

# Development of a particulate matter sensor for diesel engine

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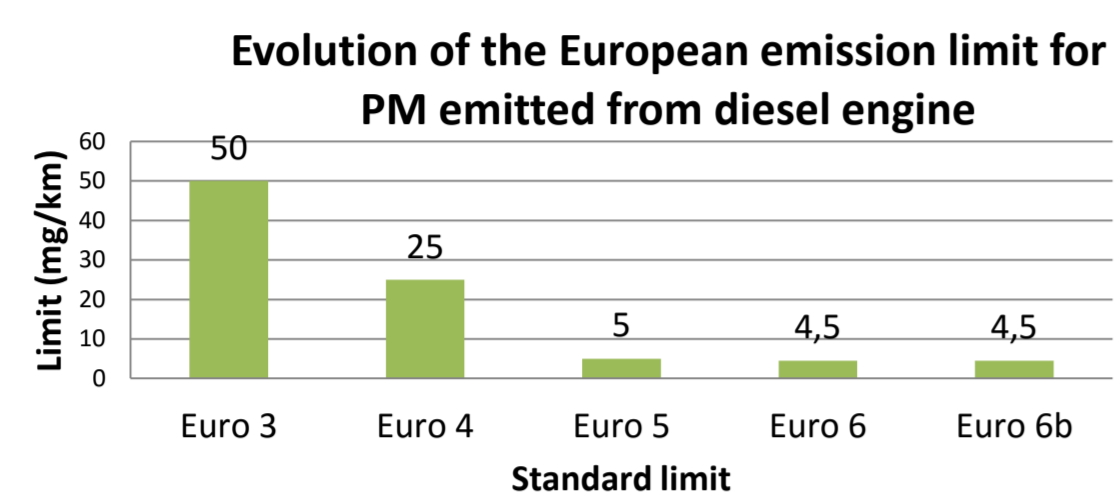
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Introduction

## Context and objectives

Emission standards for light-duty vehicles legislations become more stringent

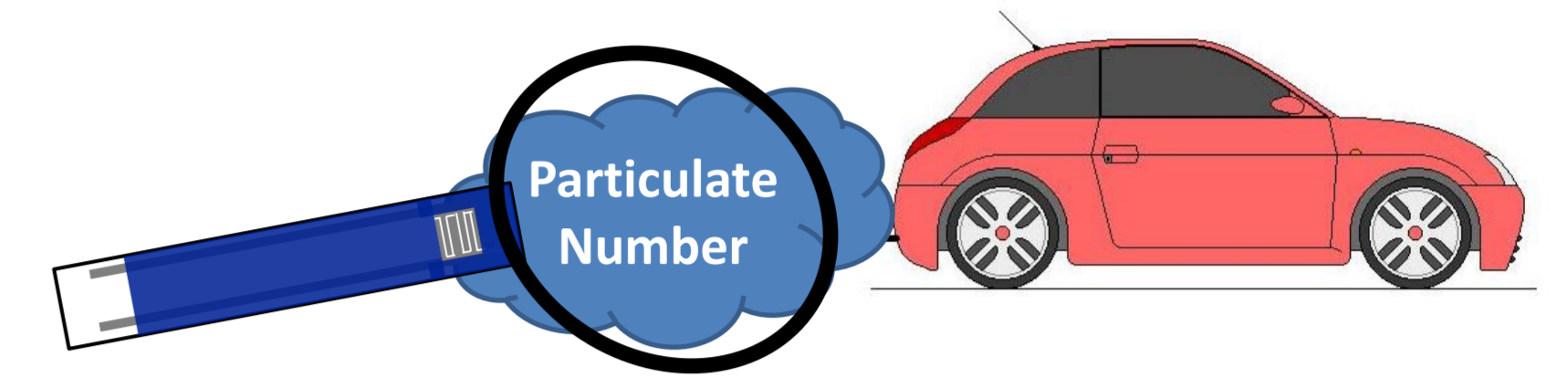


Due to the health risk of fine particles, from Euro 5, limits take into consideration the **particulate number** of emitted soot

Actual on-board technology estimates PM emissions with a differential pressure sensor across the Diesel Particulate Filter (DPF)

