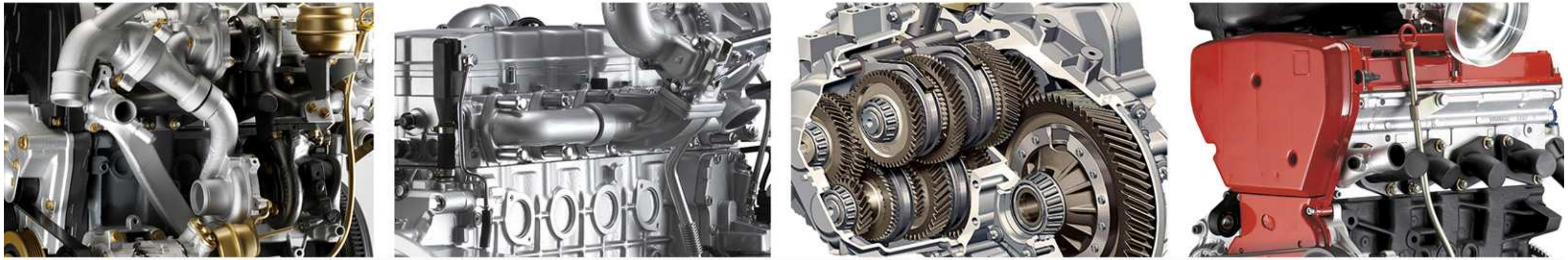
Engines and Transmissions



2008 GT-SUITE European Conference
Frankfurt am Main – October, 20th

UNIAIR Variable Valve Actuation System Modelling and Integration to the Engine in the GT-SUITE environment

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Mechanical Engineering and Basic Technologies
Engine Thermo-Fluid Dynamic Systems Department

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- Comparison between simulation results and experimental data
- Integration of the actuator model (GT-FUEL) to the engine one (GT-Power)
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- **Activity objectives**
  - development of a model of the UNIAIR variable valve actuation system in the GT-SUITE environment
  - integration of the actuator model to the engine one in a unique environment

- **Integrated simulations: why ?**
  - simulation, in engine applications characterized by additional cam lobes like internal EGR lobes and engine braking lobes, of the effect on the UNIAIR valve lift of the gas pressures, variable with engine speed and load

- **Integrated simulations: to do what ?**
  - internal EGR analyses
  - engine braking analyses
  - actuator design optimization

The UNIAIR Actuator Technology (1/2)

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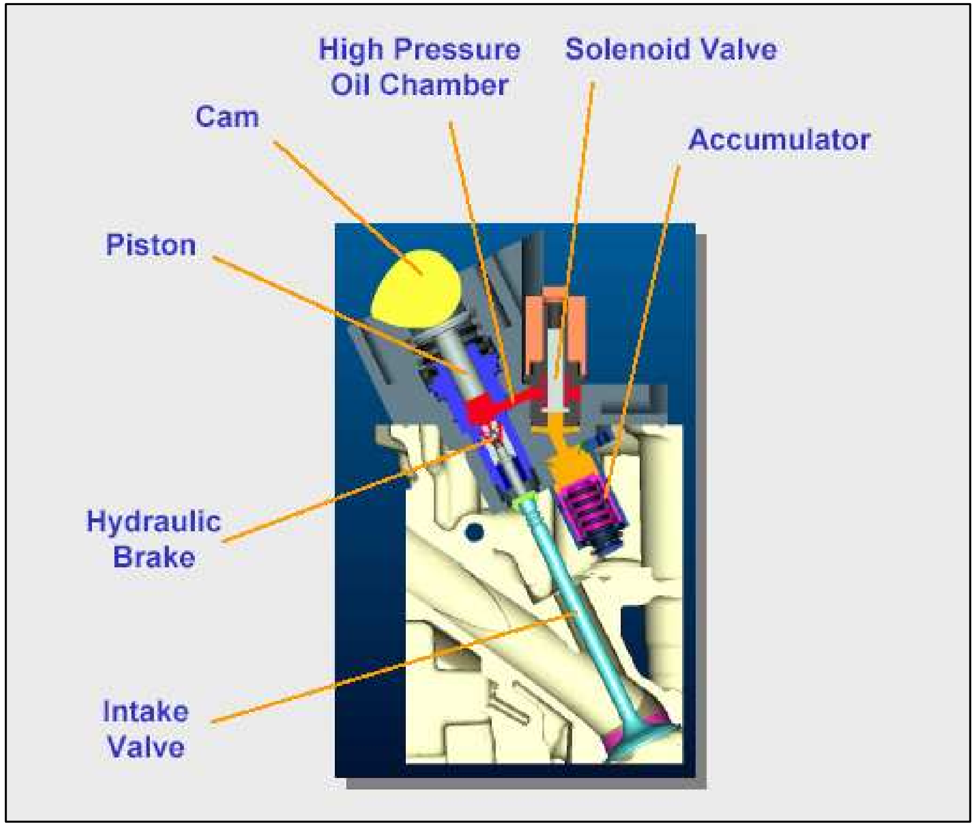

An oil volume is interposed between the cam and the valve

The piston acts as a pump, being its effective displacement controlled by a normally opened solenoid valve

The oil layout is divided in high pressure and medium pressure zones

The valve seating velocity is kept behind safe thresholds by the hydraulic brake orifices

An accumulator piston is provided in the medium pressure circuit for the actuator filling recovery after valve lift control (LIVO, EIVC)

The system communicates to the engine lubrication system for the fluid losses recovery

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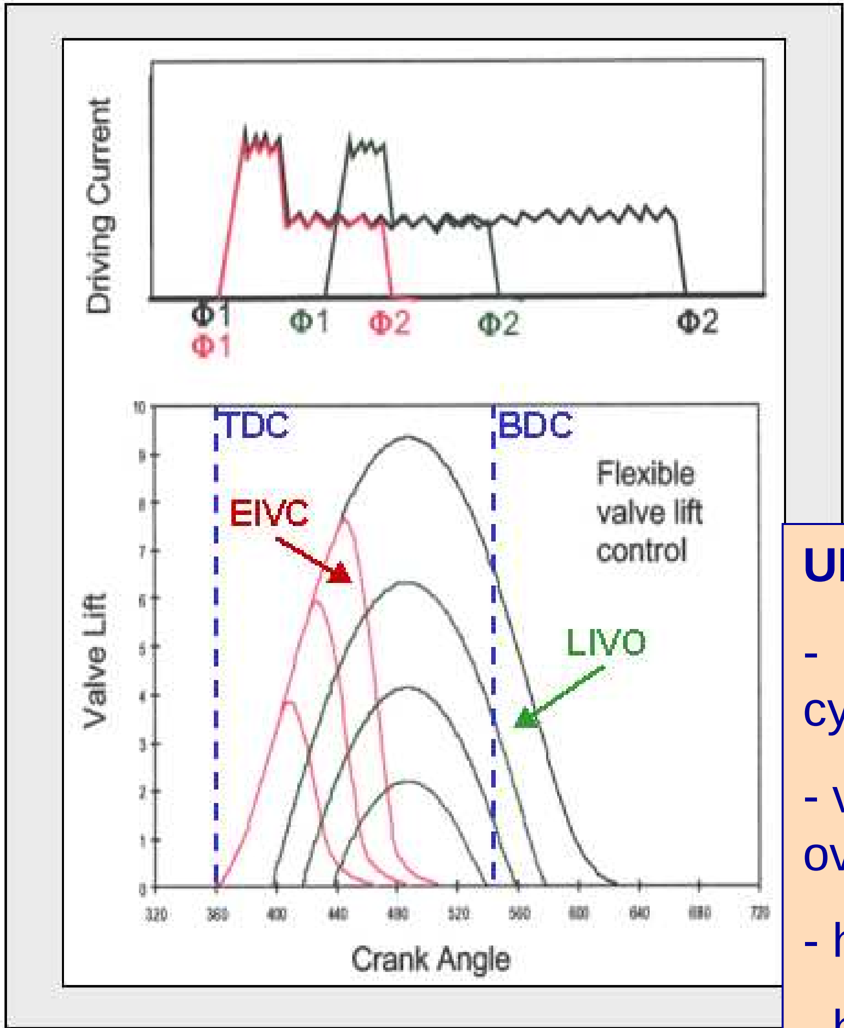

Valve lift controls

EIVC ↔ solenoid valve deactivated before the cam closing angle (Φ2 control)

LIVO ↔ solenoid valve activated after the cam opening angle (Φ1 control)

UNIAIR system benefits

- ‘cycle-by-cycle’ and ‘ cylinder-by-cylinder’ fully variable valve actuation
- volumetric efficiency optimization over the whole engine speeds range
- handling of a de-throttled engine
- handling of additional cam lobes

UNIAIR system – Actuator architecture overview
High pressure circuit

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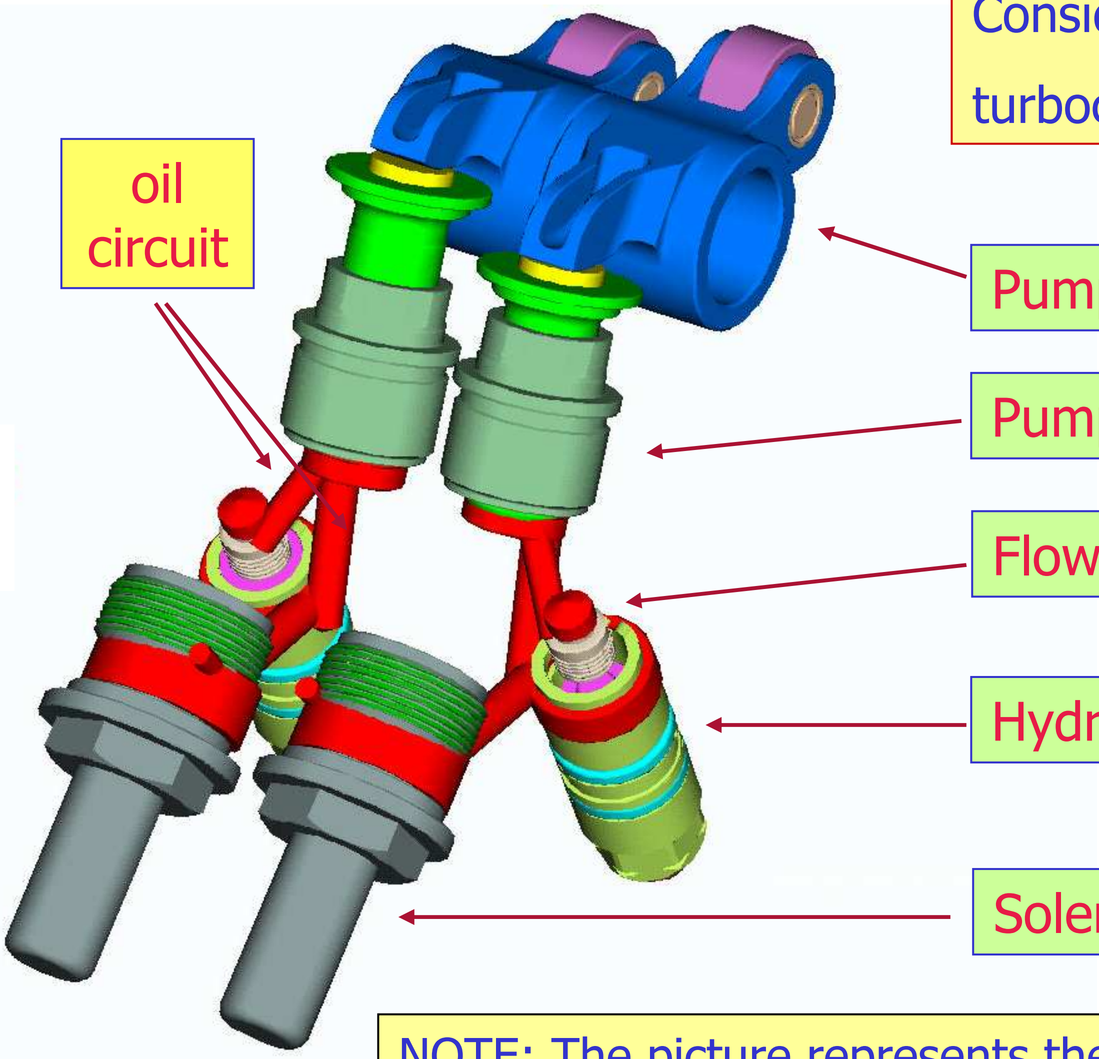
Considered application: turbocharged Diesel engine



