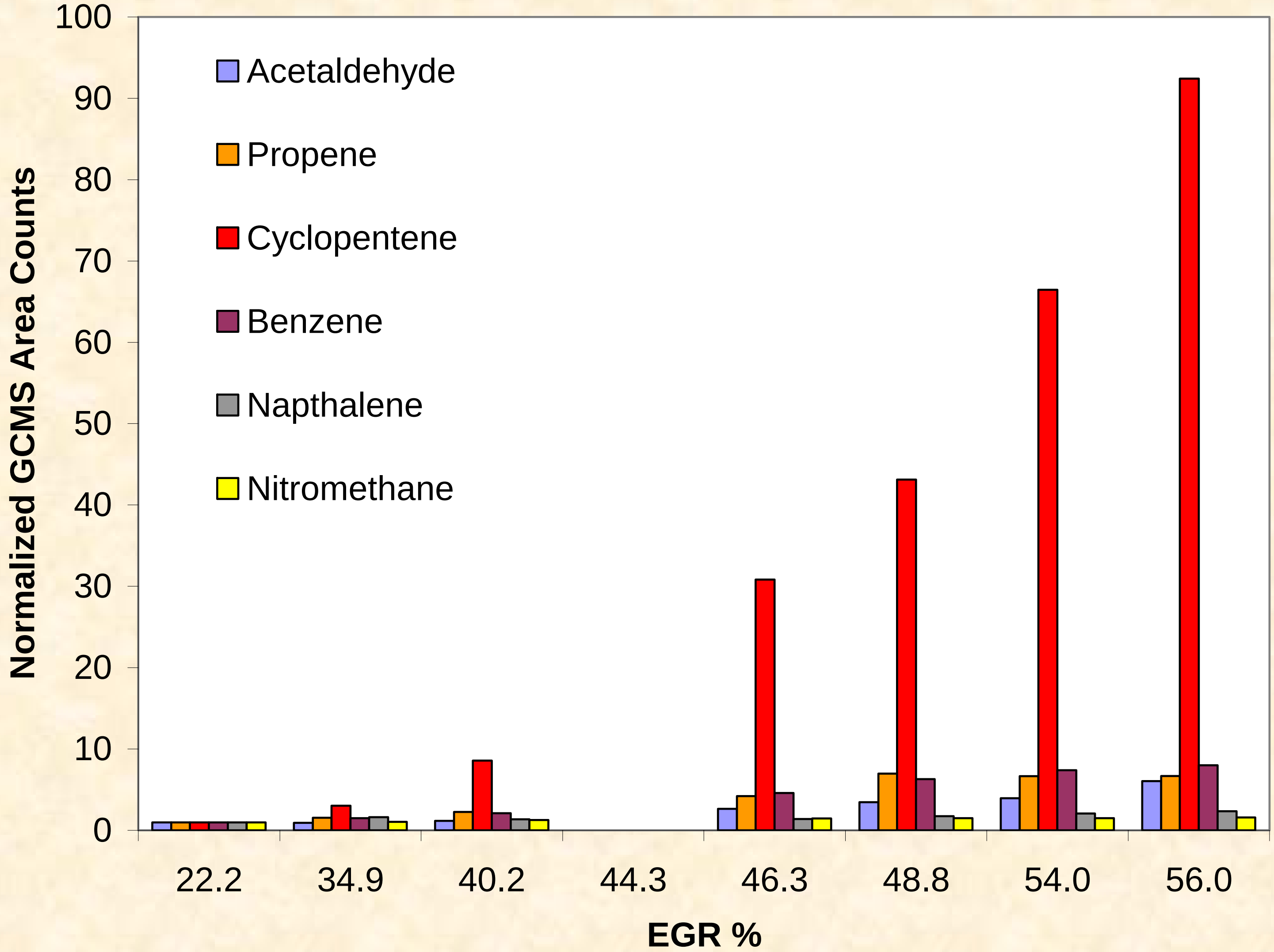
GC/MS analysis shows high EGR produces many short-chain HCs not present in the fuel