This technology

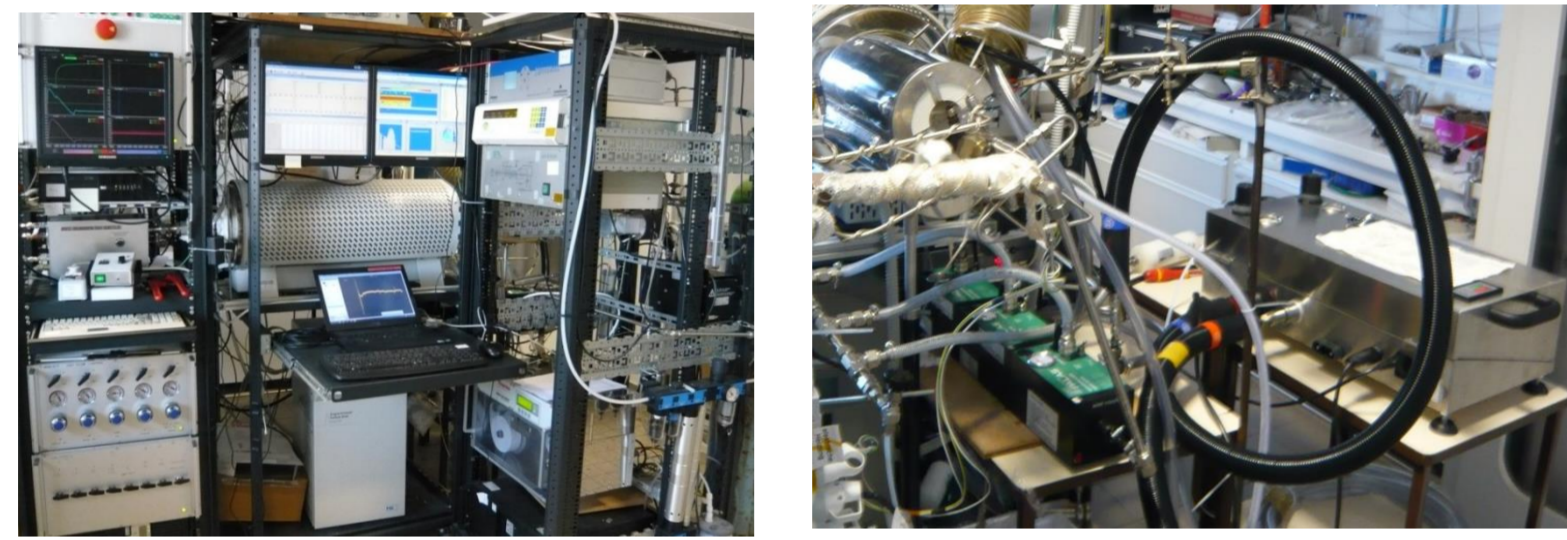
- Shows a limited sensitivity
- Perform only mass measurement
- Can not measure when there is a DPF failure



There is a need for an on board sensor able to detect DPF failure and to determine the number and the size of soot particles