NOTE: The picture represents the actuators of two valves

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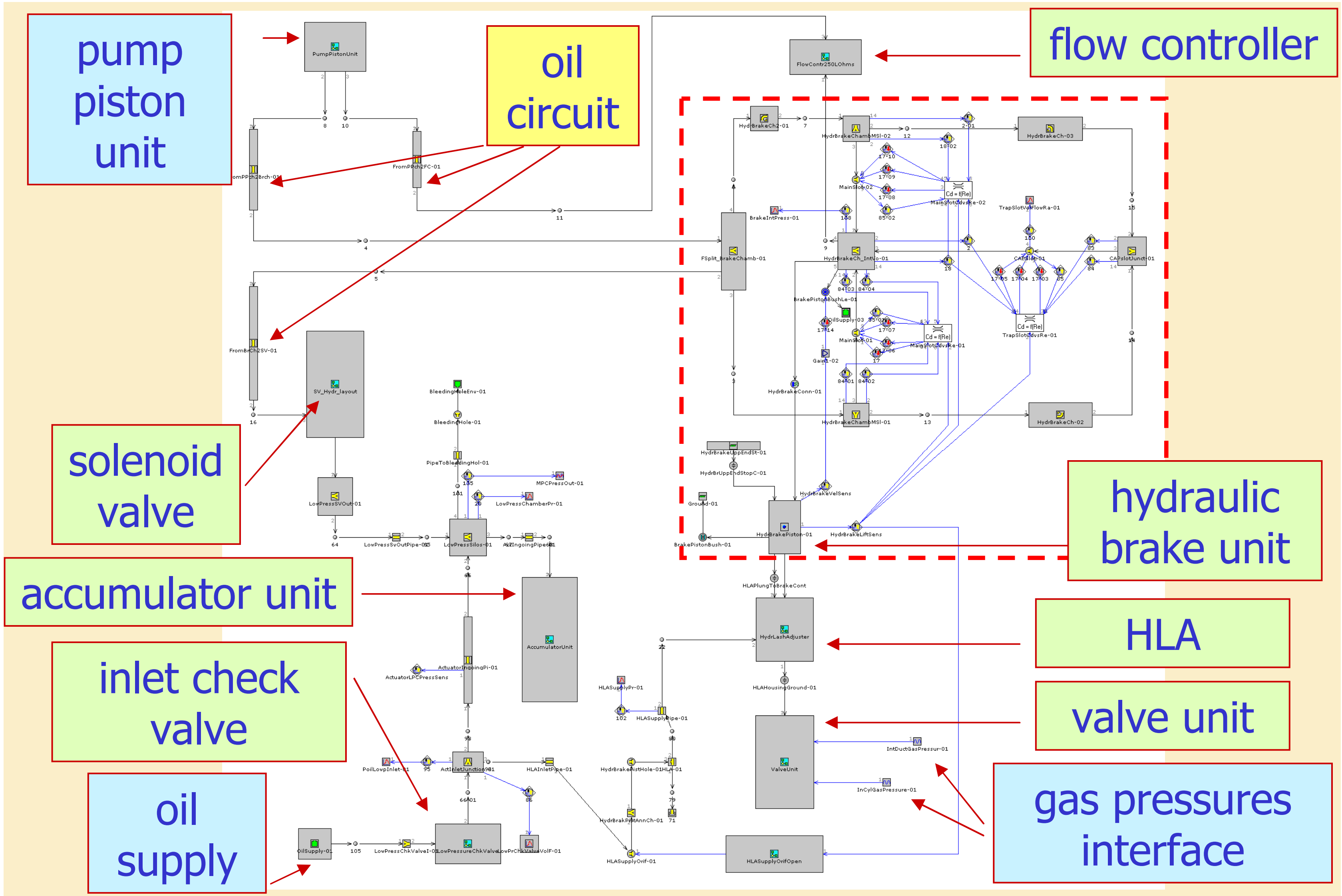

GT-SUITE sketch of the UNIAIR Variable Valve Actuation System
Details on the pump piston unit modelling

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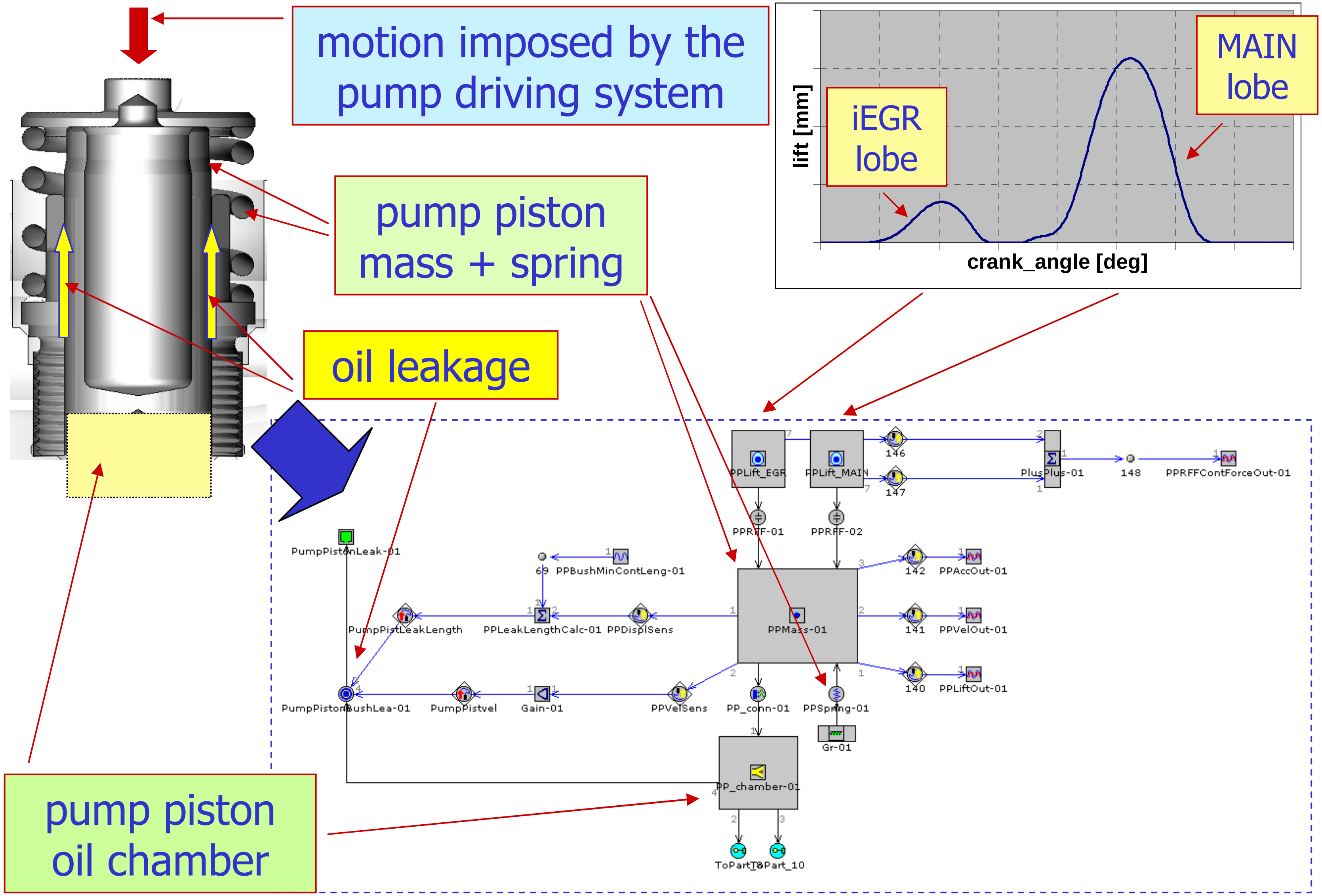

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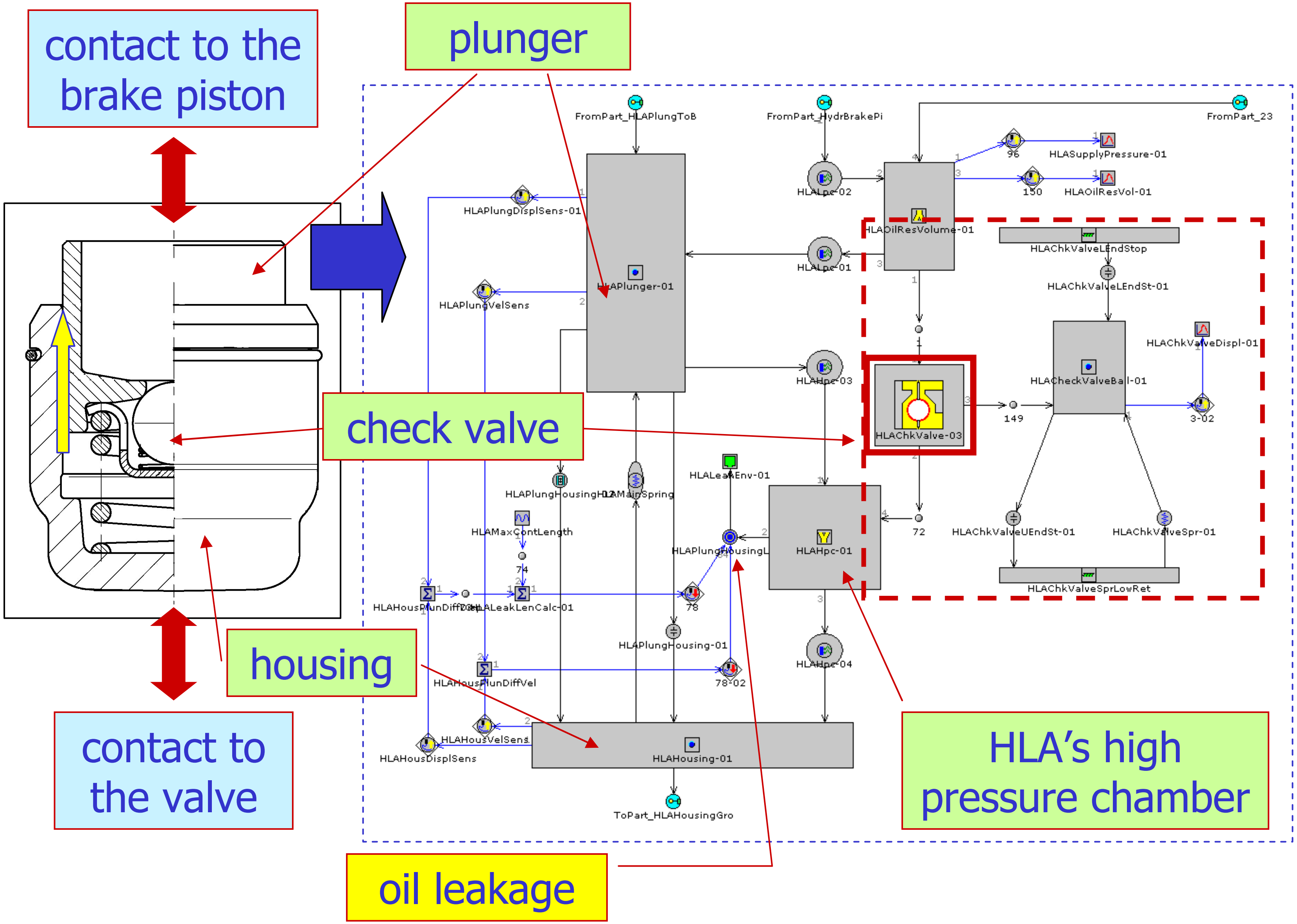