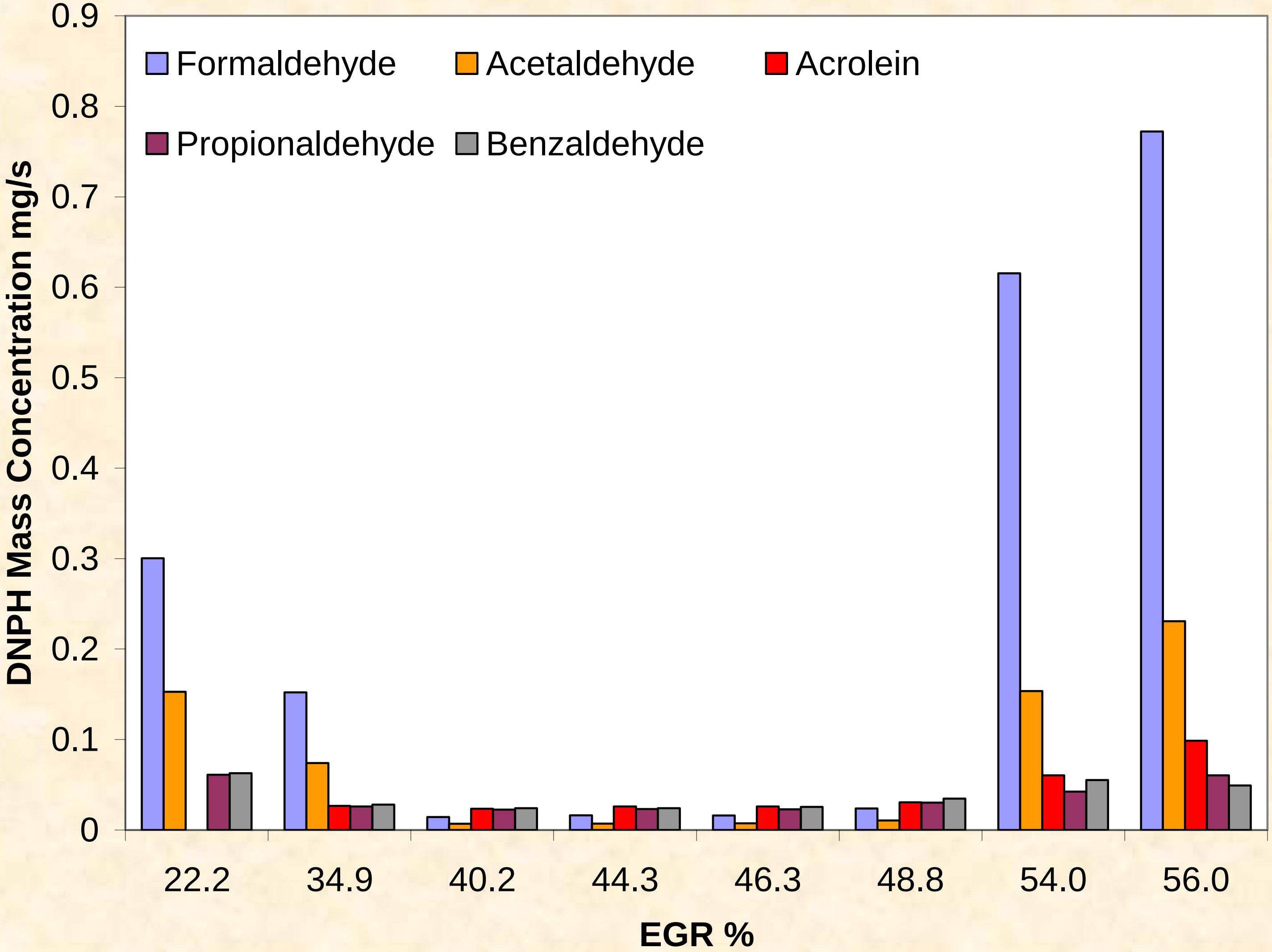
Comparison of nontraditional mode with OEM shows increase in fuel and short-chain HCs



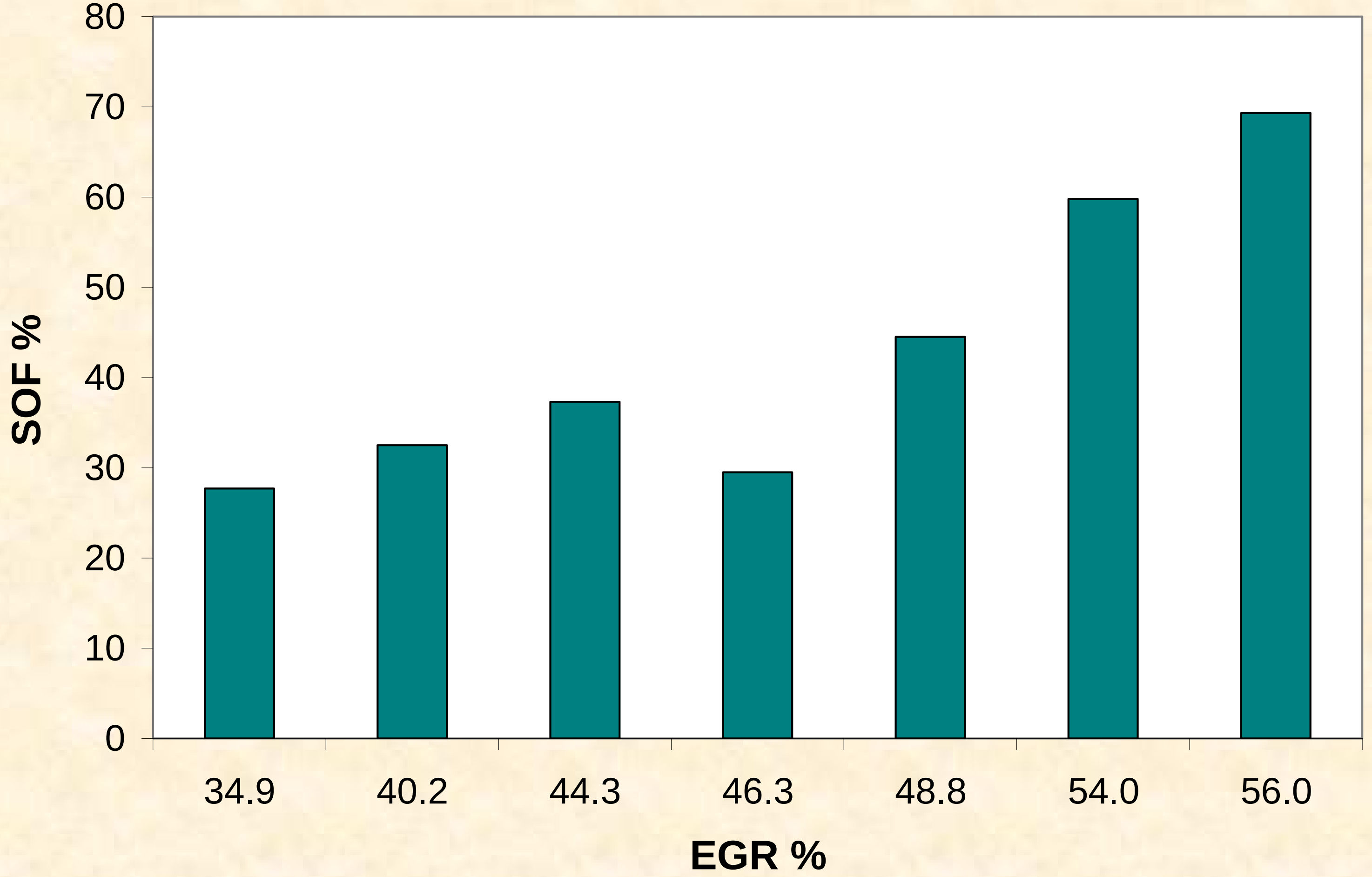
Partial oxidation products increase compared to fuel HCs as EGR increases



