# Assessment of a Laser-Induced Incandescence Sensor for Real-Time Particulate Emissions Measurement

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- **Motivation**
  - Support increased technical productivity by developing process technology to more effectively and efficiently estimate concentrations of particulate matter (PM) in Diesel engine exhaust
  - This will enable the further development of emissions compliant engine products
    - Develop efficient and effective soot management and dosing strategy for DPF's (diesel particulate filters)
    - Develop effective engine calibrations for reducing PM levels at different engine conditions
    - Facilitate further development of emissions compliant engine products

# LII Development For Soot Emissions Characterization

- **Background**
  - Currently “Gravimetric PM Sampling System” is used to measure PM, which is not real-time
  - Laser Induced Incandescence (LII) is a real time, non-intrusive soot measurement techniques for rapid characterization of diesel particulate emissions
  - The LII method has the advantage of being able to sample and report particulate emissions from either the direct exhaust or from a dilution tunnel facility

# LII Development and Evaluation

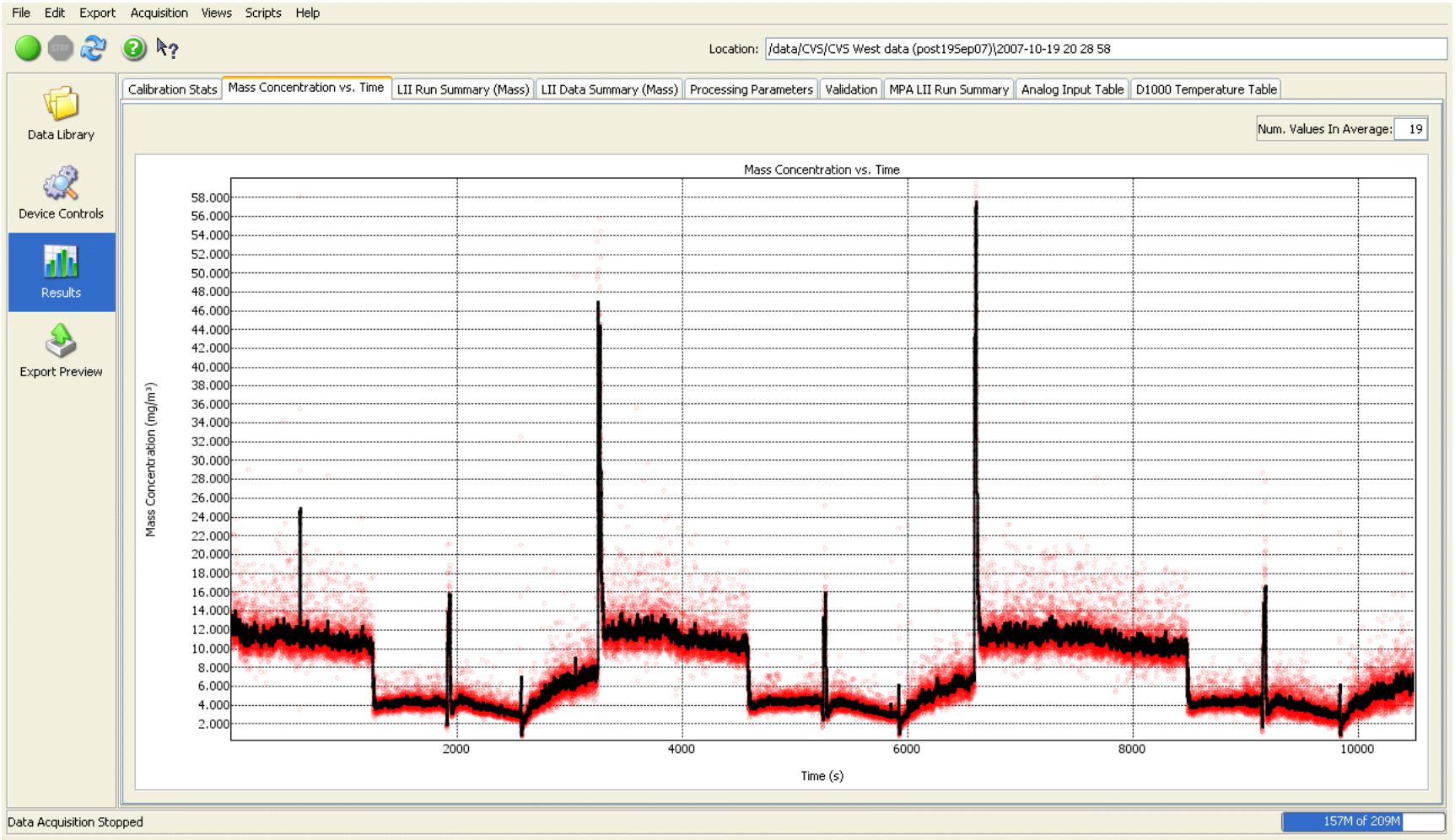
- Artium LII-200 Instrument
  - LII technique evaluated was developed and patented by NRC Canada
  - Artium Technologies Inc. commercialized LII-200
  - LII-200 has 4 sub-systems:
    - LII power supply
    - Gas Flow Controller
    - LII Sensor Head
    - On-board computer with AIMS software (Advanced Instrument Management System)

