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Zurich Aug. 19-21, 2001

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

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Problem addressed

The present cluster of projects is aiming at providing a complete and integrated approach at the European level, on passenger vehicle diesel exhaust aftertreatment, with emphasis on particulate emissions control for Euro IV and beyond, emission standards.

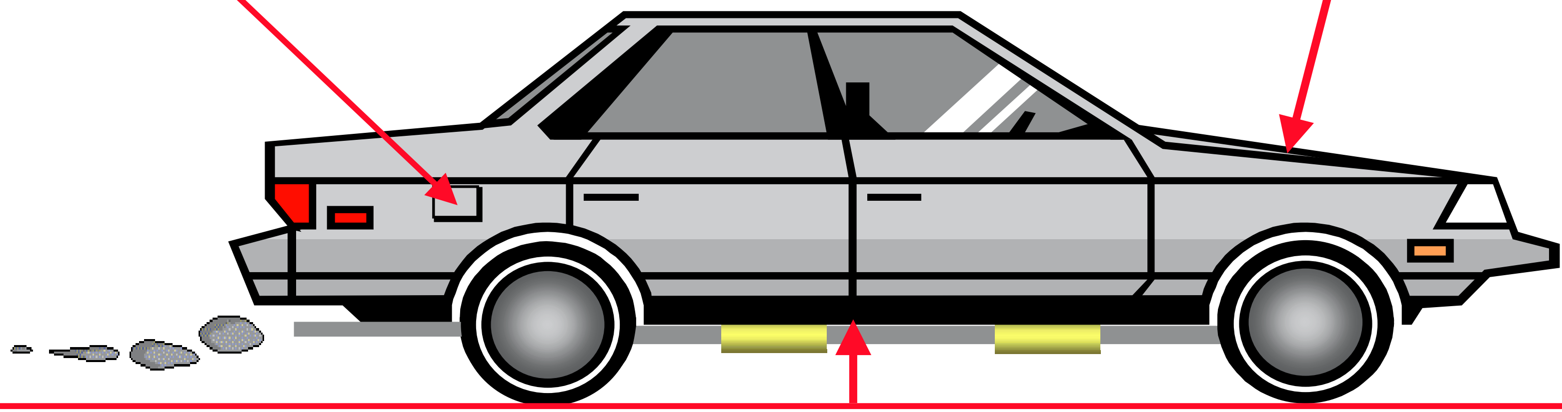
DEXA CLUSTER (2001 – 2005)
A systems approach to diesel emission control

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 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 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)

CLUSTER MANAGEMENT

ART-DEXA

DURATION:1/2/2000-31/1/2003

Coordinator:
Gianmarco Boretto
CR FIAT

SYLOC-DEXA

DURATION:1/2/2000-31/1/2003

Coordinator:
Peter Prenninger
AVL List GmbH

STYFF-DEXA

DURATION:1/5/2002-31/04/2005

Coordinator:
Wilhelm Branstaetter
U. LEOBEN

PSICO-DEXA

DURATION:1/1/2000-31/12/2002

Cluster Coordinator:
Athanasios G. Konstandopoulos
CERTH/CPERI

DEXA CLUSTER STRUCTURE -1

PSICO-DEXA

Particle Size & Composition

- Assessment and benchmarking of **methods**
- Assessment of **engine management** effects
- Assessment of **aftertreatment technologies** effects

DELIVERABLE:

M&T methodology for quality assessment of Diesel Exhaust Particulate Aftertreatment Technology

ART-DEXA

Advanced Regeneration Technologies

- Basic **trap** selection and materials screening
- Active **regeneration** measures screening
- Trap and **control** system manufacturing
- **Bench performance** testing-integration with **DeNox** technology
- **Vehicle performance** testing
- **Demonstrator**

DELIVERABLE:

Demonstration of reliable and cost-effective Diesel Exhaust Particulate Aftertreatment Technology

SYLOC-DEXA

System Level Optimization and Control

- **Sub-module** development
- **Validation** data for sub-modules
- **Simulator** development
- **Simulator validation** and system optimization
- **Optimized** demonstrator design

DELIVERABLE:

Efficient and cost-effective concurrent engineering design tools for Diesel Exhaust Aftertreatment Technology

Cluster of Critical Technologies: Diesel Exhaust Aftertreatment (DEXA)

STYFF-DEXA

DEXA CLUSTER STRUCTURE-2

STYFF-DEXA

Dynamic Flow Analysis in Foam Media

- **Reconstruction** methods for foams
- **Lattice-Boltzmann** flow solver
- **Particle Submodule** development
- **Acoustics submodule** development
- **Simulator validation** and interface to SYLOC-DEXA

DELIVERABLE:

Validated simulation tool for particle filtering and acoustics application of foams in Diesel Exhaust Aftertreatment Technology

EW PROJECT

OTHER PREMTECH PROJECTS

OTHER EU PROJECTS

FUTURE PROJECTS

Cluster of Critical Technologies: Diesel Exhaust Aftertreatment (DEXA)

