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Diesel engine control based on structure-borne noise

(FVV No. 1075)

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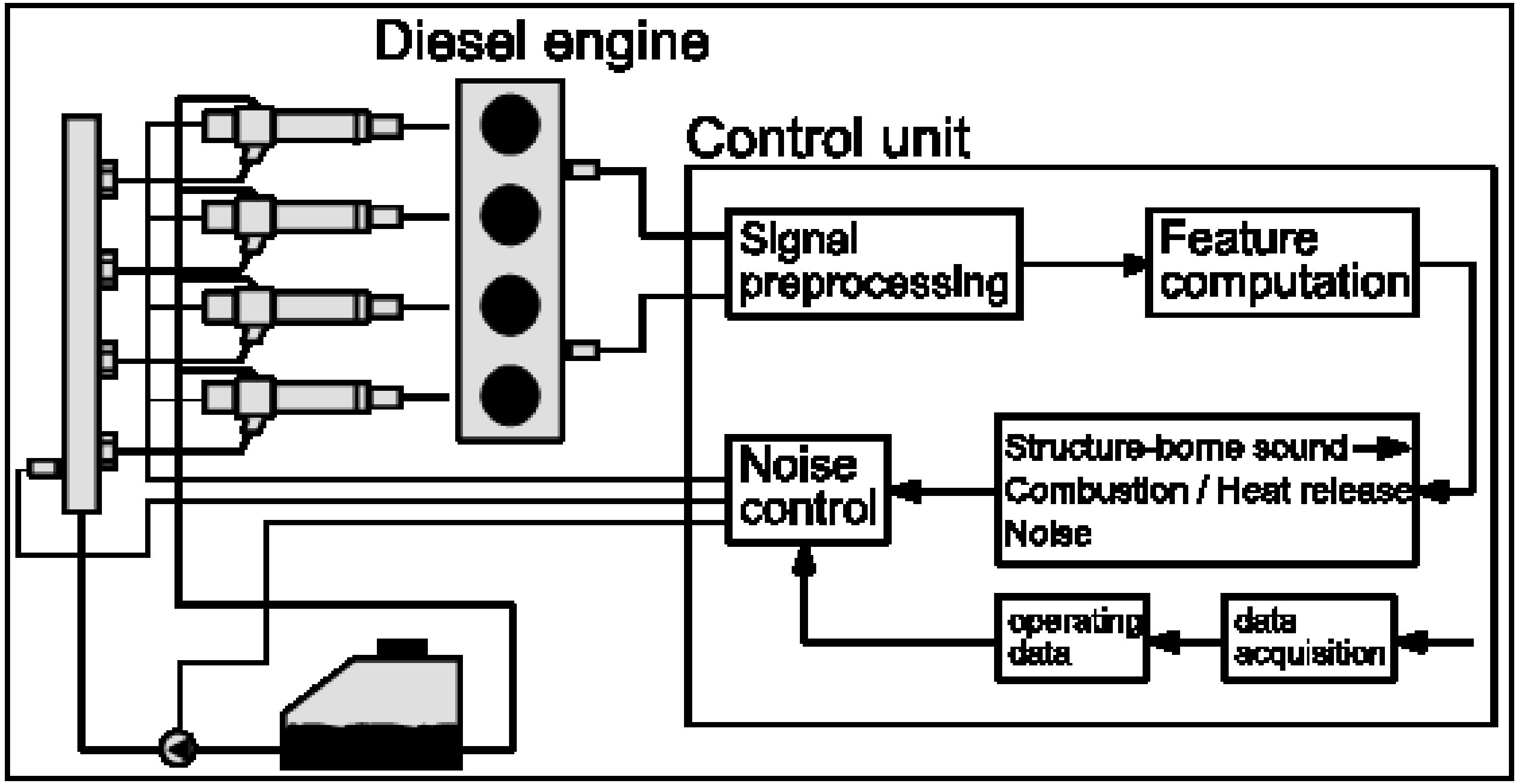
Background and Idea

Cylinder Pressure Based Engine Control



1. Diesel engine control based on structure-borne sensor signals
2. Annoying Diesel noise: Measurement and consideration for control
3. Optimization of the Diesel grade ("Dieselnote" - DN)

Research Aims

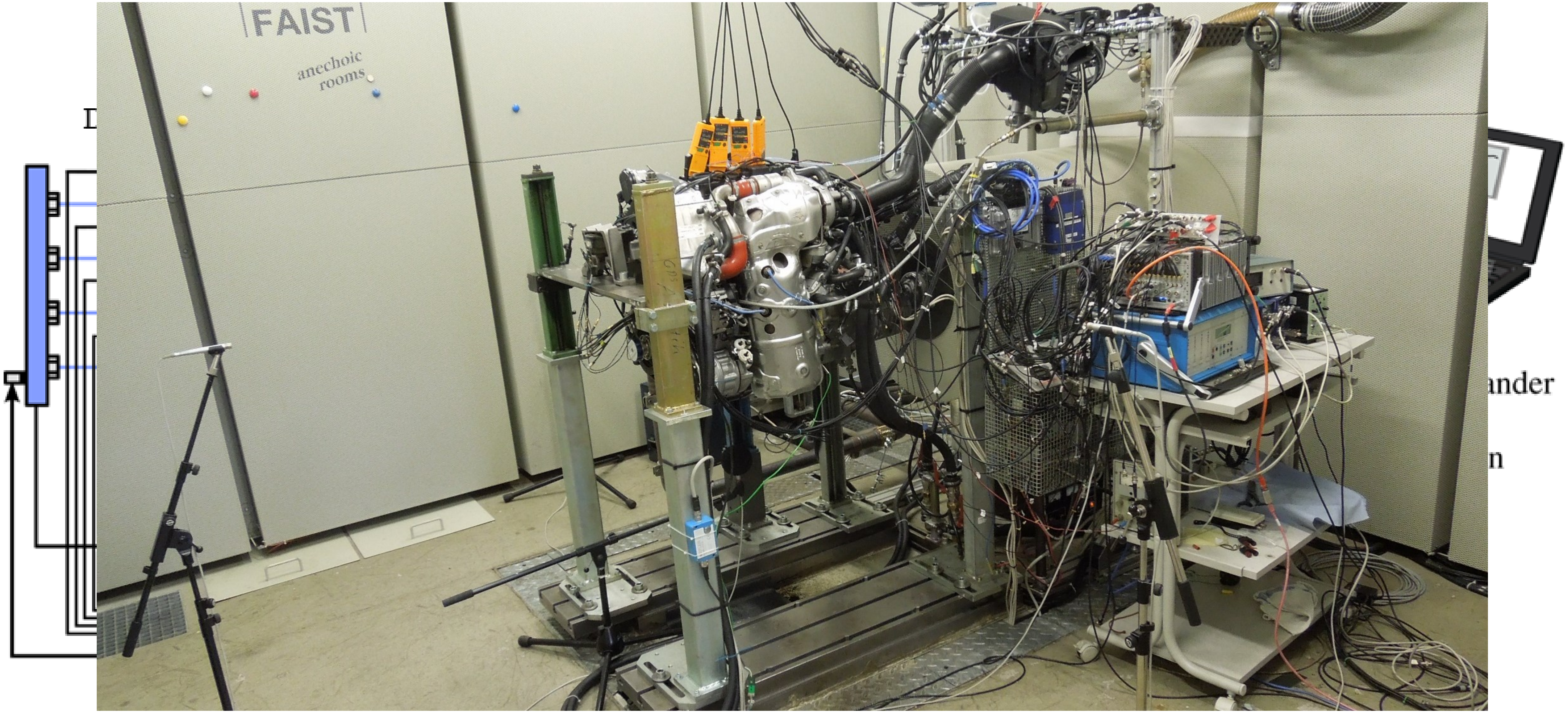
1. Estimation of combustion features ($p_{mi}\ , p_{max}\ and\ \alpha_{q50}$) based on structure-borne noise
   → **Virtual Pressure Sensor**

