

Fuel-Air Mixing Explored with Optical Probes, Tomography and Large Eddy Simulations

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Infrared LEDs for Fuel Concentration Measurements

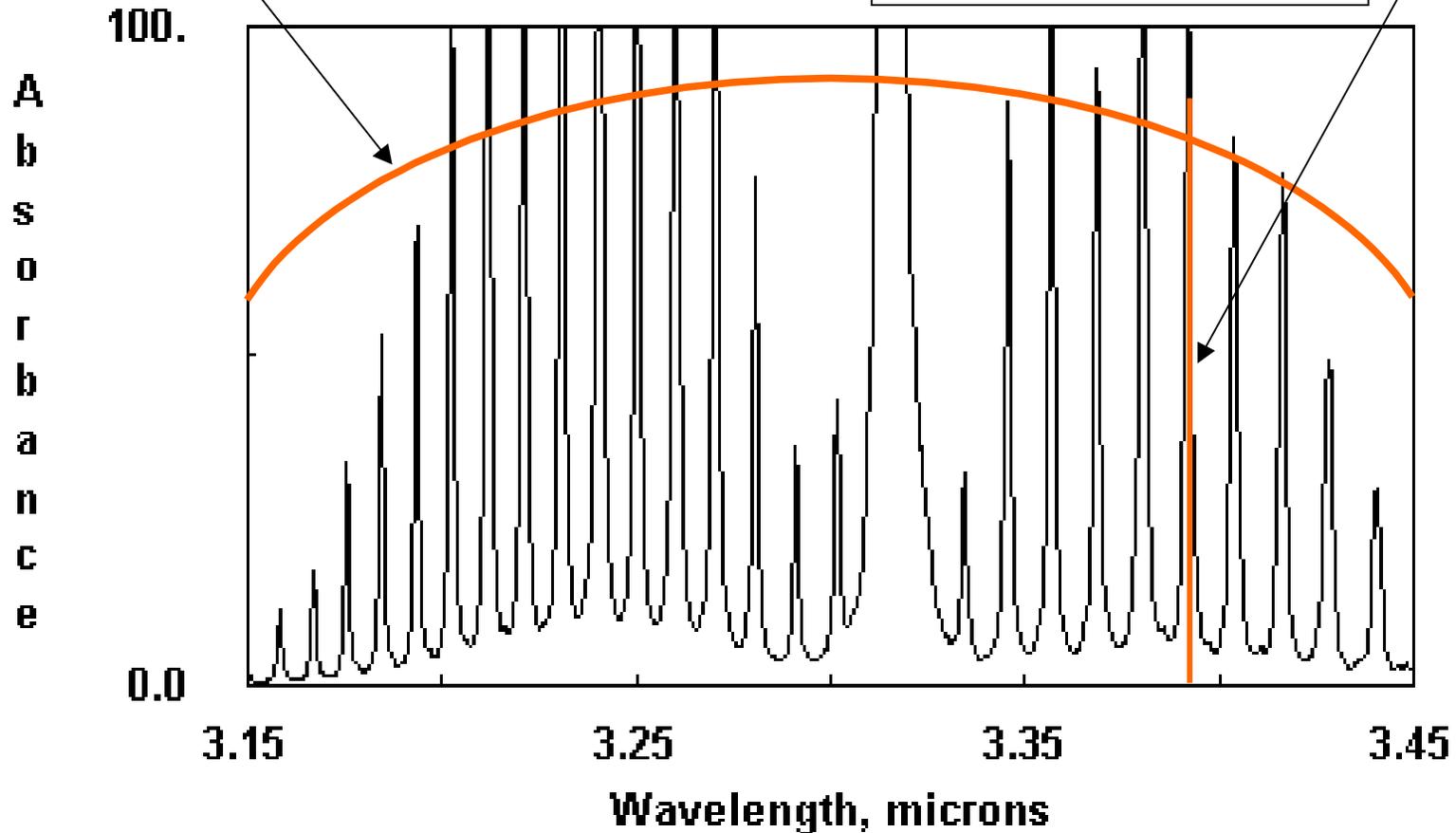
- LEDs Are More Compact and Less Expensive than Conventional Lasers
- Fuel is More Transparent to IR LED than to IR Laser - for Some Applications (High Pressure, Long Pathlength) this is an Advantage
- Developing “Broad-Band Absorption Coefficient” for Quantitative Measurement of Methane Concentration with IR LED

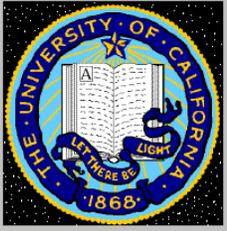


IR LED Is Not “Opaque” to CH₄ Absorption at 10 Bar

LED Output
(Arbitrary Units)

