The Diesel Exhaust Aftertreatment (DEXA) Cluster of the EU Growth Program

Athanasios G. Konstandopoulos[1, *], Gianmarco Boretto[2,†], Peter Prenninger[3], and Wilhelm Brandstaetter [4]

[1]Aerosol & Particle Technology Laboratory, CERTH/CPERI
[2]Centro Ricerche Fiat
[3]AVL List, GmbH.
[4] Christian-Doppler-Laboratory for Applied Computational Thermofluiddynamics (CDL/ACT)

ABSTRACT

In 2000 a consortium of 8 industrial partners and 7 research institutes with partial funding from the European Commission (EC) Growth Programme formed the Diesel Exhaust Aftertreatment (DEXA) Cluster and undertook the task to provide a complete and integrated approach at the European level, for diesel exhaust aftertreatment, with emphasis on particulate matter. The DEXA cluster consisted of three closely interlinked projects and in 2003 the DEXA cluster concluded by demonstrating the successful development of critical technologies for diesel exhaust particulate aftertreatment, without adverse effects on NO_x emissions and maintaining the fuel economy advantages of the diesel engine towards the EURO IV emission standards horizon and beyond.

* E-mail: agk@cperi.certh.gr
† Currently at FIAT-GM Powertrain

INTRODUCTION

In the present paper the most important results from the DEXA cluster projects are presented. These cover 1) the development of advanced catalytic particulate control technologies and their integration on two demonstrator vehicles 2) the development of an efficient and user-friendly simulation toolkit for the computer-aided design and engineering of integrated Diesel exhaust aftertreatment systems and its application for the design and optimization of the demonstrator emission control systems, and 3) the development of novel particulate size and composition measurement methodologies and their application for the evaluation of the particulate control technologies deployed on the demonstrator vehicles.

CONCLUSIONS

The results of the DEXA cluster are expected to increase the competitiveness of European automotive industry and accelerate the adoption of particulate control technology.

SLIDE PRESENTATION

THE DIESEL EXHAUST AFTERTREATMENT (DEXA) CLUSTER OF THE EU GROWTH PROGRAMME

A. G. Konstandopoulos*, G. Boretto**, P. Prenninger*** & W. Brandstaetter****

DEXA CLUSTER PARTNERS

The cluster consists of 4 projects involving 15 partners from 7 different European countries with long-term R&D experience in Diesel exhaust aftertreatment and engine technologies.

Center for Research and Technology - Hellas
Chemical Process Engineering Research Institute
Ινστιτούτο Τεχνικής Χημικών Διεργασιών
Aerosol & Particle Technology Laboratory

Fiat Research Center

RENAULT

CHRISTIAN DOPPLER FORSCHUNGSGESELLSCHAFT
ACT
APPLIED COMPUTATIONAL THERMOFLUIDDYNAMICS

ISTITUTO MOTORI
RERUM CAUSAM COGNOSCERE - 1940

POLITECNICO DI TORINO 1859 - 1906

JM Johnson Matthey

ZEUNA STÄRKER

AVL

FEV

Università di Napoli Federico II

CUTEC INSTITUT GmbH

WIZARD Zahoransky KG

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

OBERNOSTERER STRICKSTOFFE® GESELLSCHAFT mbH

DEXA CLUSTER (2000-2003):
A systems approach to diesel emission control

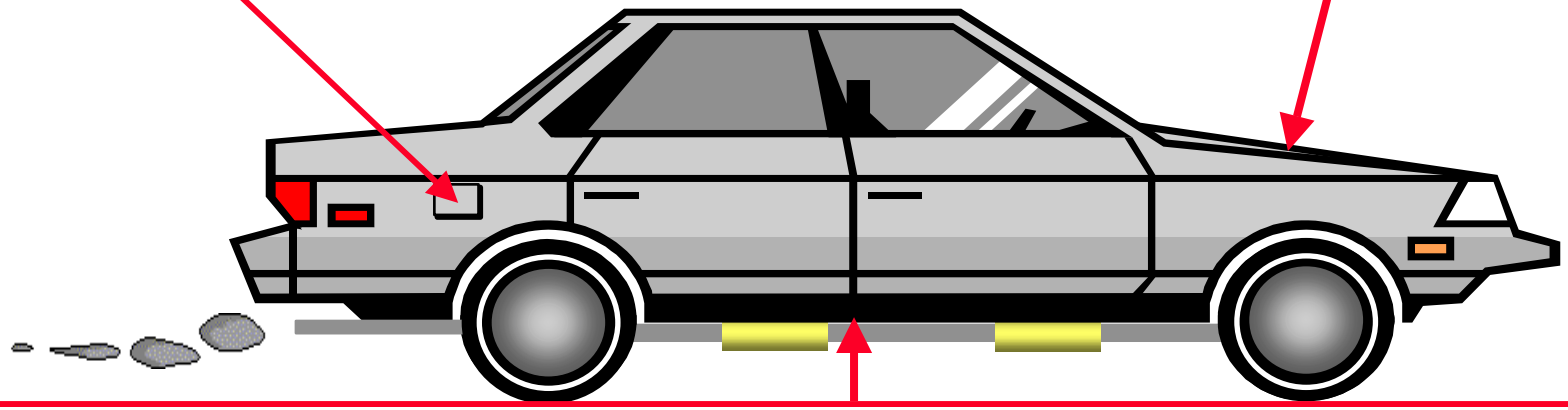
Fuel/Lube oil

→ Effects of Sulfur - content/composition on emissions and aftertreatment system

In-cylinder measures

→ Advanced Fuel Injection

→ Combustion mode



DEXA

Real time soot nanoparticle measurement

→ Size/Composition

Raw vs. Dilute

Exhaust Aftertreatment System

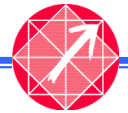
→ Novel device designs (filters, catalysts)

→ CAE tools for system Design/Optimization/Control (traps, DeNOx system, Ox. Cat.)

