Development of a methodology for in-board assessment of the efficiency of air quality filters

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Ambre DELATER, Sébastien FABLE, Brice BERTHELOT, Cécile RAVENTOS, Jessica QUERON and <u>Olivier LE BIHAN</u>

ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

Contact: jessica.queron@ineris.fr

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QABINE 1&2

+ Partner from Industry

1. Assessment of the filter efficiency → real conditions

2. Exposure: mean concentration

3. Particle characterization

State of the art:

- In lab
- Proposal of Qabine: *in situ* (highways in Paris)

Challenges

1. Instrumentation
2. Sampling point: speed
3. Sampling point: place, direction
4. Transfert efficiency: assessment, improvement
5. Test *in situ*

Optical techniques

Most used approach: optical techniques

- Easy-to-use
- Mobile
- Real time information (down to 1s)

Limitations:

- Calibration with « perfect » particles
- Volumetric mass: only 1 value, to be chosen
- Optical diameter
- Cannot detect particles < 300 nm

Reference Method: gravimetry

Challenge 1: Instrumentation → decision

Reference method= gravimetry

impactor DEKATI

⇒ Cascade impactor
⇒ PM1, PM2.5, PM10
⇒ Weighing: EN12341

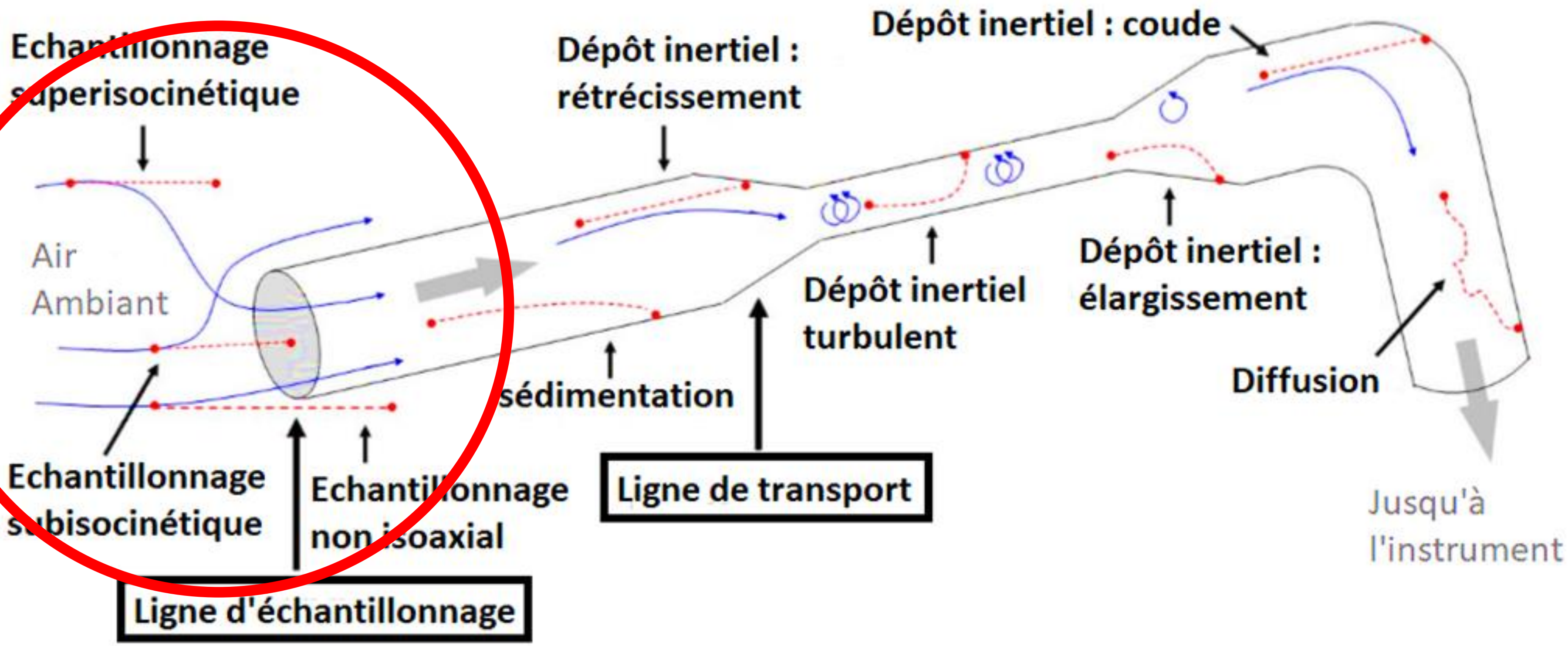
Nota: high flow (30 lpm)