High EGR also exhibits high formaldehyde and acetaldehyde formation

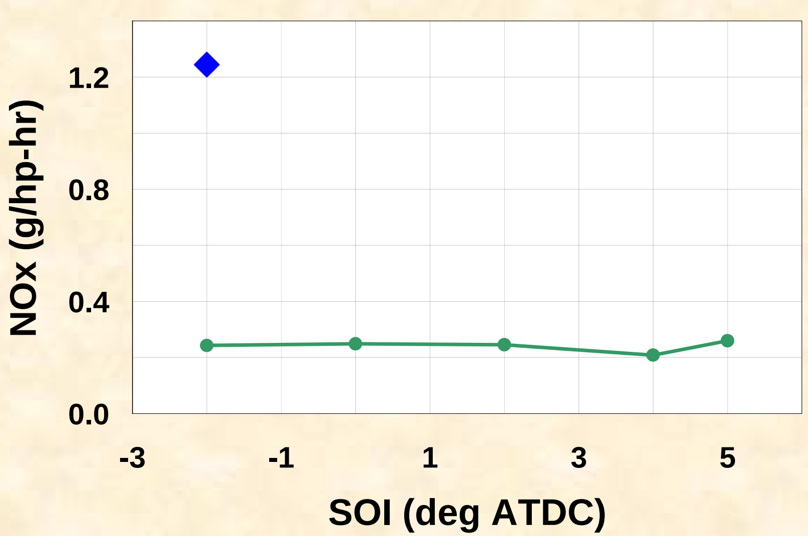


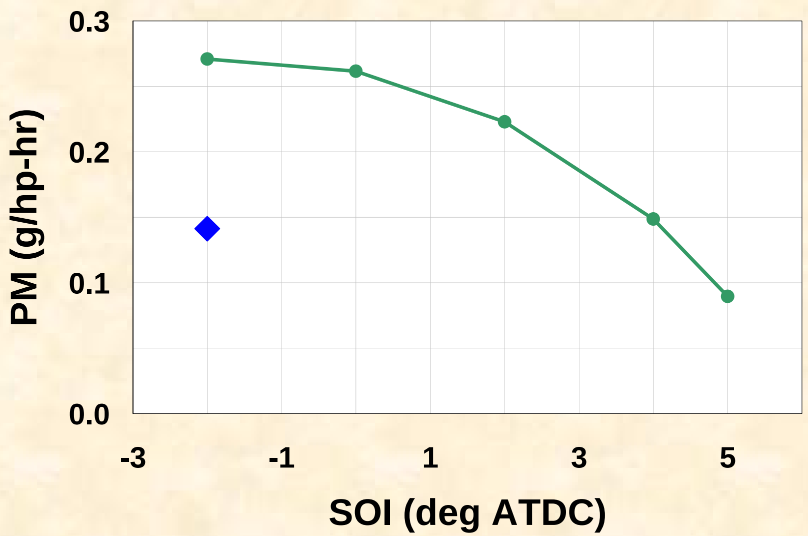
Soluble Organic Fraction (SOF) of particulate matter increases significantly at higher EGR levels