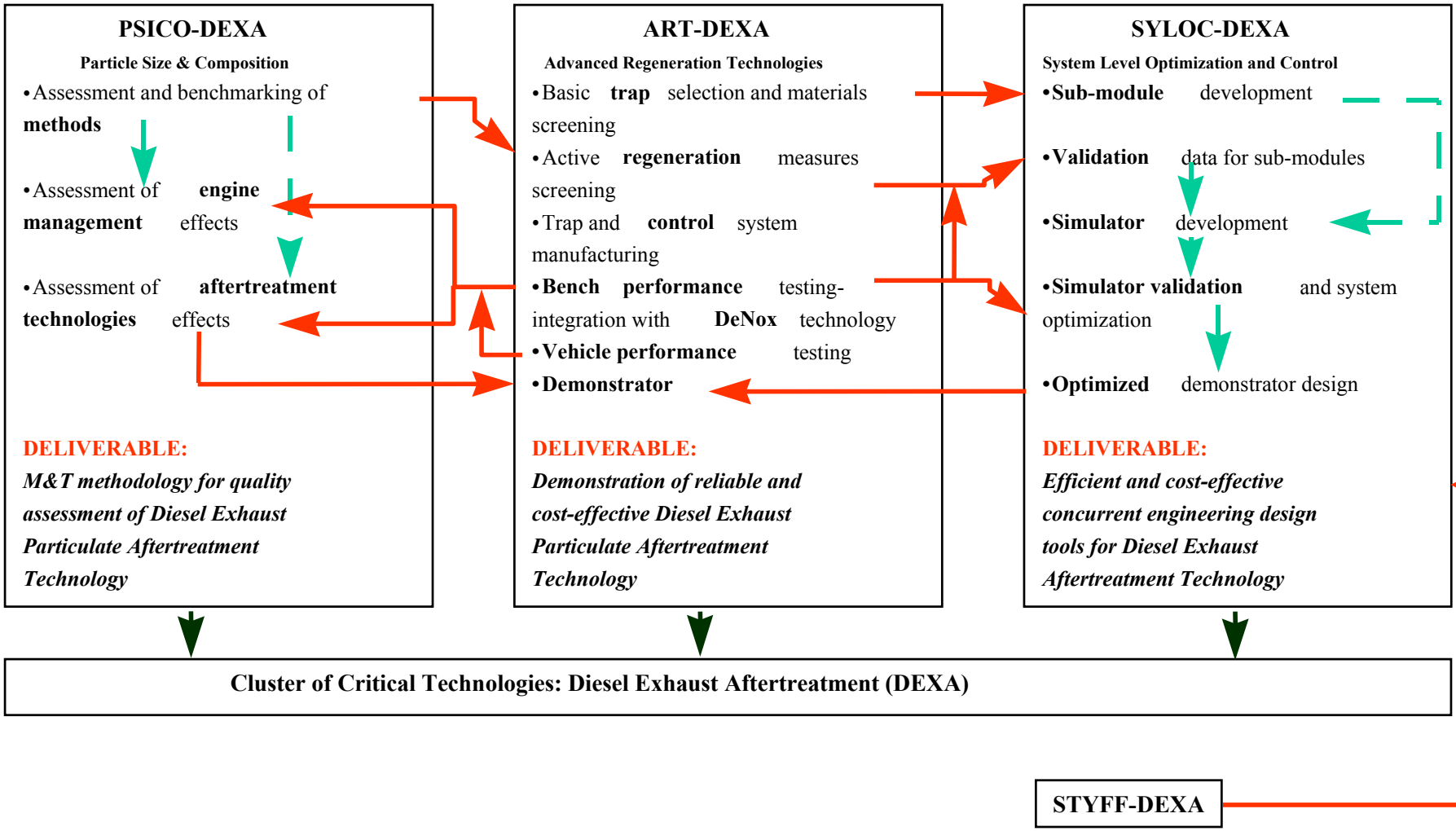
DEXA Cluster Projects

The DEXA cluster focuses on 3 aspects of diesel particulate emissions:

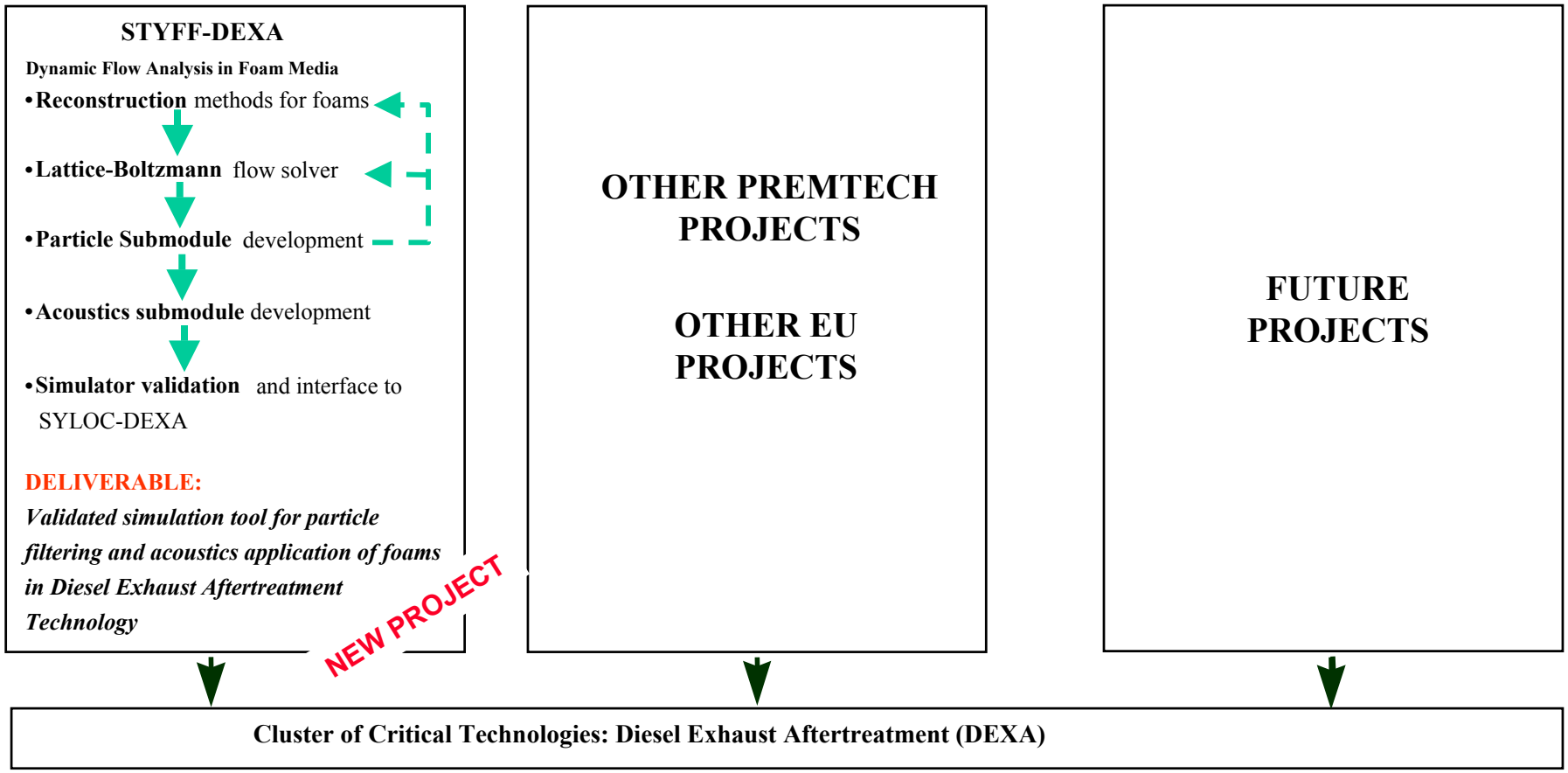
- component technology integration in two demonstrator vehicles (Project ART-DEXA)
- system design and simulation tools (Projects SYLOC-DEXA, STYFF-DEXA)
- quality assessment and measurements of nanoparticles (Project PSICO-DEXA)