Sampling points:

- Upstream the filter
- Indoor air in the car (« dowstream »)

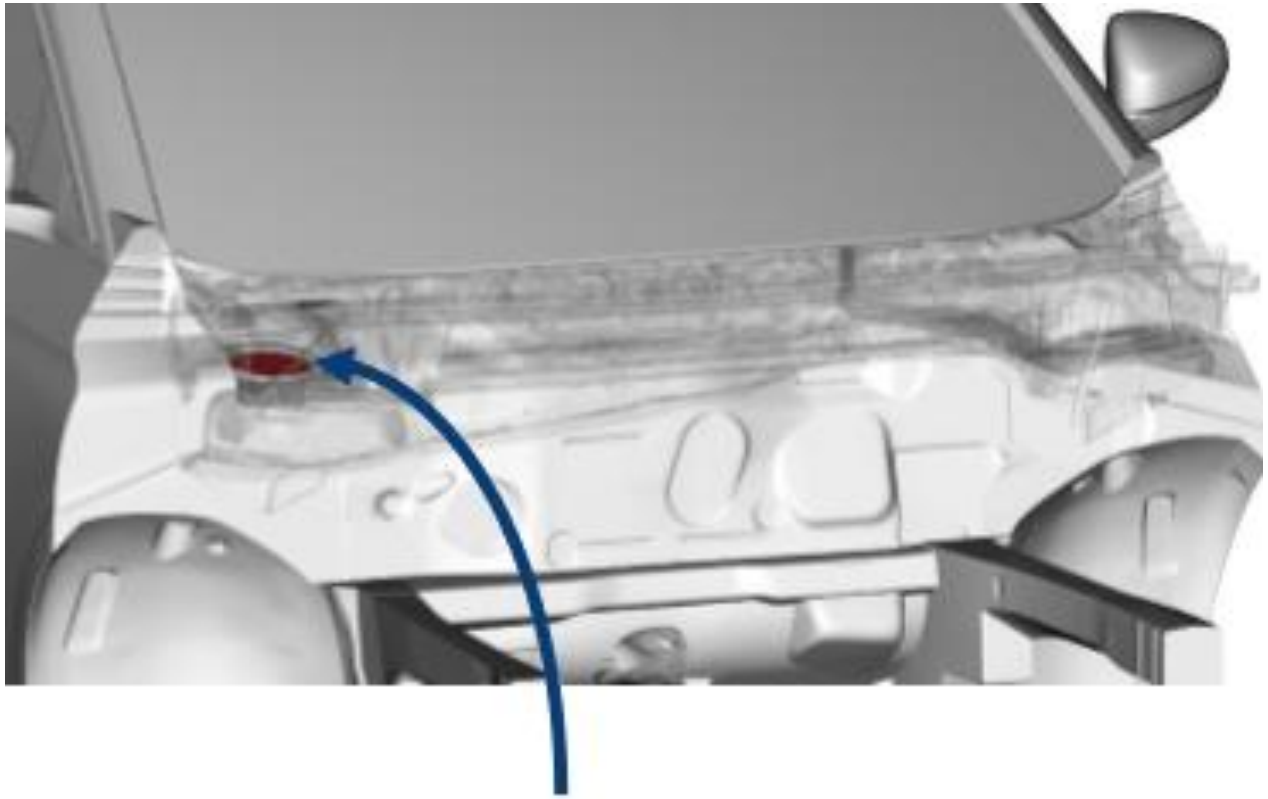
Challenge 2: outdoor sampling

Speed at the sampling point:
In ambient air; in-tube
Need for a STABLE speed in ambient air!