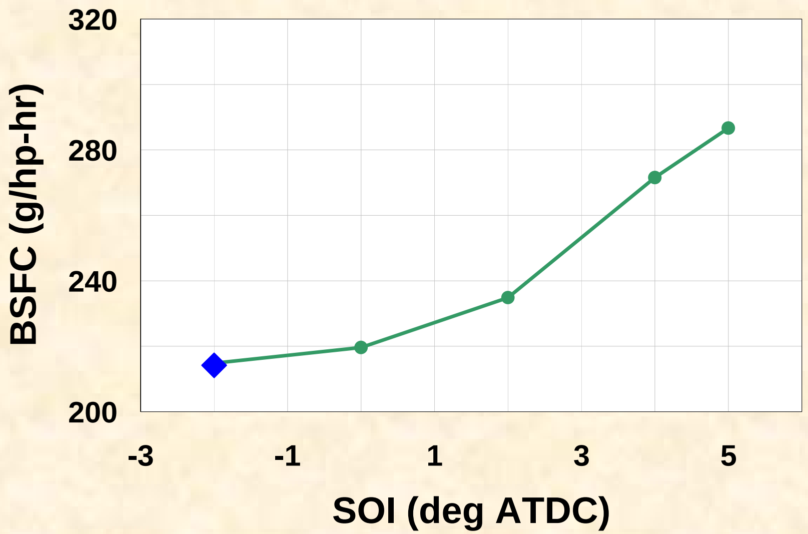


~30-40% SOF typical for "normal" operation of this engine

Lower engine-out emissions observed under low load with Approach Two

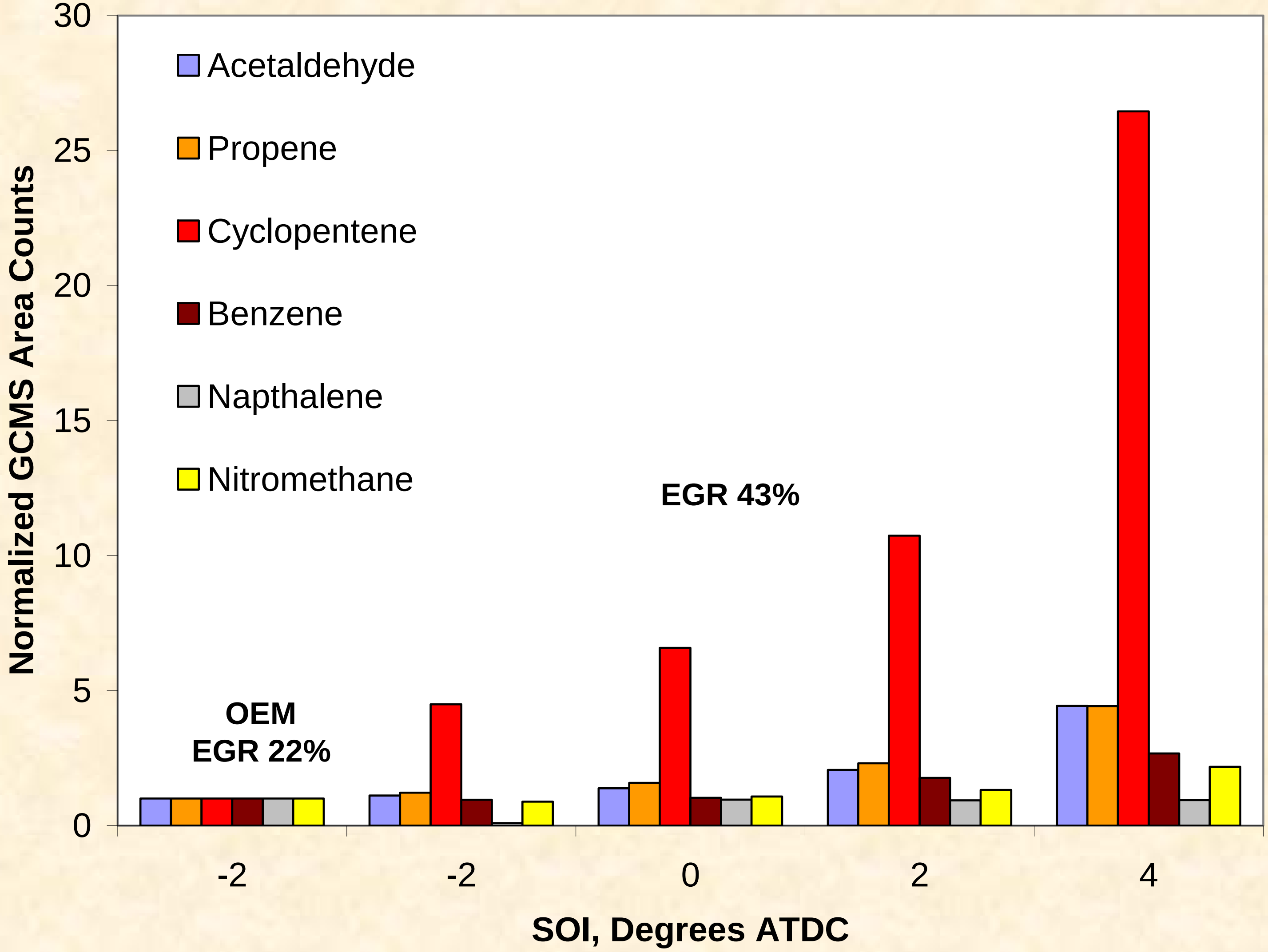