DEXA CLUSTER STRUCTURE -1

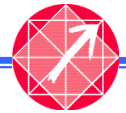


DEXA CLUSTER STRUCTURE-2



DEXA CLUSTER DELIVERABLES (March 2003)

- **ART-DEXA**
  - Two optimized vehicle demonstrators with advanced PM emission control meeting Euro IV PM+NO_x standards
- **SYLOC-DEXA**
  - Exhaust aftertreatment system simulator tool and component database
- **PSICO-DEXA**
  - Database of engine management and emission control technology effects on particle size & composition
- **STYFF-DEXA**
  - Validated computational engine for reconstruction of porous cellular structures



ART-DEXA Summary

- Two demonstrator vehicles characterized by Euro IV compliant NO_x and Particulate emissions in new state (particulate emission lower than 0.0025 g/km on NEDC cycle has been assessed) have been built up, combining promising catalytic particulate filter solutions with effective active regeneration strategies

- The average increase of fuel consumption is lower than 2%

- Ageing test (26.000 km): no deterioration of DPF and DOC

- The cost and the environmental impact (LCA) estimated for the whole system appears to be competitive compared to a fuel-additive based solution

ART-DEXA DEMONSTRATORS

ART-DEXA DEMONSTRATORS

•DEMONSTRATOR A:

Engine: 1.9 dm³

Exhaust system:

-Close coupled catalyst (0.6 dm³)

-Cordierite oxidation catalyst 5.66" x 3.54", 400 cpsi / 6.5 mils)

- "Mainstream Advanced" catalysed particulate filter

•DEMONSTRATOR B:

Engine: 2.2 dm³

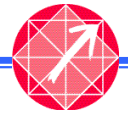
Exhaust system:

-Cordierite oxidation catalyst 5.66" x 3.54", 400 cpsi / 6.5 mils)

-"Sidestream Advanced" catalysed particulate filter

SYLOC-DEXA Summary

- **Submodels for**
  - Filters
  - Catalysts
- **Database of component technologies**
  - Exhaust system layouts
  - Filter materials and configurations
  - Catalysts
- **Computational interfaces/platforms**
  - Engine cycle simulation
  - Exhaust pipe CFD
  - Filter/Catalyst parameters
- **Validation Data**
  - Emission control components
  - System lay-out for vehicle demonstrators