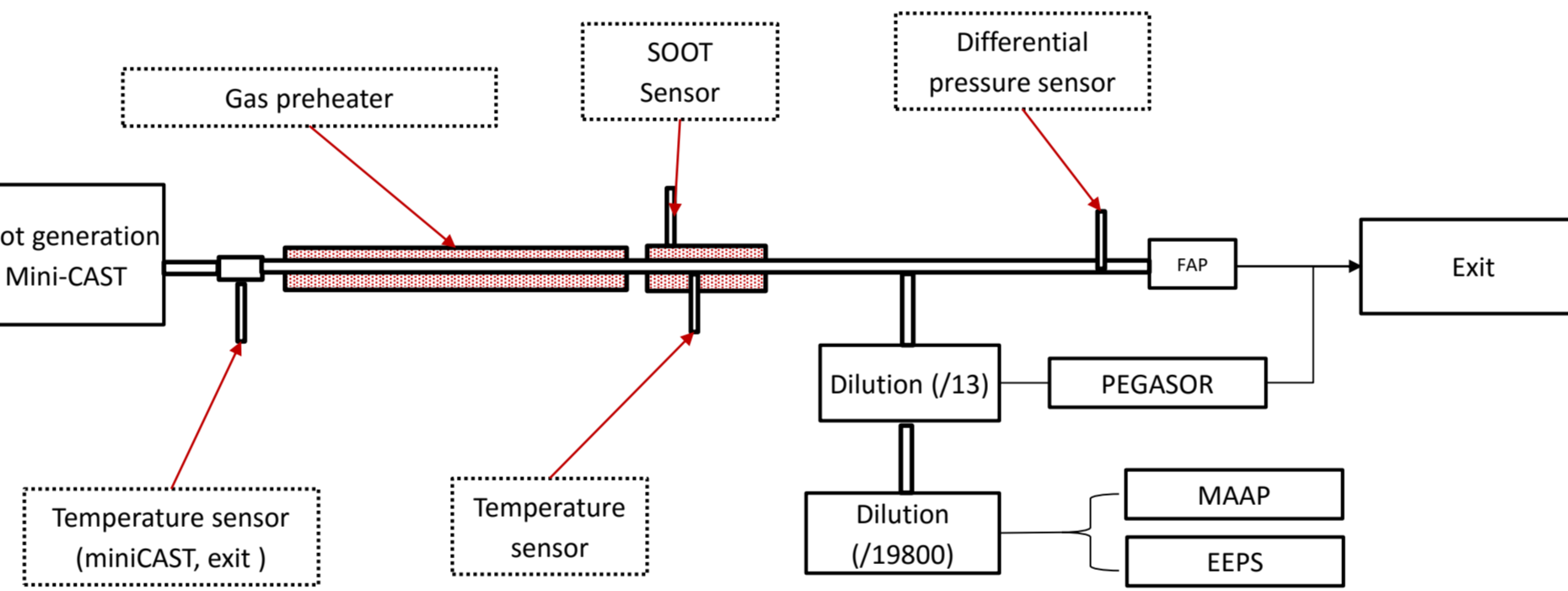
Soot generation

## Test bench photograph



## Experimental setup

### Test bench Schematic

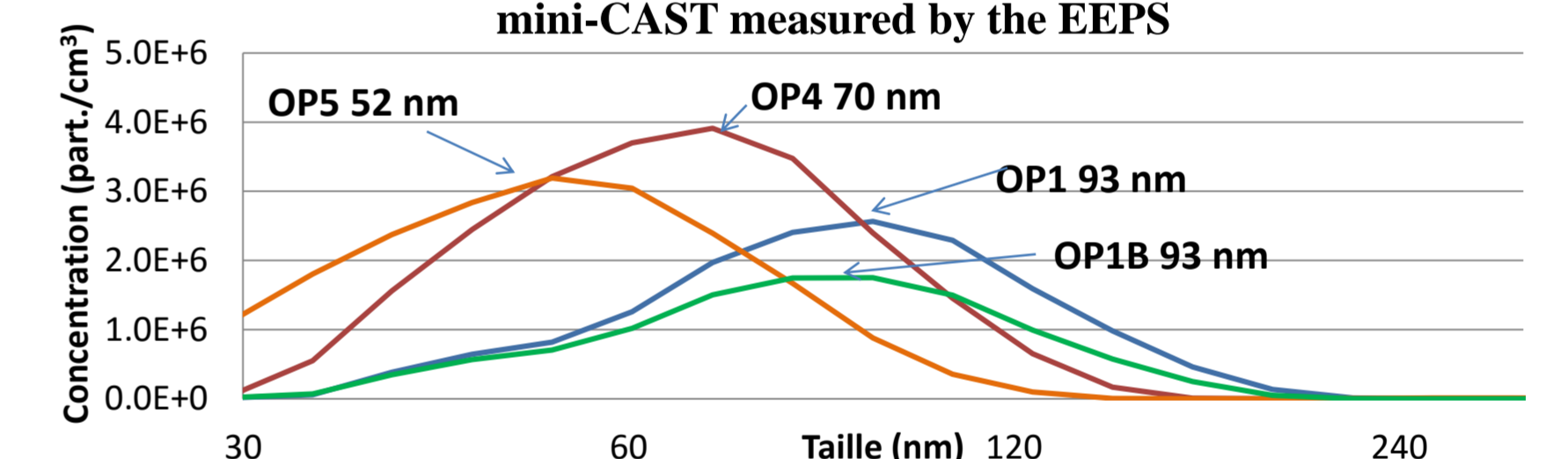


### Soot generator (Mini-CAST) operation points (OP)

OP	Propane flow (L/h)	Air flow (L/h)	Mixture richness propane/air
OP1	3.6	93.0	0.97
OP1B	3.1	80.1	0.97
OP4	3.6	90.0	1.00
OP5	3.6	88.2	1.02

- Mini-CAST produces soot particles from the combustion of a propane/air mixture. Concentration and soot size depend on the mixture richness
- Three analyzers are used :
  - EEPS : (Engine Exhaust Particle Sizer) Measures the number and the size distribution
  - MAAP : (Multi-Angle Absorption Photometer) Measures the black carbon mass concentration
  - PEGASOR : Mass concentration estimation from leakage current measurement of charged particles

### Size distribution for the different operation points of the mini-CAST measured by the EEPS



- Soot size decreases with the propane/air ratio
- OP1 and OP1B have the same size distribution but with different concentrations
- Permit to compare different concentrations but with similar size distribution