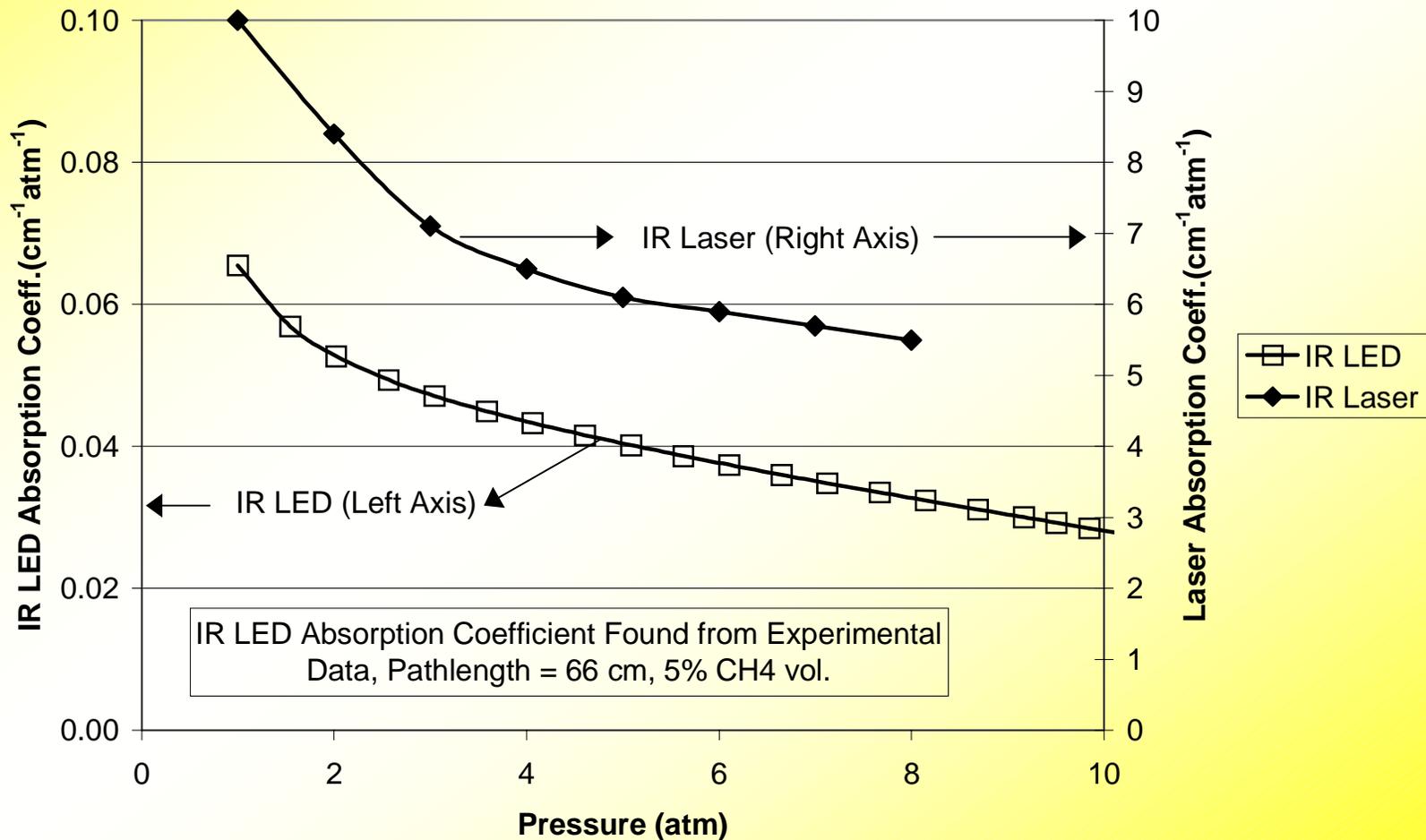
3.392 μm Laser Output
(Arbitrary Units)