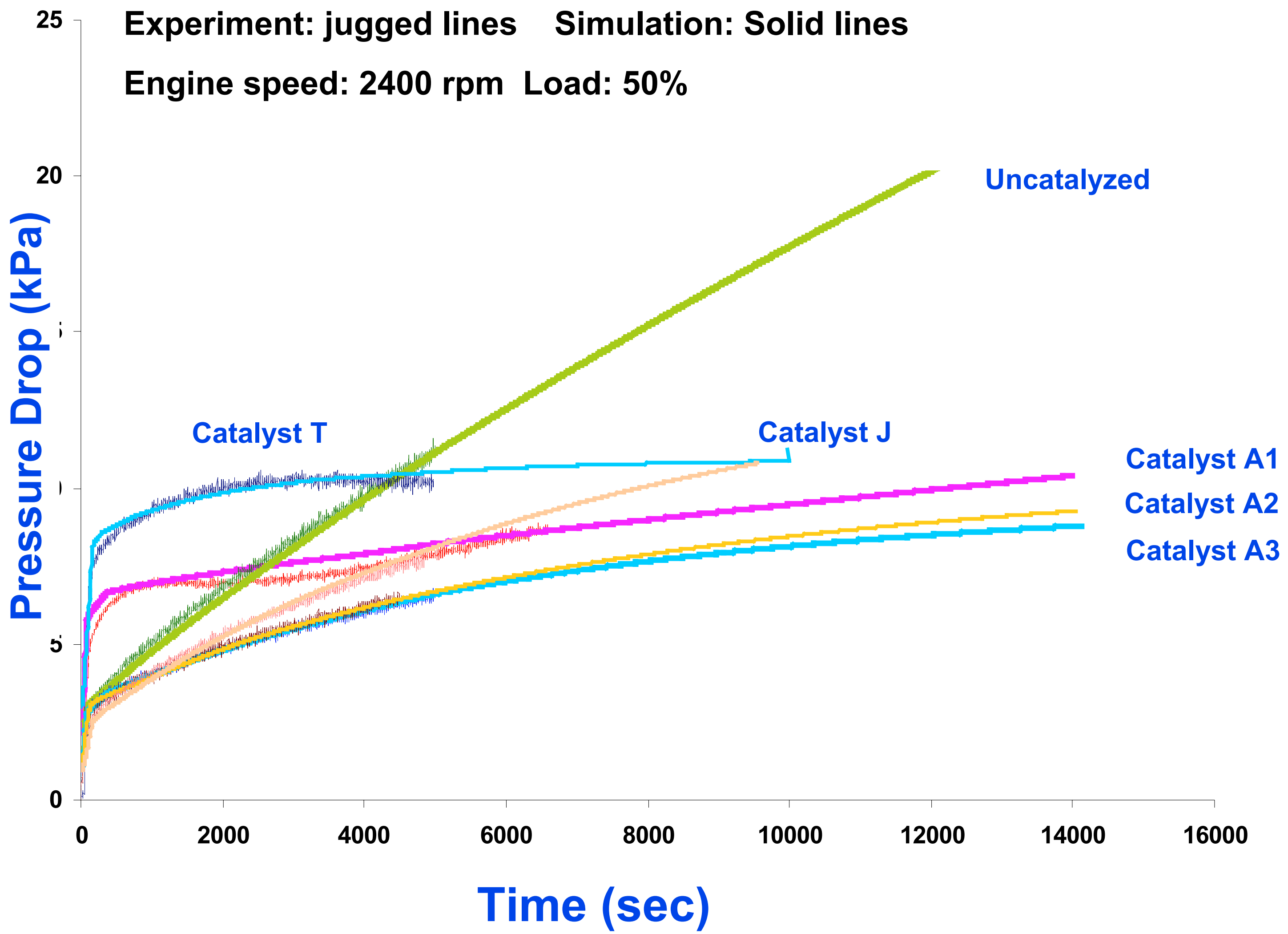
ART-DEXA Summary

- **Basic Trap Selection and Material Screening**
  - Different trap concepts have been investigated both internal and external to the project
  - Three promising component technologies have been selected for further development for demonstrator vehicles
- **Active Regeneration Measures Screening**
  - Active engine management leading to regeneration potential and its effect on fuel consumption and driveability has been studied
- **Trap and Control System Manufacturing**
  - Filter operation, diagnostics and control algorithms have been developed and programmed
  - Control system manufacturing is achieved

SYLOC-DEXA Summary

- **Submodel procurement is completed**
  - Filters
  - Catalysts
- **Database of component technologies is in place**
  - Exhaust system layouts
  - Filter materials and configurations
  - Catalysts
- **Computational interfaces/platforms defined**
  - Engine cycle simulation
  - Exhaust pipe CFD
  - Filter/Catalyst parameters
- **Validation Data collection in progress**
  - Emission control components procured and tested
  - System lay-out for vehicle demonstrators completed

PARTICULATE EMISSION CONTROL SYSTEMS: EXPERIMENT AND SIMULATION



NEW PROJECT

STYFF-DEXA Summary

- Kick-off was in July 2002
- 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