Challenge 2: outdoor sampling → decision

Is it possible to stabilize the speed for upstream sampling?



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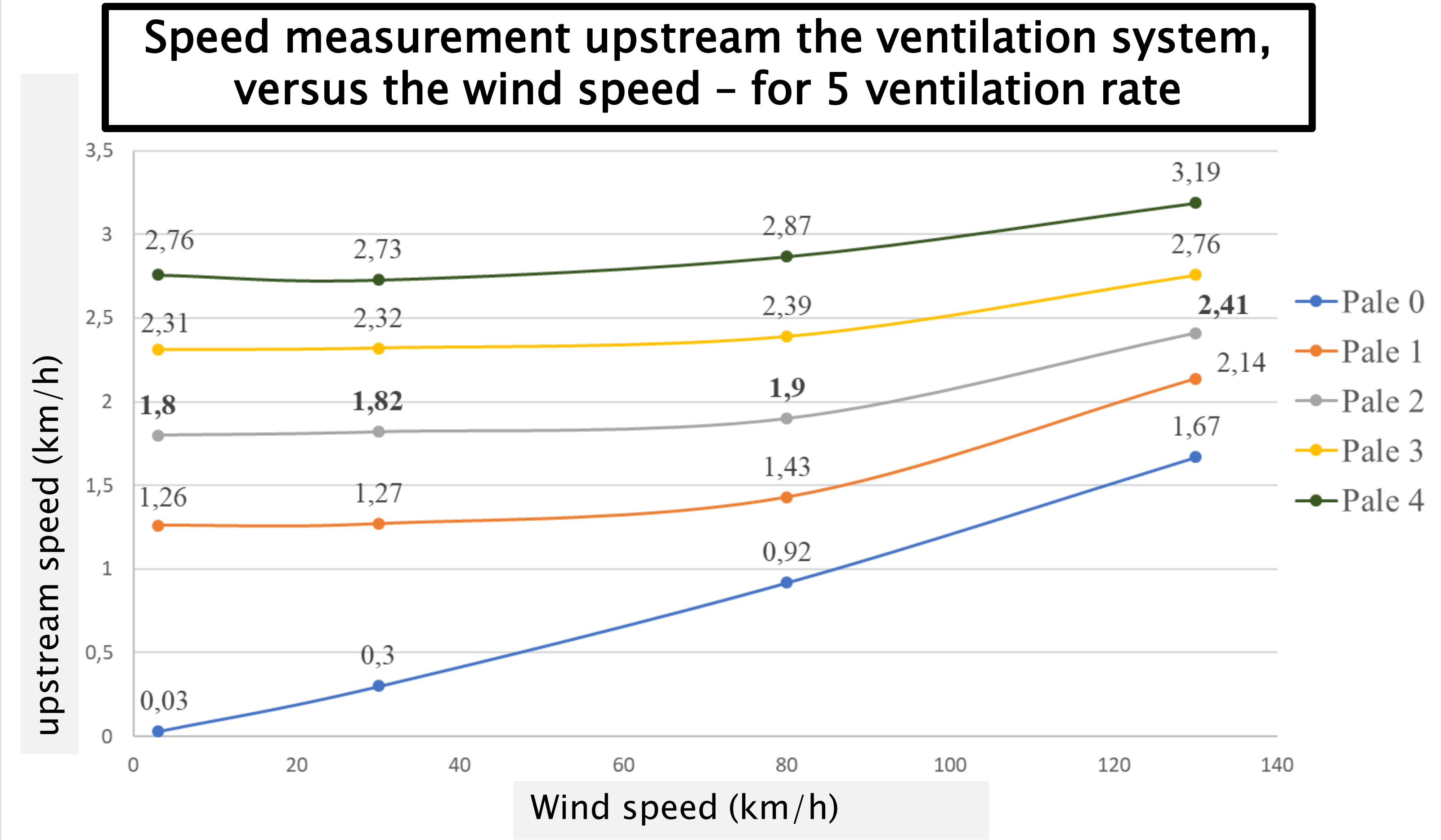
Challenge 2: outdoor sampling

Is it possible to stabilize the speed for upstream sampling?