- LII Advantages and Features
  - Measures real-time soot concentration (ppb & $mg/m^3$)
  - Sample dilution not required, can be used to estimate soot volume fraction (SVF) in raw exhaust
  - Insensitive to presence of other emission particulate or gas species
  - Data recording frequency: 1–20 Hz and connectivity with host data acquisition system
  - Ease of operation, portable to transport and maintenance free working
  - Absolute intensity calibration
  - High resolution ($0.01mg/m^3$) and high repeatability (2-5%)

# LII Development and Evaluation

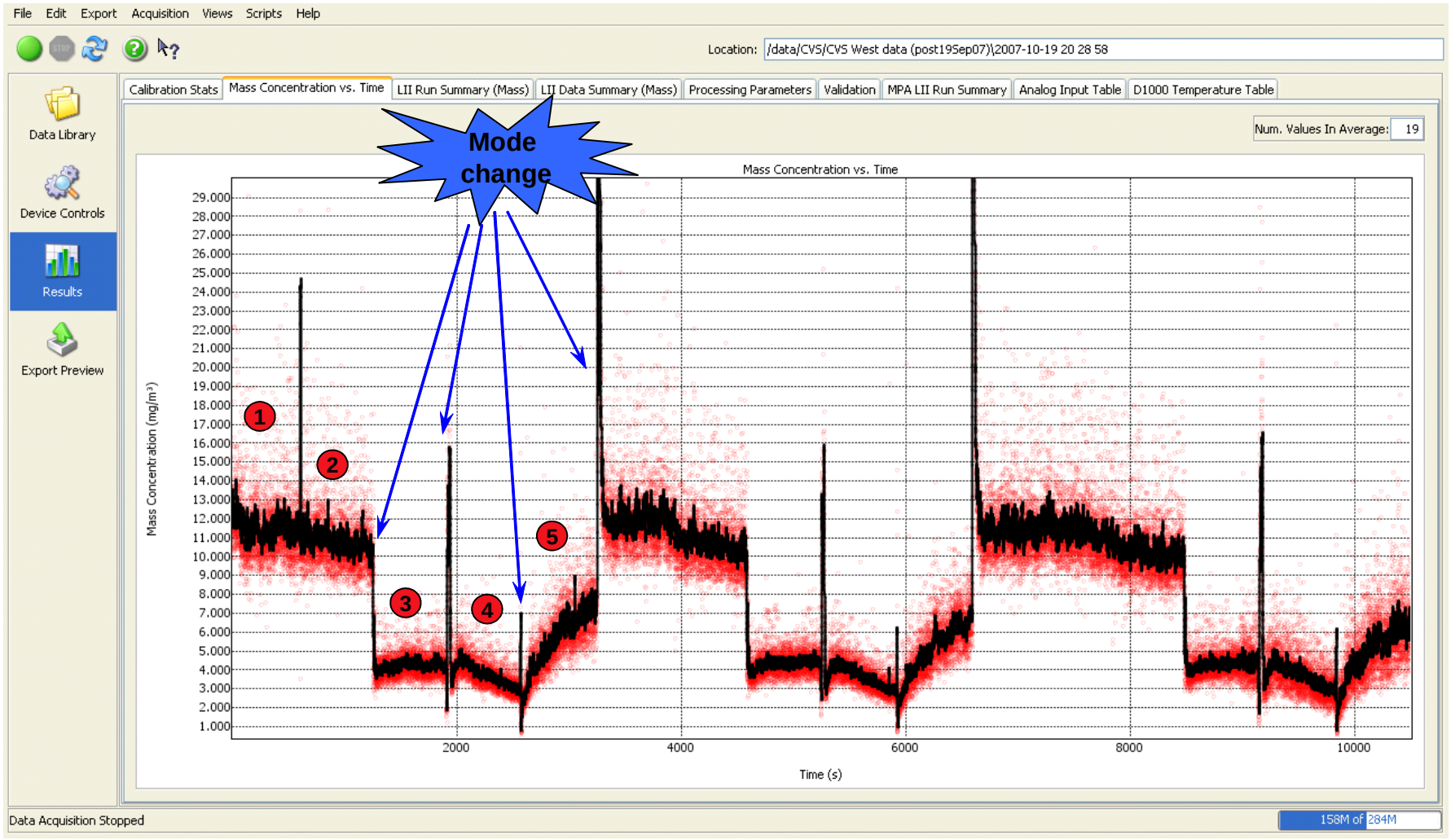
- **Approach**
  - In the present investigation, the LII instrument was evaluated extensively at the Constant Volume Sampling (CVS) emission laboratory at the **Cummins Technical Center**, where a Cummins' standard gravimetric PM measurement system is available as a comparative standard
  - Collaborative efforts between **Cummins Inc.** and **Artium Technologies, Inc.** are ongoing with the goal of advancing the LII capability for measuring real time soot at pre- and post DPF locations at transient and steady state engine operating conditions