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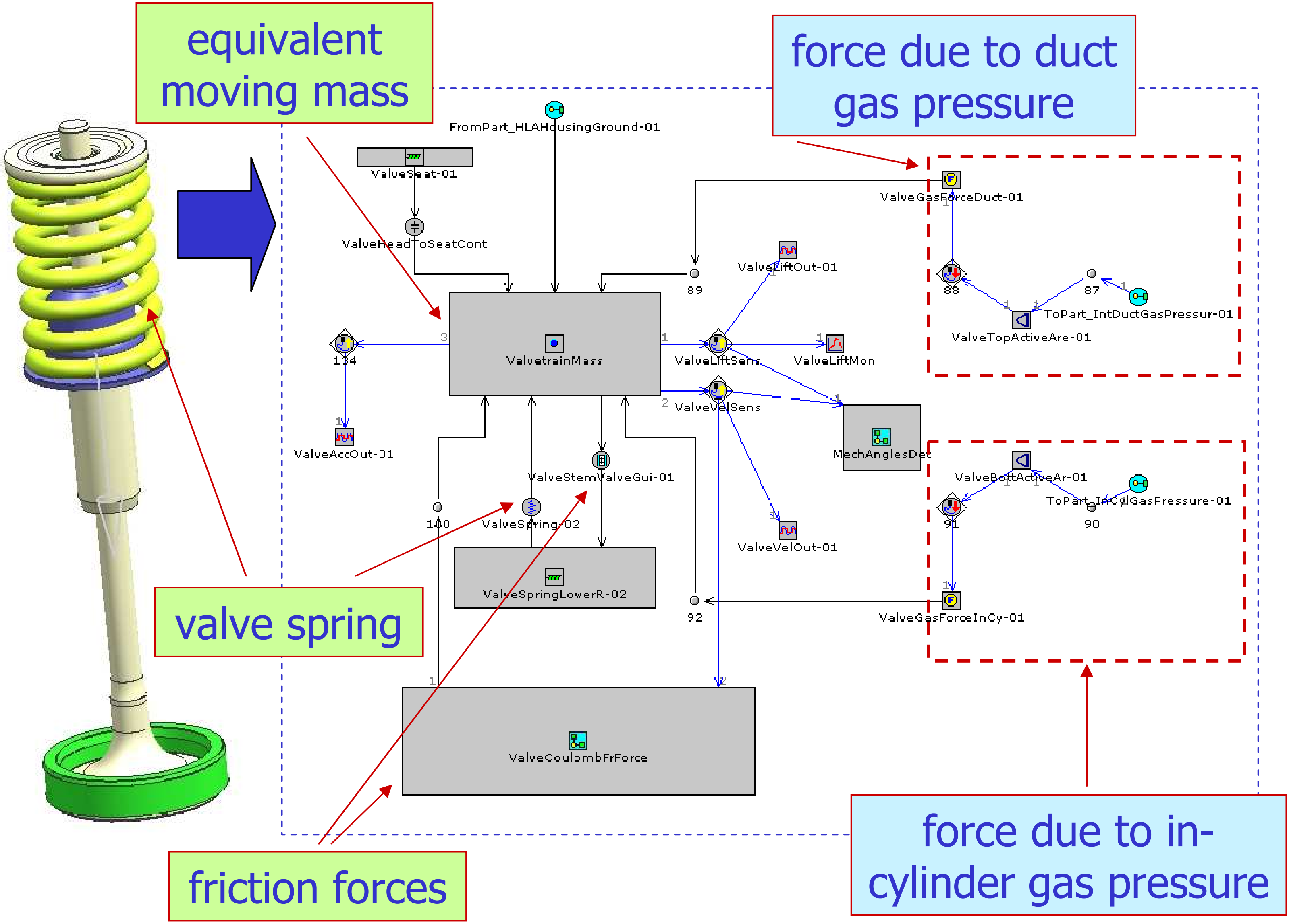

POWERTRAIN TECHNOLOGIES

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- model developed with the aim to implement the physics of the system
- geometry of the oil circuit modelled with an high level of detail
- evolution of the system considered as adiabatic (heat transfer multiplier of pipes and flowsplits set to zero)
- global stiffness of the system modelled as superposition of the hydraulic contribution (oil + free air + oil vapour) and the mechanical one (deformation of the pump driving system, pumping of the oil circuit boundaries, ...)
- the flow behaviour of fixed and variable opening orifices has been handled developing a dedicated compound template which estimates the discharge coefficient as a function of the instantaneous flow regime (laminar, turbulent)
- the developed model refers to the actuator of one intake valve of a selected engine cylinder

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- the comparison between simulation results and experimental data acquired at the motored test bench is shown in the following slides in two forms:
    - instantaneous patterns of valve lift and oil pressure in the high pressure chamber
    - actuator characteristic maps (valve opening and closing angles plotted against the solenoid valve electrical control angle $\Phi 1$ or $\Phi 2$)
- hot oil temperature and different engine speeds and valve controls are considered
- the parameters set of the model comes from a preliminary identification

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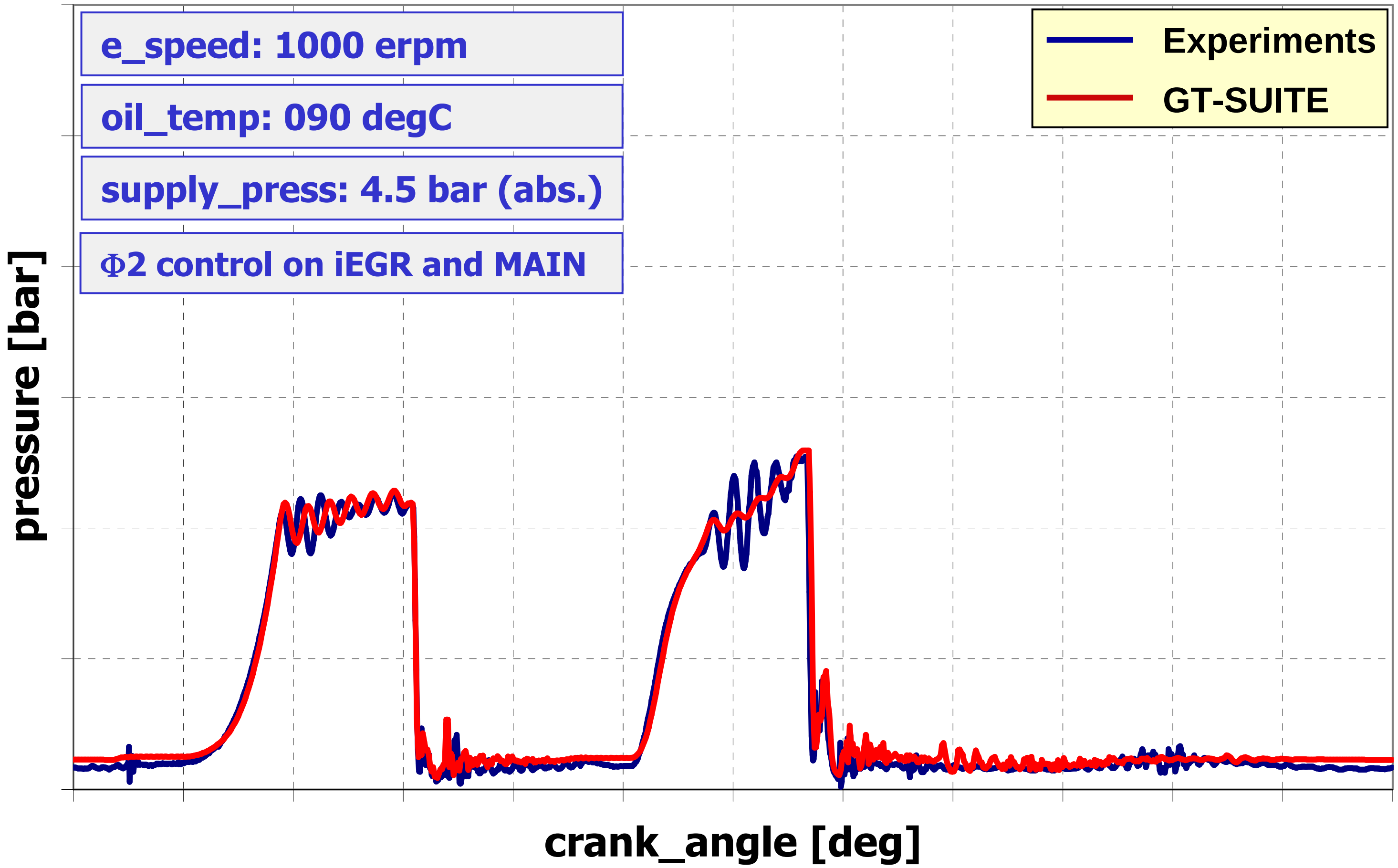
High pressure chamber pressure pattern



Comparison between simulation results and experimental data
Instantaneous patterns

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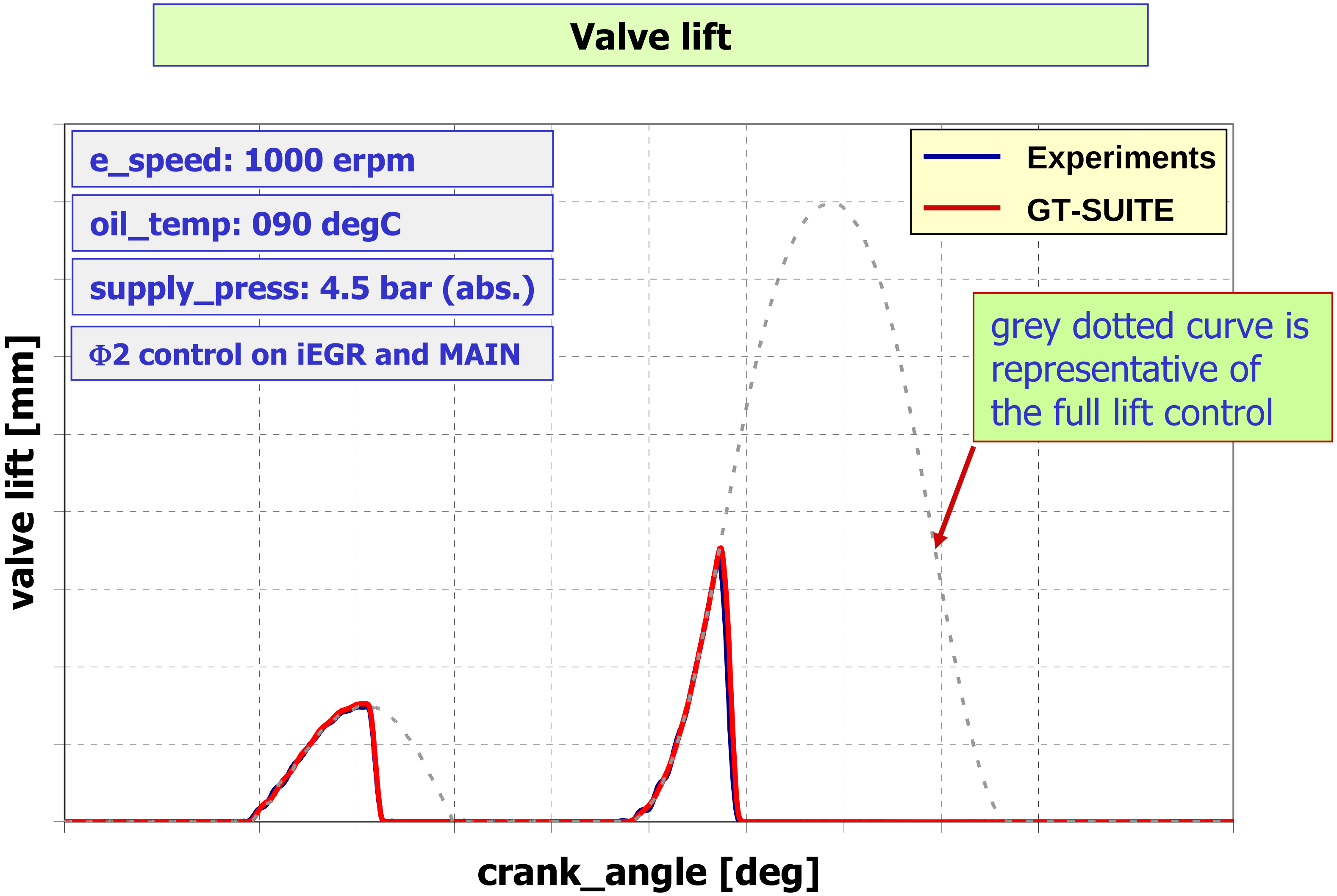