### Soot characteristics produced by the soot generator (MiniCAST) depending the operation point (OP)

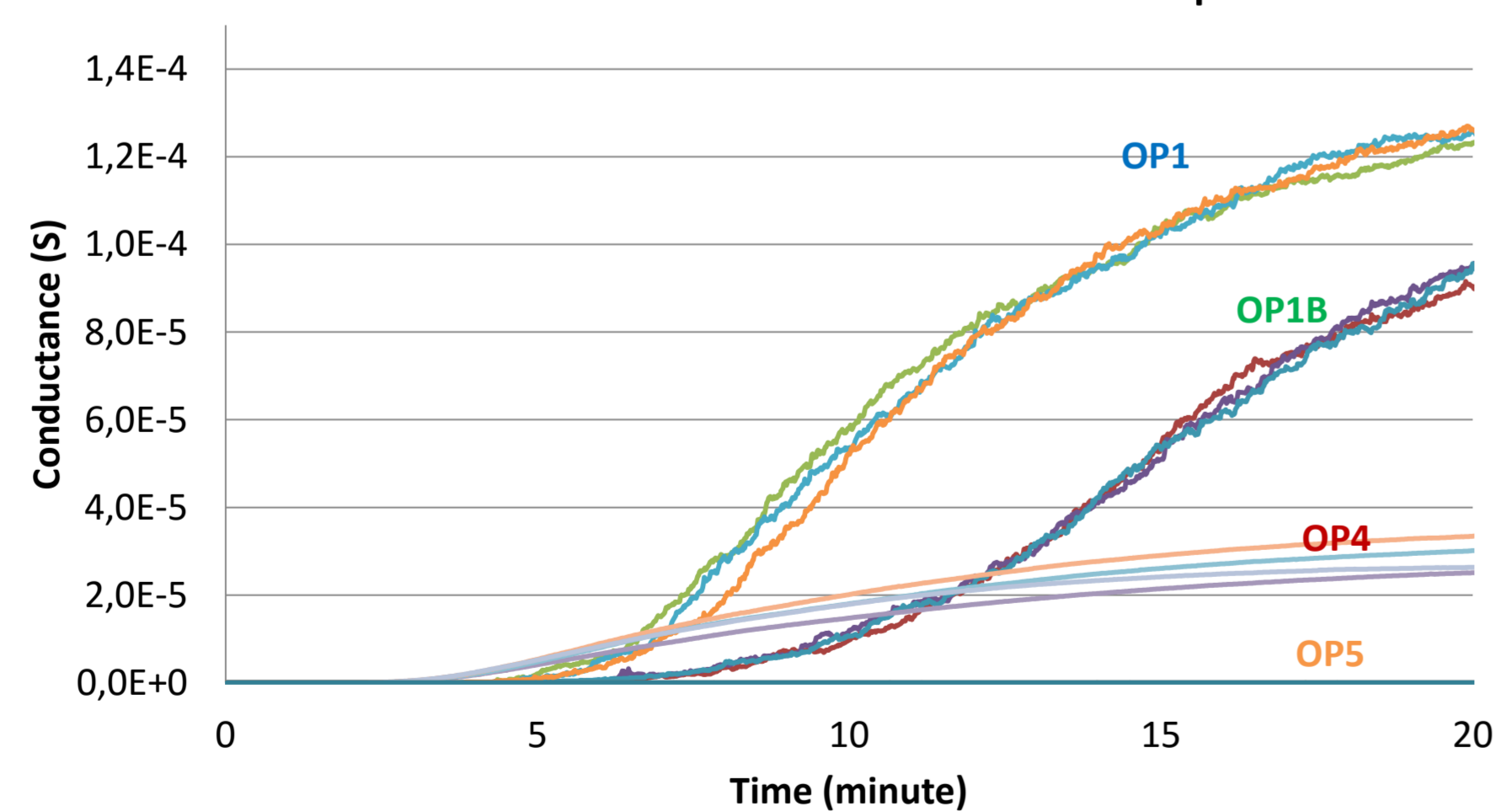
OP	Mixture richness propane/air	EEPS particles/cm <sup>3</sup>	PEGASOR mg/m <sup>3</sup>	MAAP mg/m <sup>3</sup>
OP1	0.97	1.7 E+8	94	143
OP1B	0.97	1.2 E+8	61	81
OP4	1.00	2.5 E+8	91	70
OP5	1.02	2.1 E+8	55	22

- Weak variation of the soot number
- OP1B and OP5 : OP1 and OP4 : similar mass concentration (PEGASOR)
- OP4 and OP1B : similar black carbon mass concentration (MAAP)