SYLOC-DEXA TOOLKIT

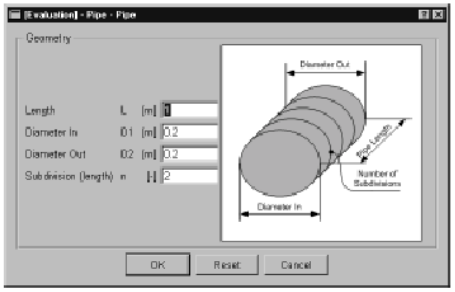


Figure 14: *Straight pipe module*

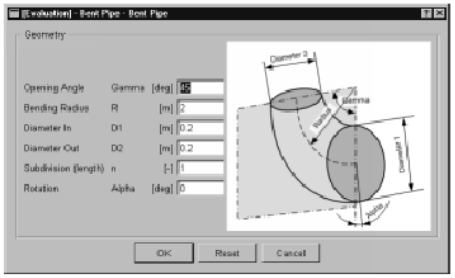
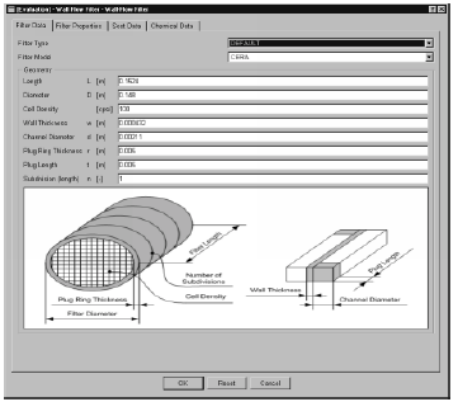
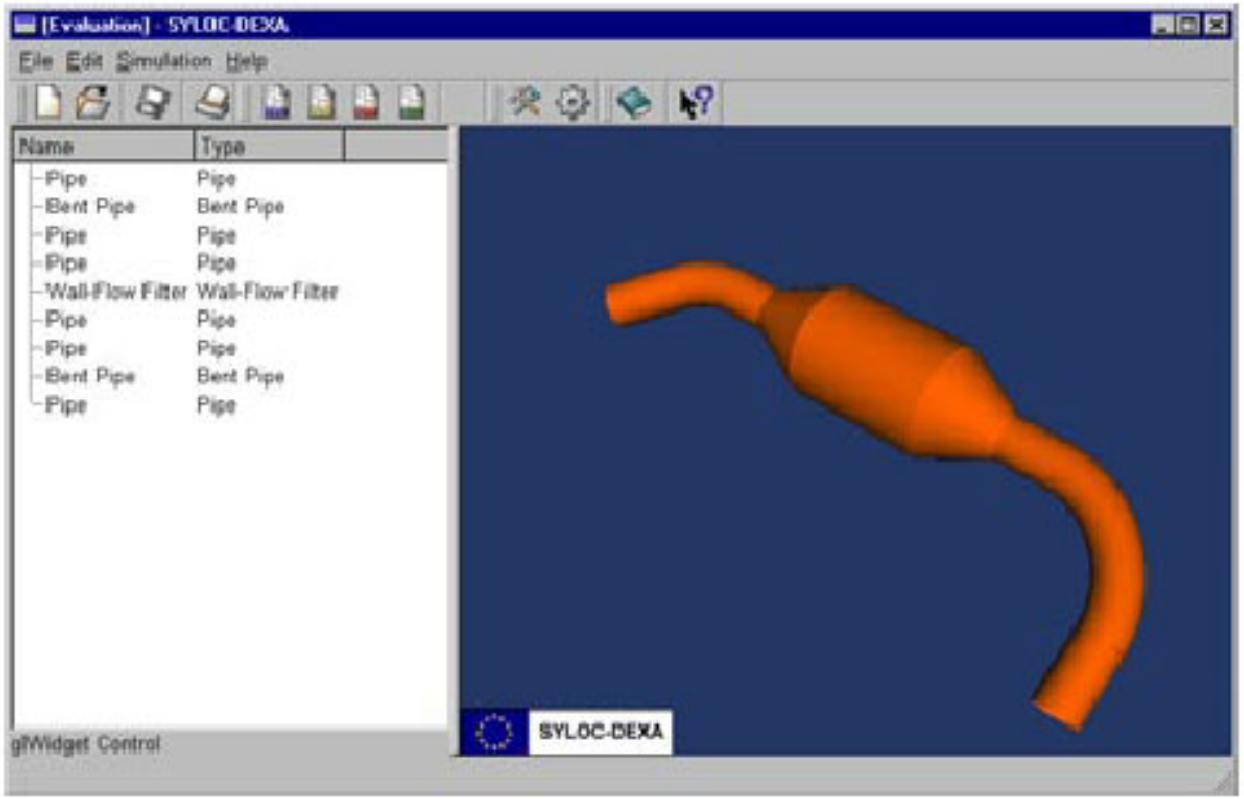
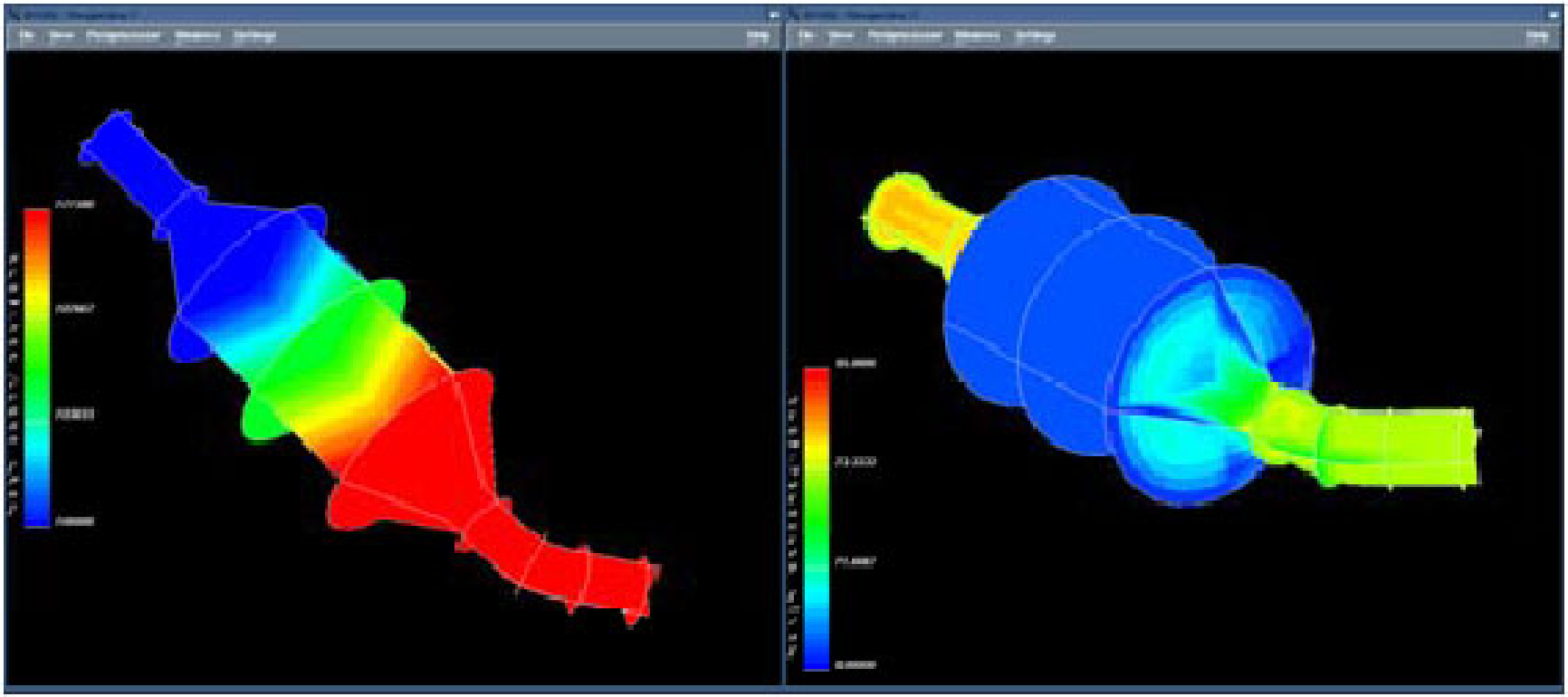