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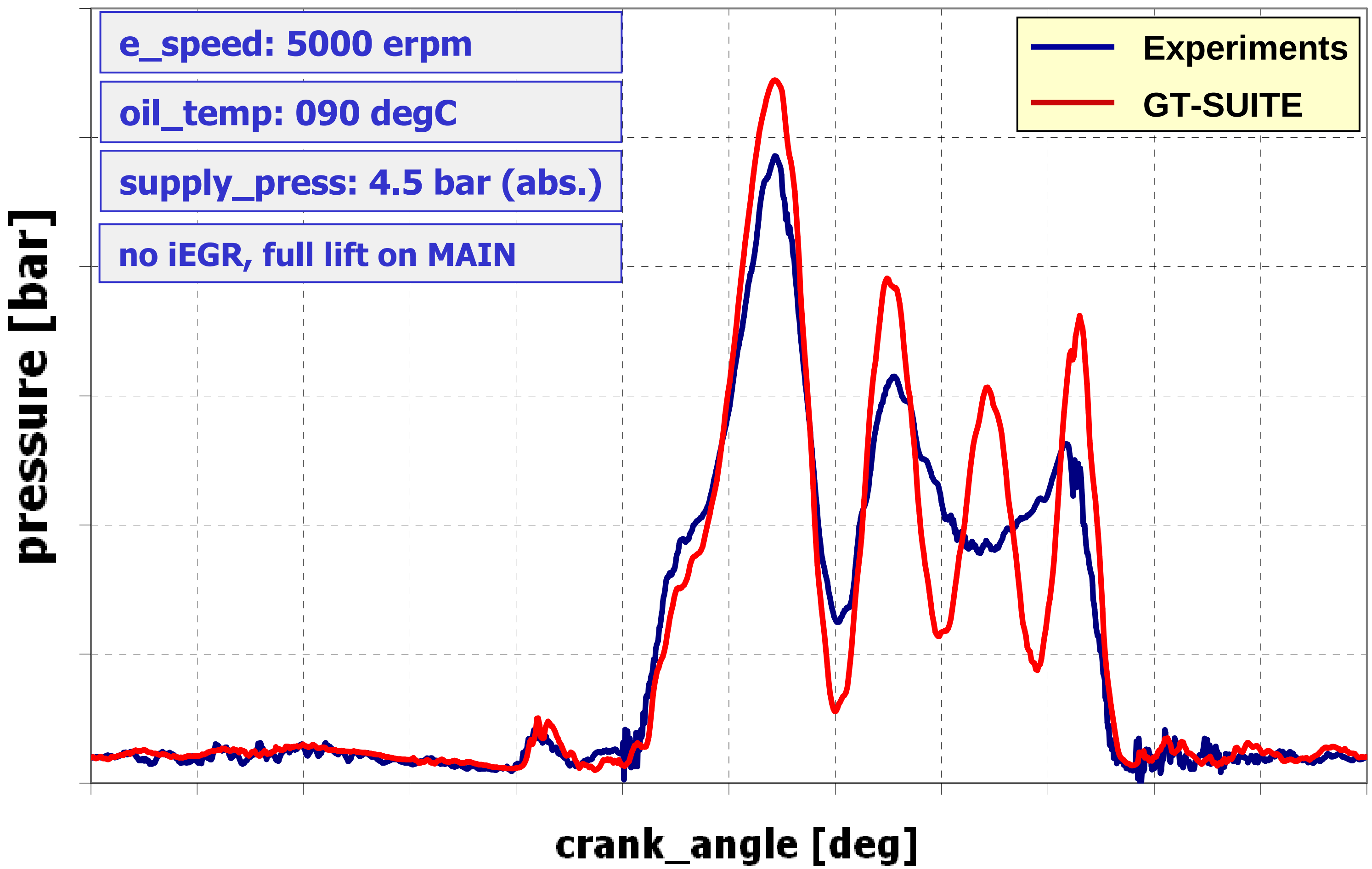

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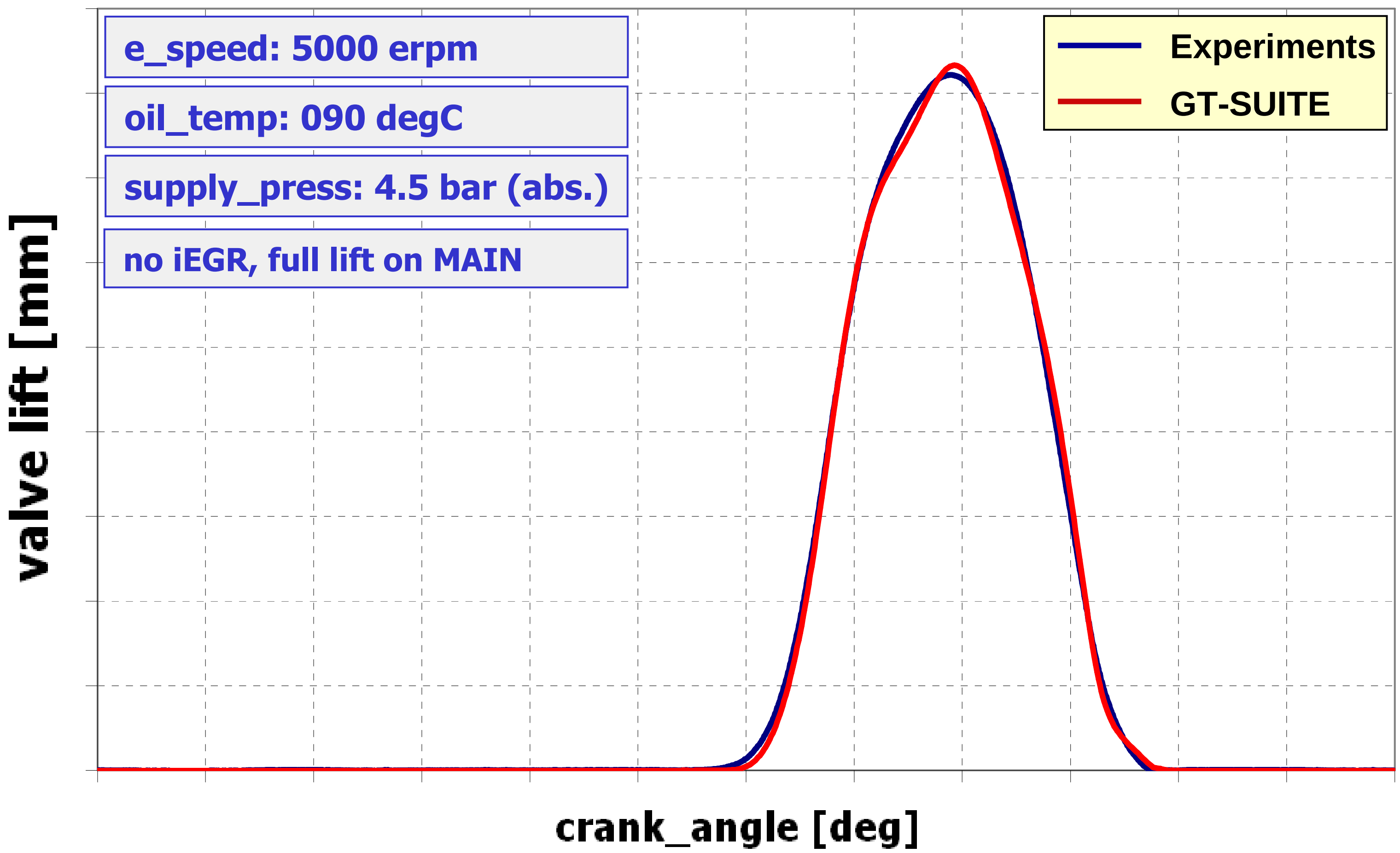
Valve lift



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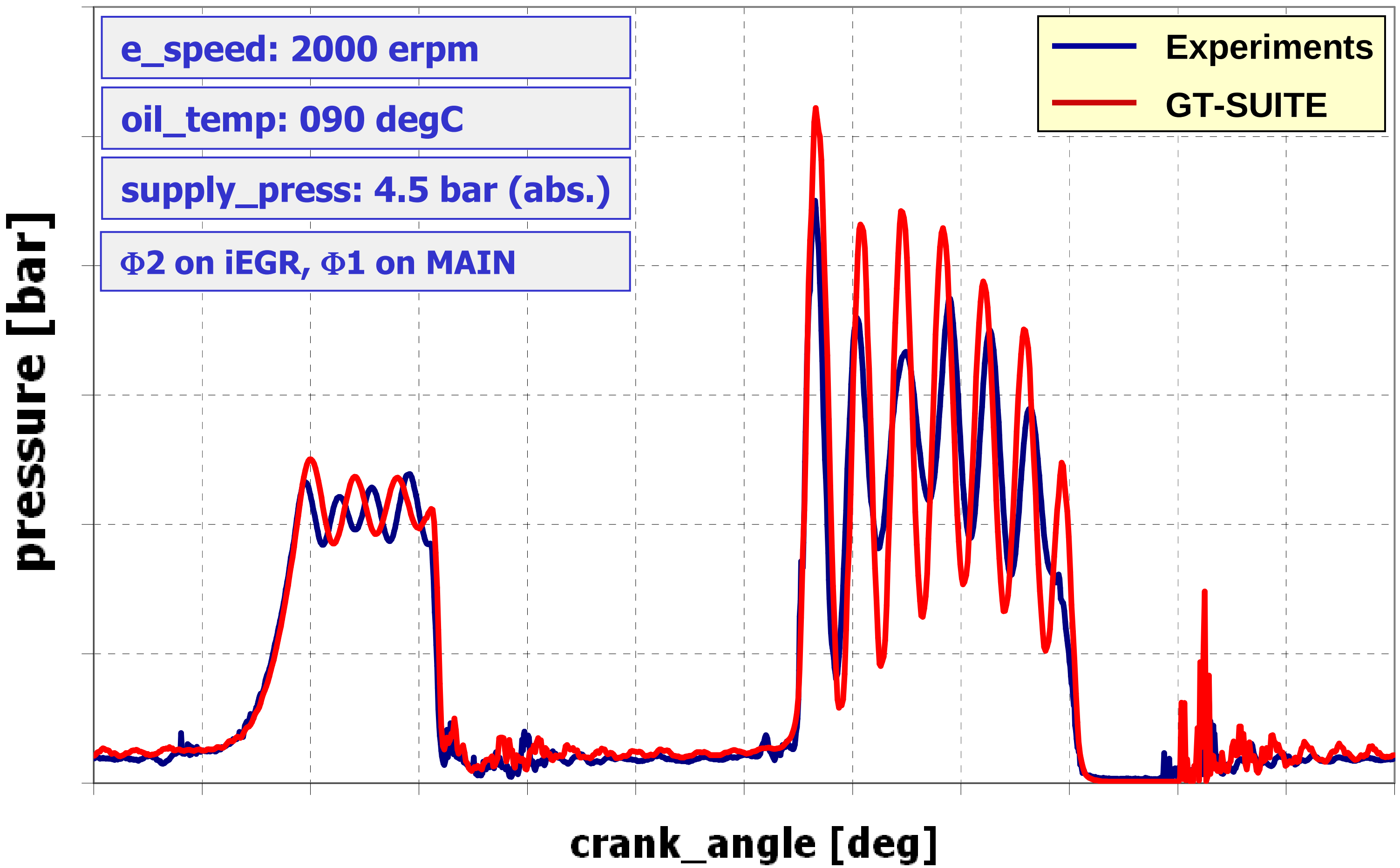