2. Prediction of airborne noise based on structure-borne noise
   → **Virtual Noise Sensor**

3. Optimization of the Diesel grade according to the annoying Diesel noise with constraints

Engine Test Bench

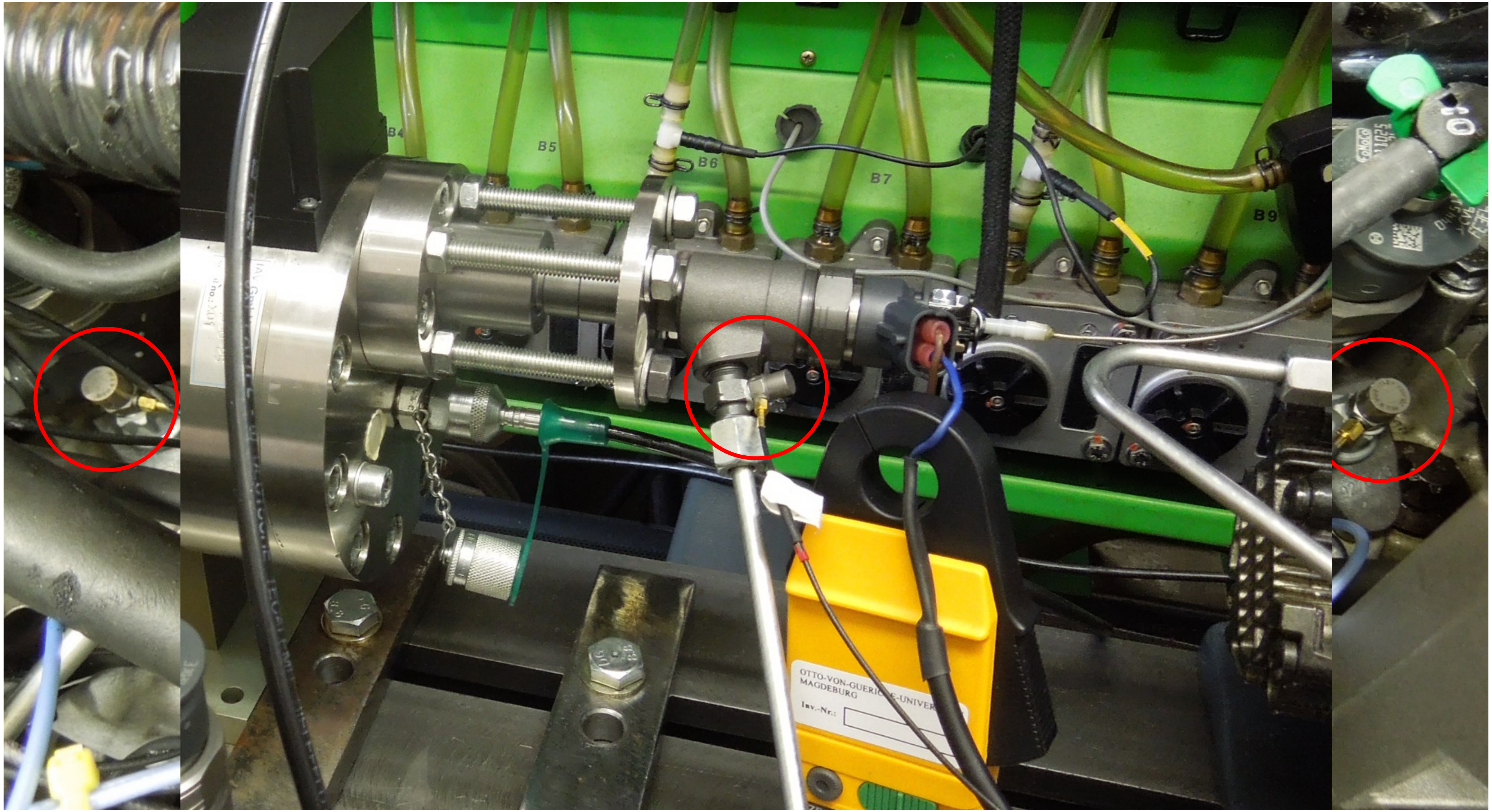
Schematic Structure



- Acoustic test bench with sound-absorbing walls and exhaust gas measurement system
- 4 cylinder Diesel engine with common rail system
- 17 structure-borne noise sensors (1D & 3D), 4 microphones, 4 pressure sensors with indicating system

Engine Test Bench
Injector Test Bench

Experimental Setup in Magdeburg



Virtual Pressure Sensor

Aim: Estimation of combustion features (p_{mi} , p_{max} and α_{q50}) based on structure-borne noise

- Coherence analysis between structure-borne noise signals and pressure signals → best sensor position
- Correlation analysis between position features and pressure characteristics
- Regression analysis to estimate the combustion characteristics α_{q50}, p_{mi} and p_{max} with structure-borne noise signals
- Regression models of combustion characteristics with Virtual Pressure Sensor

Virtual Pressure Sensor

Smoothed-Pseudo-Wigner-Ville Analysis (SPWV)

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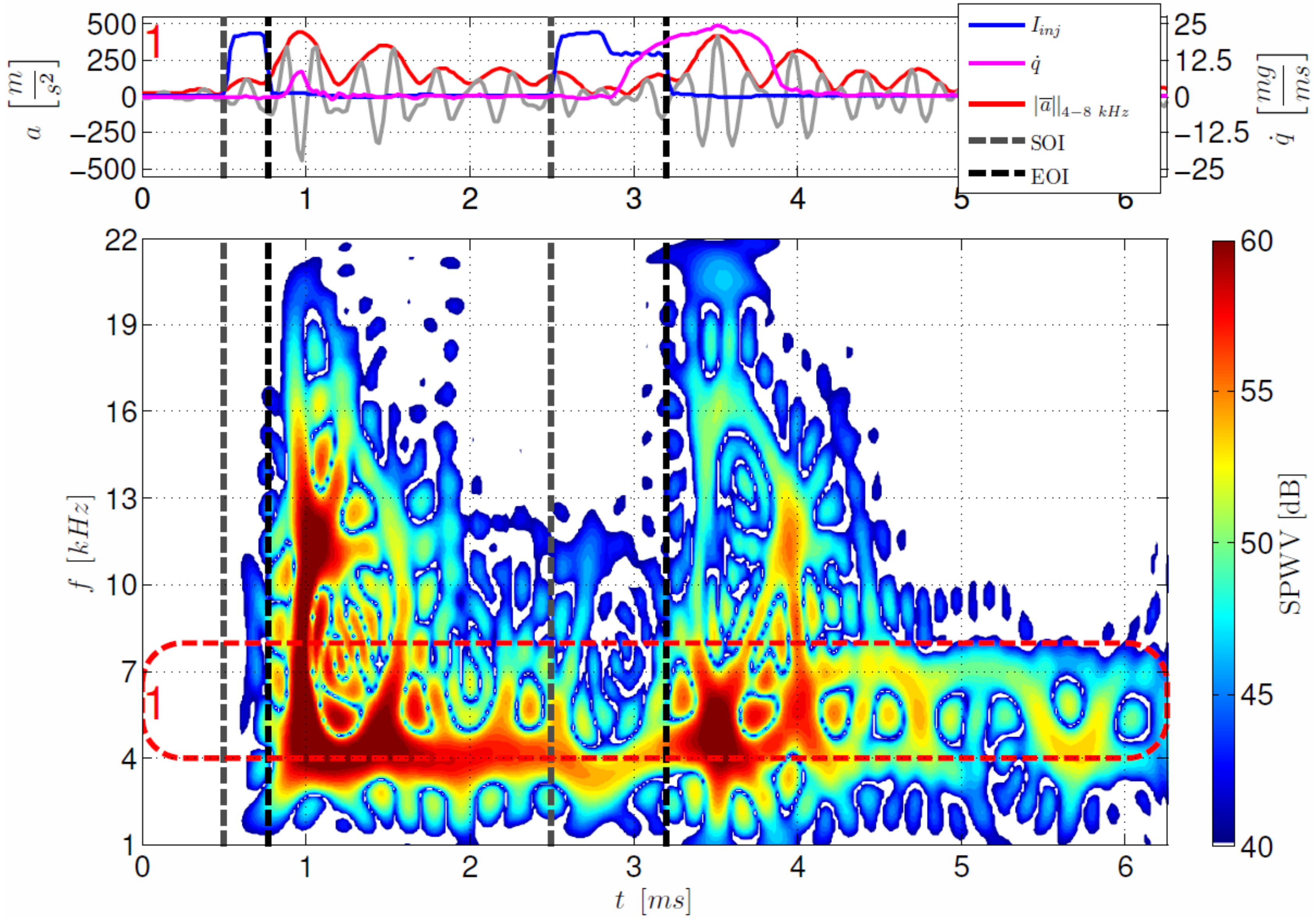
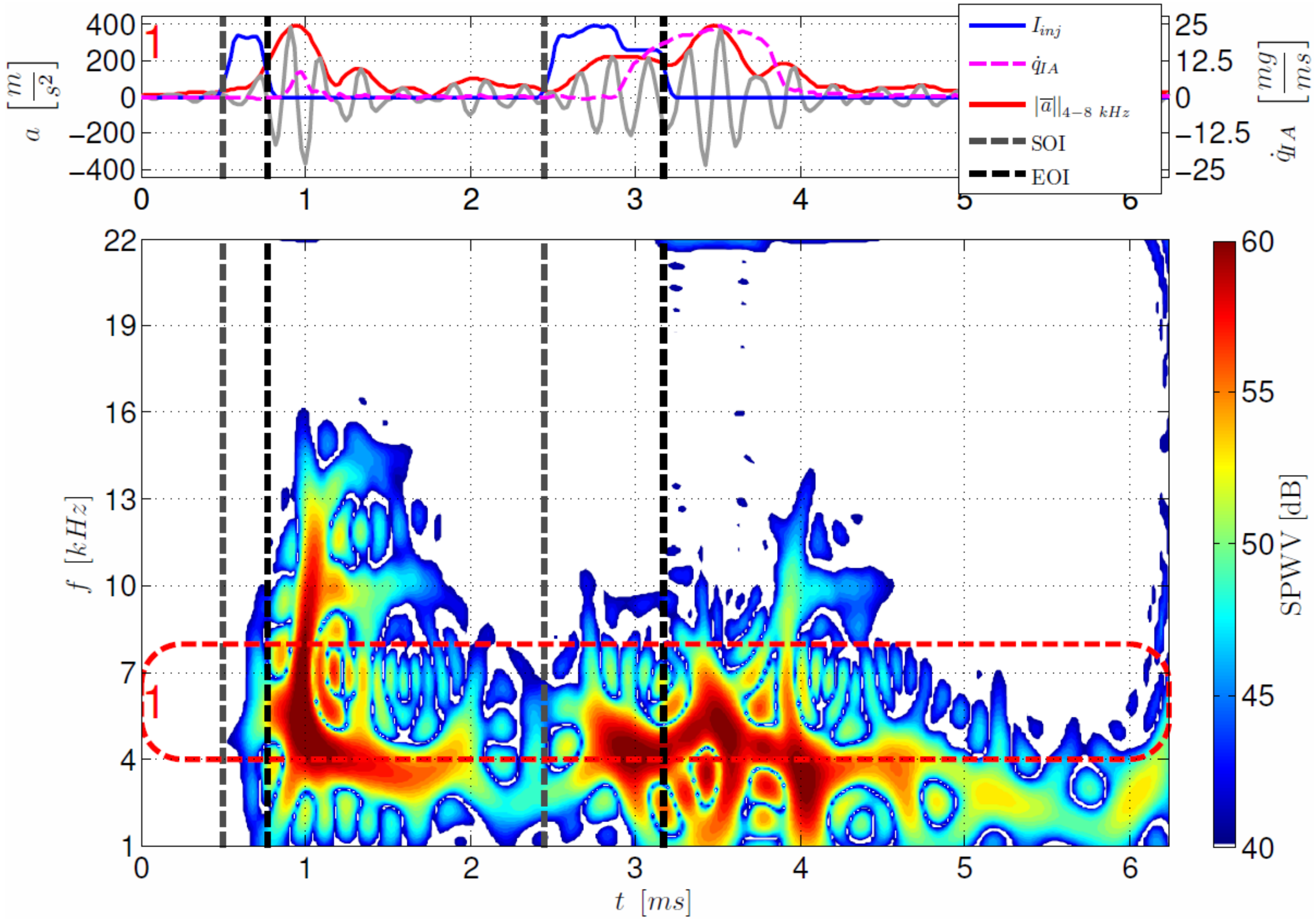
Adapted operating point: 1750 rpm / 100 Nm, rail pressure = 865 bar, main injection duration = 721 µs