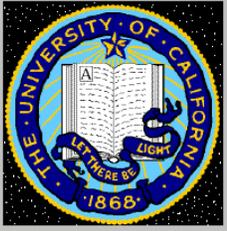




IR LED Absorption Shows a Consistent Pressure Dependence

Absorption Coefficient vs. Pressure, IR LED and 3.392 μm Laser





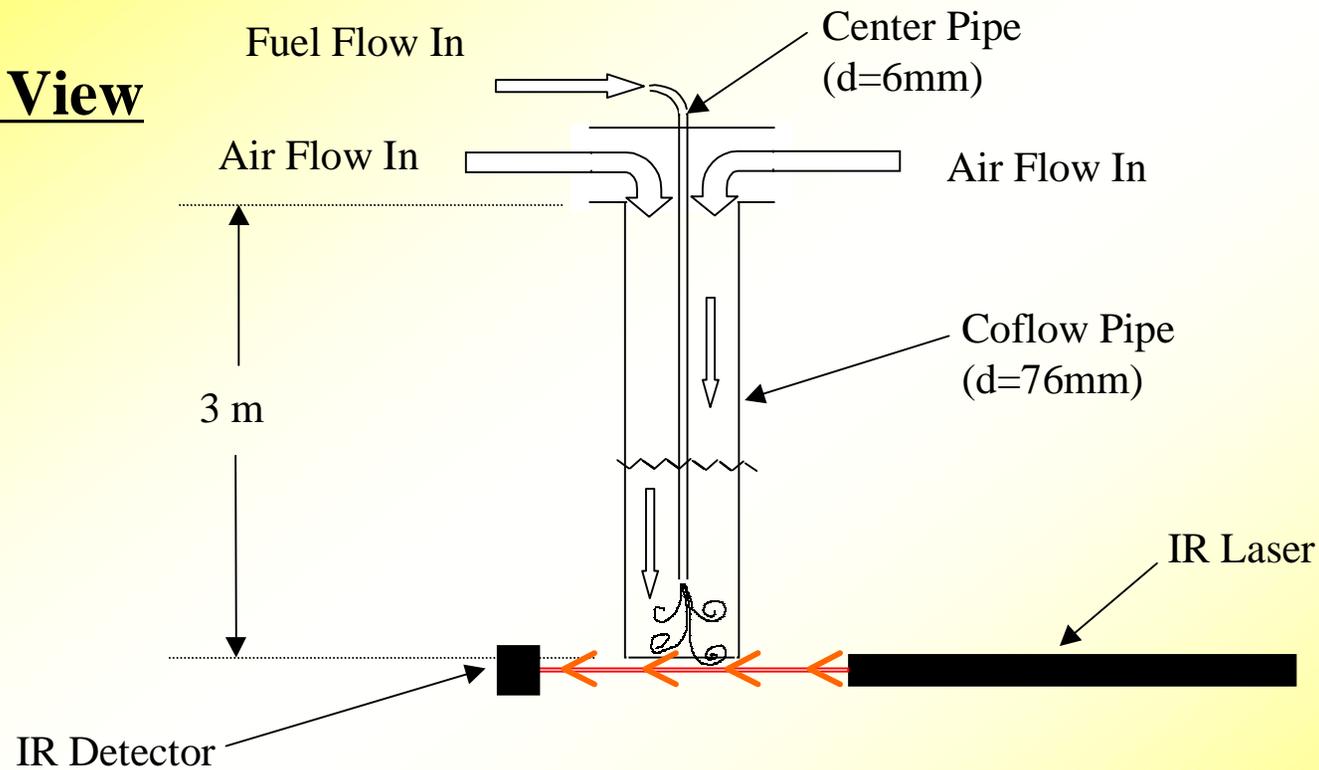
Fuel-Air Mixing Study in a Coannular Pipe Flow

- Fully Developed Turbulent Flow
- Focus on Tomographic Reconstruction of both the Average and RMS Radial Profile of Fuel Concentration
- Genetic Algorithm Applied for this Numerical Reconstruction
- LES Modeling of System Compared with Experimental Results

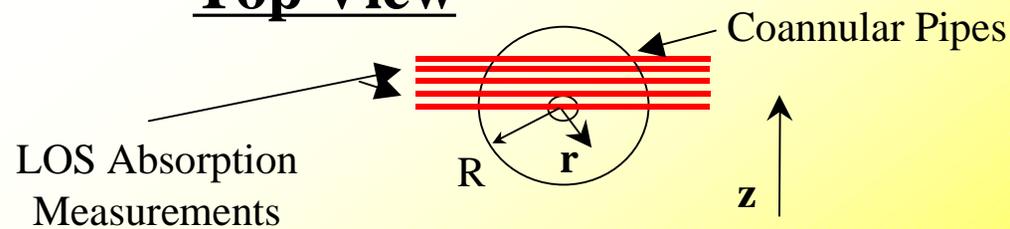


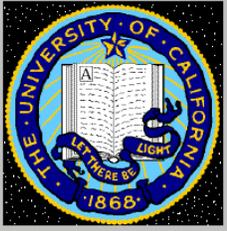
Setup Focus: High Re, Fully Developed Flow