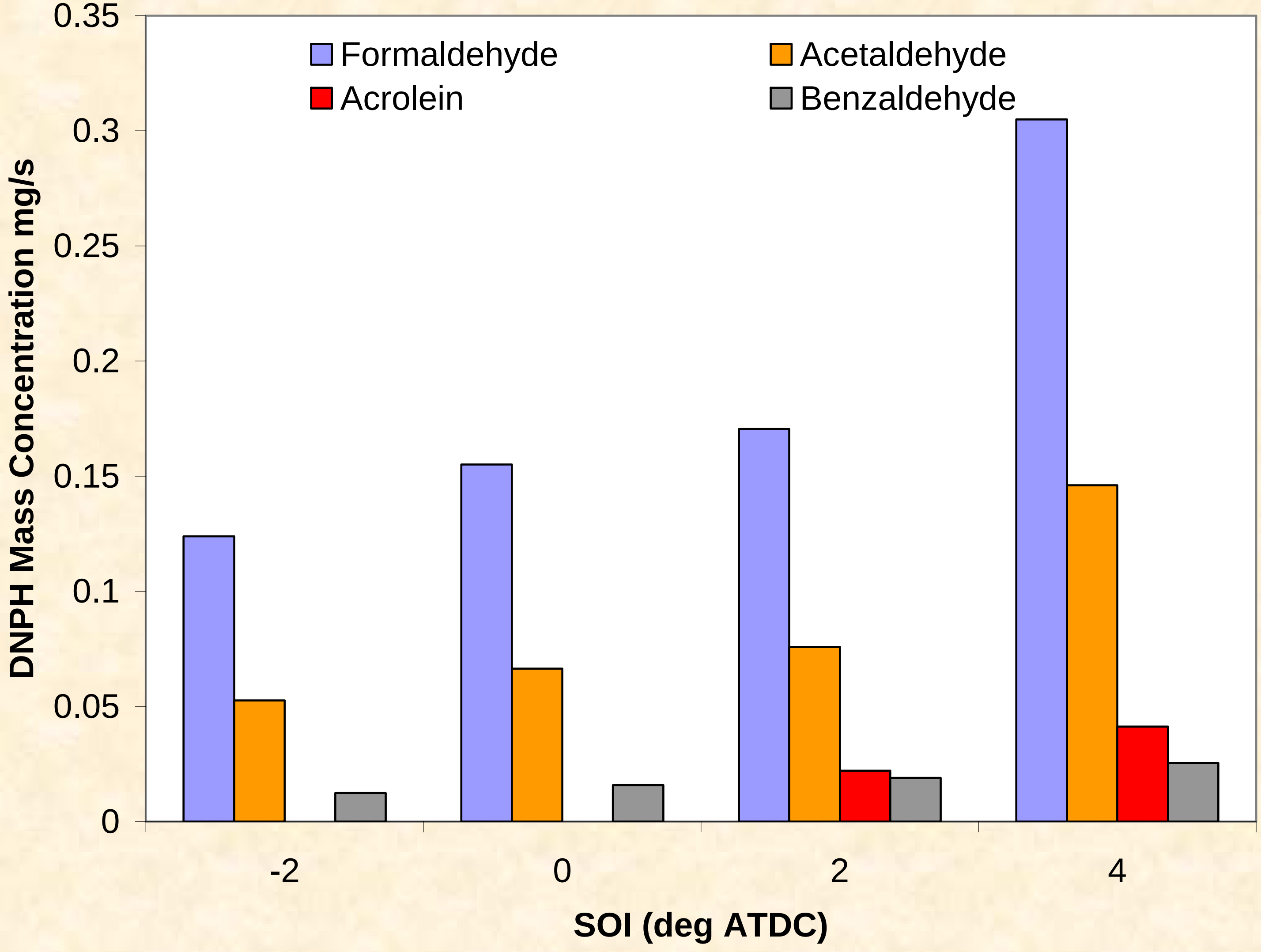


- 1500 rpm, 2.6 bar BMEP
- OEM EGR 24% (blue diamond)
- SOI sweep EGR 43%
- NOx and PM reduction less significant than in Approach One.