PSICO-DEXA Summary

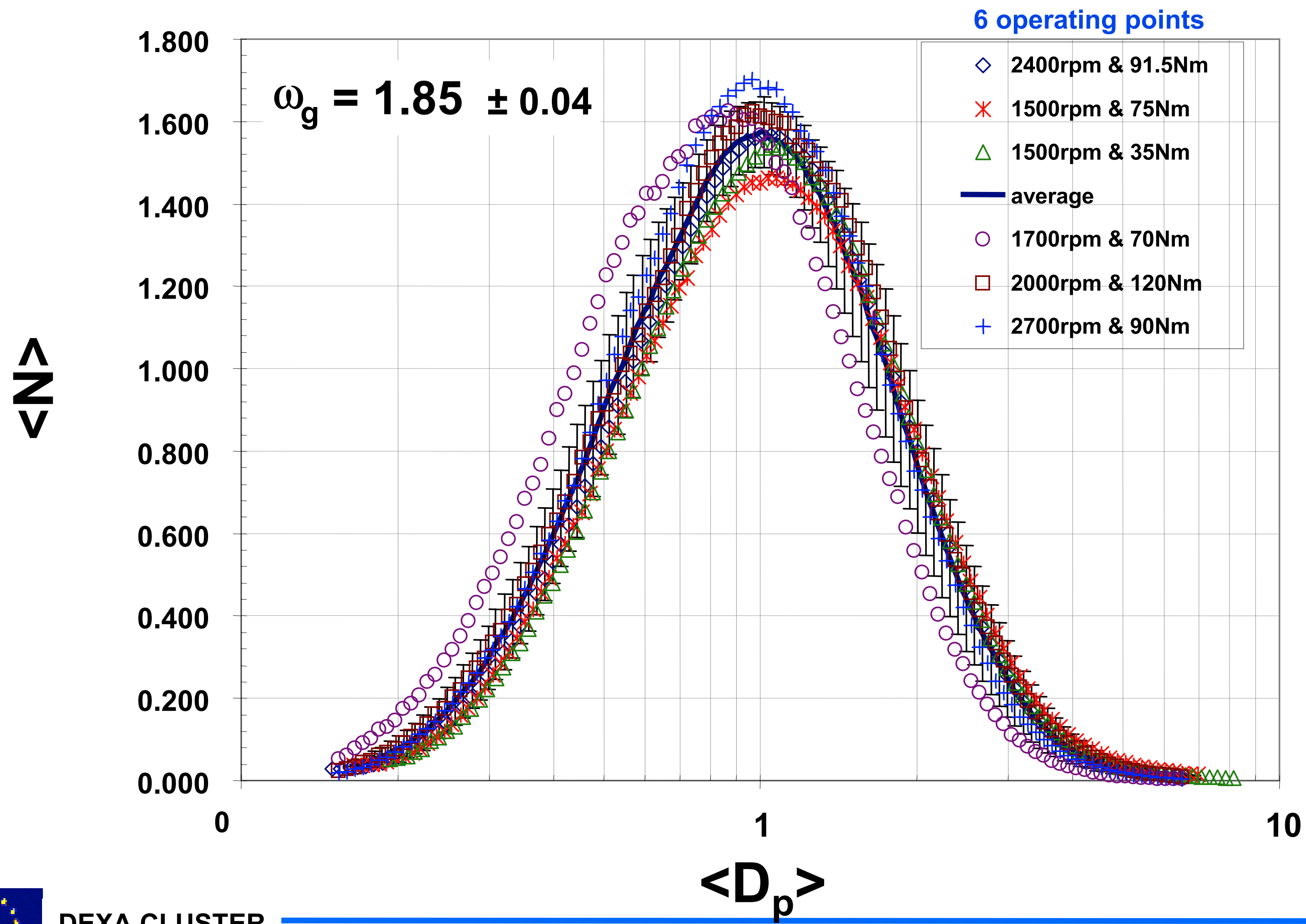
- **Size measurement techniques**
  - Mobility techniques define the standard and real time performance has been demonstrated (TDMPS). New analysis to connect number and mass based distributions for fractal particles
  - Multiwavelength optical techniques are promising
- **Composition measurement techniques**
  - 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 are 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

DEXA CLUSTER DELIVERABLES (March 2003)

- **ART-DEXA**
  - Two optimized vehicle demonstrators with advanced particulate emission control
- **SYLOC-DEXA**
  - Exhaust aftertreatment system simulator tool and its application for the optimization of demonstrator system layout
- **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