Sensor results

## Mass concentration effect

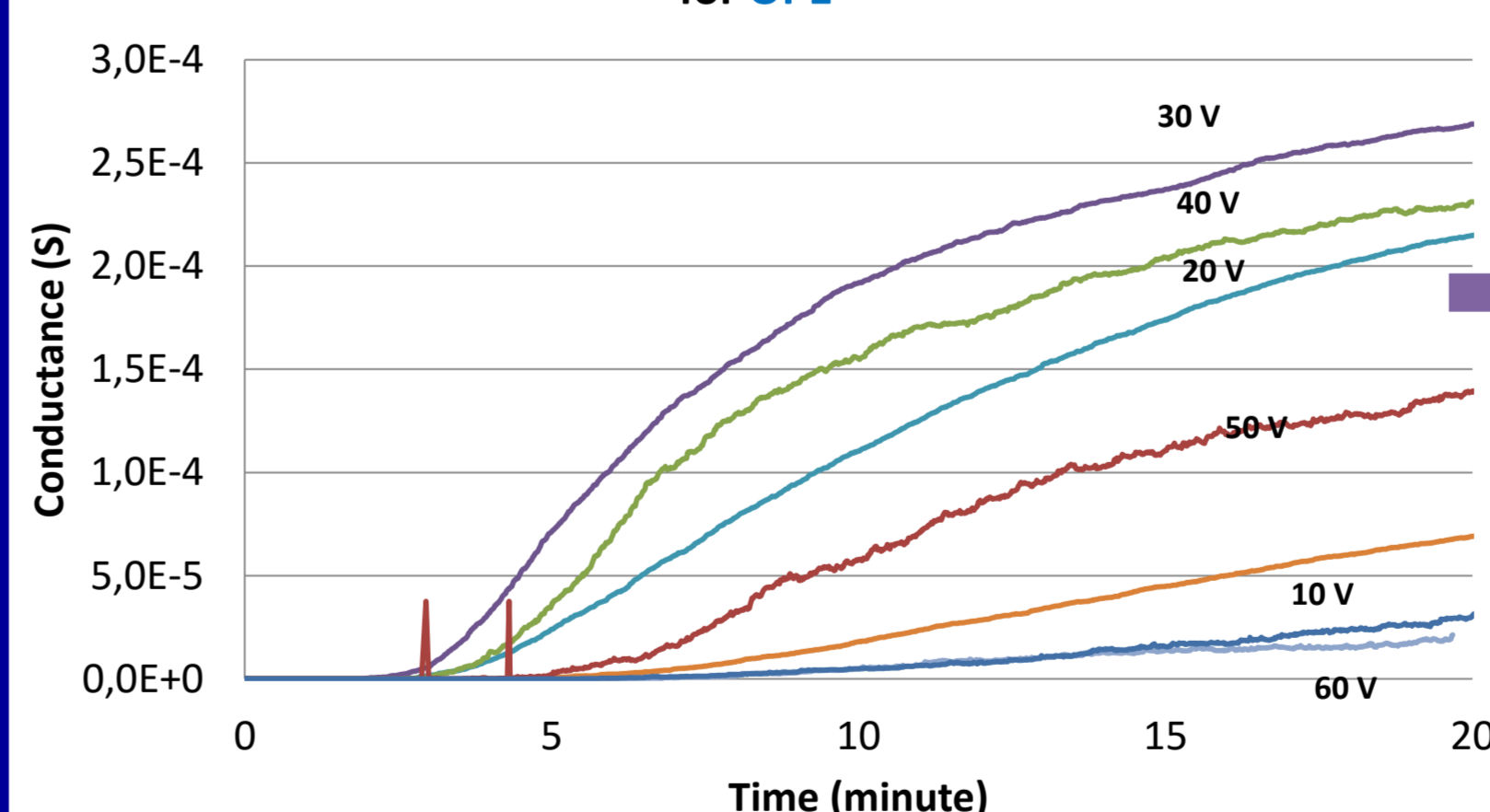
### Conductance measurement for each OP for 60 V polarization



- Good repeatability for the same operation point
- High soot mass sensitivity at equivalent size distribution (OP1 and OP1B)