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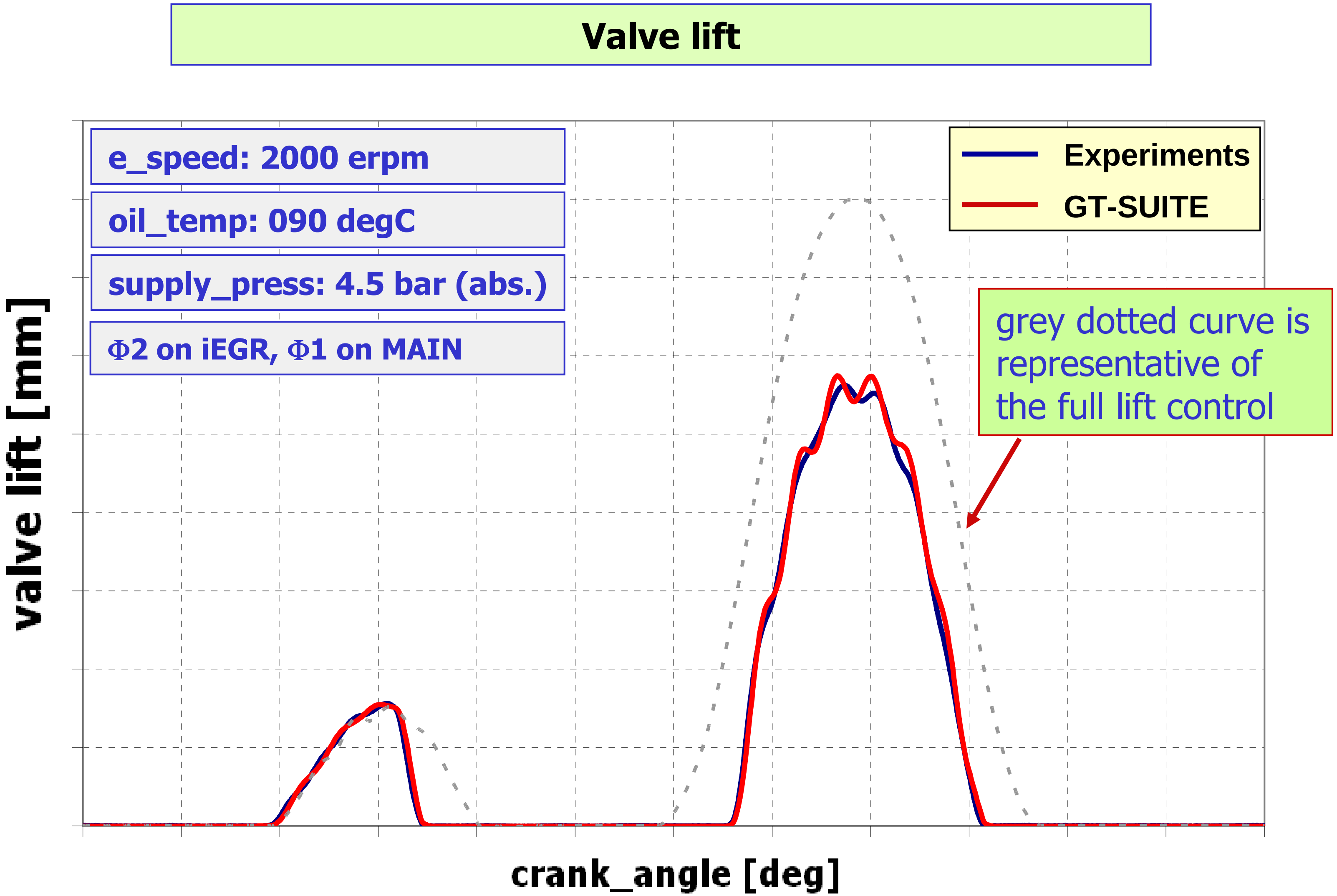

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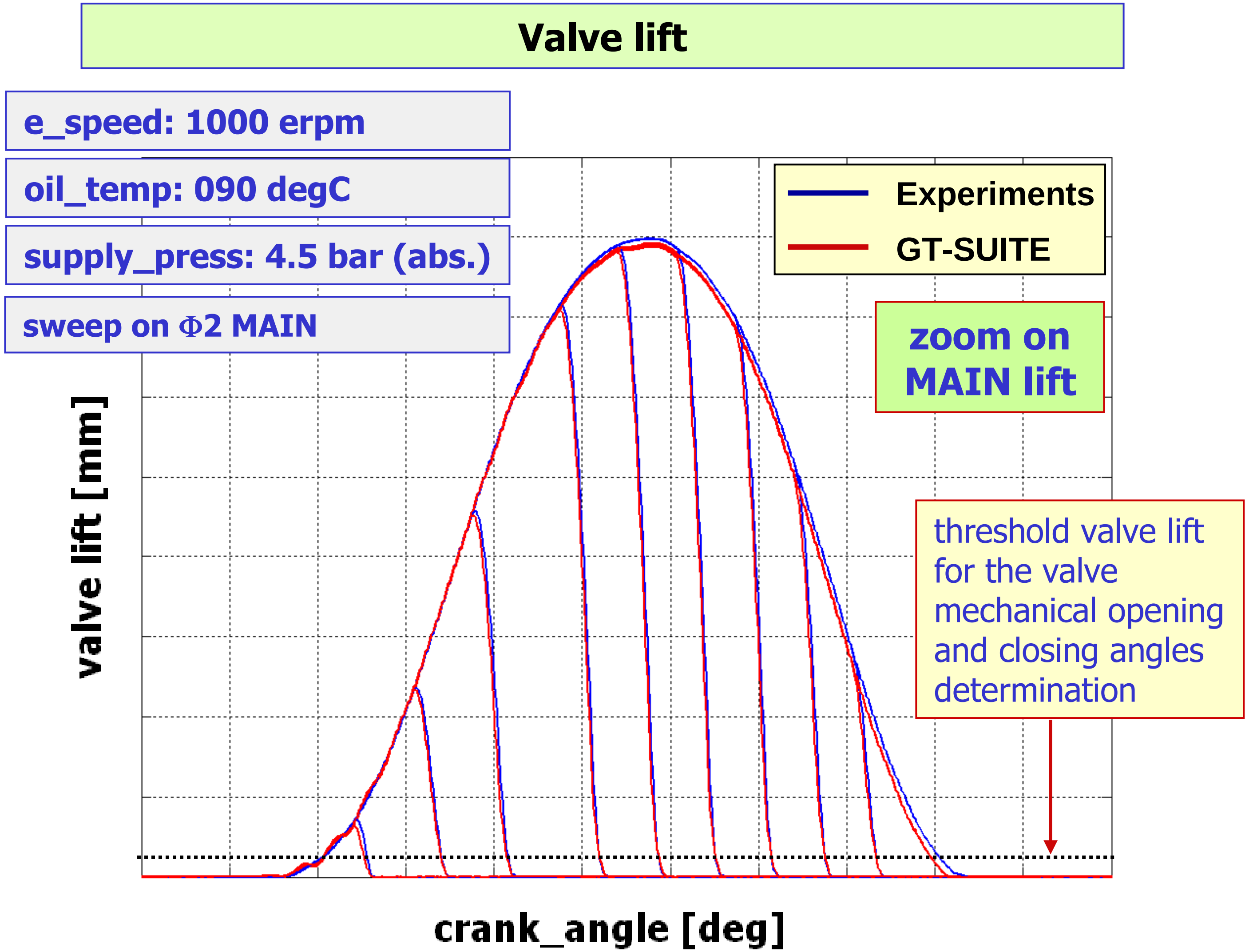

Actuator characteristic maps - valve closing angle vs SV control

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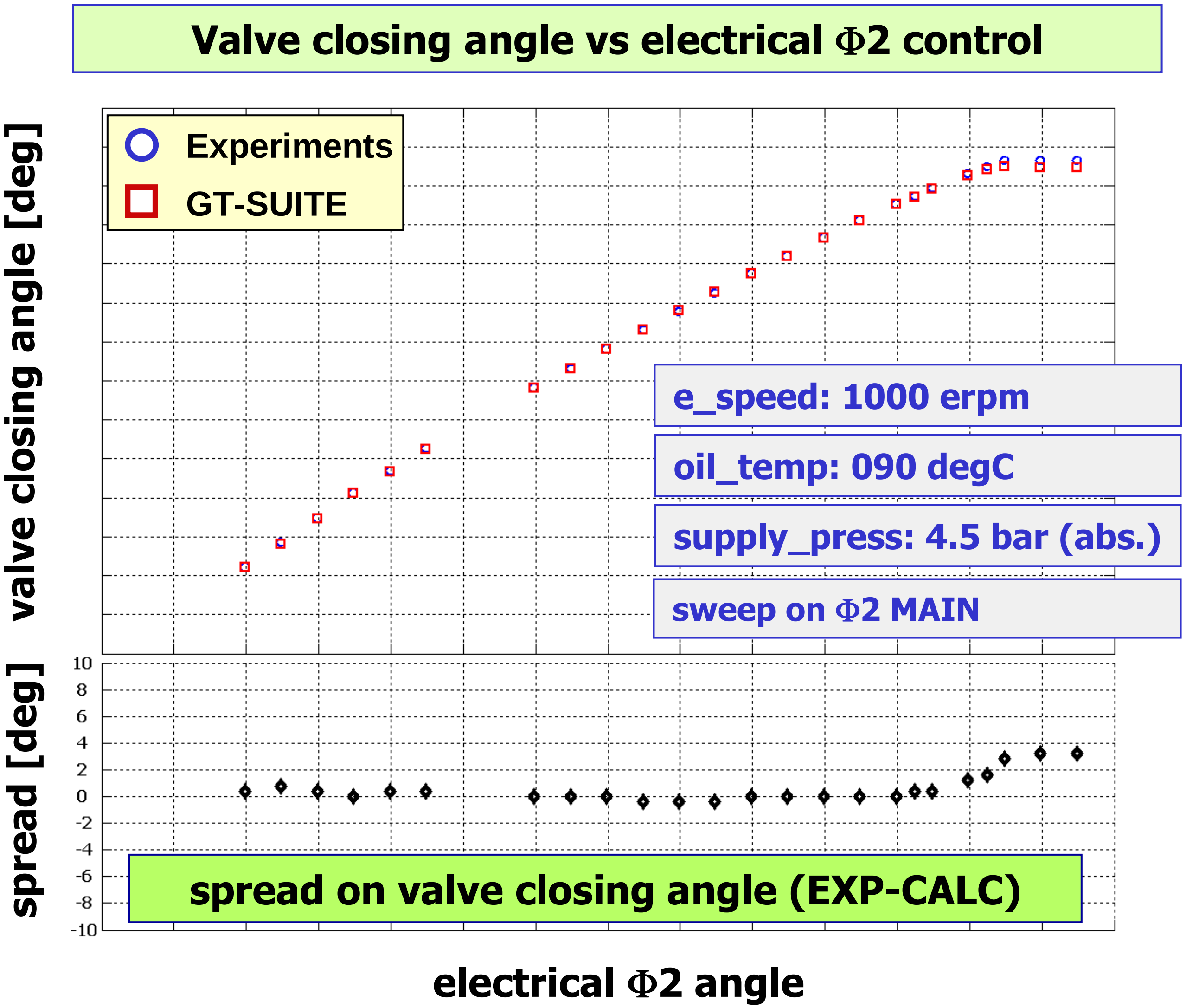