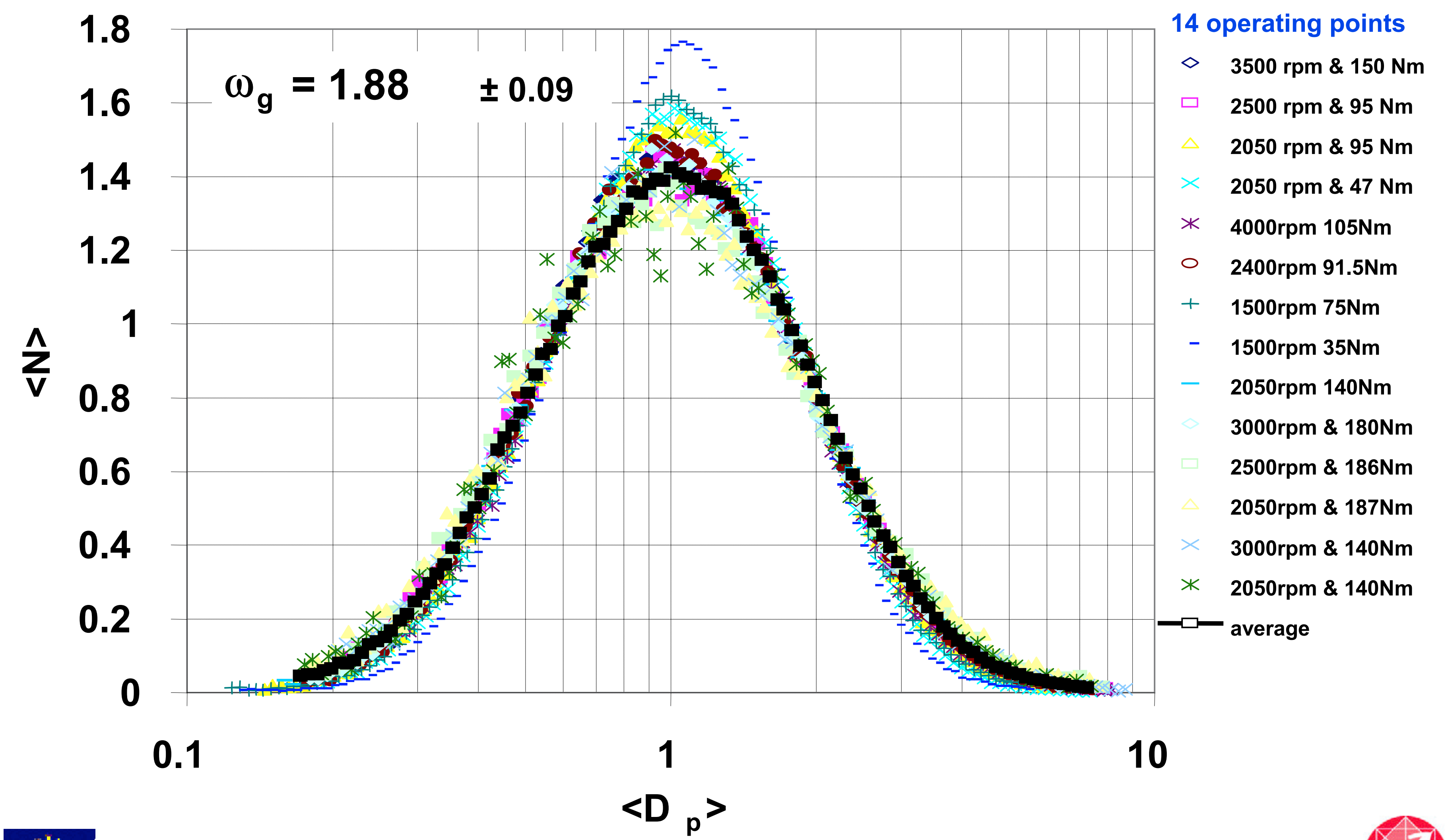
UNIVERSAL LOGNORMAL SIZE DISTRIBUTION-1

1.9L Turbo Diesel DI engine with conventional fuel injection

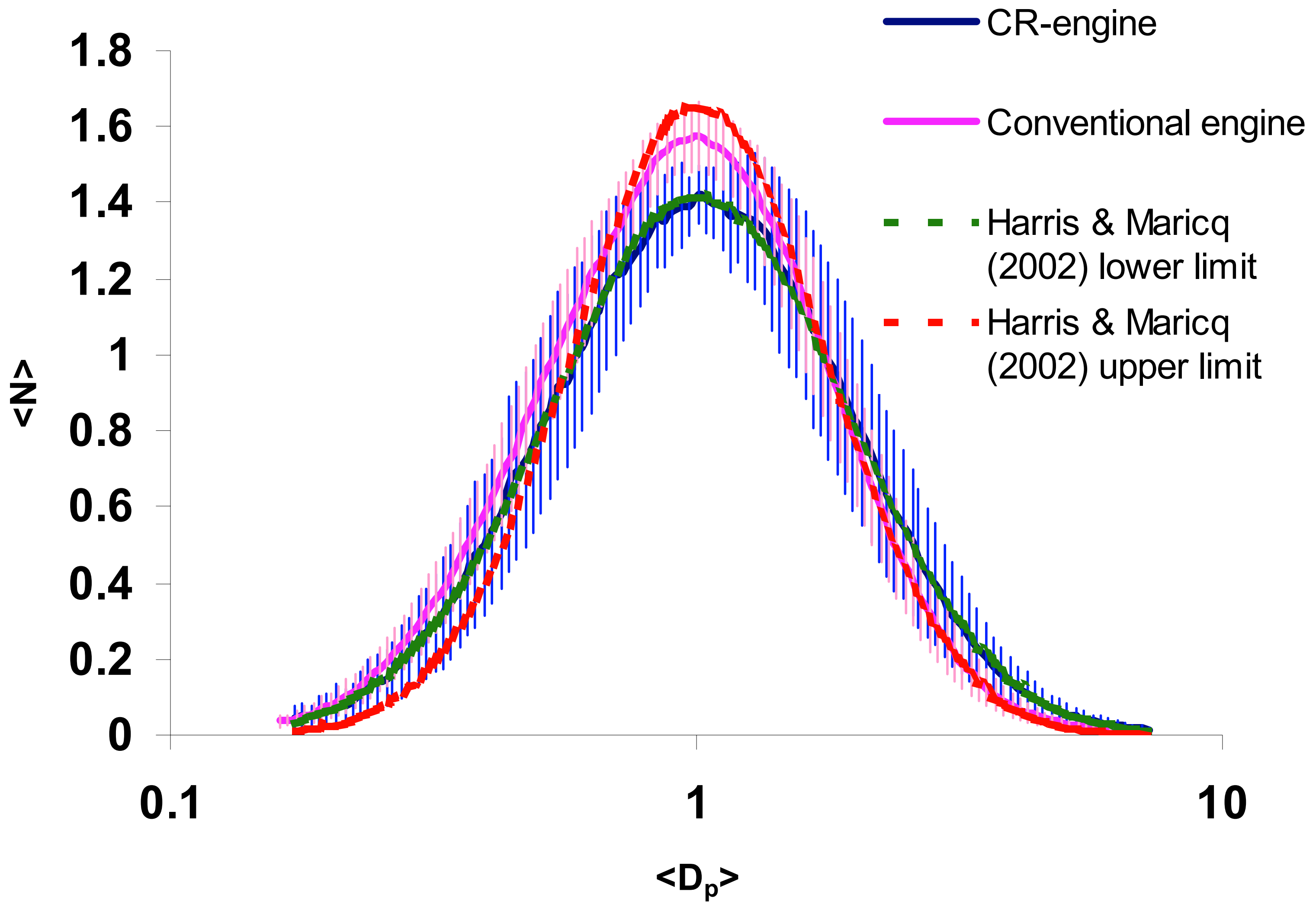


UNIVERSAL LOGNORMAL SIZE DISTRIBUTION-2

1.9L Turbo Diesel DI engine with common rail fuel injection

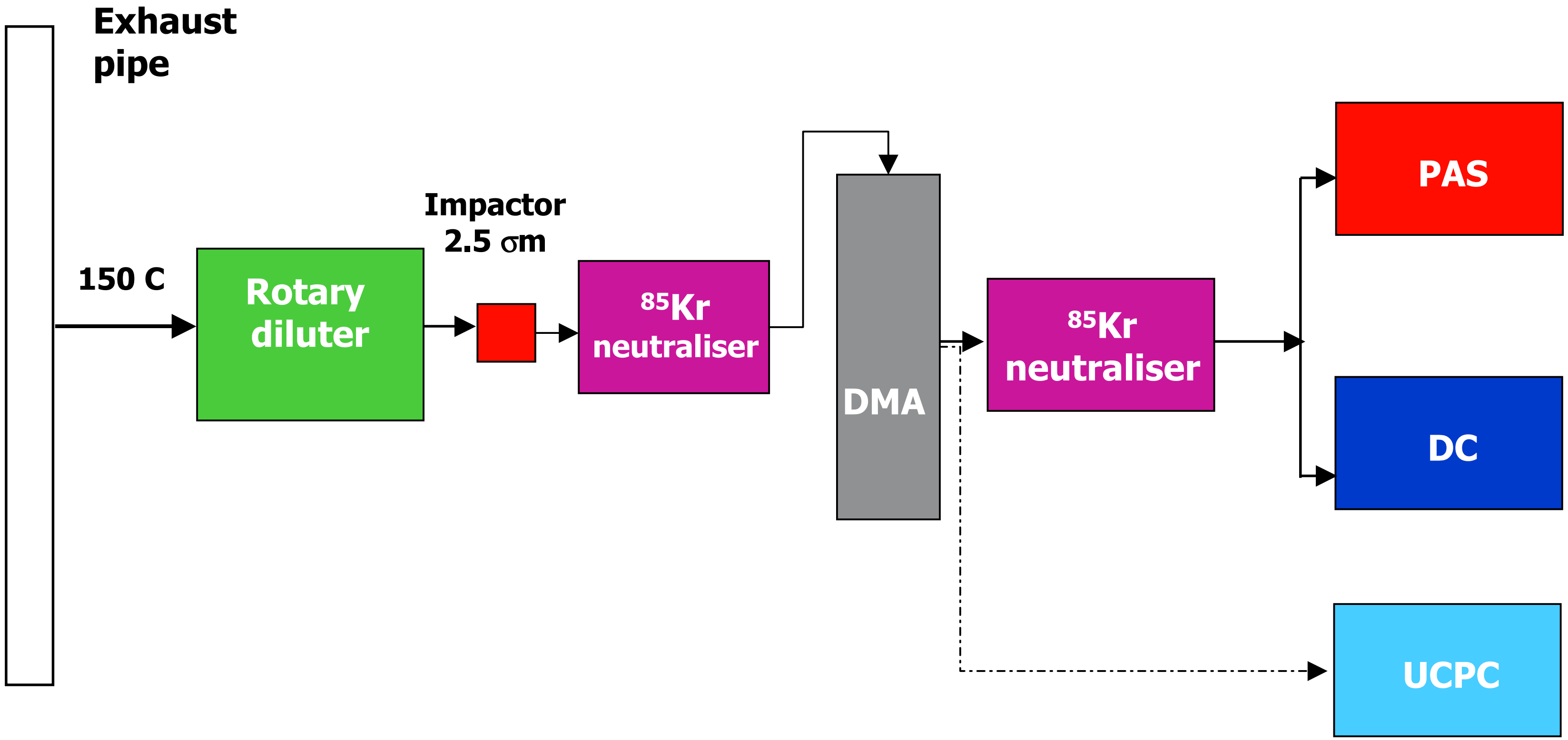


UNIVERSAL LOGNORMAL SIZE DISTRIBUTION
Comparison to Literature



DEXA CLUSTER

DMA-PAS/DC IN SERIES SETUP