Figure 15: *Bent pipe module*

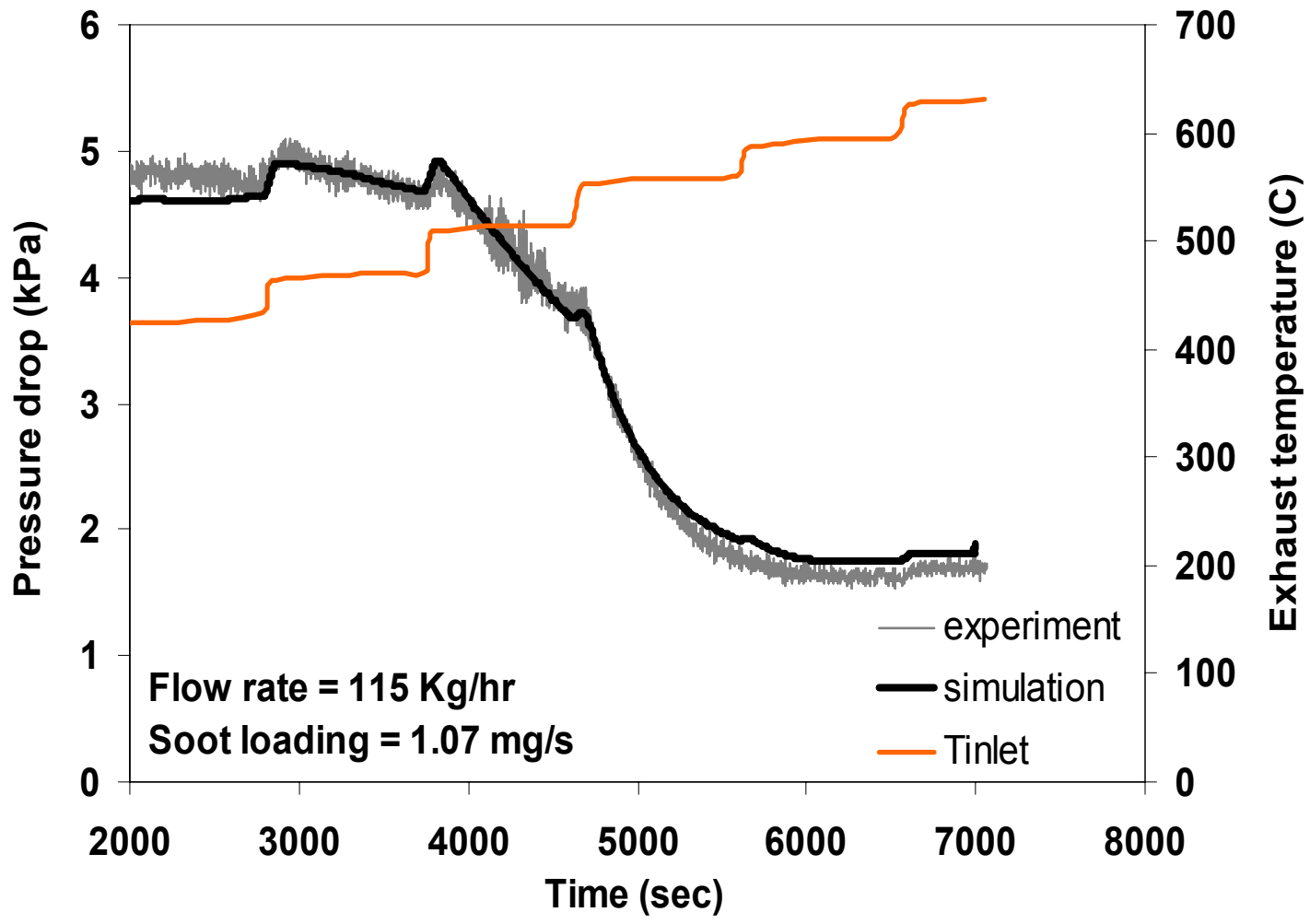




SYLOC-DEXA TOOLKIT



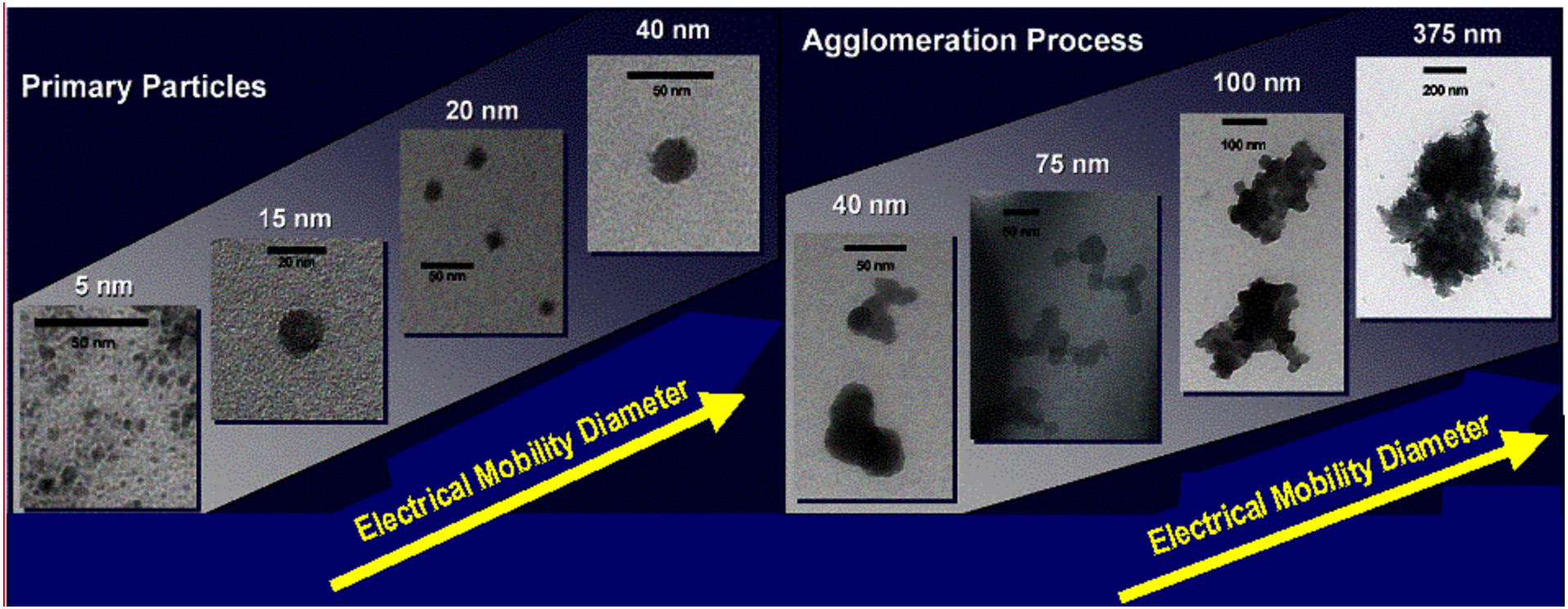
VALIDATION


Pressure drop (kPa)
Exhaust temperature (C)
Time (sec)
0
1
2
3
4
5
6
0
100
200
300
400
500
600
700
2000
3000
4000
5000
6000
7000
8000
Flow rate = 115 Kg/hr
Soot loading = 1.07 mg/s
experiment
simulation
Tinlet