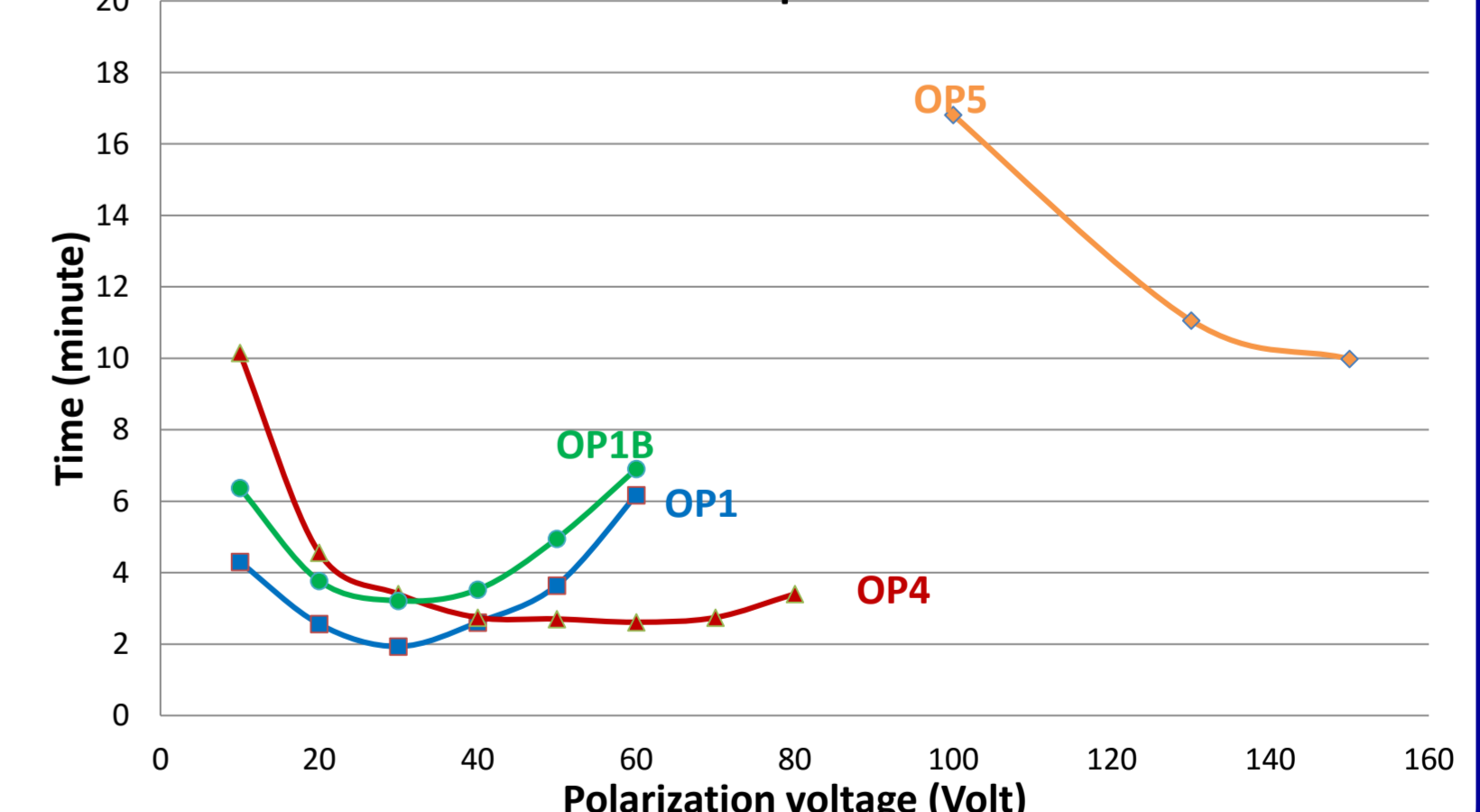
## Polarization voltage effect

### Sensor response as a function of the polarization voltage for OP1



- Sensor response strongly depends on the polarization level
- The soot collection rate shows an optimum depending on the polarization
- The optimum voltage is higher when the particles are smaller