FOR SIZE RESOLVED COMPOSITION MEASUREMENT



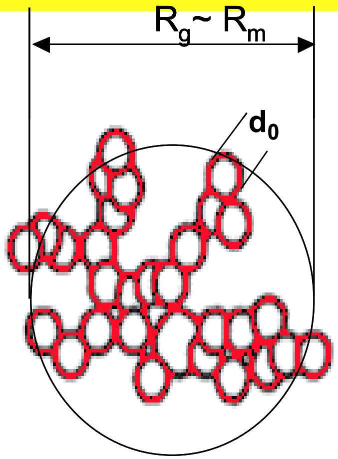
FUCHS SURFACE OF A DIESEL AGGREGATE

$$\mathrm{Fuchs}(x) \mid \phi x^2 1.657 \frac{\mathrm{Kn}(x)}{\mathrm{SCF}(x)} \mid \left[\begin{array}{ll} \phi x^2 & \mathrm{Kn}(x) \Downarrow \leftarrow \\ 1.657\,\mathrm{Kn}(x) \phi x^2 \Im x & \mathrm{Kn}(x) \Downarrow 0 \end{array} \right.$$

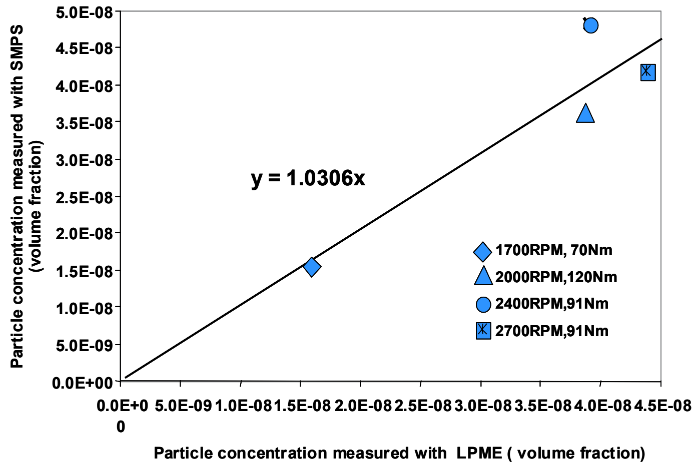
$$\mathrm{Kn}(x) \mid \frac{2\varsigma}{x} \qquad \varsigma \mid \tau \sqrt{\frac{\phi MW}{2RT}} \qquad \mathrm{SCF}(x) \mid 1\,2\,\mathrm{Kn}(x)(1.257\,2\,0.4 e^{4\frac{0.4}{\mathrm{Kn}(x)}})$$

Mob. Diam.	Mob. surface	Number of primary particles in aggregate	Fuchs surface	Fractal aggregate surface	Fuchs fractal aggregate surface
D_m	ϕD_m^2	$N_A = k_m (D_m/d_0)^{1.82}$	$\mathrm{Fuchs}(D_m)$	$N_A \phi d^2_0$	$N_A\ \mathrm{Fuchs}(d_0)$