Wind tunnel tests

Results: for pale 1 to 4, below 80 km/h,

- The upstream wind speed is related to the car ventilation, not to the ambient air speed
- So it is possible to sample particles with a stable speed in the sampling environment

=> **Pale 2**

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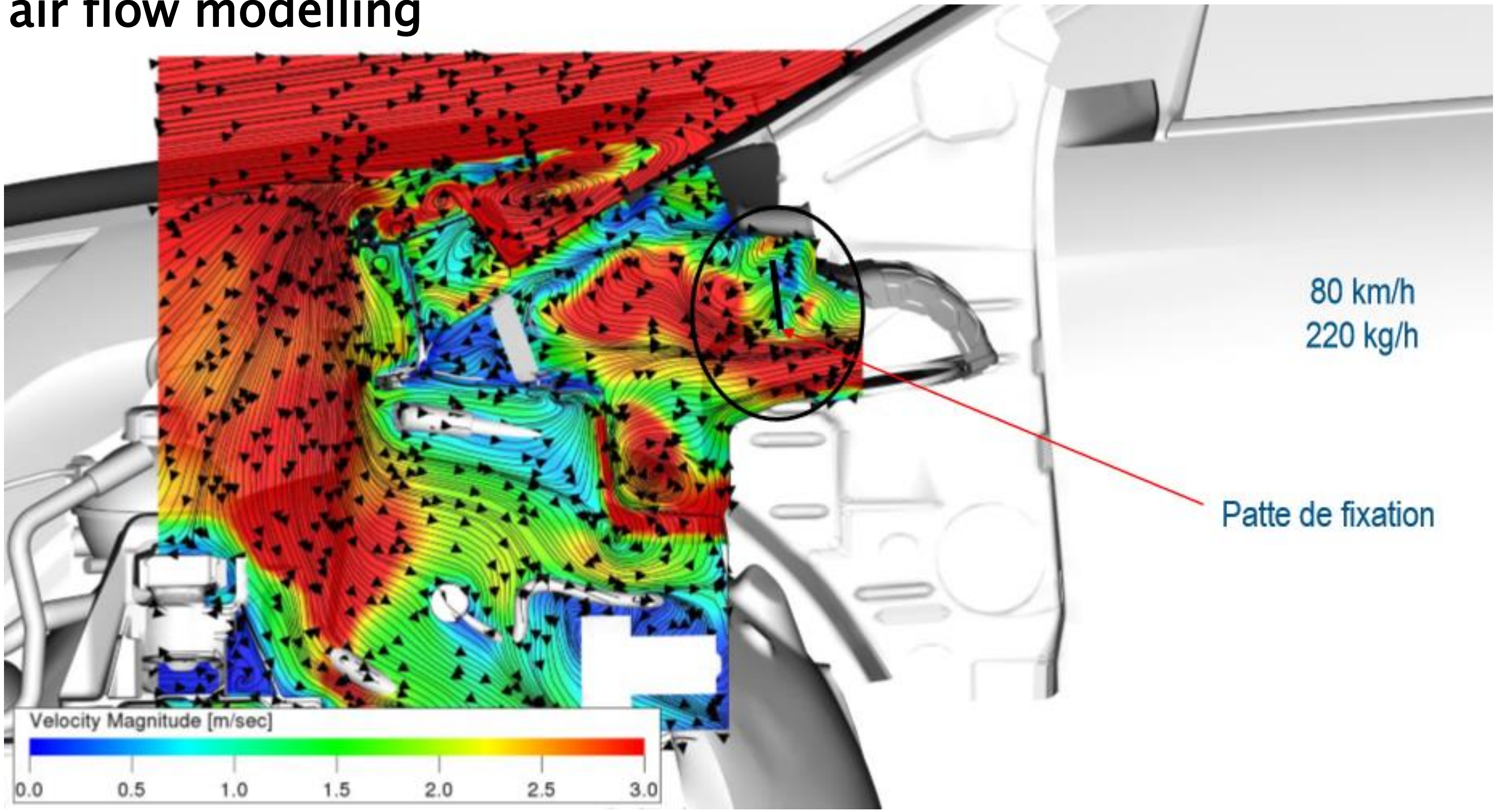
Challenge 3: sampling point and sampling direction