Side View

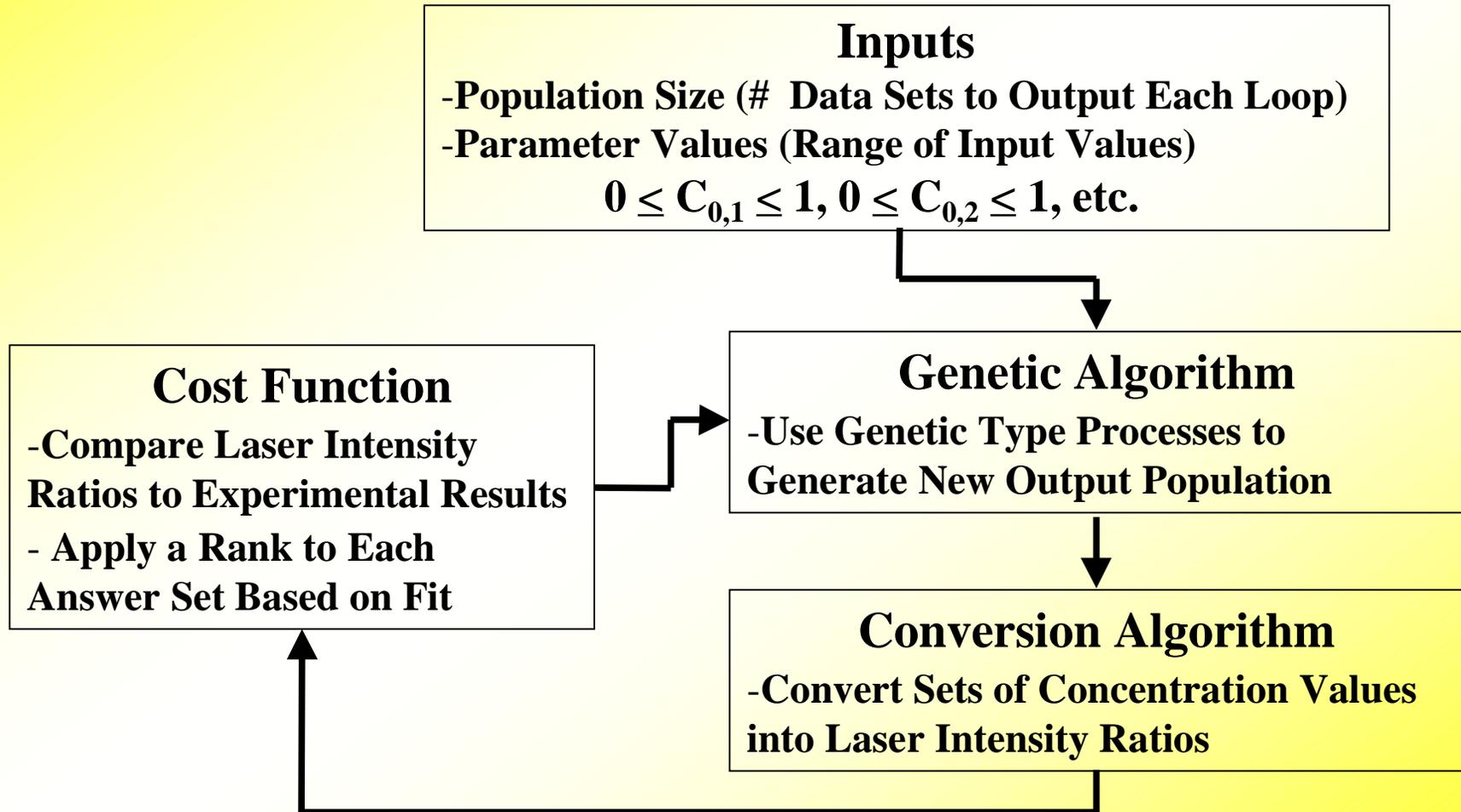


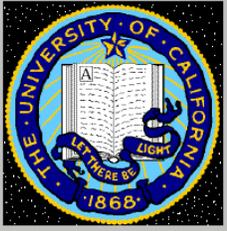
Top View



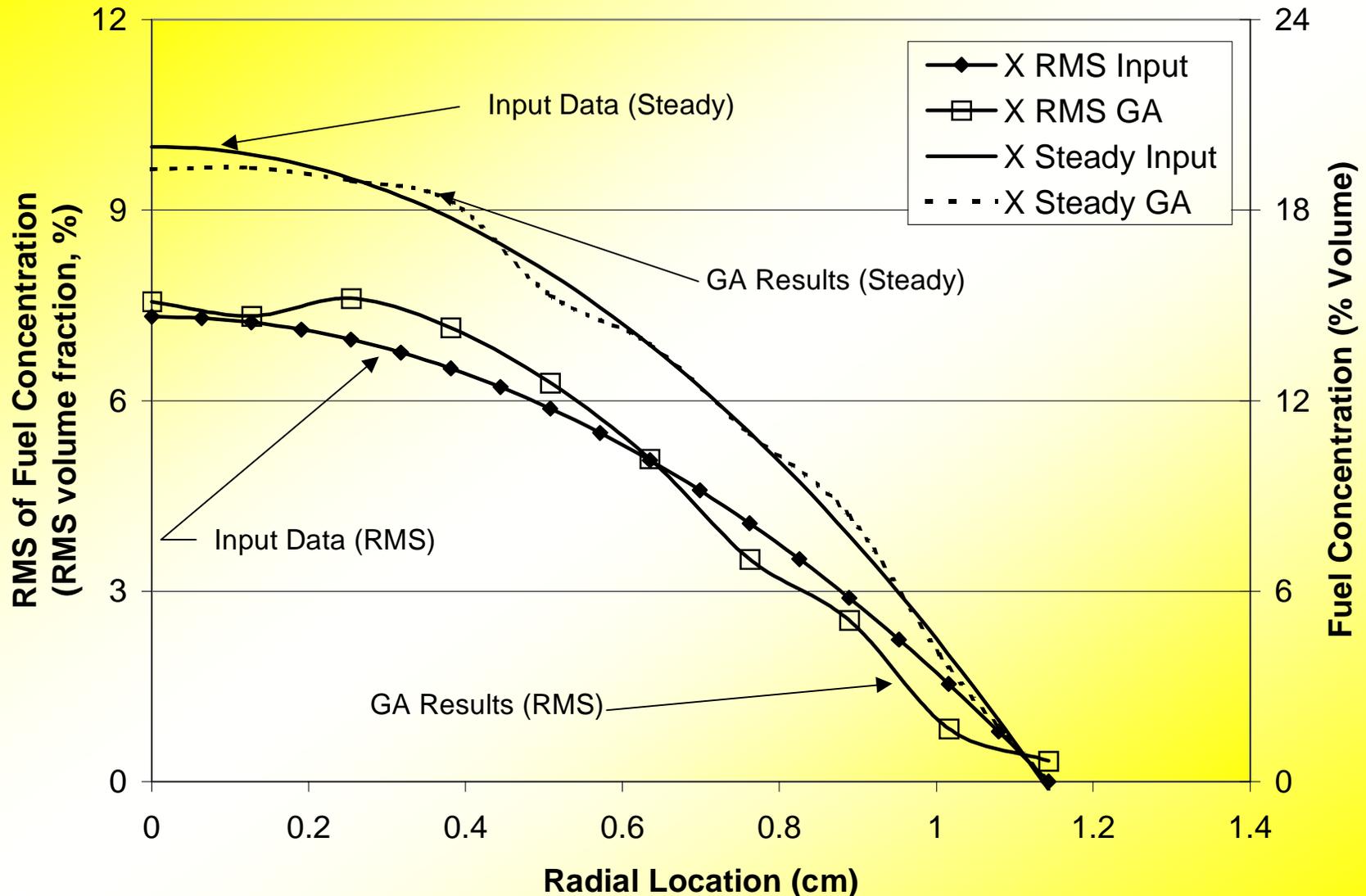