Engine model (GT-Power) and UNIAIR model (GT-FUEL) coupling

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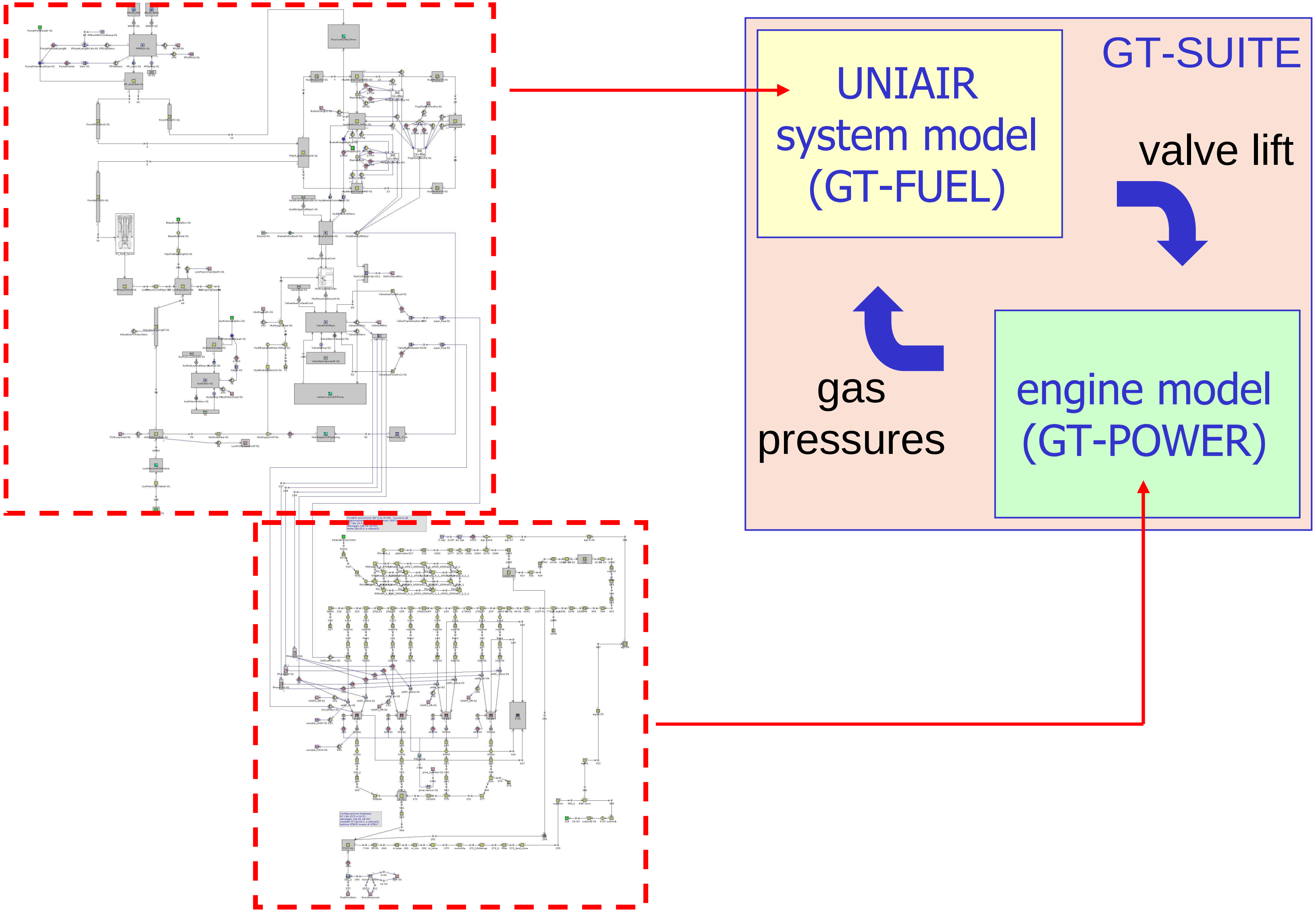
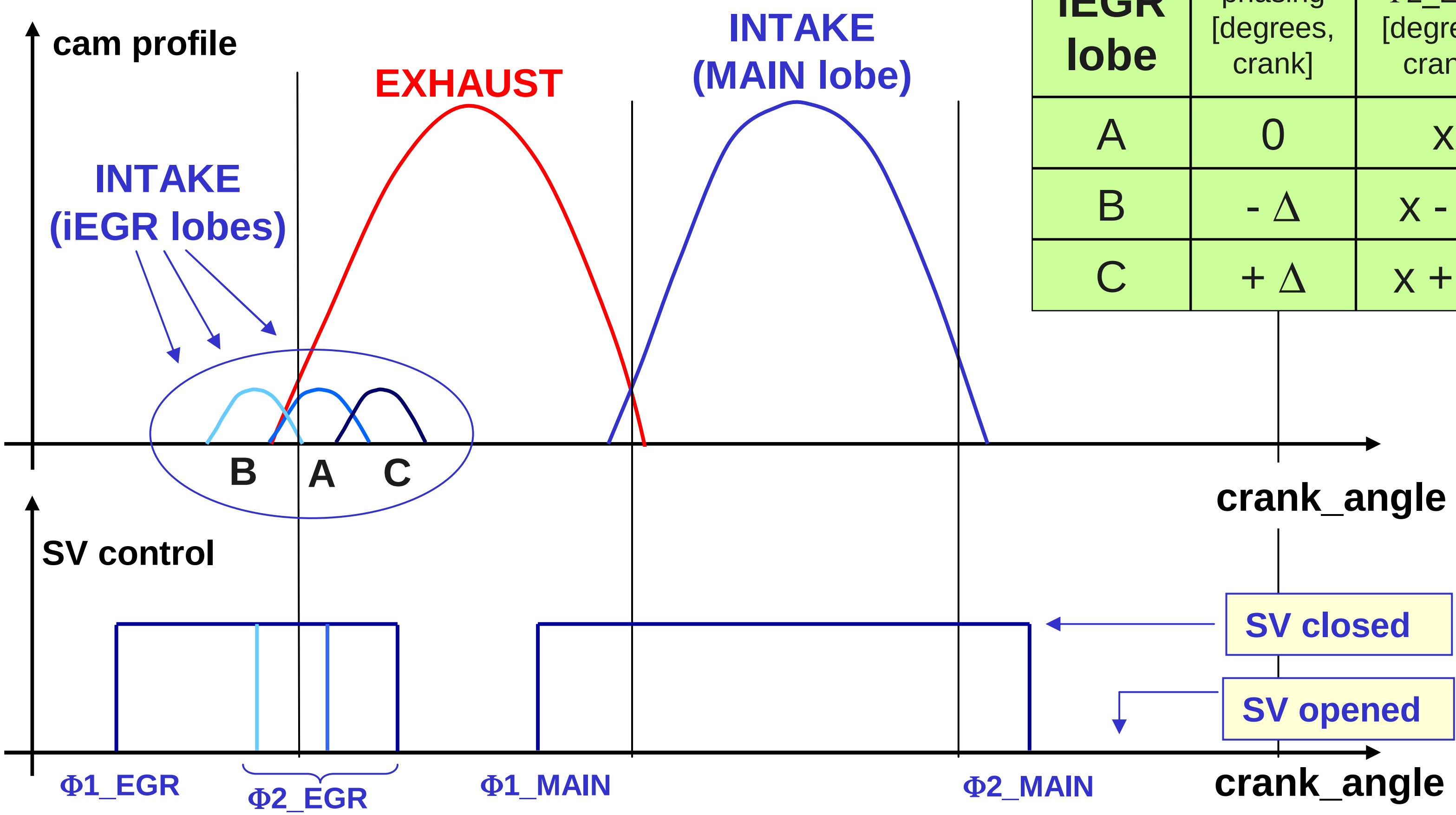


- **engine operating conditions: part load, 2000 erpm, hot oil condition**
- **iEGR lobe control follows the phasing variation**



iEGR lobe	phasing [degrees, crank]	Φ2_EGR [degrees, crank]
A	0	x
B	- Δ	x - Δ
C	+ Δ	x + Δ

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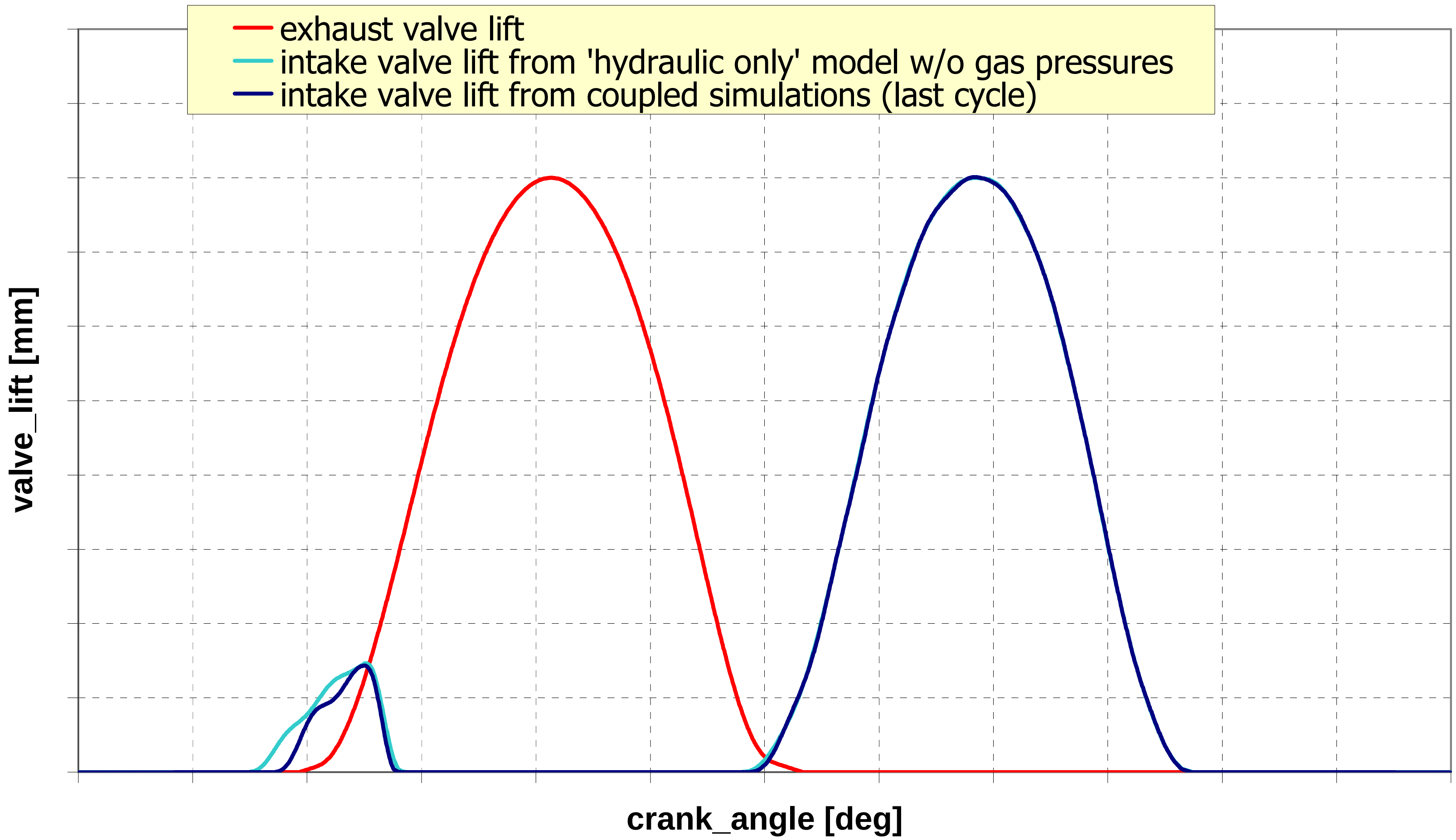
Effect of the gas pressures for the anticipated lobe (lobe B) – valve lift