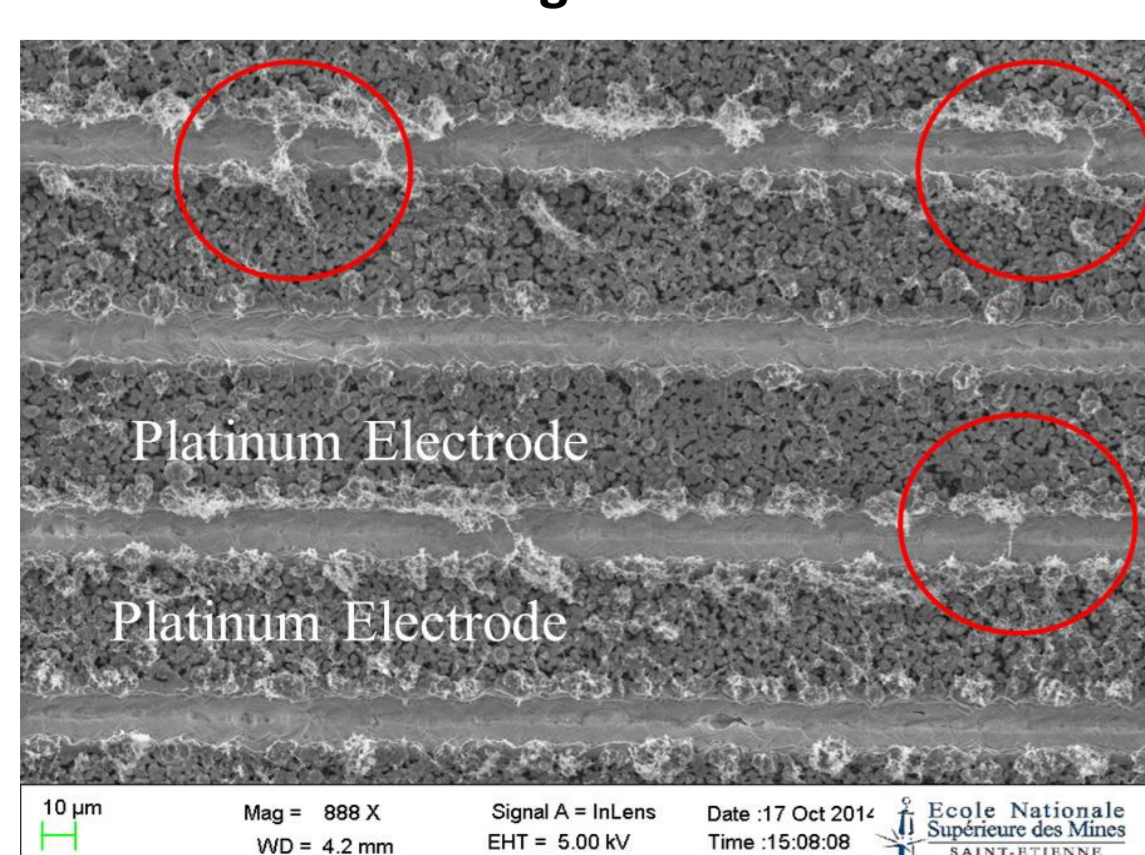
### Loading time to reach 10<sup>-7</sup> S versus the polarization voltage for different Operation Points