# Example Data from the Artium LII 200 Instrument



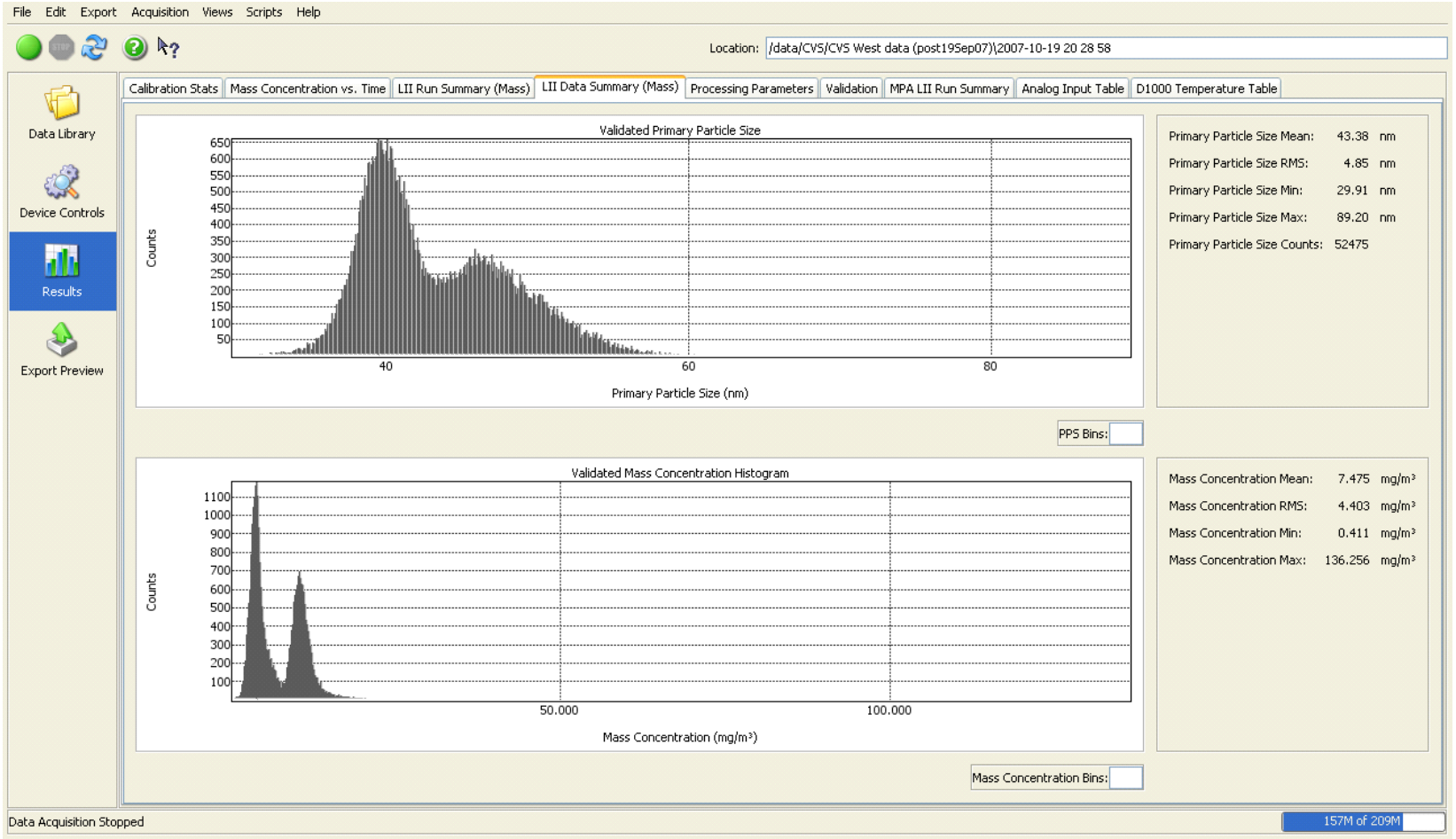

***Soot mass concentration (mg/m³) vs. time (s)***

# Example Data from the Artium