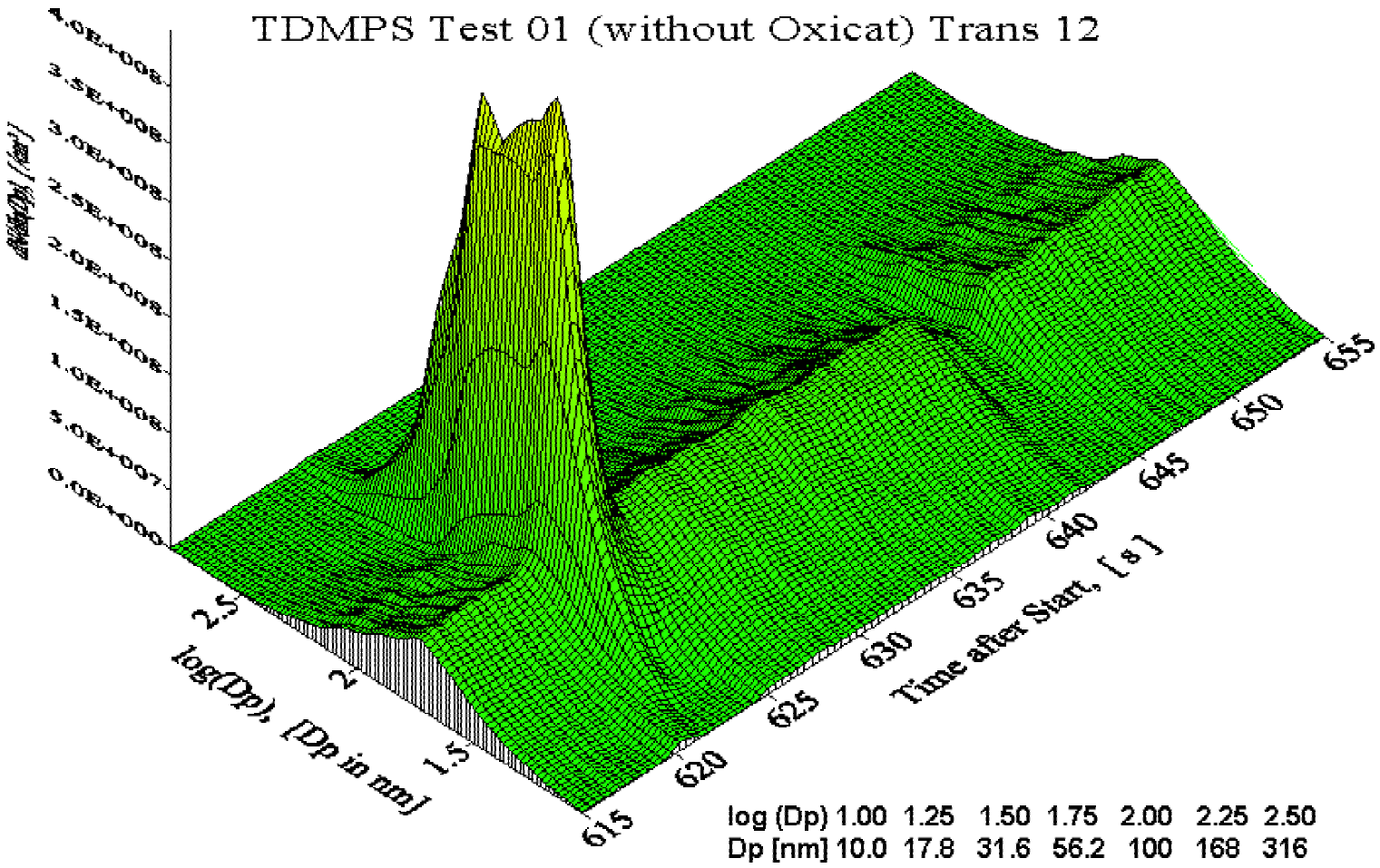
PSICO-DEXA Summary

- **Size measurement techniques**
  - Mobility techniques define the standard and real time performance has been demonstrated (TDMPS). New analysis to connect number and mass based distributions for fractal particles
  - Multiwavelength optical techniques are promising
- **Composition measurement techniques**
  - Baseline/Post-catalyst/Post filter changes of particles studied with emphasis on sulfate formation
  - Neutron activated Gamma-ray spectroscopy for trace elements on particles is demonstrated
- **Joint size-composition measurement techniques**
  - Thermophoretic Sampling/AEM, Size specific photoelectric yield, and size specific gamma-ray spectroscopy were developed and applied
- **Assessment of Engine Management & Aftertreatment Effects**
  - Strategies and aftertreatment technologies based on ART-DEXA
  - Assessment of technologies under normal and regeneration operation