Genetic Algorithm for Tomographic Reconstruction





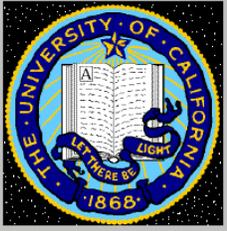
Time-Varying Parabolic Profile Test Case for GA – Results are Promising



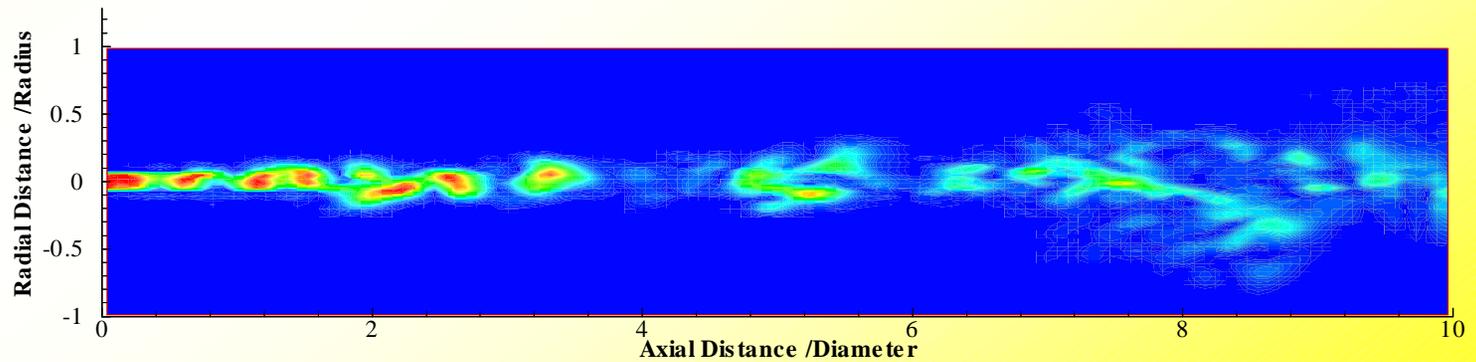
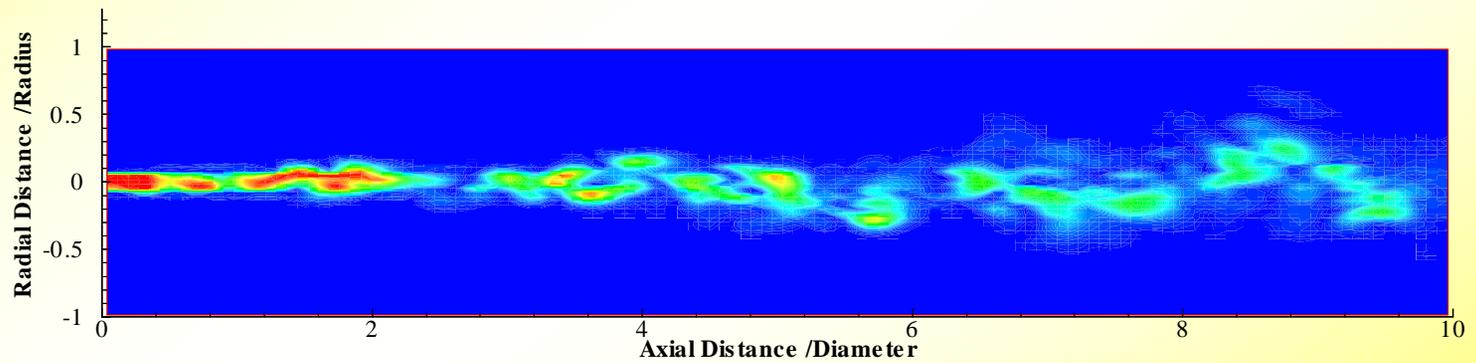
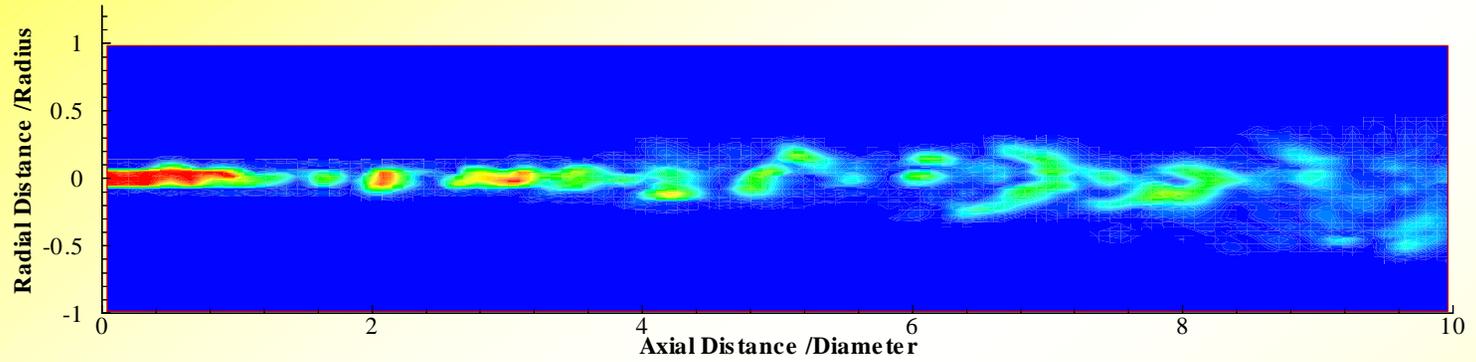