Virtual Pressure Sensor

Smoothed-Pseudo-Wigner-Ville Analysis (SPWV)

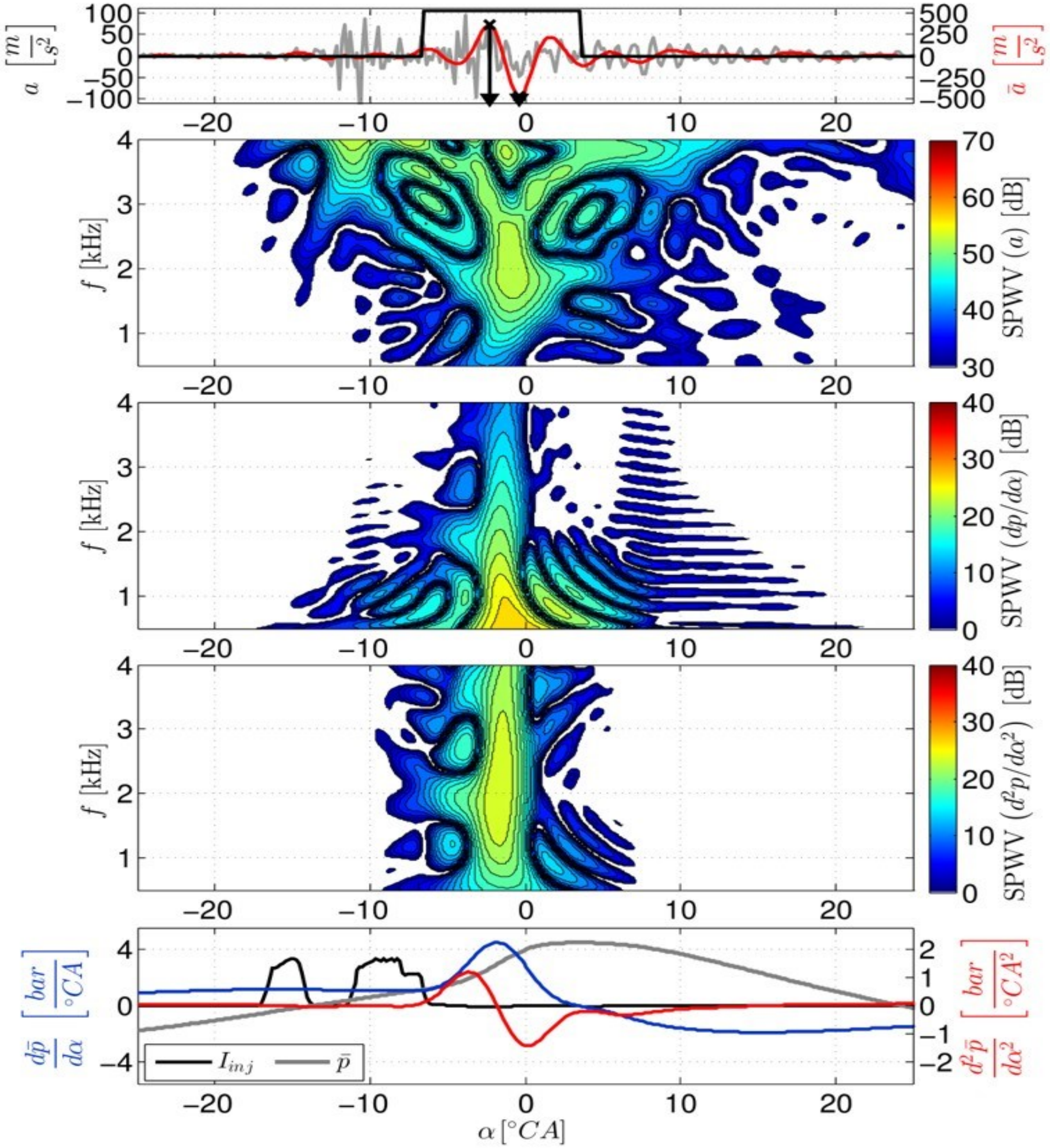
Engine operating point: 1750 rpm / 100 Nm, rail pressure = 865 bar, main injection duration = 721 µs



Virtual Pressure Sensor

Smoothed-Pseudo-Wigner-Ville Analysis (SPWV)

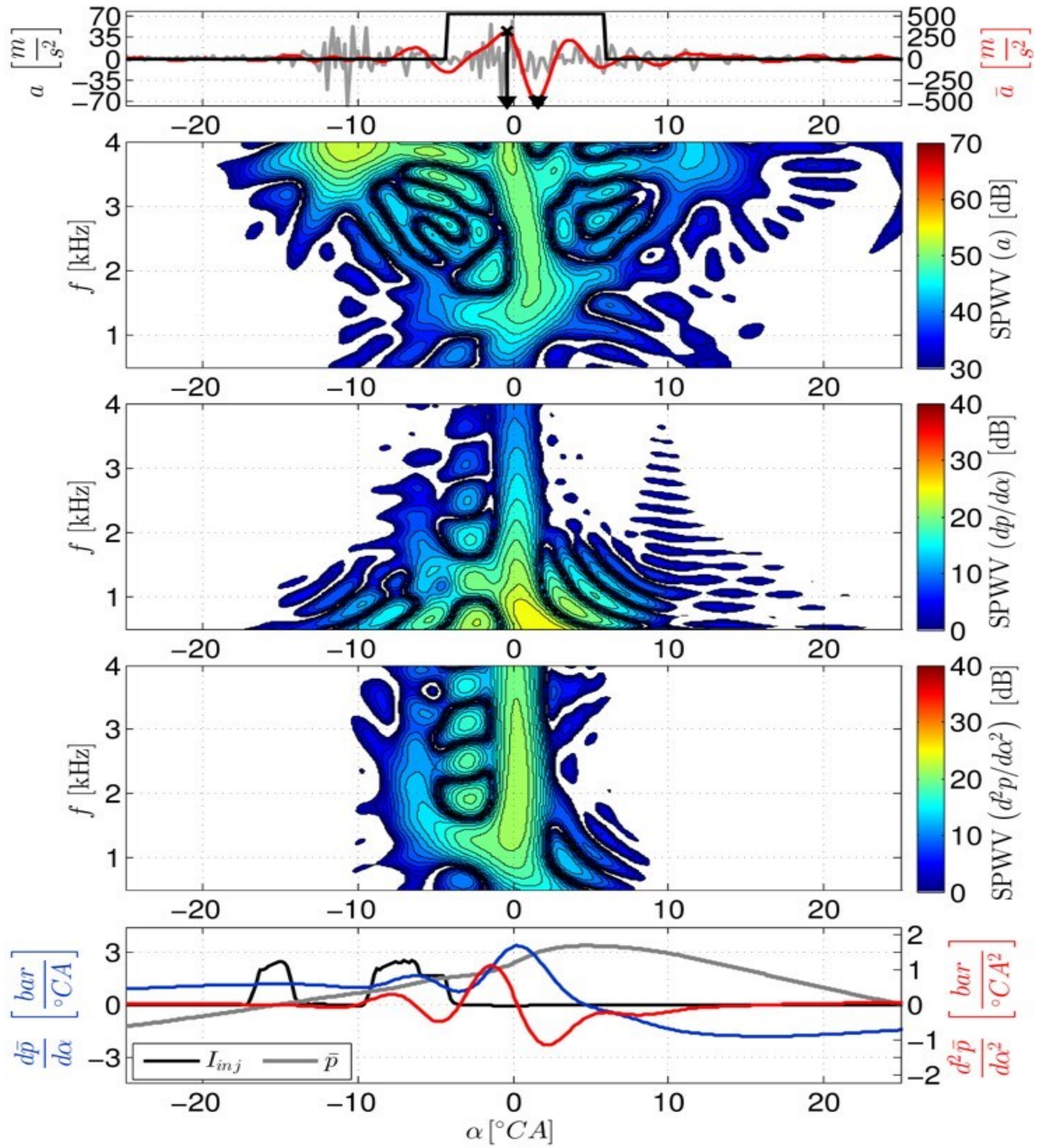
Start of main injection $(SOI_{mi}) = 11\,°BTDC$



Virtual Pressure Sensor

Smoothed-Pseudo-Wigner-Ville Analysis (SPWV)