FRACTAL PREFACTOR OF DIESEL AGGREGATES: SMPS vs. LPME* CORRELATION



***LPME: Long Path Multiwavelngth Extinction**

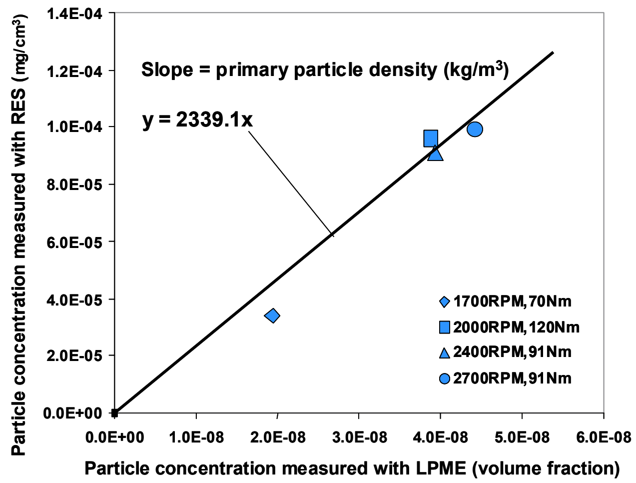


The SMPS vs. LPME correlation is the same for:

$$N_A \mid k_m \left(\frac{2R_m}{d_0}\right)^{D_f}$$

$$k_m \mid 3.9 \quad D_f \mid 1.82^{*} \quad d_0 - 32\ \text{nm} \ \text{or}$$

$$k_m \mid 1.76 \quad D_f \mid 2.4^{**} \quad d_0 - 32\ \text{nm}$$



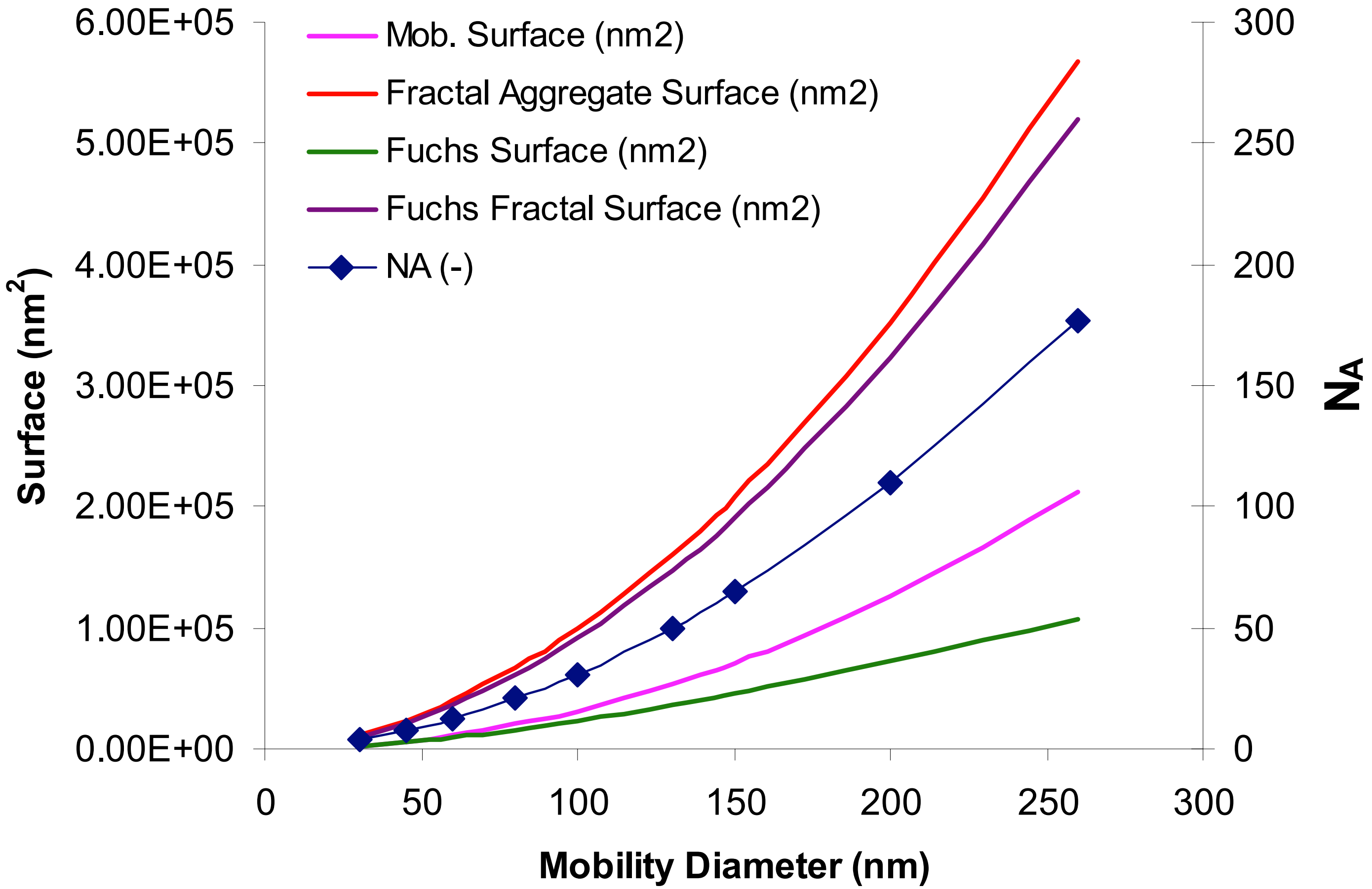
Konstandopoulos et al. (2001)