Time-Dependent, 3-D LES

- Time Dependent Fluctuations in a Combustor Often Lead to Poorer Performance
- In Most Combustion Models (RANS), Time Resolved Details Not Predicted
- LES Gives Time Resolution, but Requires More Computer Cycles
- LES May Become the Preferred Model in the 21st Century (Retains Temporal Aspects of Flow, while Requiring Less Computational Effort than DNS)



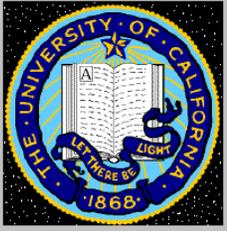
LES Snapshots of CH₄ Distribution



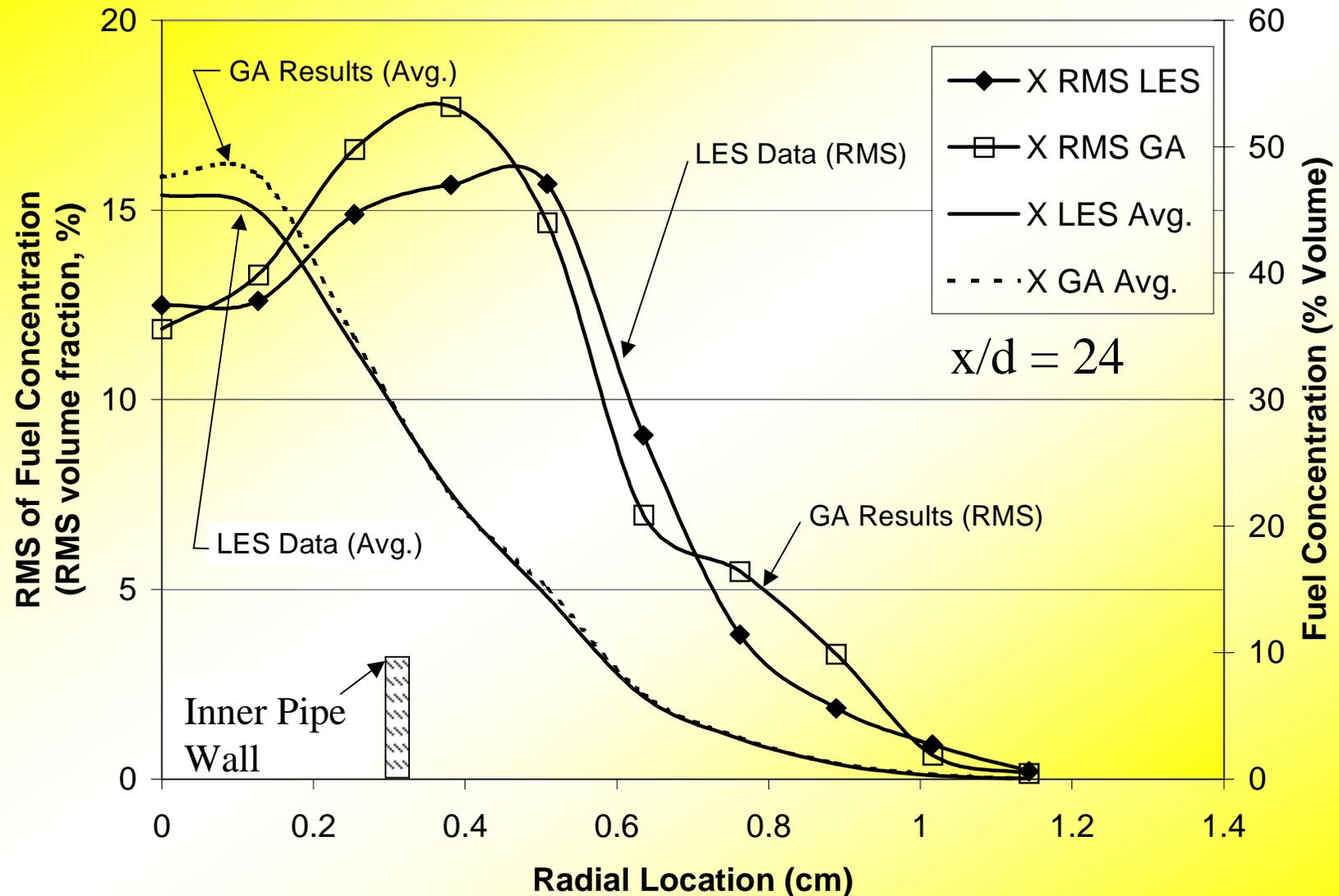


USE of LED to Generate GA “Test Case”

- To Further Test The Performance of the GA Program, a LOS Absorption Test Data Set was Generated from the Predictions of the LES Model
- A Set of LES Results for Time-Dependant Fuel Concentration Profile was Used to Generate a LOS Absorption Profile for the GA Reconstruction Program
- The Results of the GA Program are then compared with the LES Results, that Were Used as a Starting Point

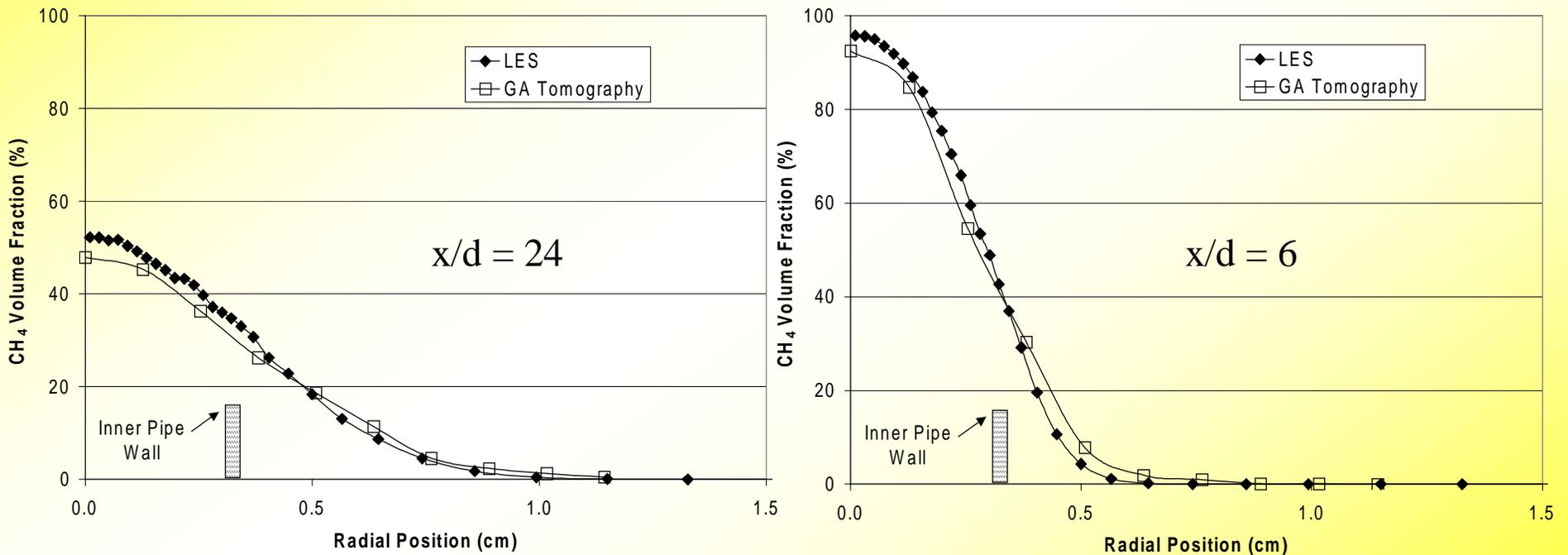


LES Output & GA Results from LES Data (i.e., Synthetic Input Data)