LII 200 Instrument



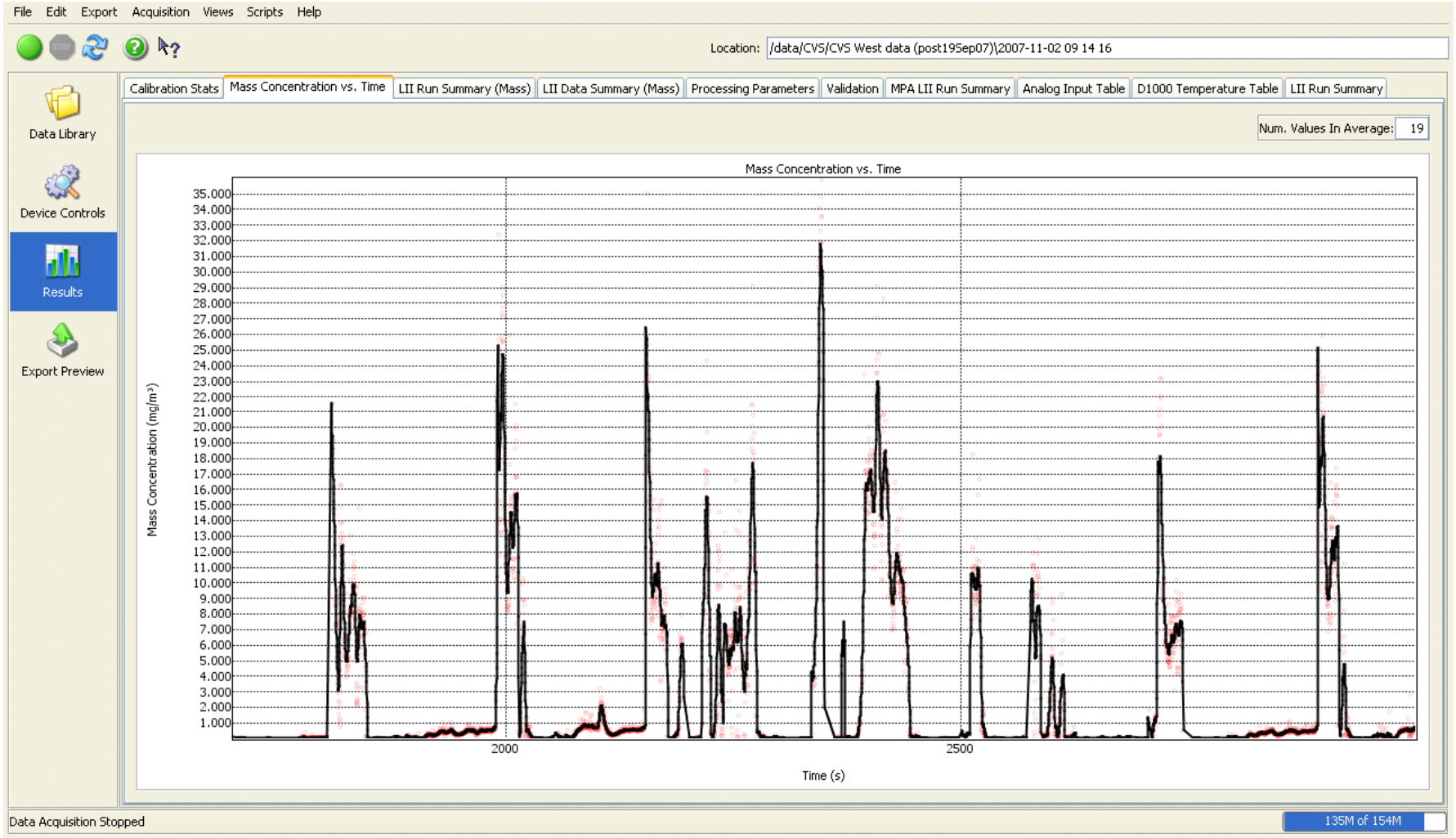

***Five-mode steady-state tests with 3 repeats***

# Example Data from the Artium LII 200 Instrument