air flow modelling



Results: for pale 2, at 80 km/h,

- Same order of magnitude than measured speed
- Confirmation that the upstream wind speed is defined by car ventilation
- Selection of a sampling point out of the recirculation zone
- Sampling direction // to the air flow

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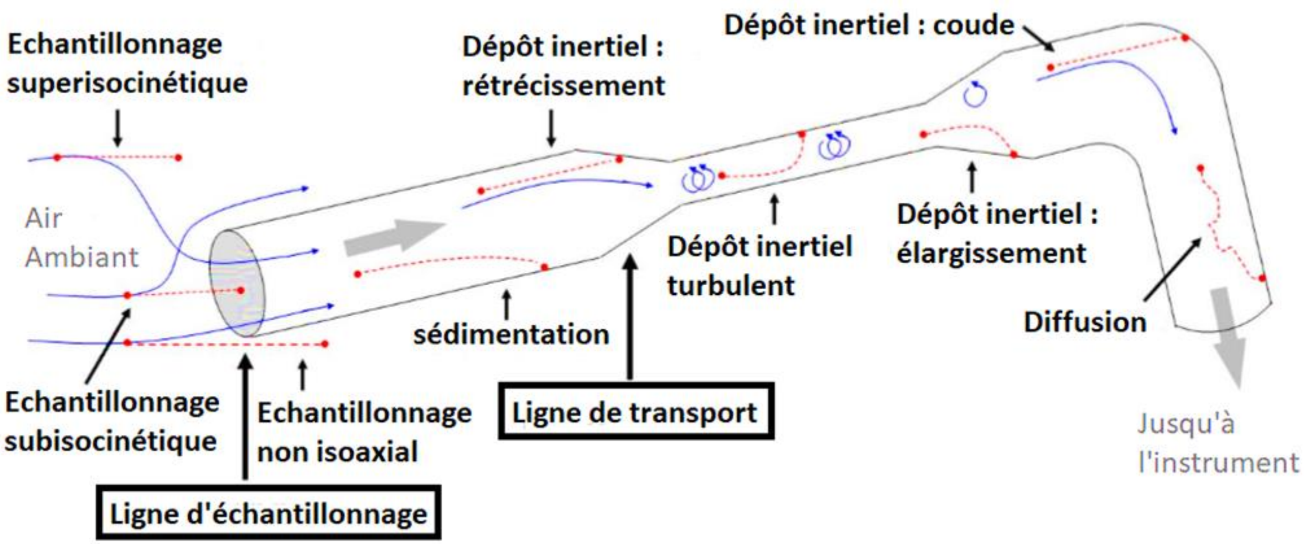
Particle losses - calculation

(Sampling efficiency) x (Transport efficiency) = Transfert efficiency



=> Software
Particle Loss Calculator
State of the art
[Baron et Willeke, 2005]