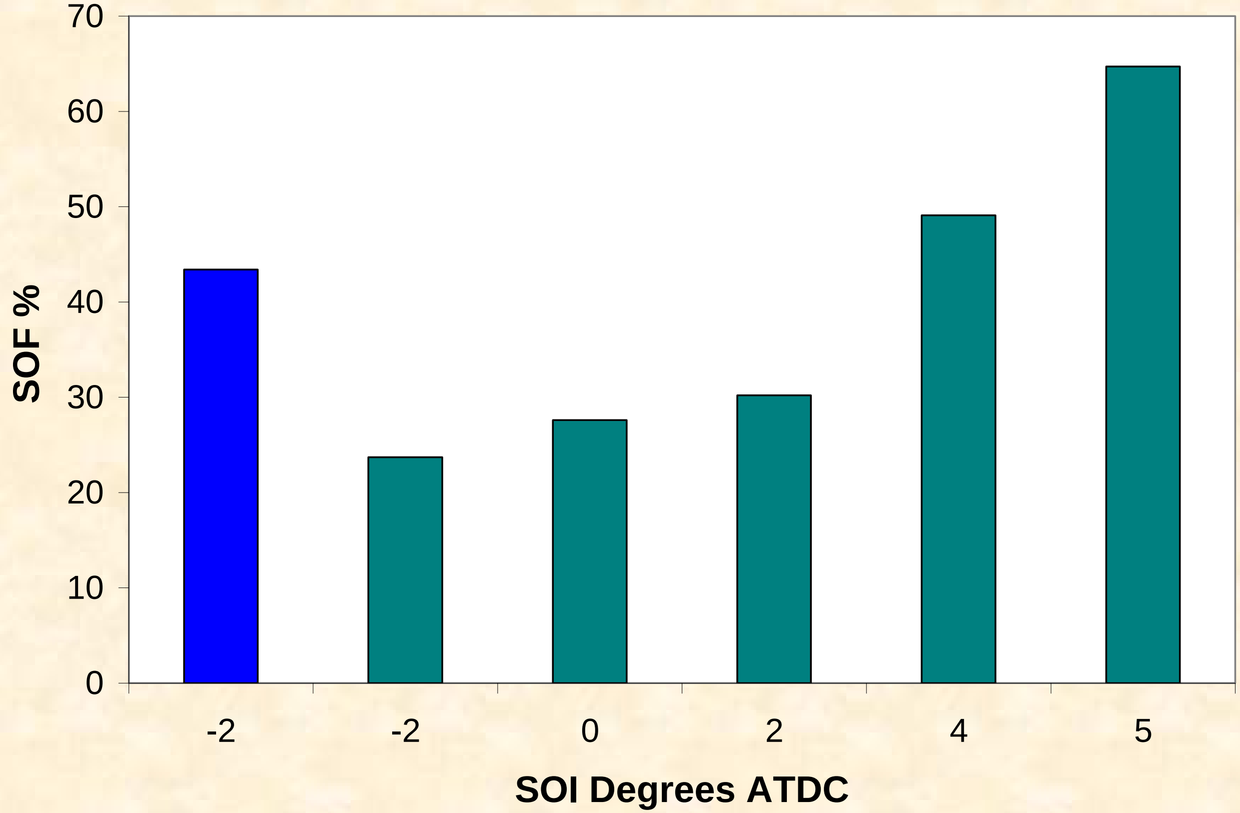
Increase in partial oxidation products not as significant as observed for Approach One



Aldehyde emissions were also less pronounced than with approach one.

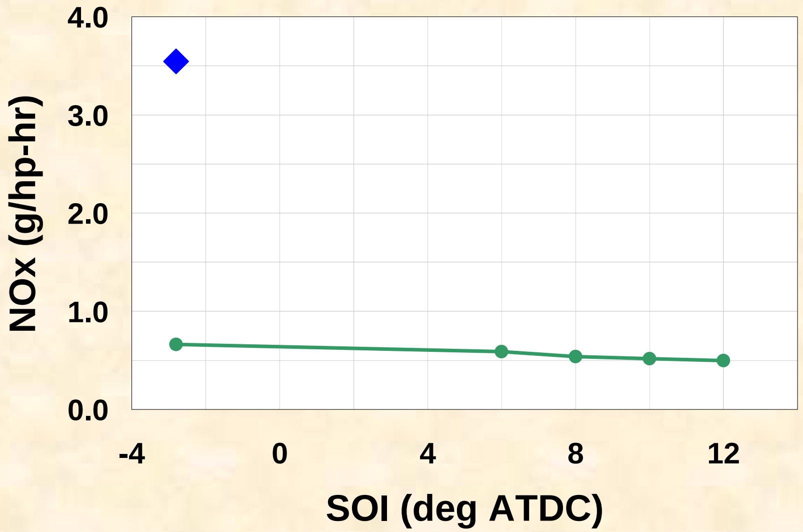


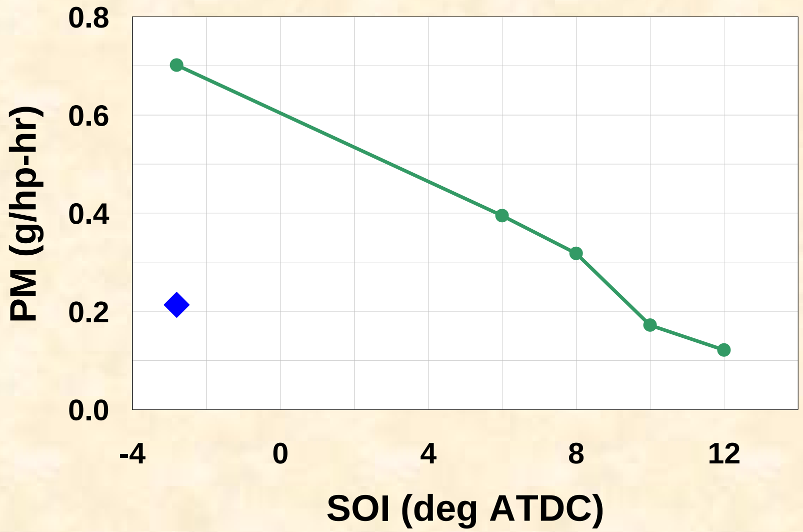
PM SOF increases significantly with retarding injection timing