Particle Morphology

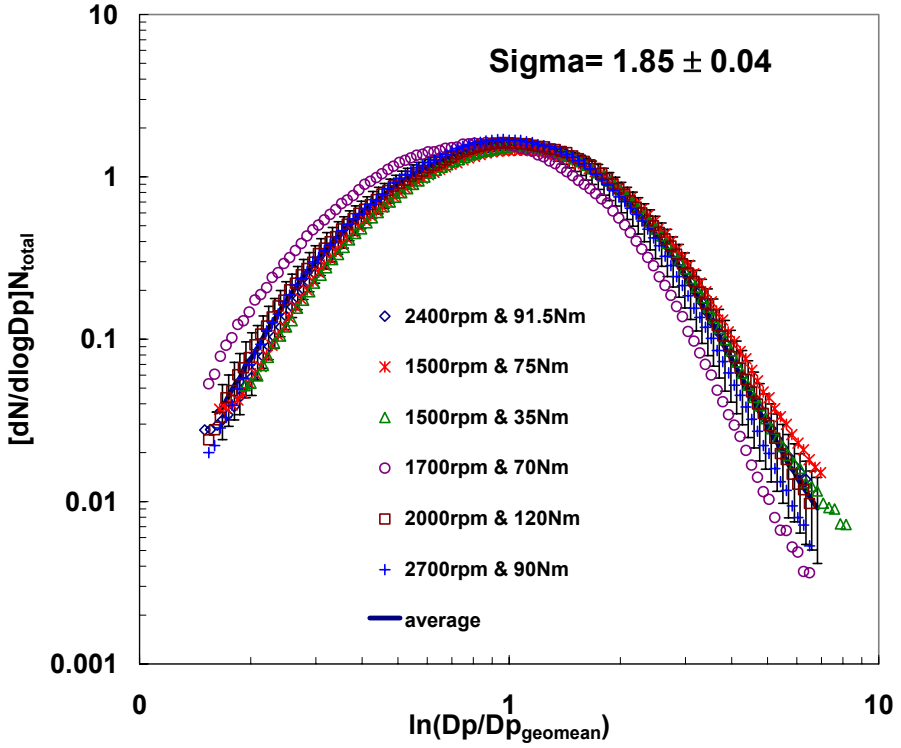


Transient Test with TDMPS

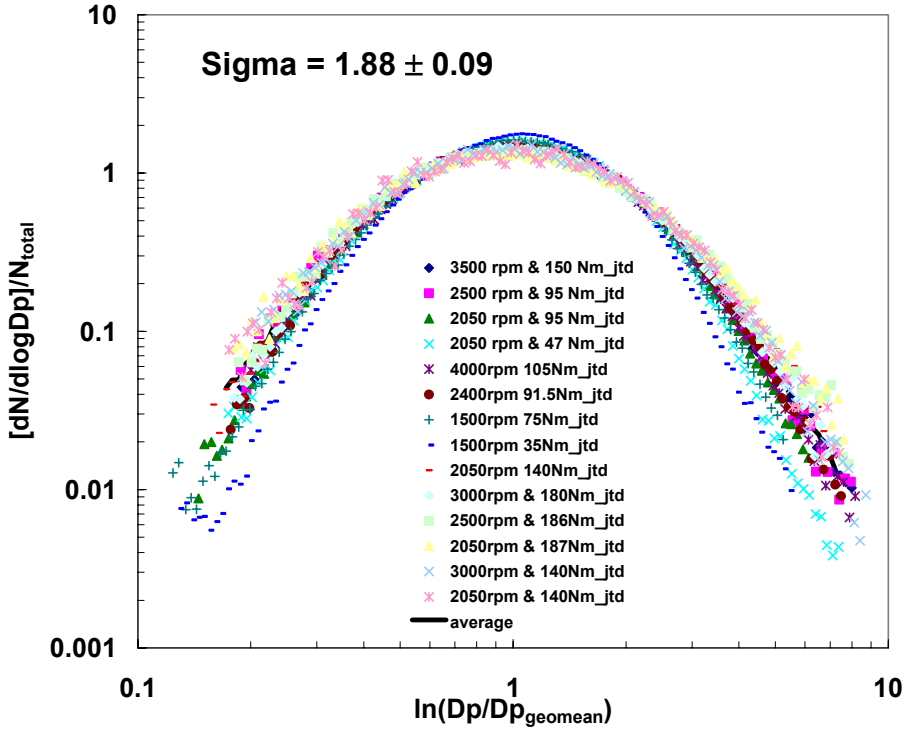


Universality of particle size distribution

EURO II

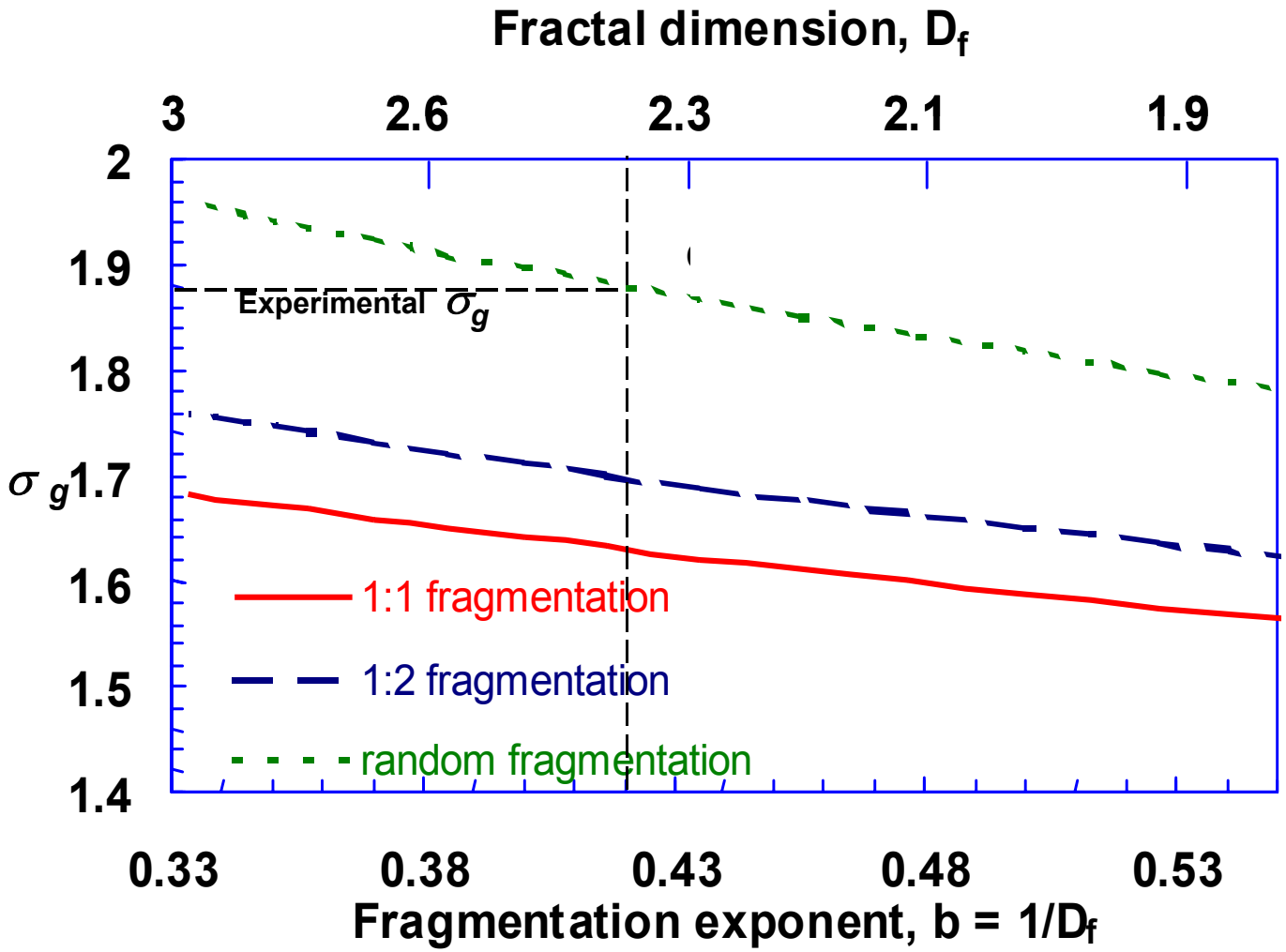


EURO III

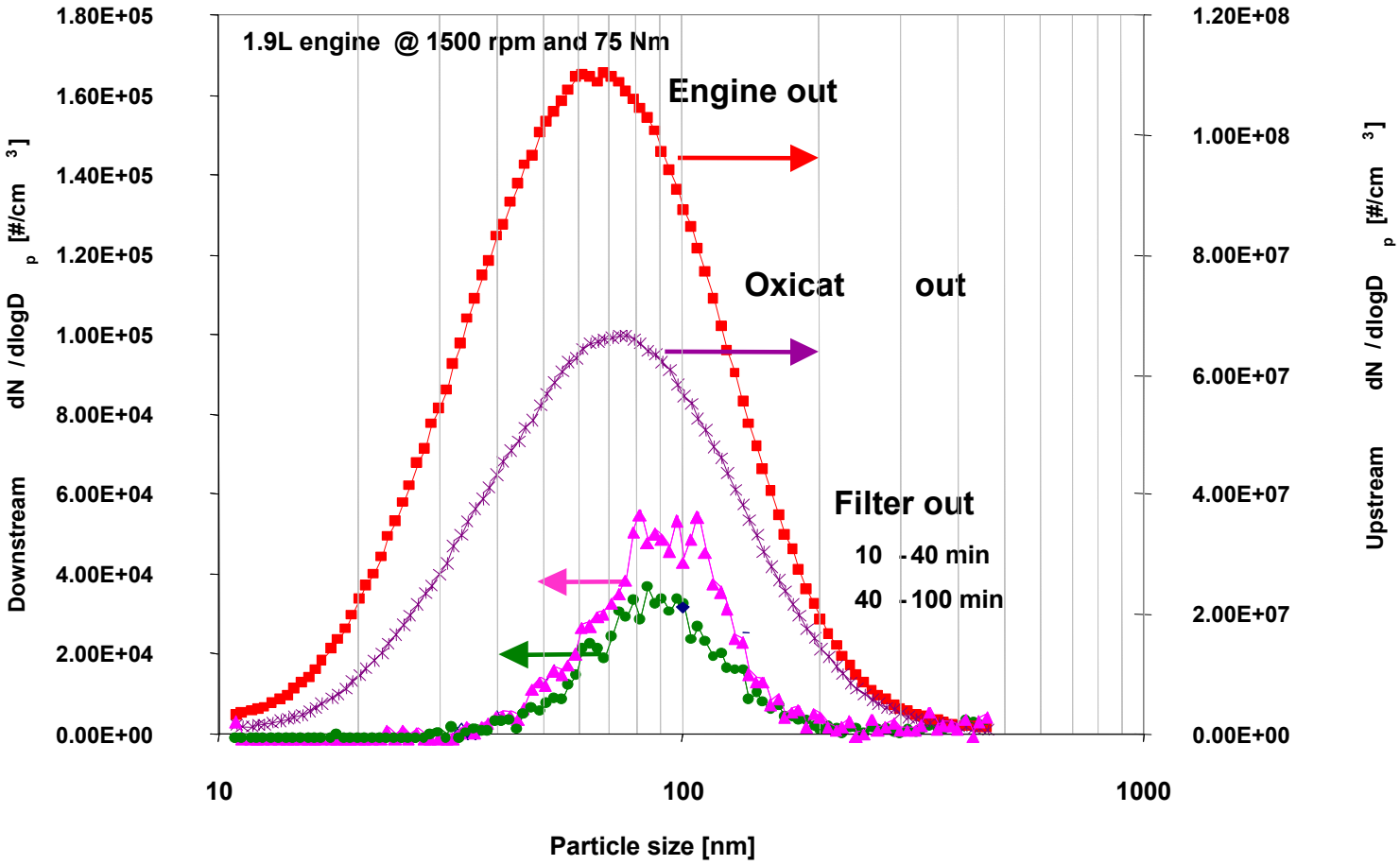


Simulation based on competition between coagulation and oxidative fragmentation

(see the poster session)



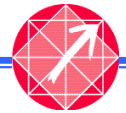
EFFECT OF OXICAT AND FILTER ON PARTICLE SIZE DISTRIBUTION



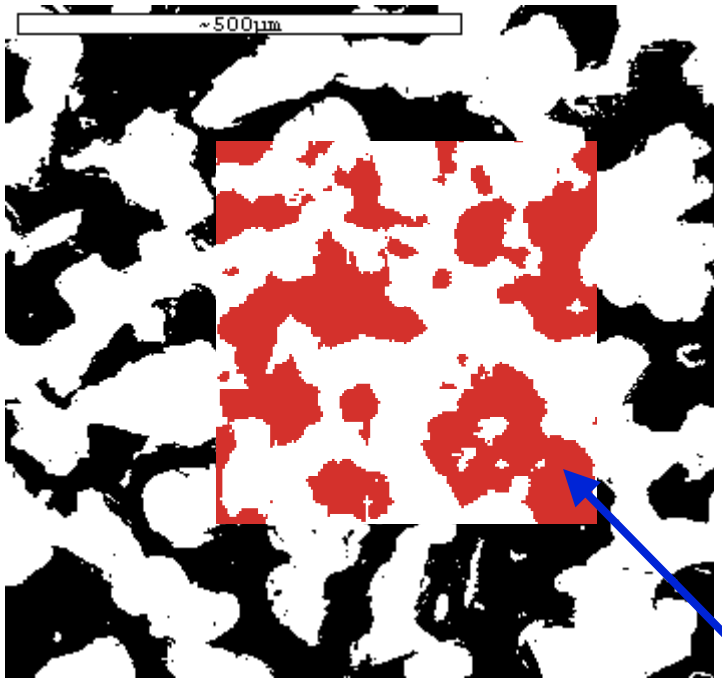