Calculation of the Transfert Efficiency

Optimisation

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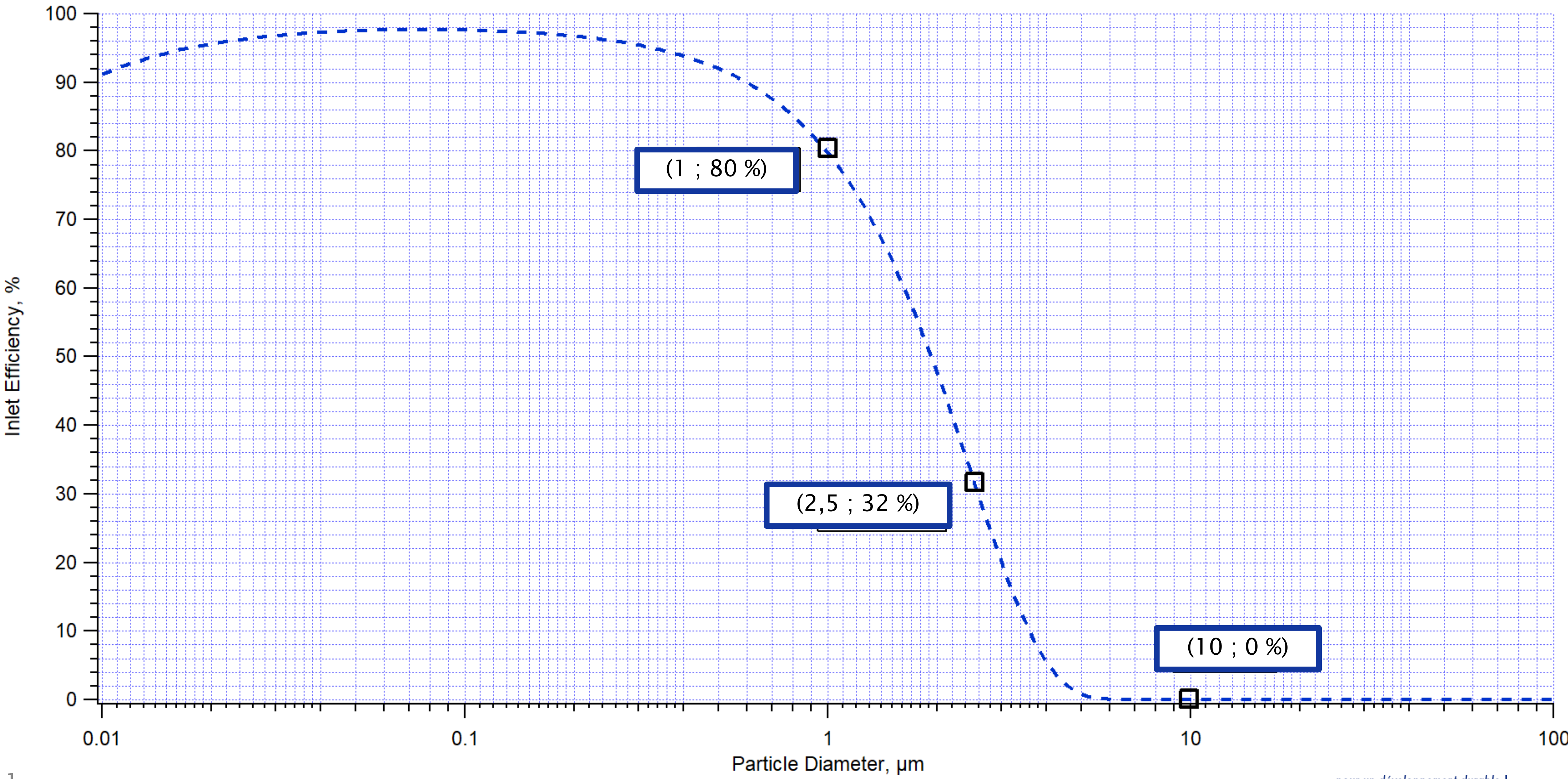
Challenge 4: definition/optimisation of the sampling line