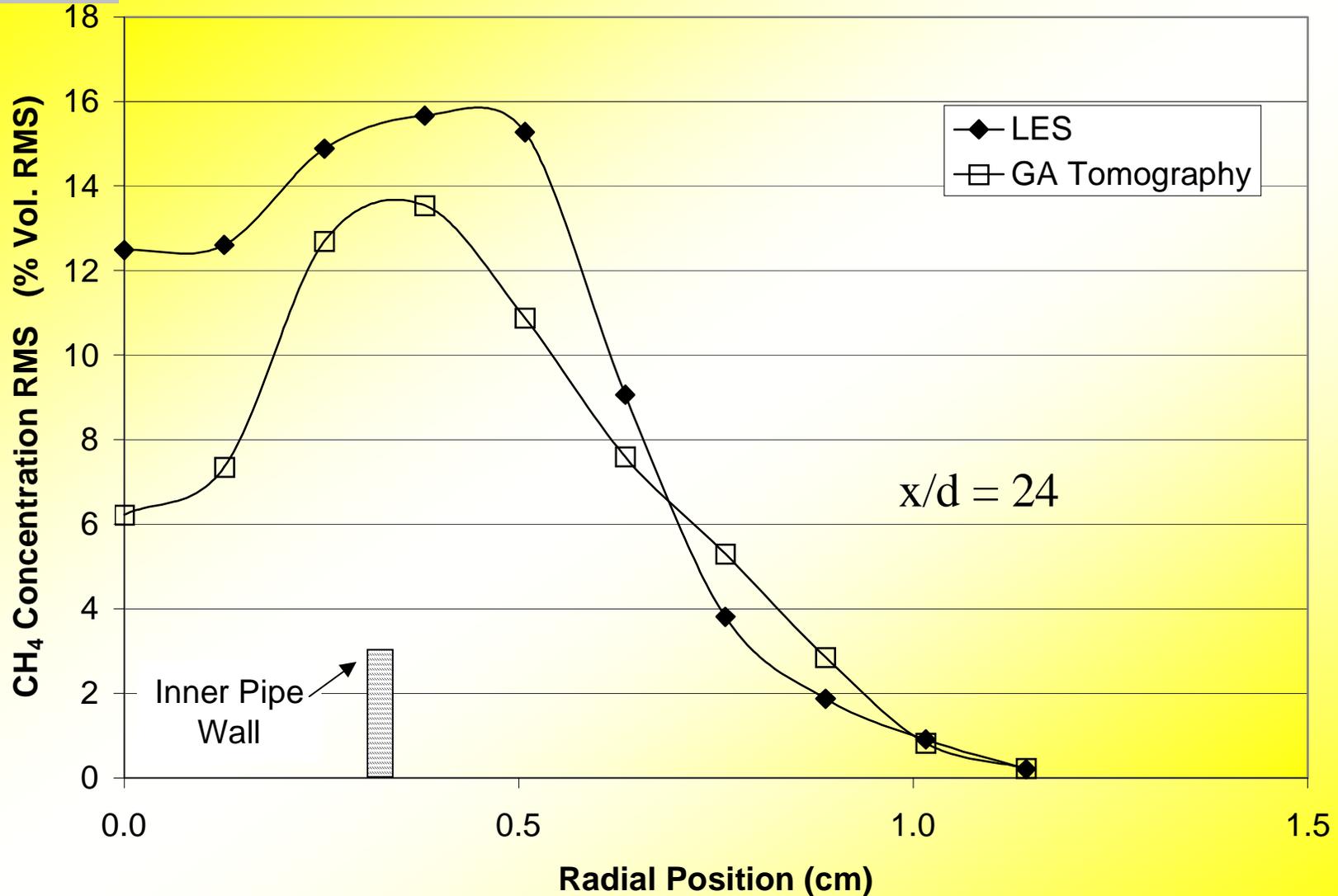
Time-Averaged LES Results Show Agreement with GA-Reconstructed Experimental Data





X_{CH_4} RMS, LES vs. GA (Expt.)

Also Shows Reasonable Agreement





Summary

- IR LED Can Quantify Fuel Concentrations (Even at High Pressure)
- Hence, Potential for IR LED as Low-Cost, On-Engine Diagnostic
- Tomographic Reconstruction – GA-Based Approach has Reproduced Time-Averaged and (Importantly) RMS Concentration Profile, this is a new Result!
- LES – Model Results Agree Well with Experiment, Showing Promise for Other Applications of LES



Work in Progress

- Use IR LED to Quantify the Mixing of a LPM injector (10 Bar Optical Access Combustor at Solar Turbines, Inc.)
- Modify Genetic Algorithm Code to Reconstruct Non Axis-Symmetric Coannular Pipe Flow Mixing
- More on Theory of X_{CH_4} RMS Reconstruction – Show Mathematically (if Possible) What Amount of Time-Dependant Information is Recoverable from the LOS Measurements