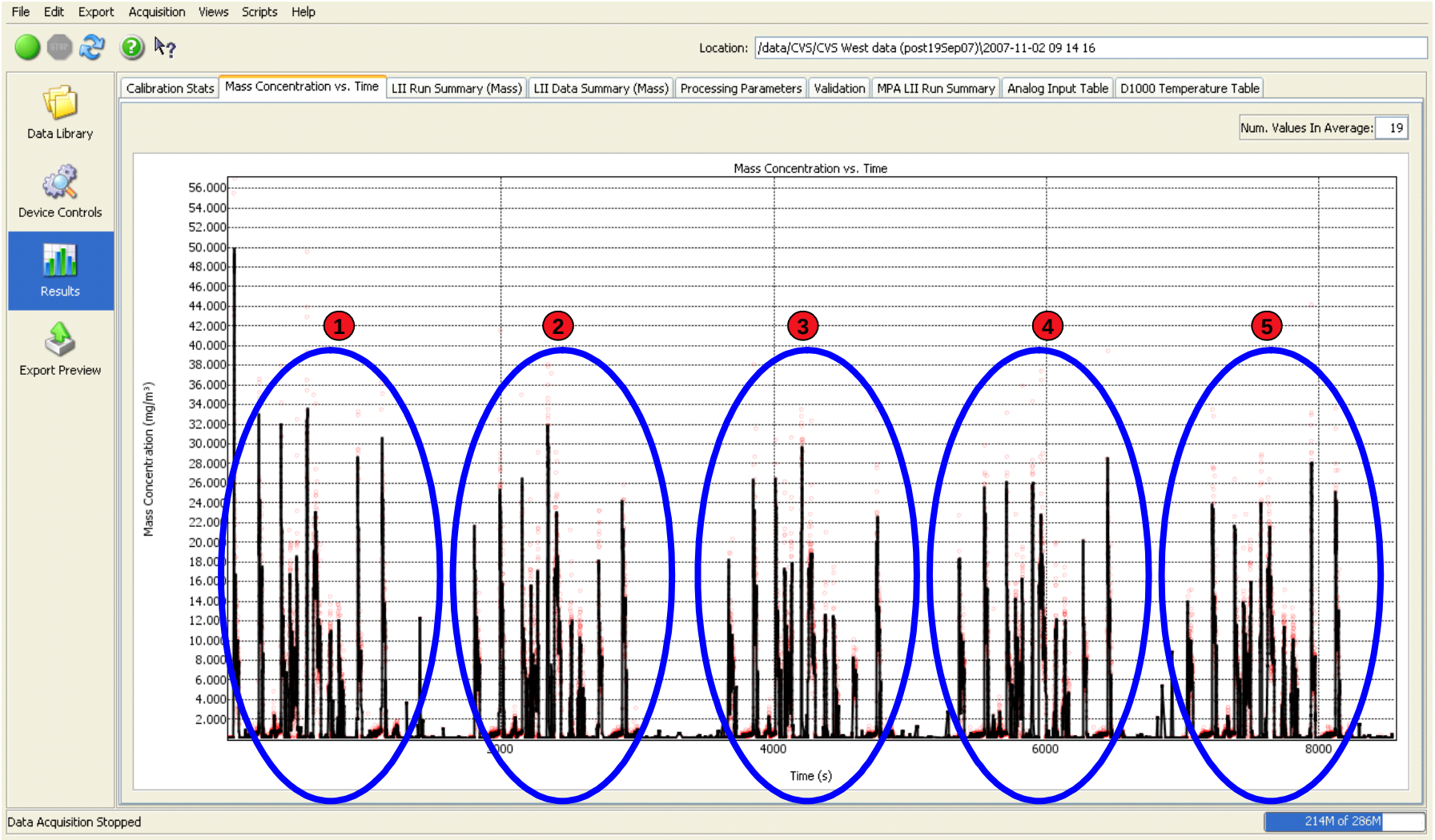

***Data summary [Top – validated particle size (counts vs. size); Below – validated mass concentration histogram (counts vs. mg/m³) ]***