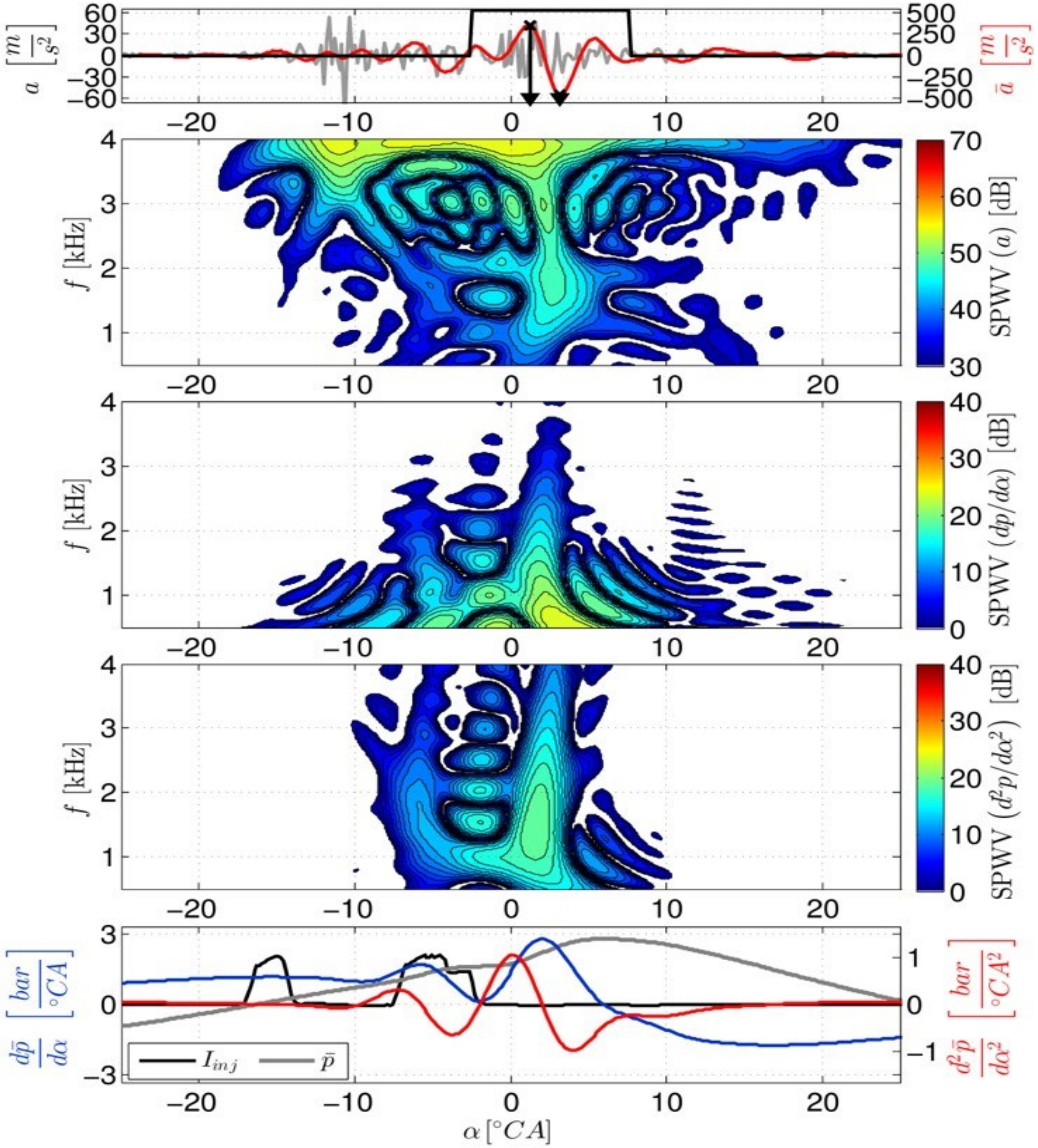
Start of main injection $(SOI_{mi}) = 9\,°BTDC$



Virtual Pressure Sensor

Smoothed-Pseudo-Wigner-Ville Analysis (SPWV)

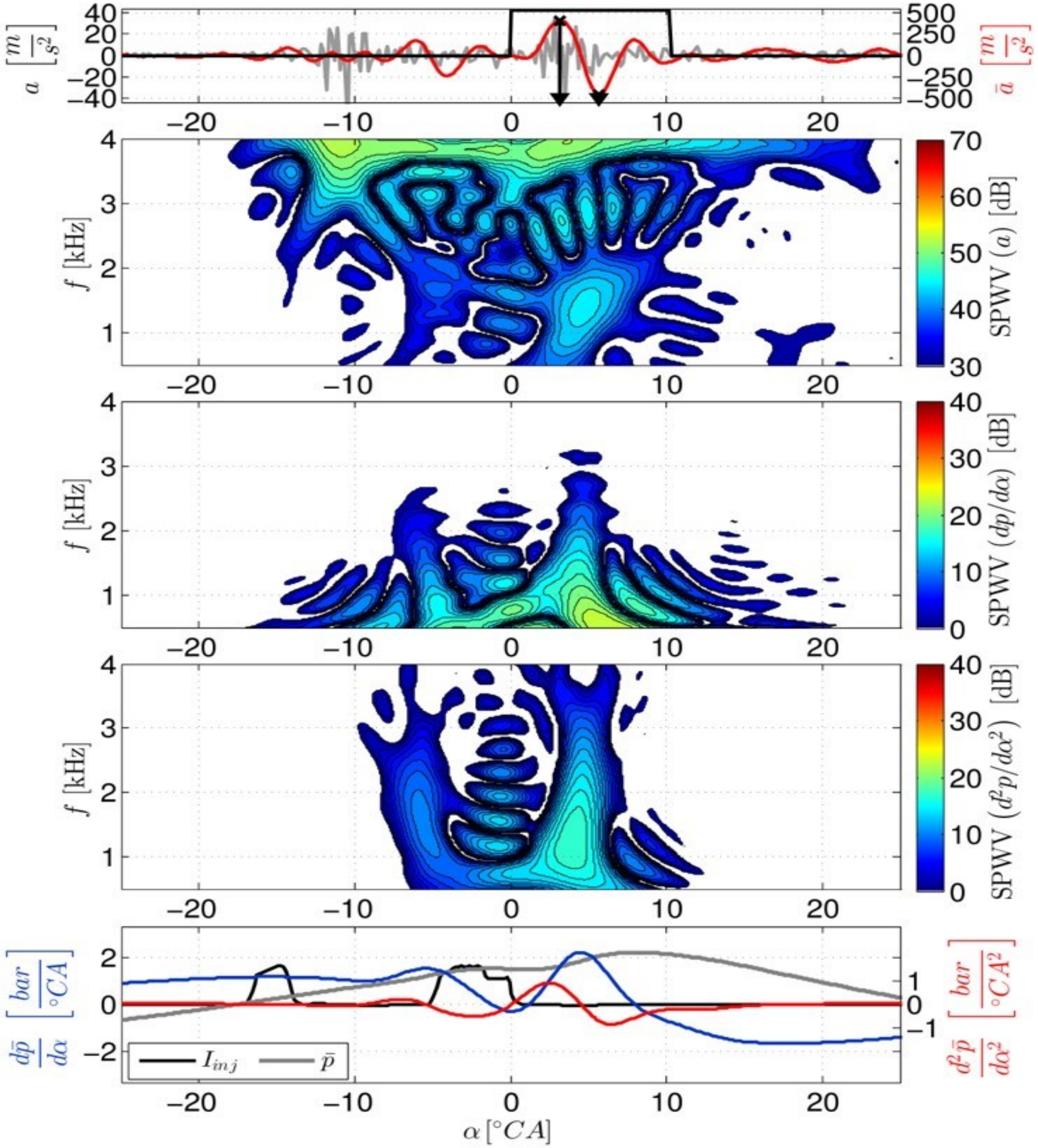
Start of main injection $(SOI_{mi}) = 7\,°BTDC$



Virtual Pressure Sensor

Smoothed-Pseudo-Wigner-Ville Analysis (SPWV)

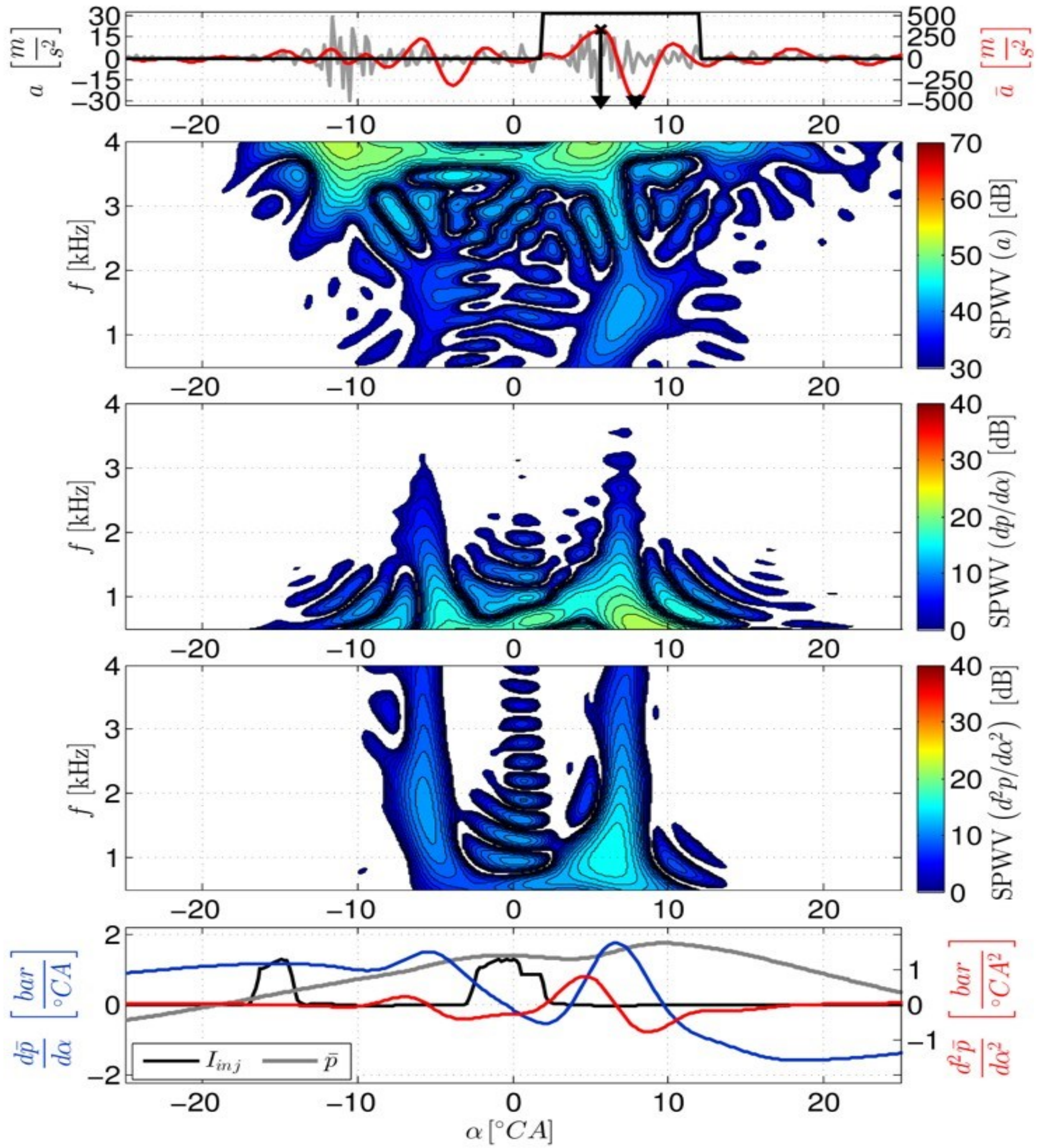
Start of main injection $(SOI_{mi}) = 5\,°BTDC$