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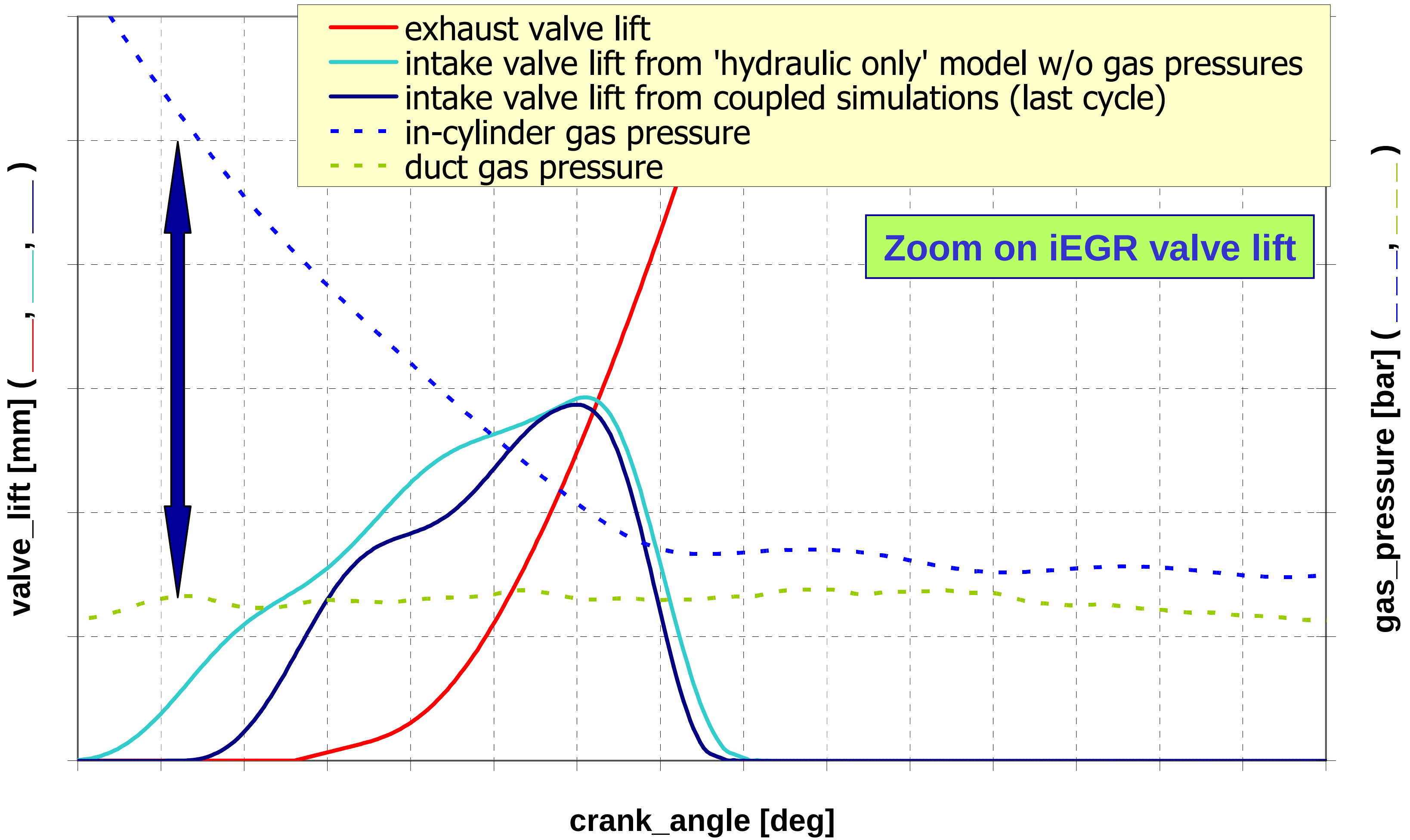

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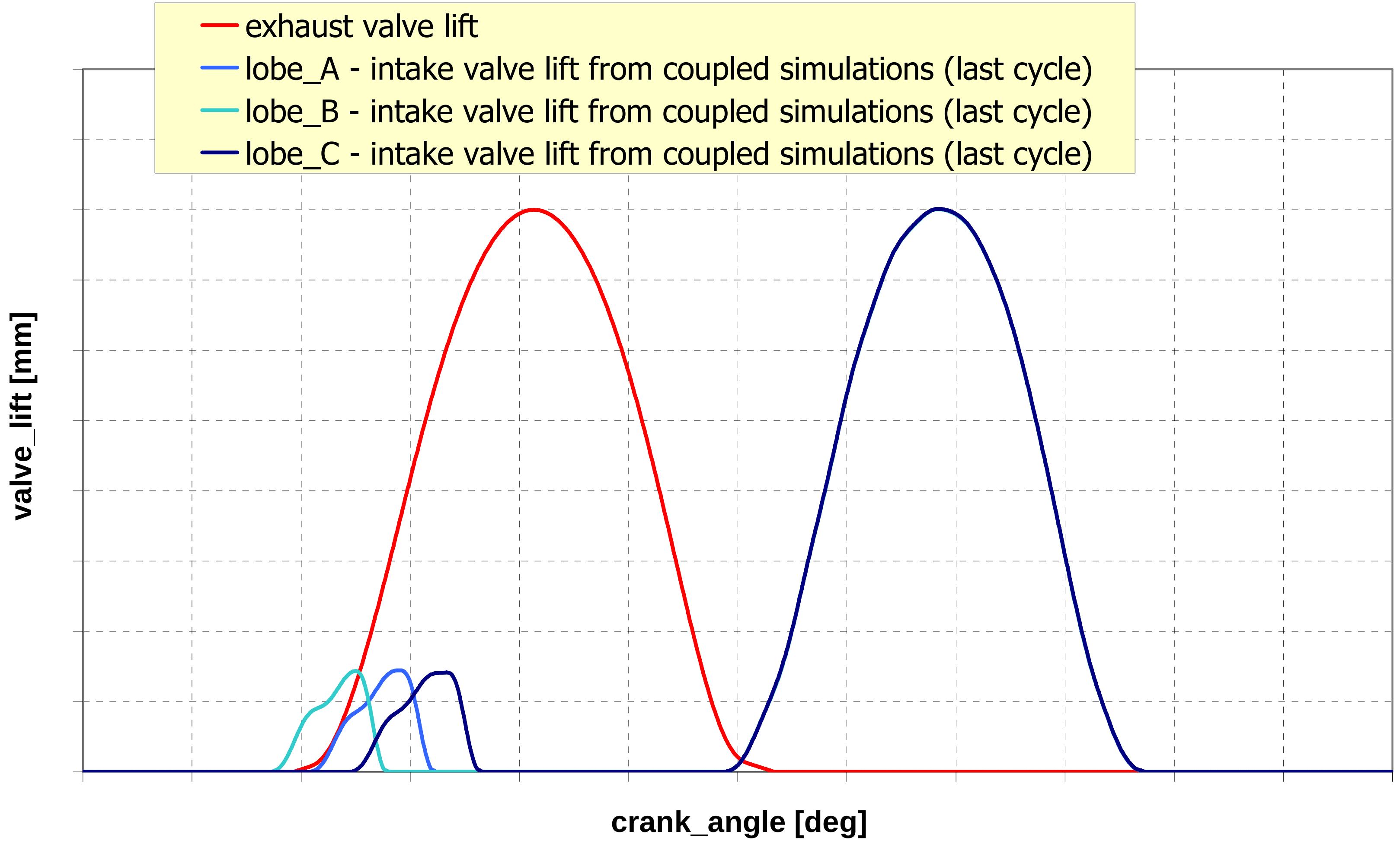

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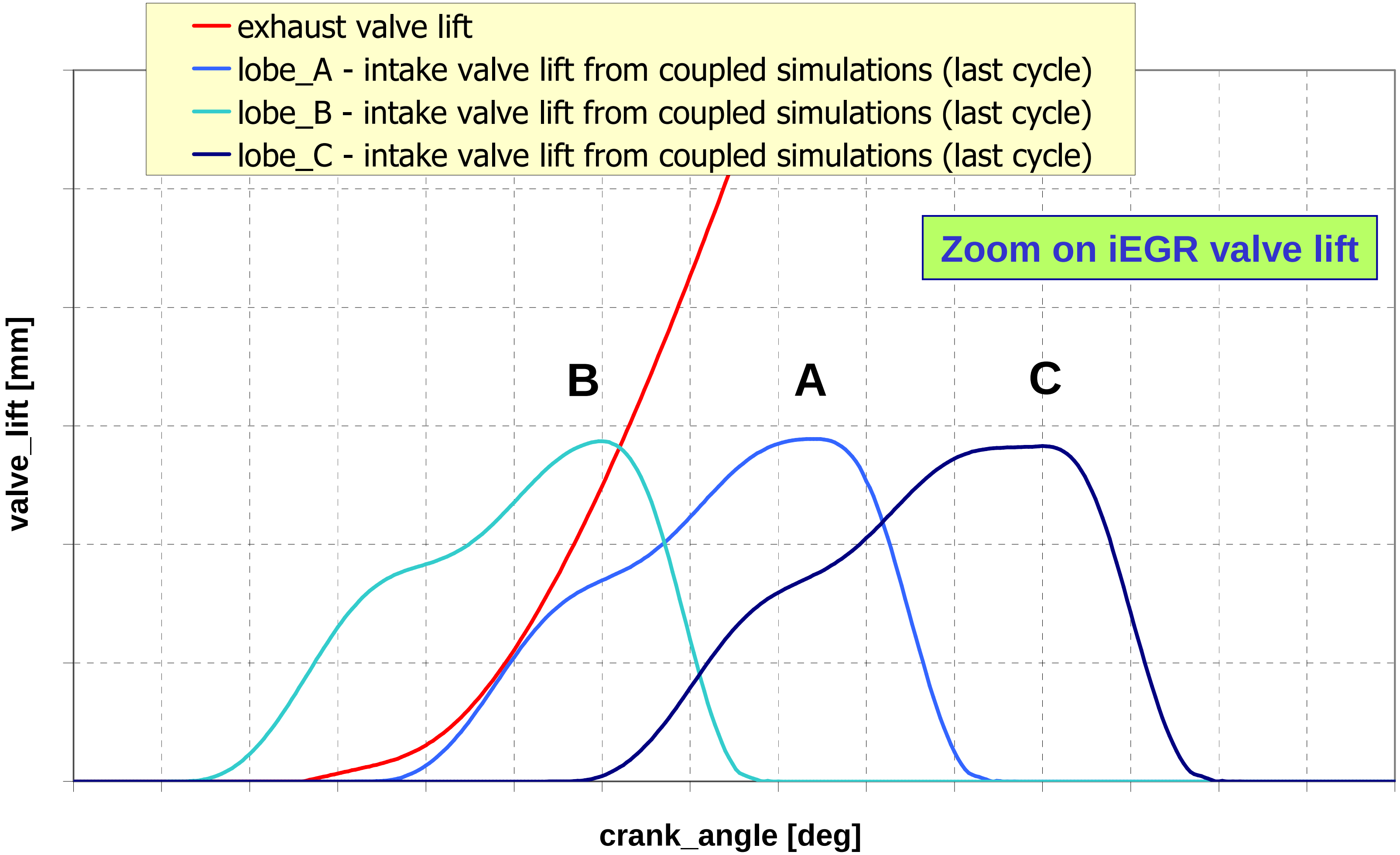

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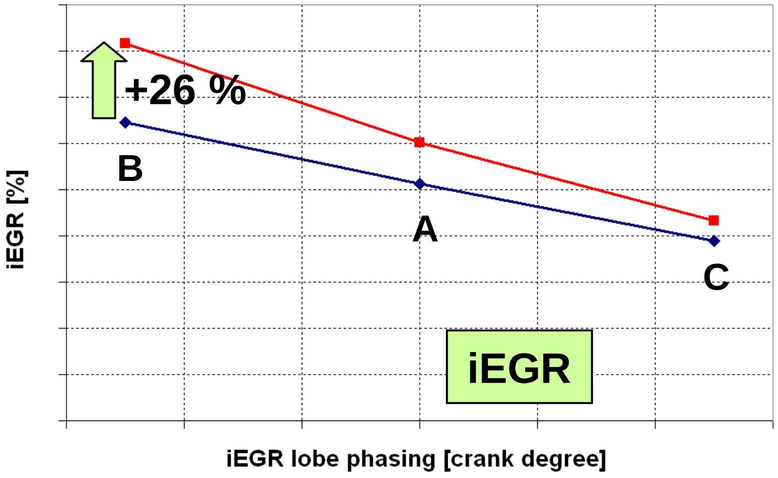