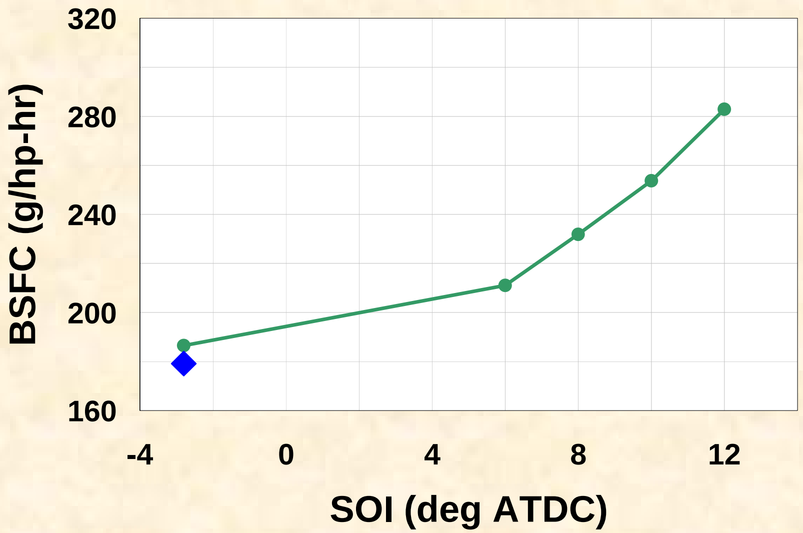


- **Increase in SOF similar to that seen for high EGR levels**
- **OEM EGR 22% (blue), Approach 2 EGR 43% (green)**

Lower engine-out emissions observed under medium load conditions using Approach Two







- **1500 rpm, 5.2 bar BMEP**
- **~50% load on this engine.**
- **OEM EGR 0% (blue diamond).**
- **SOI sweep EGR 24% (less than maximum possible at this engine condition).**

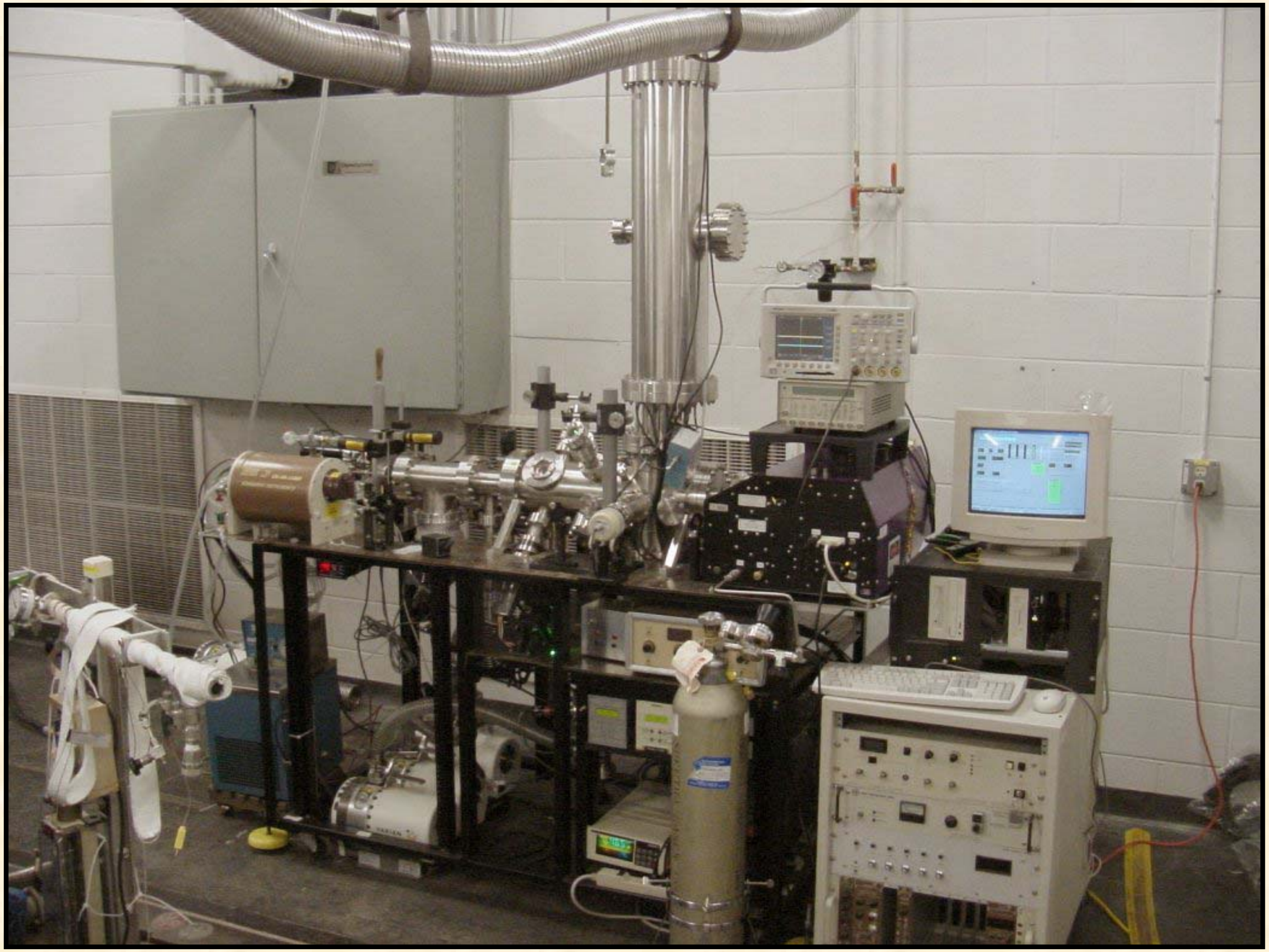
BNL staff collaboration to determine the nature of engine particles with a unique instrument.