Virtual Pressure Sensor

Smoothed-Pseudo-Wigner-Ville Analysis (SPWV)

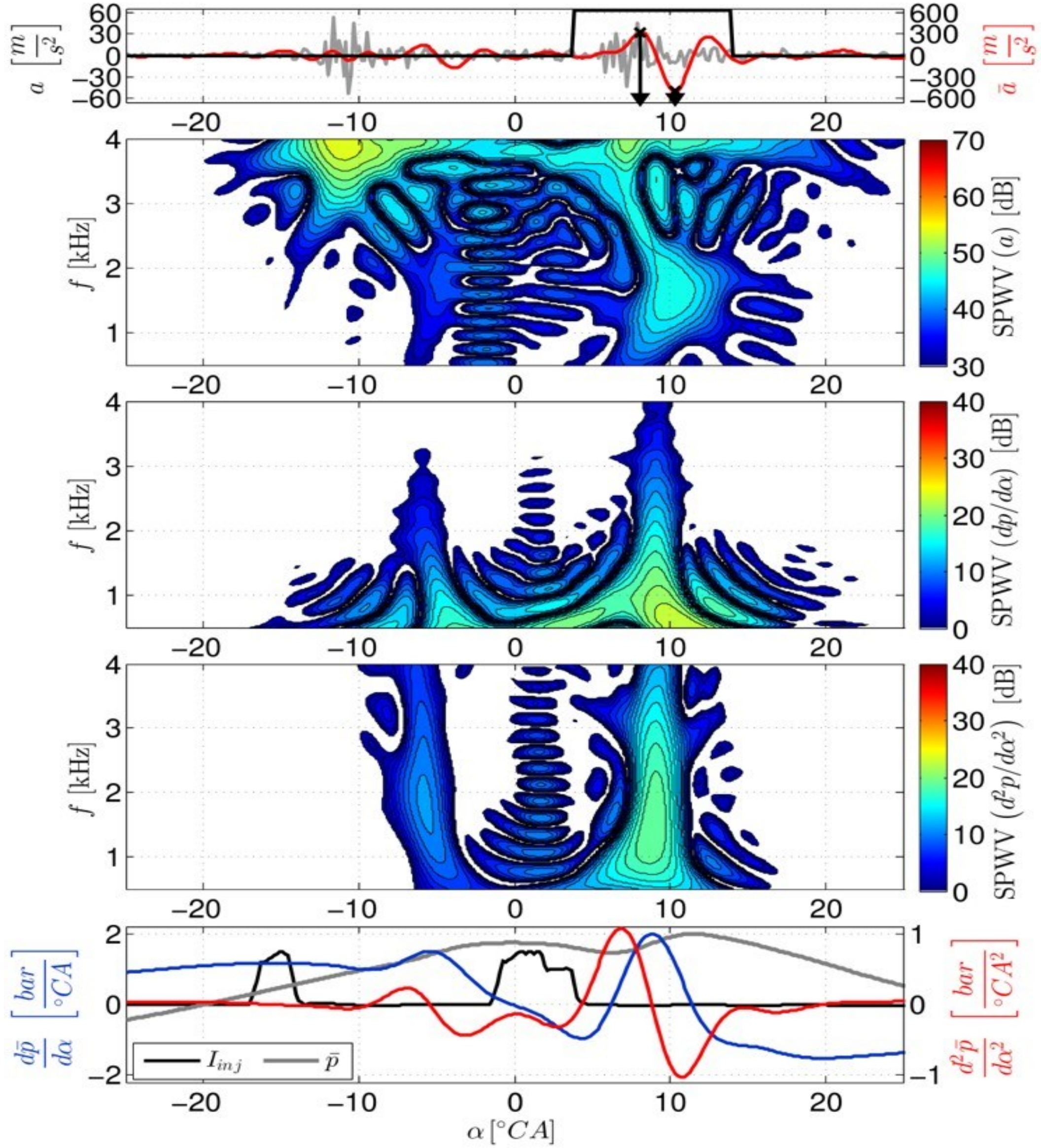
Start of main injection $(SOI_{mi}) = 3\,°BTDC$



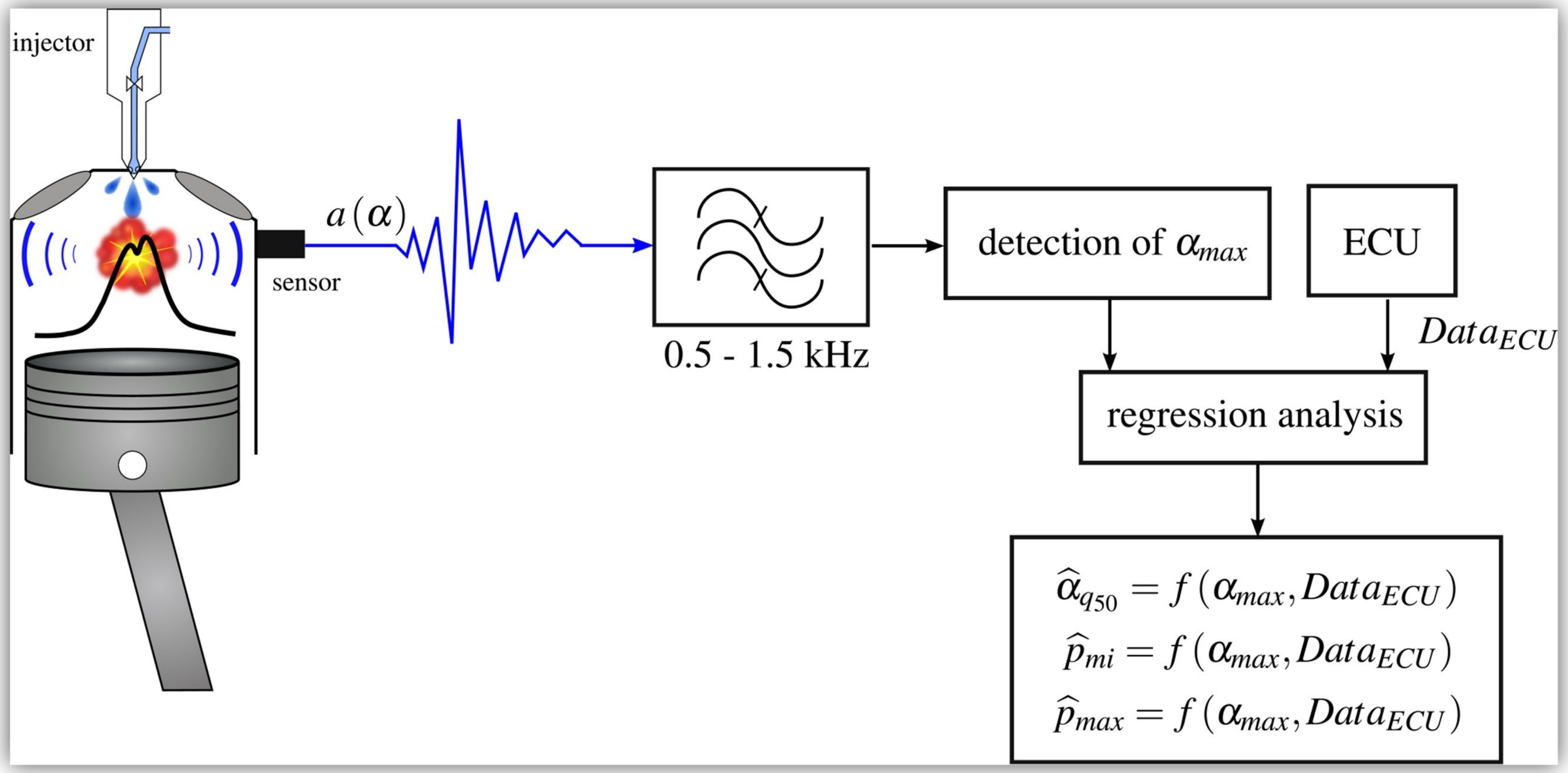
Virtual Pressure Sensor

Smoothed-Pseudo-Wigner-Ville Analysis (SPWV)