Efficiency versus diameter for a first sampling line

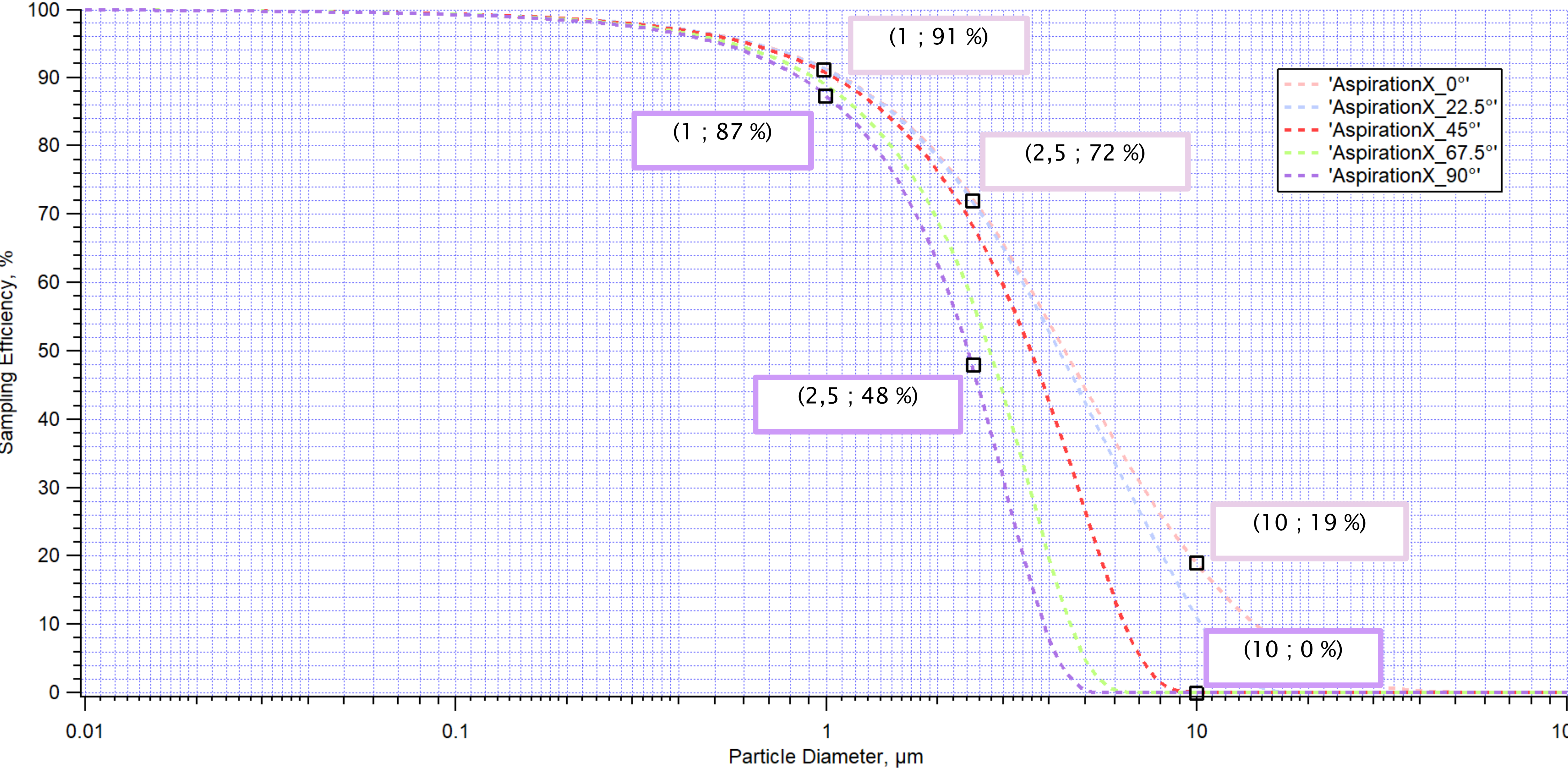
- DEKATI on the passenger seat
- Different diameters for the tubing
- 3 changes of direction