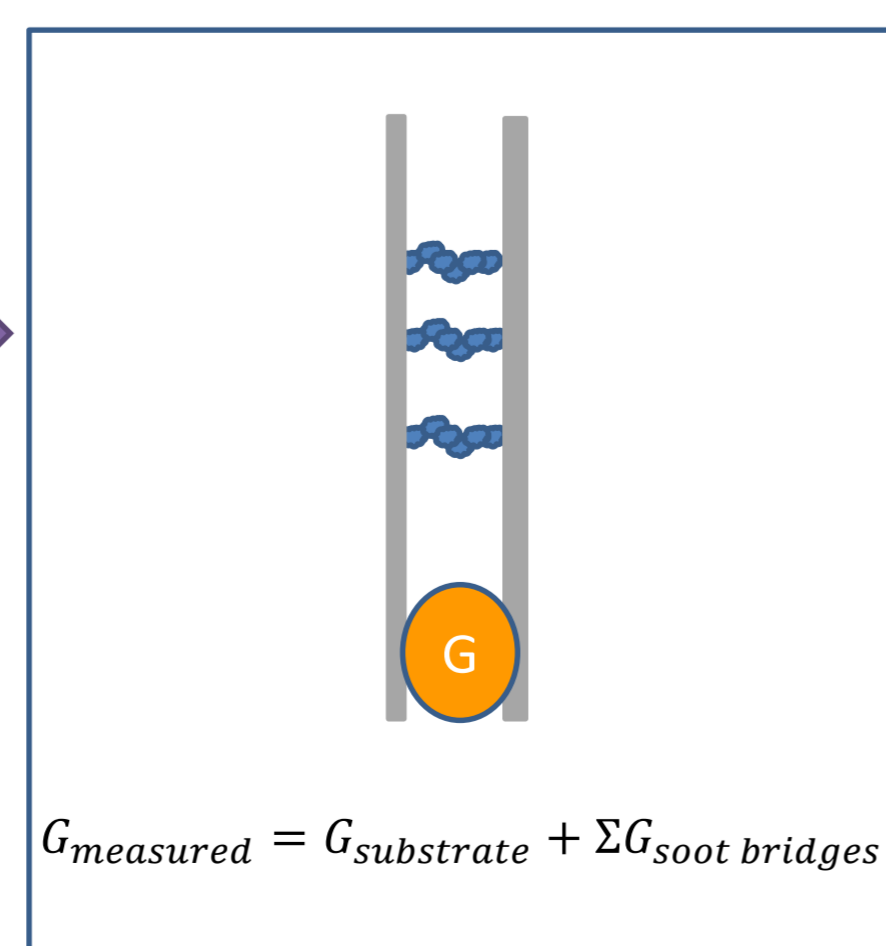
Sensor Modeling

## Model

### Soot bridge formation

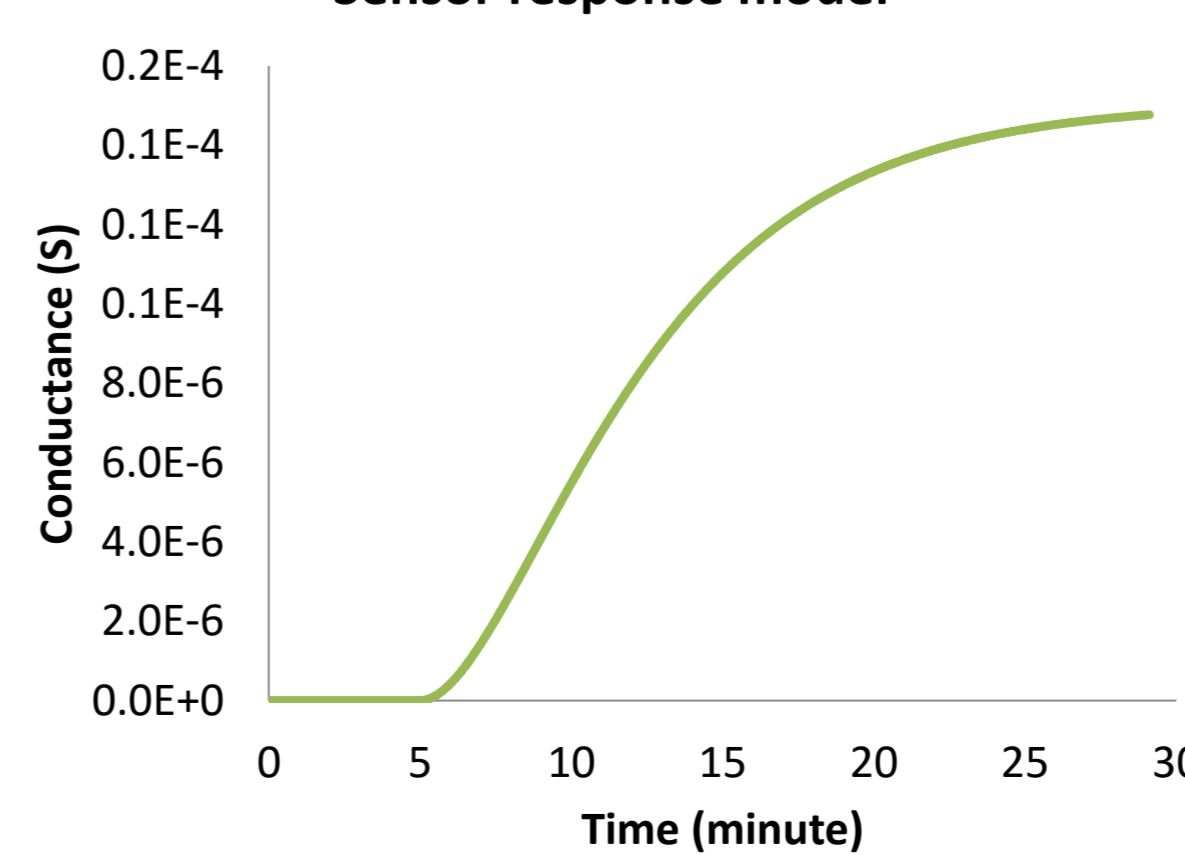


- Soot bridge arrangement makes contacts between the platinum electrodes



- Electrical model according to Ohmic law can be used to model the sensor signal

### Sensor response model



- Prediction/measurement of the soot number

## Conclusions

- A simple sensor have been made and characterized
- The sensor demonstrates good sensitivity to particle mass
- The collection rate passes by an optimum polarization voltage
- By varying the polarization voltage, the sensor is sensitive to the particle size
- In order to build a predictive model, more parameters such as the effect of the temperature and the size distribution need to be investigated