Start of main injection $(SOI_{mi}) = 1\,°BTDC$



Virtual Pressure Sensor
Modeling

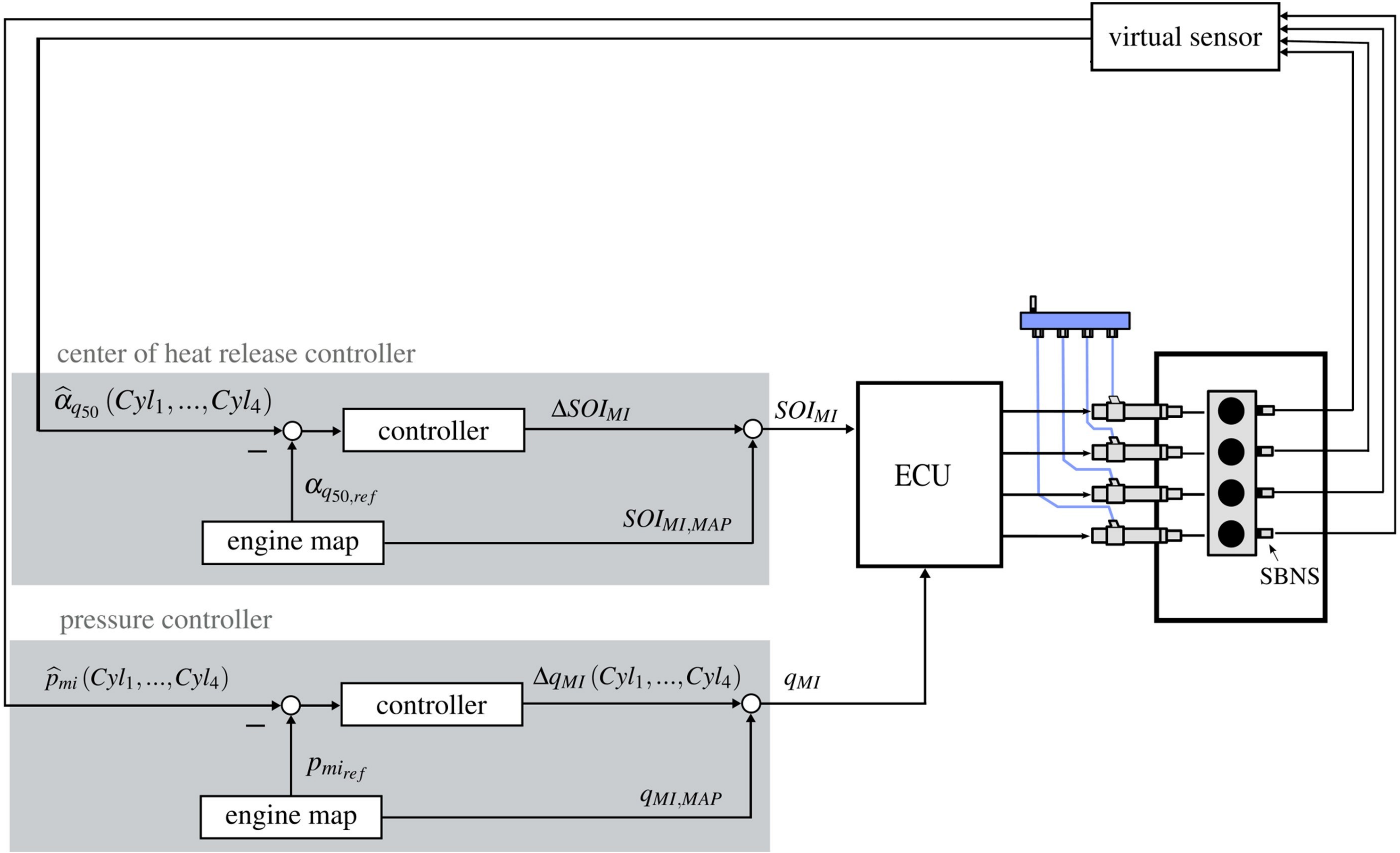


Polynomial Models:

$$\widehat{\alpha}_{q50} = f_1(\alpha_{KSmax}, SOI_{pi}, SOI_{mi}, \Delta t_{pi}, n, p_{Rail})$$
$$\hat{p}_{mi} = f_2(\alpha_{KSmax}, SOI_{pi}, SOI_{mi}, \Delta t_{pi}, n, p_{Rail})$$

Cylinder Selective Control

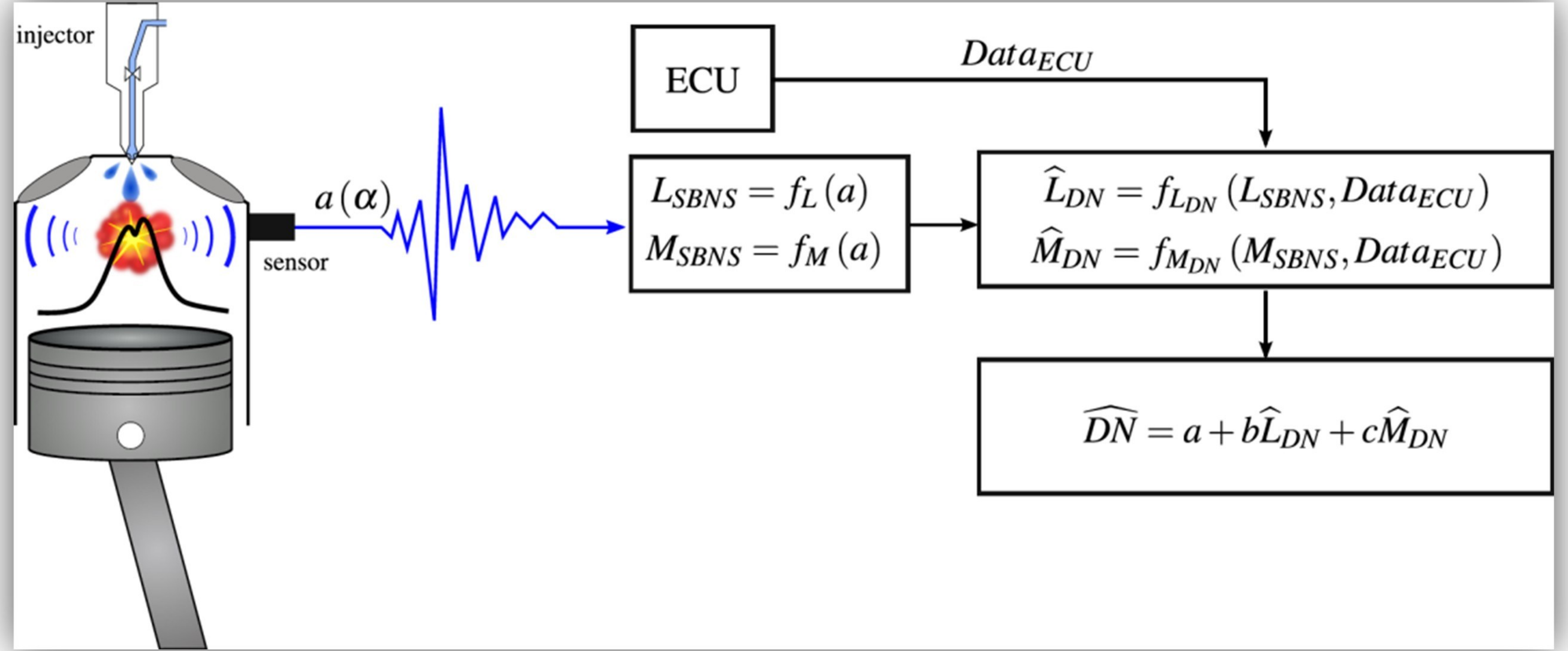
Schematic Diagram Control Structure



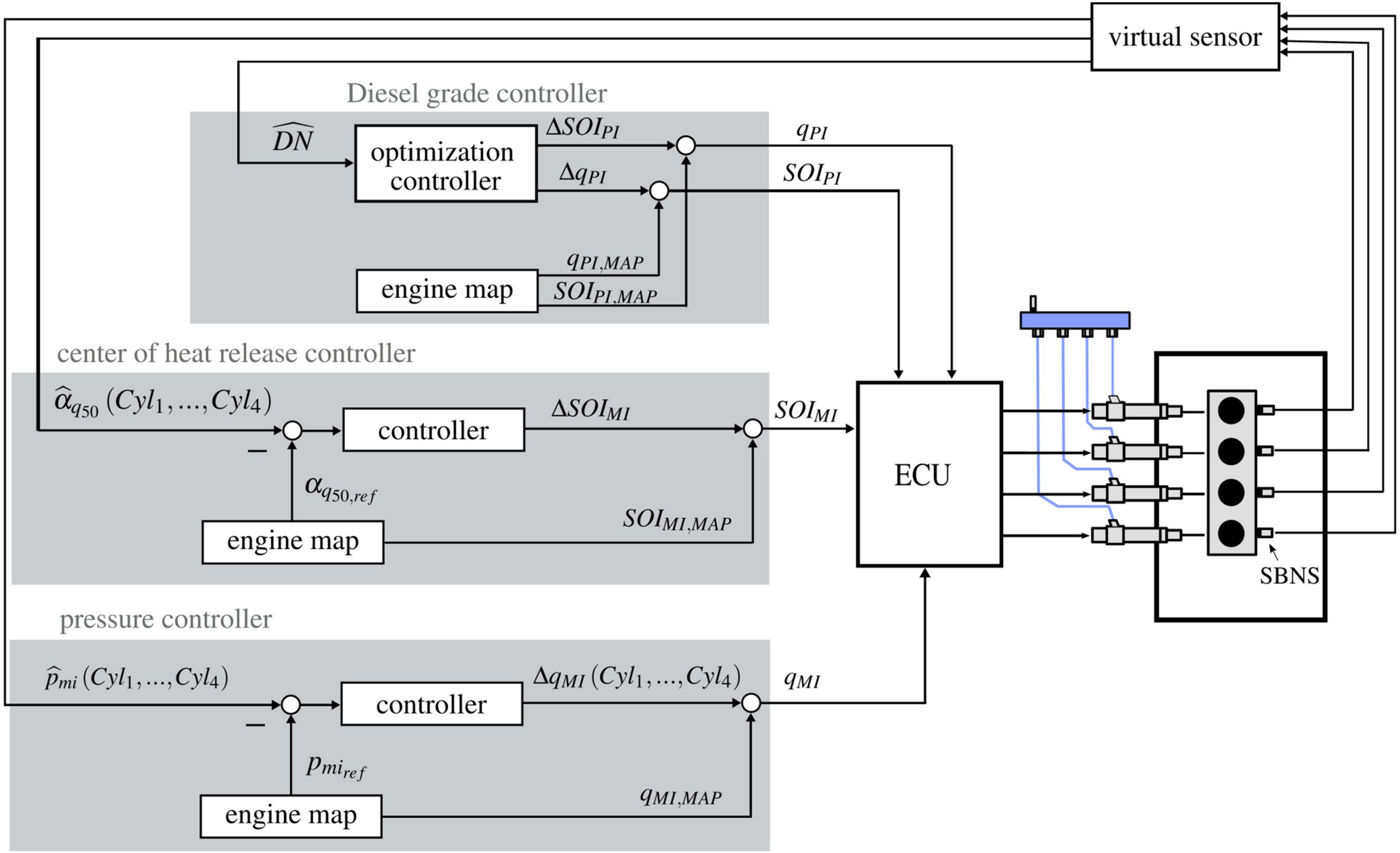
Aim: Prediction of air-borne noise based on structure-borne noise