NEW PROJECT

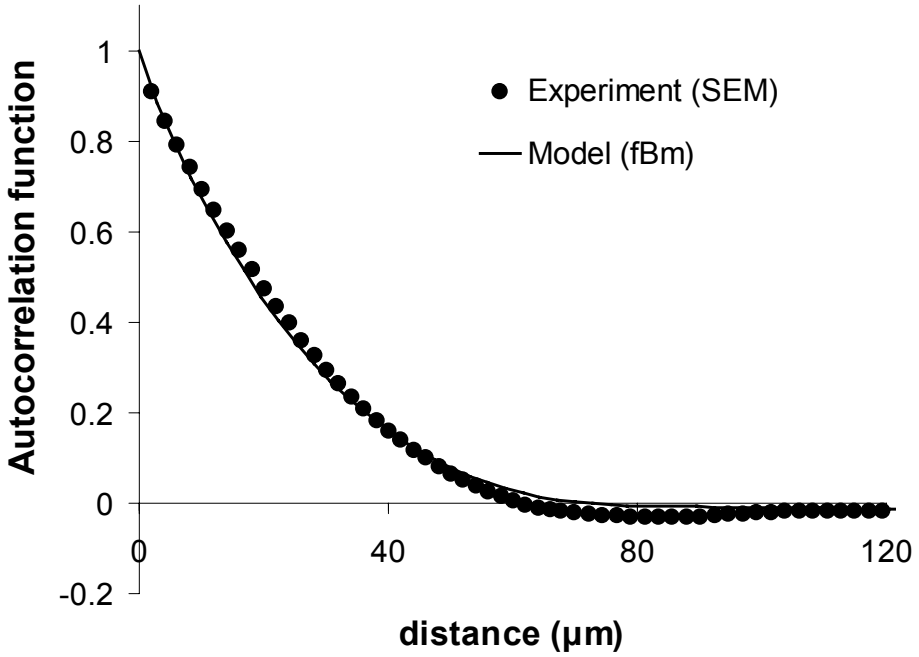
STYFF-DEXA Summary

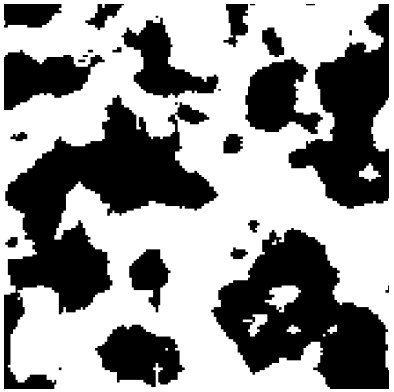
- Emphasis is on novel computational techniques for soot aggregate transport and reaction in porous media in a parallel computing environment
- Particle Emission Control as well as Noise-Abatement is studied employing porous cellular structures
- Results will be incorporated into the SYLOC-DEXA toolkit



RECONSTRUCTION & FLOW SIMULATION IN POROUS MATERIALS







RECONSTRUCTION & FLOW SIMULATION IN POROUS FOAM MATERIALS