* If particles are DLCCA clusters

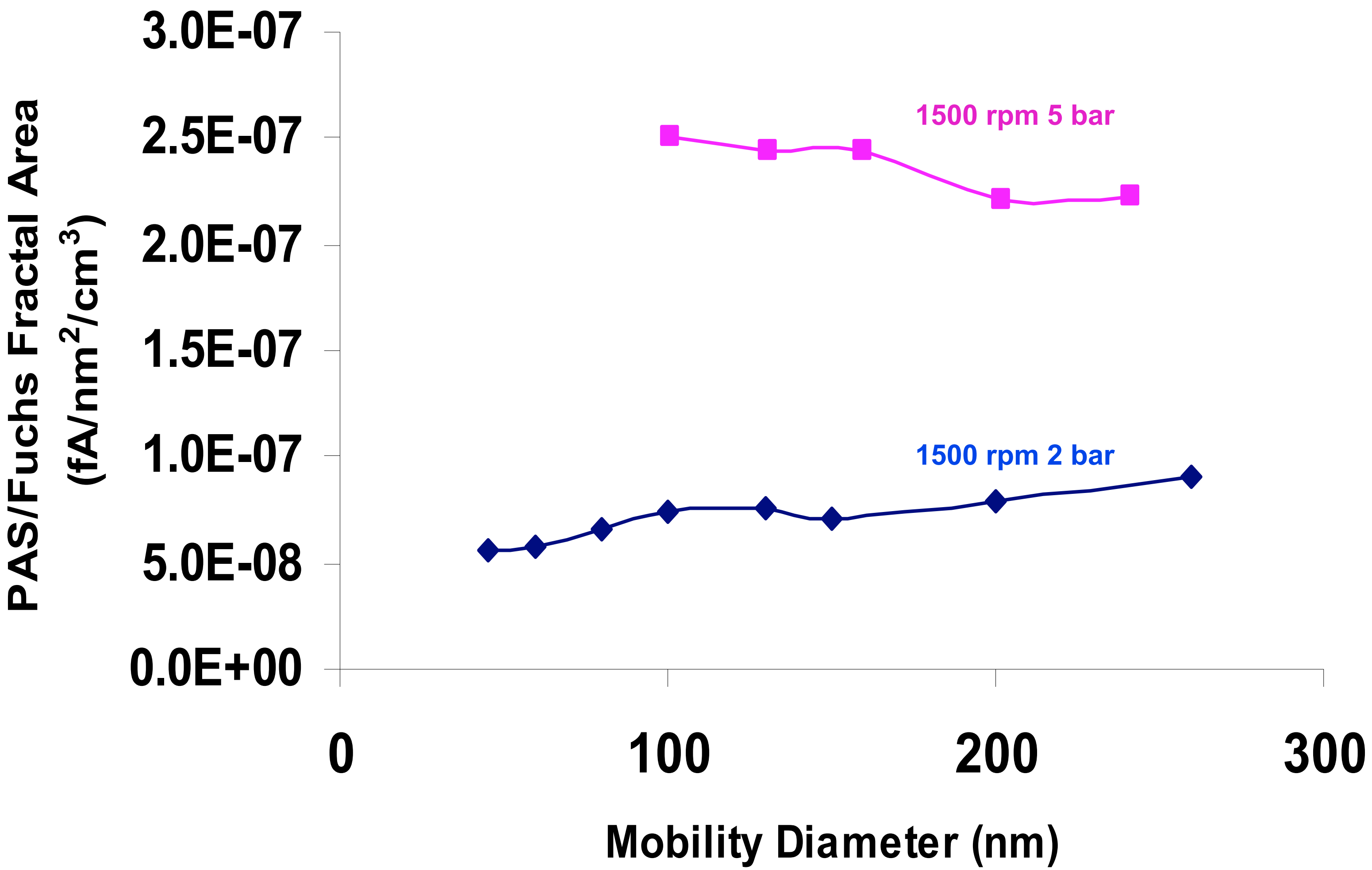
** Based on mass vs. mobility measurements of Kittelson & McMurry (2002)

“SURFACE” DEFINITIONS OF A DIESEL AGGREGATE

Example calculation for $N_A = k_m (\frac{2R_m}{d_0})^{D_f} \quad k_m = 3.9 \quad D_f = 1.82$



PAS/Total Fuchs Fractal Area For Different Engine Loads



BEYOND THE DEXA-CLUSTER

In response to the EU CALL FOR Expressions of Interest (6/02) the DEXA CLUSTER Partners have formed the

ECONET
Network of Excellence to address the

NEEDS FOR FUTURE EMISSION CONTROL SYSTEMS

- ↓ **Compactness (size reduction by > 50%)**
- ↓ **Cost (target to be defined in €/kW of engine power)**
- ↓ **Flexibility and tolerance to new fuels and engines**