- Correlation analysis between air-borne noise and structure-borne noise
- Regression analysis to estimate the Diesel grade
- Regression model of the Diesel grade

Virtual Noise Sensor
Modeling

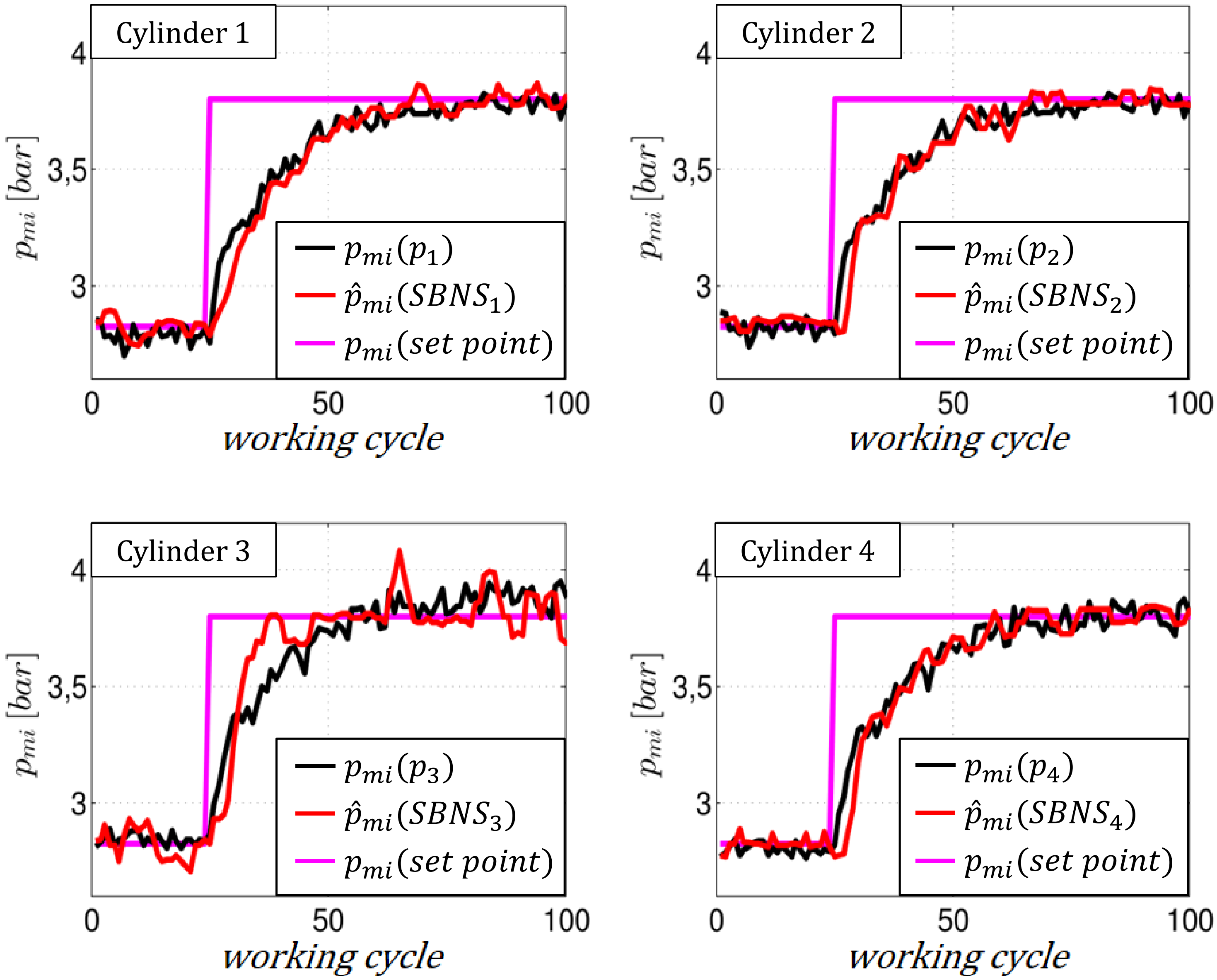


Schematic Diagram Control Structure



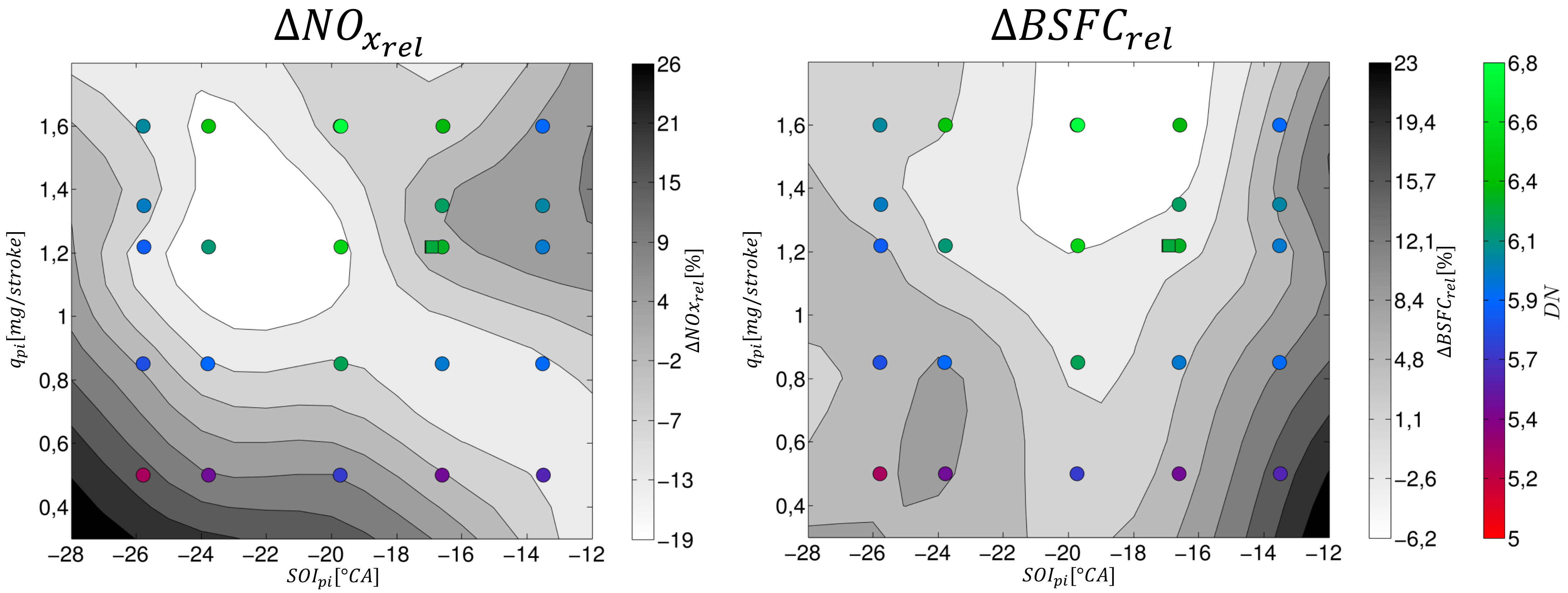
Cylinder Selective Control

Step Responses p_{mi}-Control



Optimized Diesel Grade Control

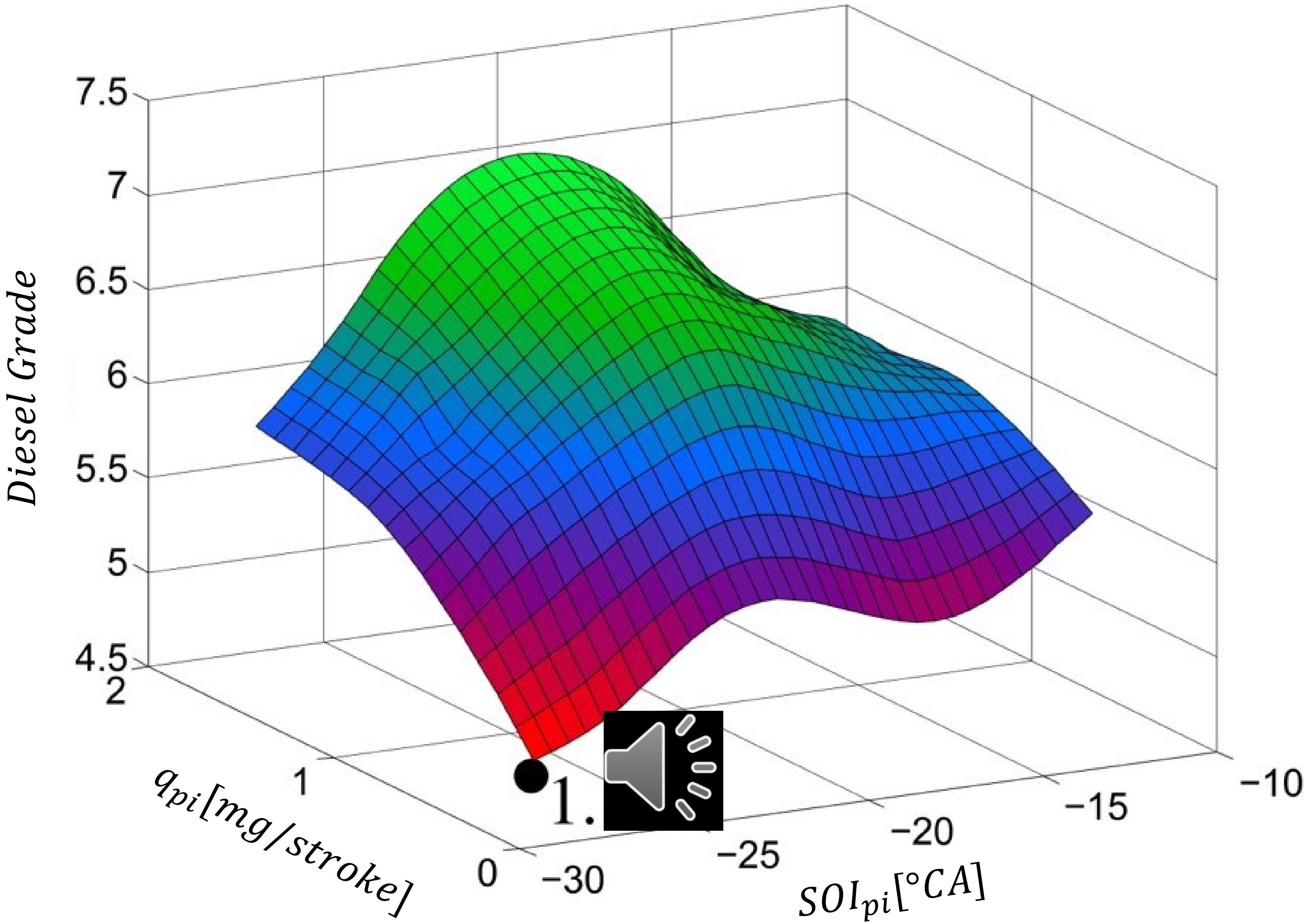
Dependencies on Emissions and Fuel Consumption