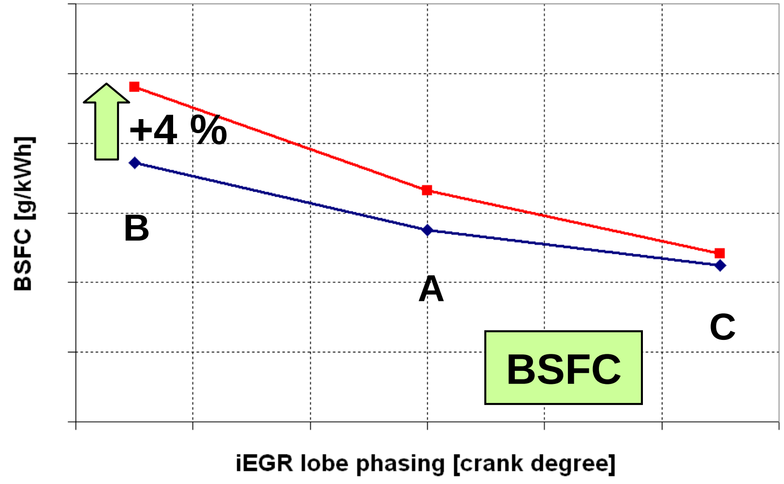

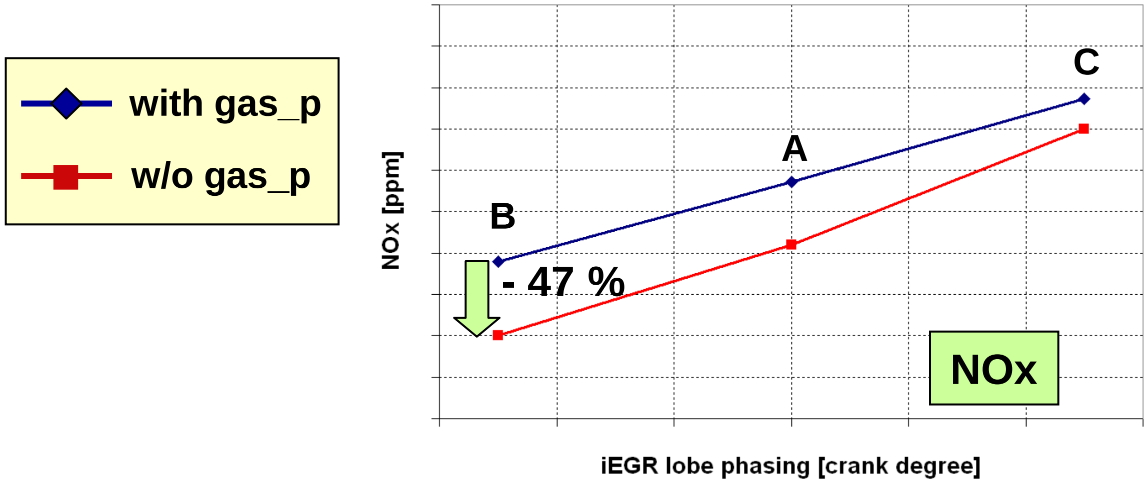

Trade-off optimization 'BSFC-NOx' (1/2)

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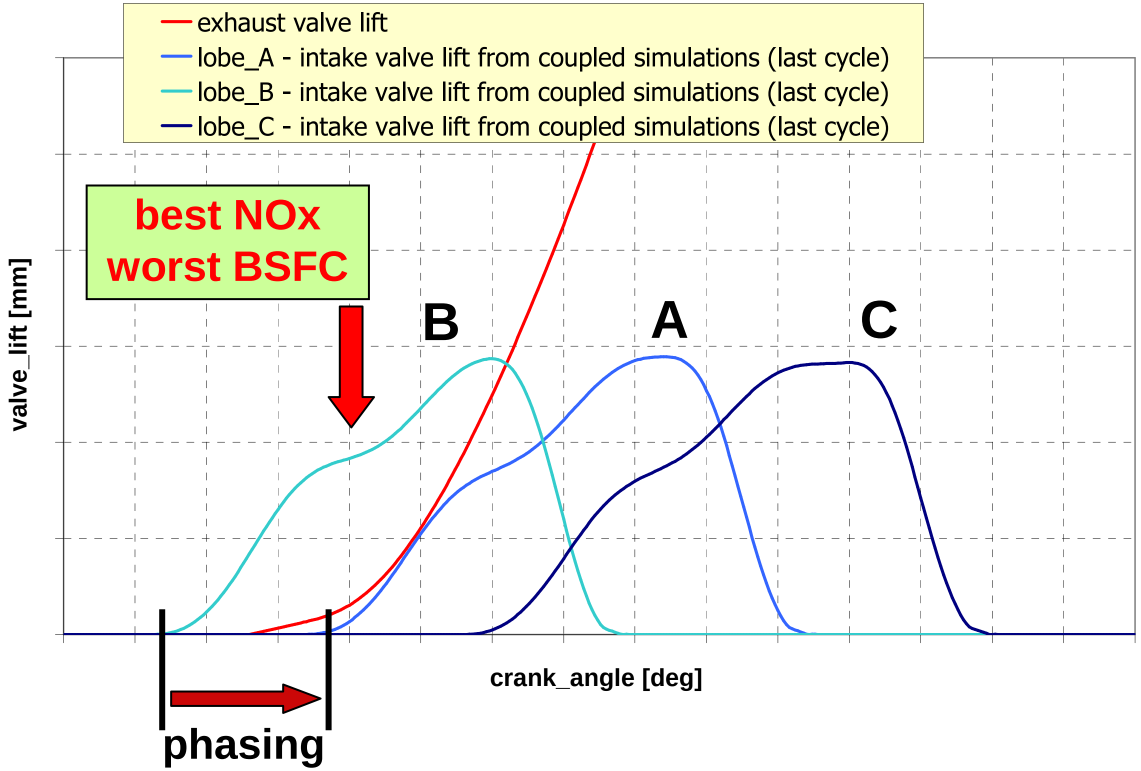
- **engine operating conditions: part load, 2000 erpm, hot oil condition**
- **iEGR lobe control follows the phasing variation**



Objective: searching for an iEGR lobe phasing and relative control in order to improve the BSFC maintaining the NOx of case B

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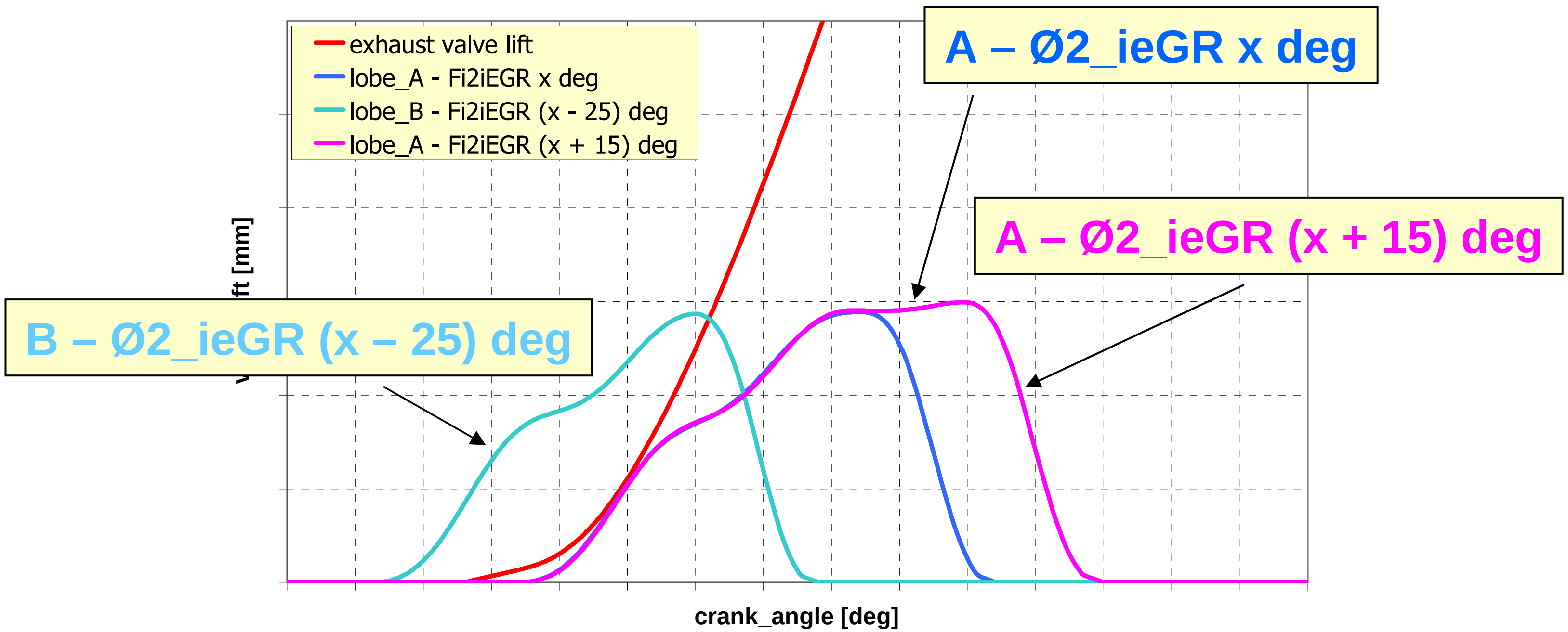

iEGR lobe	Ø2_iEGR [deg]	% iEGR	BSFC	NOx
B	X - 25	ref.	ref.	ref.
A	X + 15	≅	- 2%	≅

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- a detailed model of the UNIAIR variable valve actuation system has been developed in the GT-SUITE environment

- the elaborated model shows a level of accuracy in the description of the real behaviour of the actuator which is generally good over the whole actuator operating range

- the model of the actuator (hydro-mechanical domain) has been integrated to the model of the engine (thermo-fluid dynamic domain) with the aim to perform integrated simulations in which the valve lift generated by the hydraulic network takes into account, speed by speed and load by load, the effect of the gas pressures

- the developed tool will allow to perform engine analyses focused on the optimization of additional cam lobes (internal EGR, engine braking)

- the state of the art integrated model is characterized by the following situation in term of computational time (one PC equipped with an AMD Dual Core Processor 4400+, 2 GB RAM):

engine speed: 2000 erpm
oil temperature: 90 degC
number of cycles: 70
integrated model
GT-SUITE 6.2 build 10

→

simulation time:
~ 5 hours (~ 4.3 min/cycle)

- the model complexity reduction and/or the distributed computing feature offered by the GT-SUITE environment can be considered for the computational time reduction

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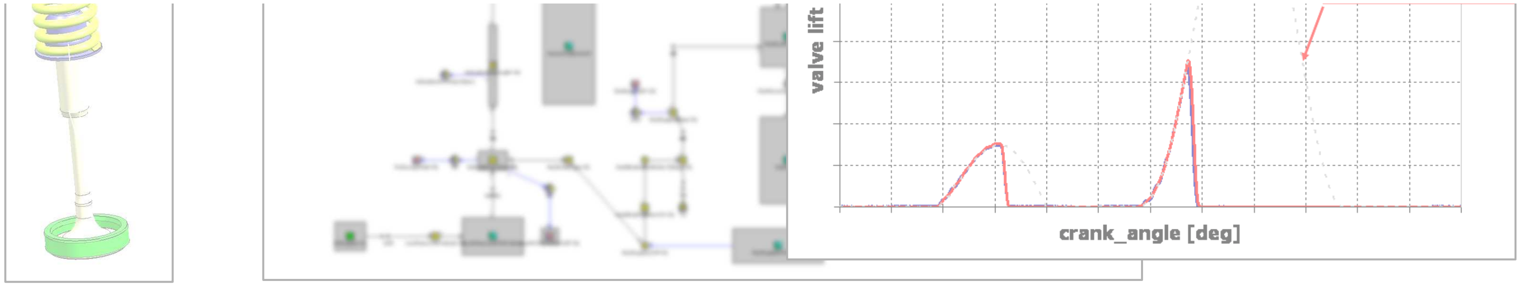
Questions ?

Thanks to Gamma Technologies and in particular to Shawn Harnish for the excellent support and ...



... thank you for your attention