SPLAT (Single Particle Laser Ablation Time of flight) Mass Spectrometer:

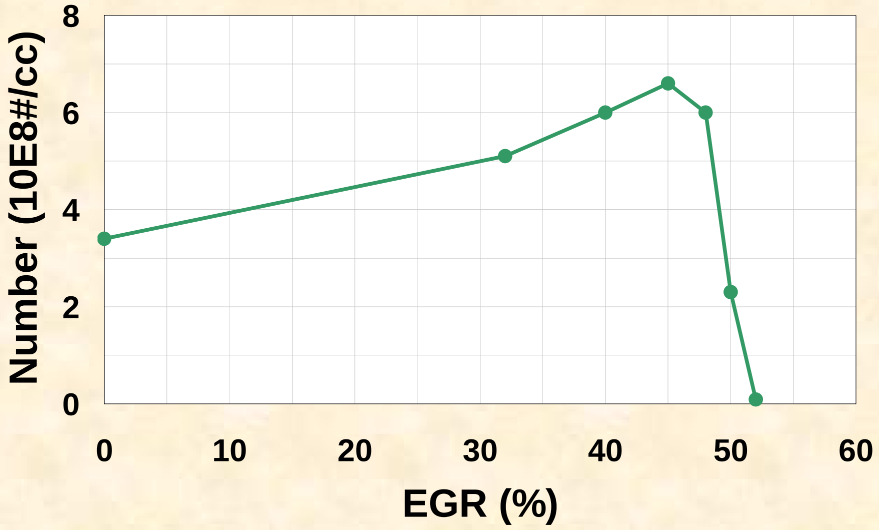
- **Measures size, density, and composition of particulates down to 50 nm**
- **Used during three week campaign at ORNL**
- **Investigated nontraditional combustion mode on 1.7 CDI engine with close-coupled oxidation catalyst**
- **Size and density changed when LTC modes when entered; PM mass disappears at highest EGR level**

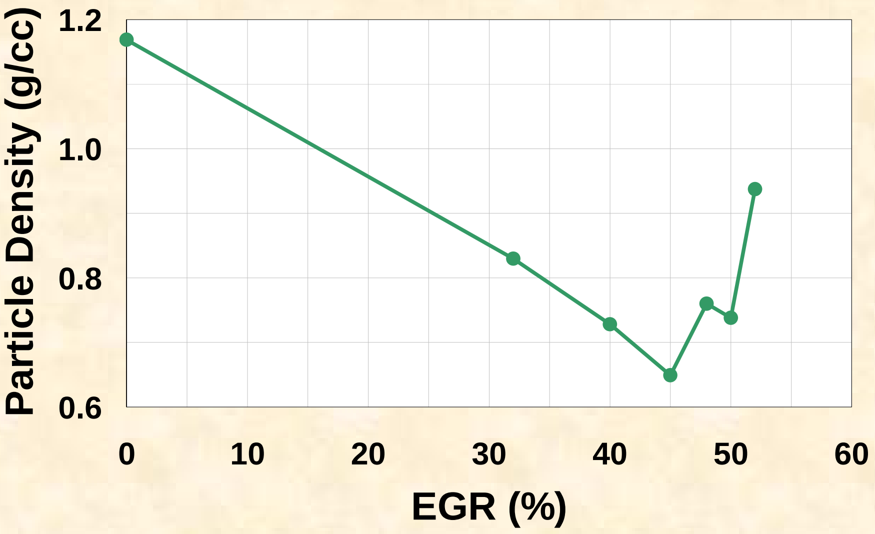
SPLAT instrument developed and operated by Brookhaven National Laboratory research staff.

A Study of Light Duty Diesel with SPLAT-MS



Concentration decreases and density increases in non-traditional combustion regimes





- **1500 rpm, “road load” (similar to previous data)**
- **Mercedes 1.7 L (same model, different engine)**
- **Oxidation catalyst installed**

Summary / Observations

- **Simultaneous reduction in NO_X and PM observed at both light and medium loads with penalty in efficiency.**
- **Detailed HC speciation shows presence of partial oxidation components.**
- **PM exhibits very high SOF.**
- **Penalty may be recoverable at some conditions.**
- **Other approaches show promise.**
- **Data analysis and continuing experiments ongoing.**

Future Work

- Removal of residual PM and HCs (e.g. using oxidation catalysts).
- Load (fuel penalty) recovery.
- HC and PM characterization of combustion regimes as well as “recovered” conditions.
- Combustion analysis based on 1/4 CAD cylinder pressure data.
- Other methods of achieving low NOx low PM.
- Effects of fuel formulation on non-traditional modes.
- Thermodynamic analysis of non-traditional combustion regimes (next FY)