- Significant correlations between the diesel grade and the pollutant emissions as well as the specific fuel consumption
- Optimization potential with regard to the target conflict between pollutant emissions, fuel consumption and noise emission is given

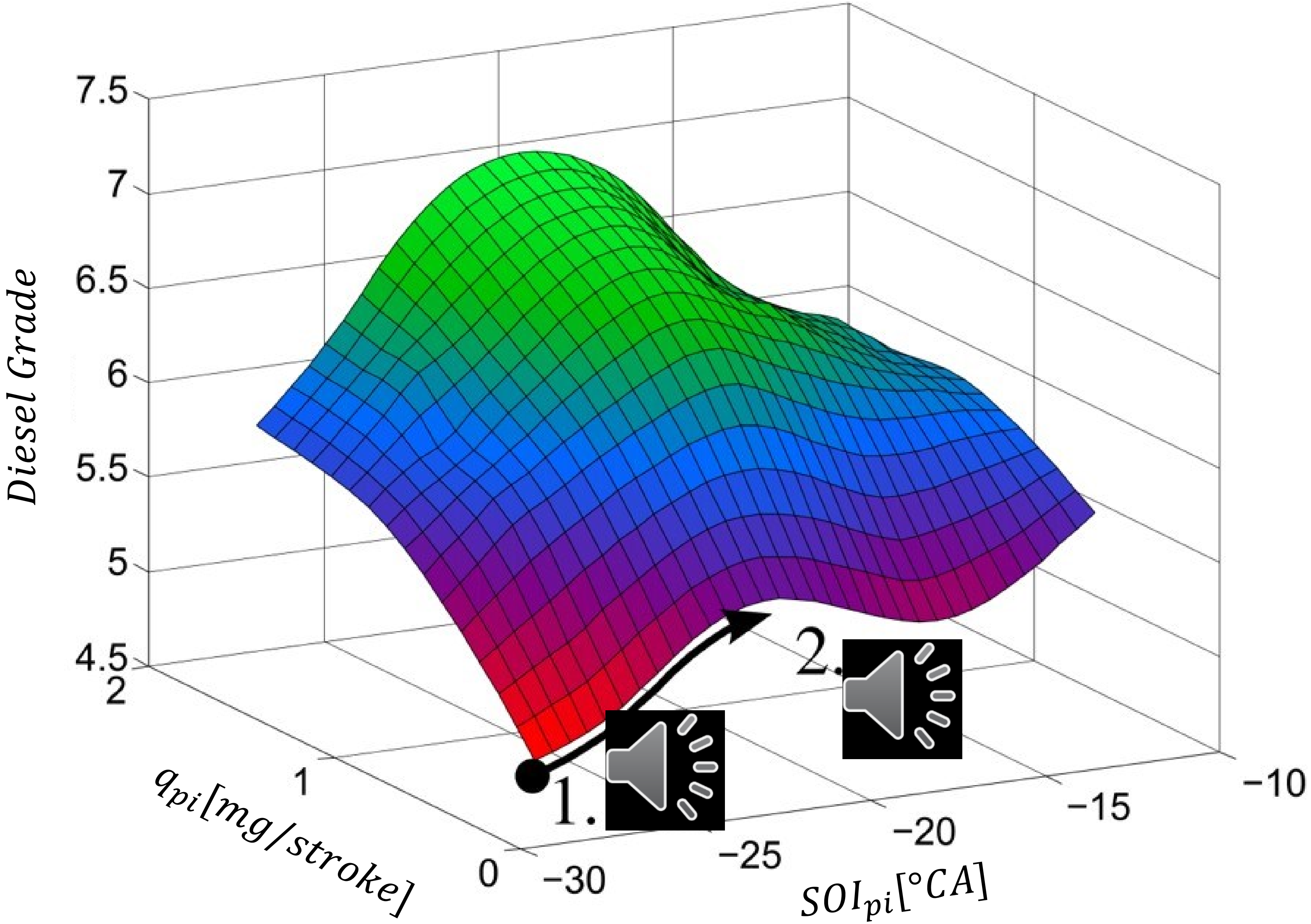
Optimized Diesel Grade Control

Iterative Gradient Algorithm – Step 1: Initialisation



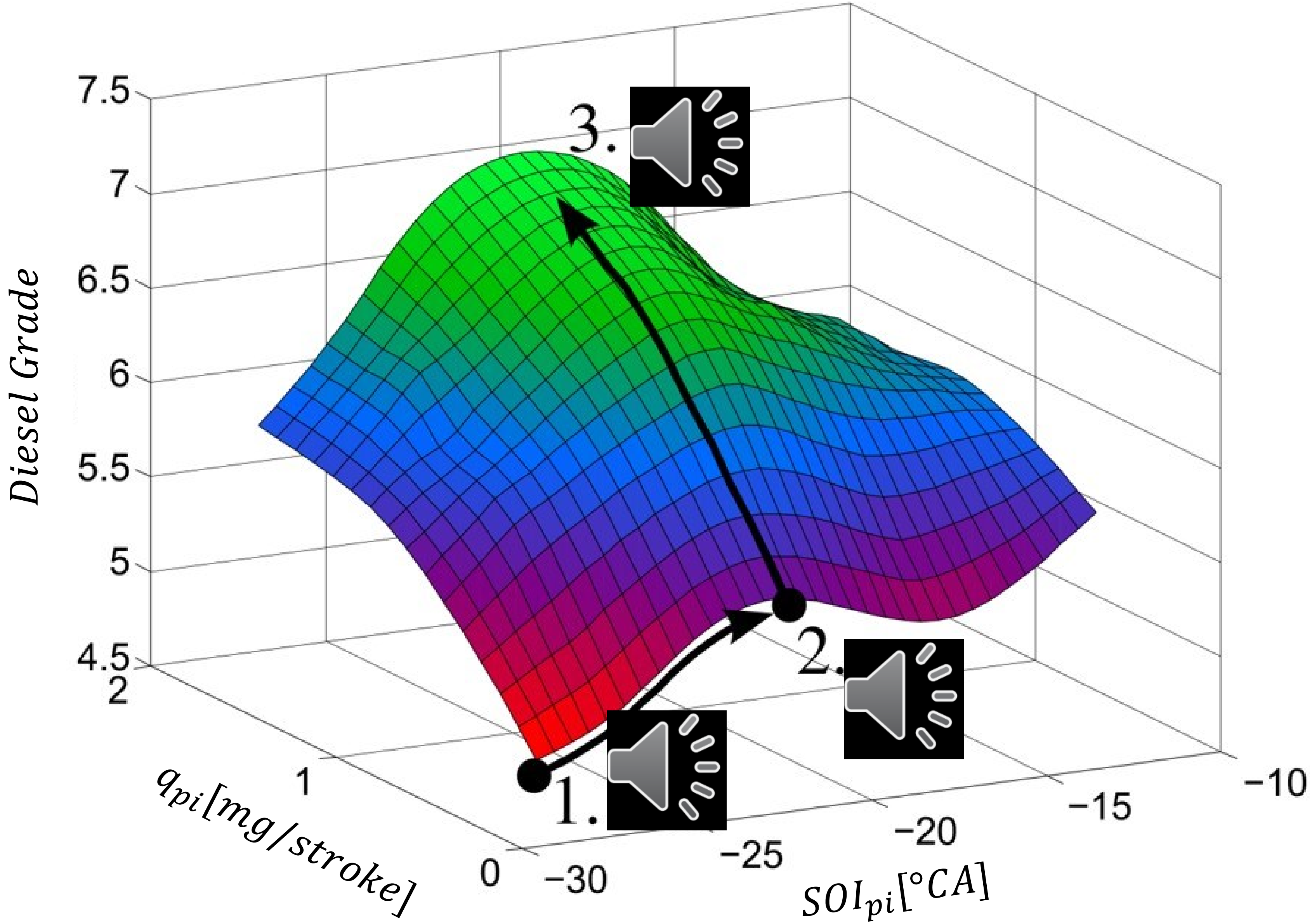
Optimized Diesel Grade Control

Iterative Gradient Algorithm – Step 2: Gradient descend method – variation of SOI_{pi}



Optimized Diesel Grade Control

Iterative Gradient Algorithm – Step 3: Gradient descend method – variation of q_{pi}



Conclusion and Outlook

Results:

- Coherence analysis
- Virtual Sensors for Diesel grade, α_{q50} and p_{mi}
- Cylinder selective noise controlled Diesel engine management
- Optimization of the Diesel grade with regard of emissions and fuel consumptions

Open points:

- Model improvement by additional signals: e.g. speed signal
- Full variable injection
- Transferability to Gasoline Engine

Thank You for Your Attention.

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