# Transient Response to Engine Soot Emissions



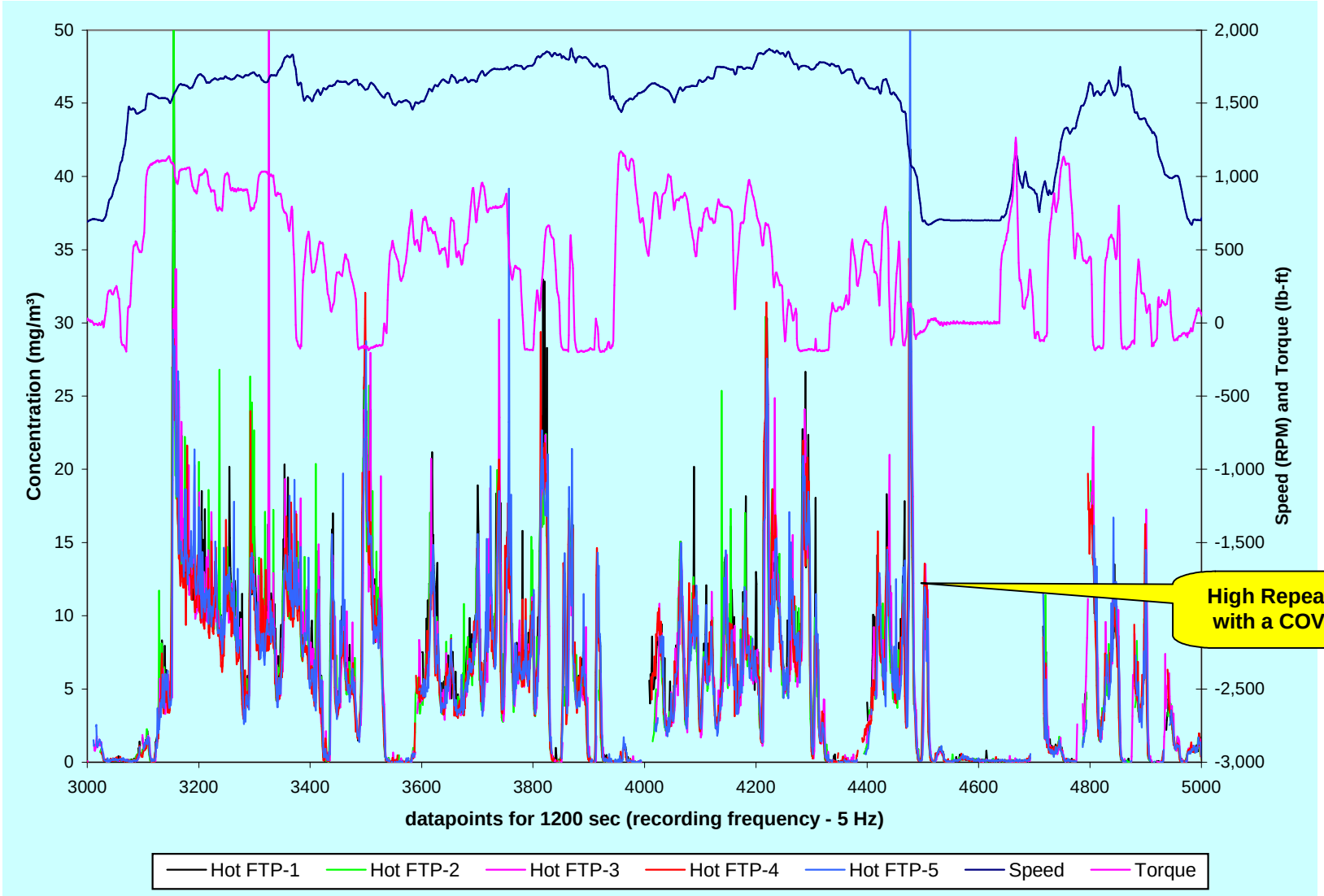

***LII transient test response, hot FTP cycle (20 min.)***

# Repeated Transient Cycles




***Five repeats of LII transient test response, hot FTP cycle (20 min.)***

# Transient Cycle Data

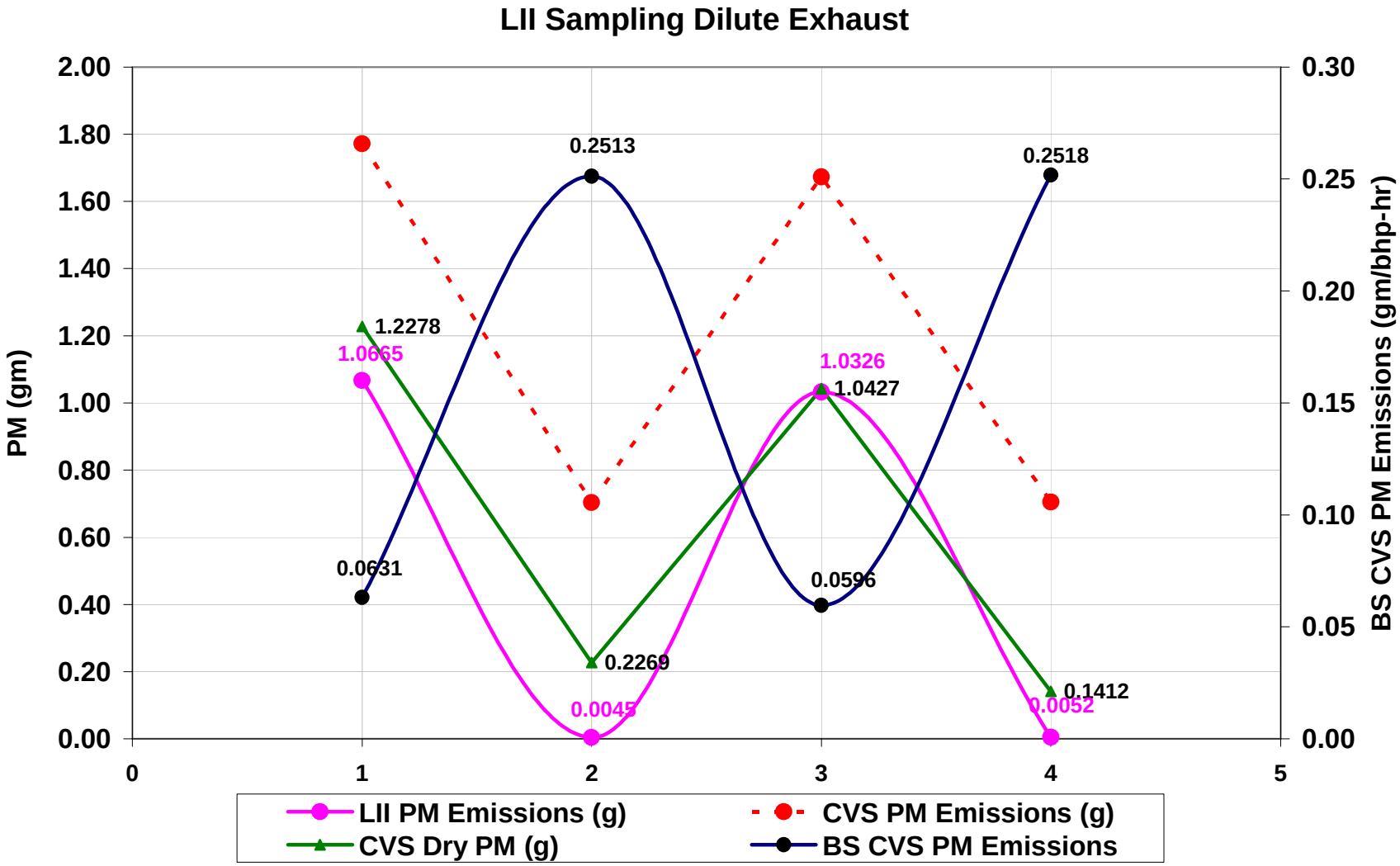


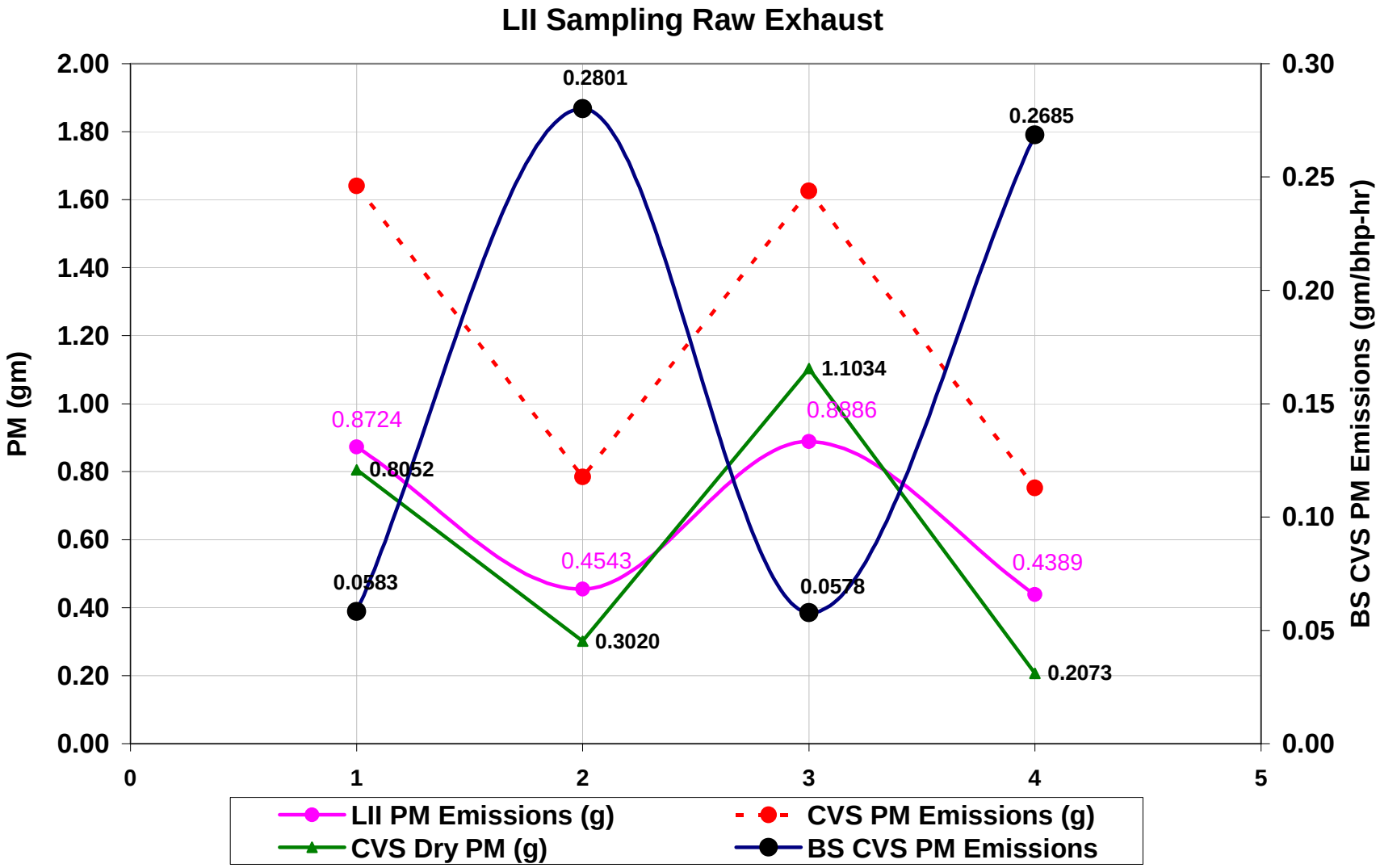

***5 repeats of LII response vs. speed and torque for transient tests, hot FTP cycle (20 min.), Coefficient of Variance (COV) of 4%.***

# Comparisons to Gravimetric Sampling

Red- Total CVS PM Emissions from Gravimetric  Green –Volatiles and other material extracted leaving only dry soot

LII measures only dry soot






- At high load, in both diluted and raw exhausts, LII measures about 95% of Dry PM from diluted exhaust measured by the Cummins Gravimetric method

# Summary

- LII current status:
  - The LII technique is capable of monitoring PM emissions by estimating soot concentration and primary particle size
  - The currently implemented improvements to the LII resulted in repeatable measurements of soot volume fraction from the LII with a short term Coefficient of Variation (COV) of 3-7% for steady state cycles and a COV of 3-5% for FTP transient cycles for the equivalent gravimetric PM level ranging from 0.01 to 1.00 g/bhp-hr
  - The correlation between time-integrated LII signals and the standard gravimetric PM measurement system was found to be robust with a correlation regression coefficient ranging from 96%-99.8%

## Summary

- LII has been tested for **Steady States, Transients, Raw Exhaust, PM Trap-out**
- LII reported similar readings compared to Dry PM measured using Cummins gravimetric method at higher load conditions, and much lower to about 0.9 to 1.2 times at low load conditions
- LII-200 has shown readiness for Prime Testing