Challenge 4: definition/optimisation of the sampling line

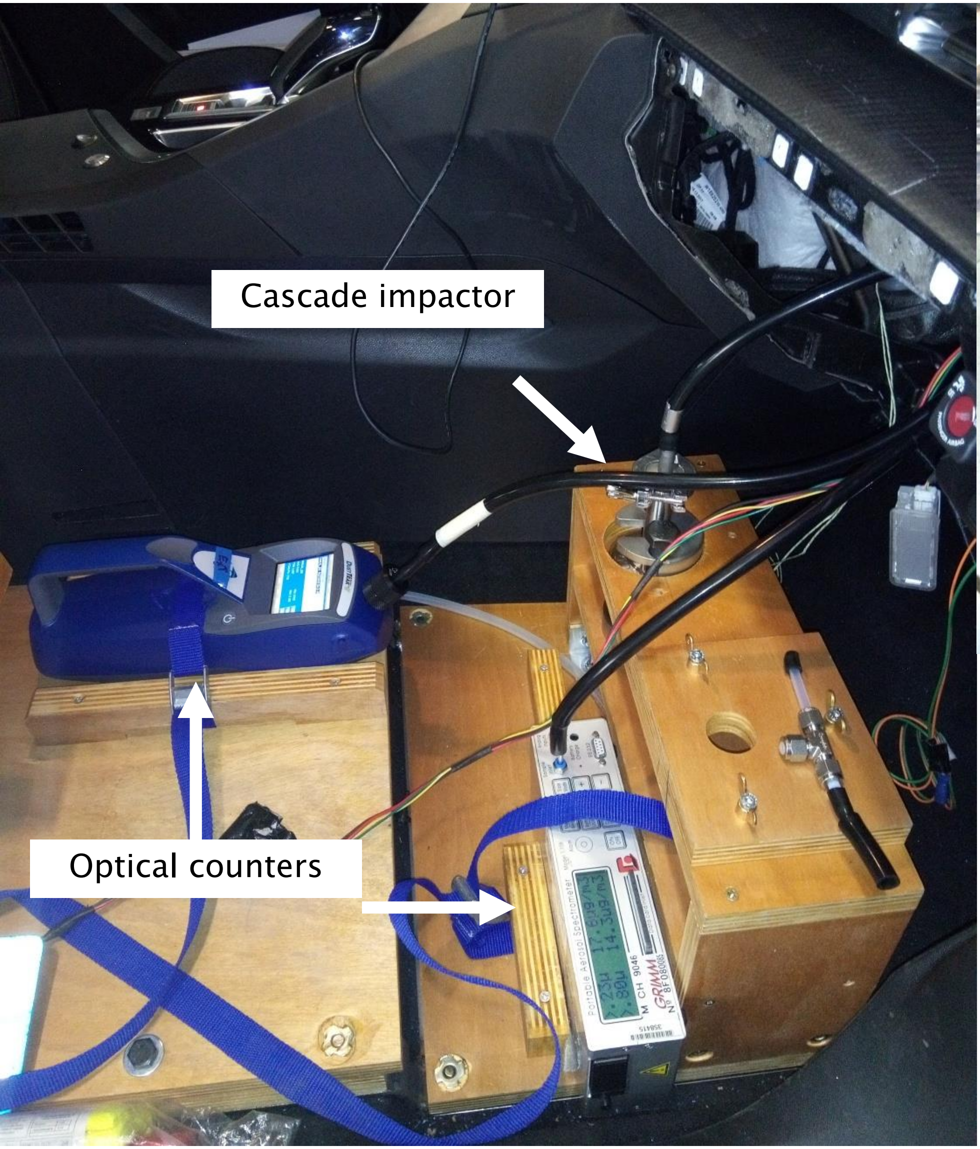
Sensitivity study

- Example: impact of the aspiration angle



Challenge 4: definition/optimisation of the sampling line optimisation

Etude d'une nouvelle ligne de prélèvement



<u>Improvements</u>:
- Shorter tubing (−50%)
- 3 changes of direction => 1 slight
- Larger diameter

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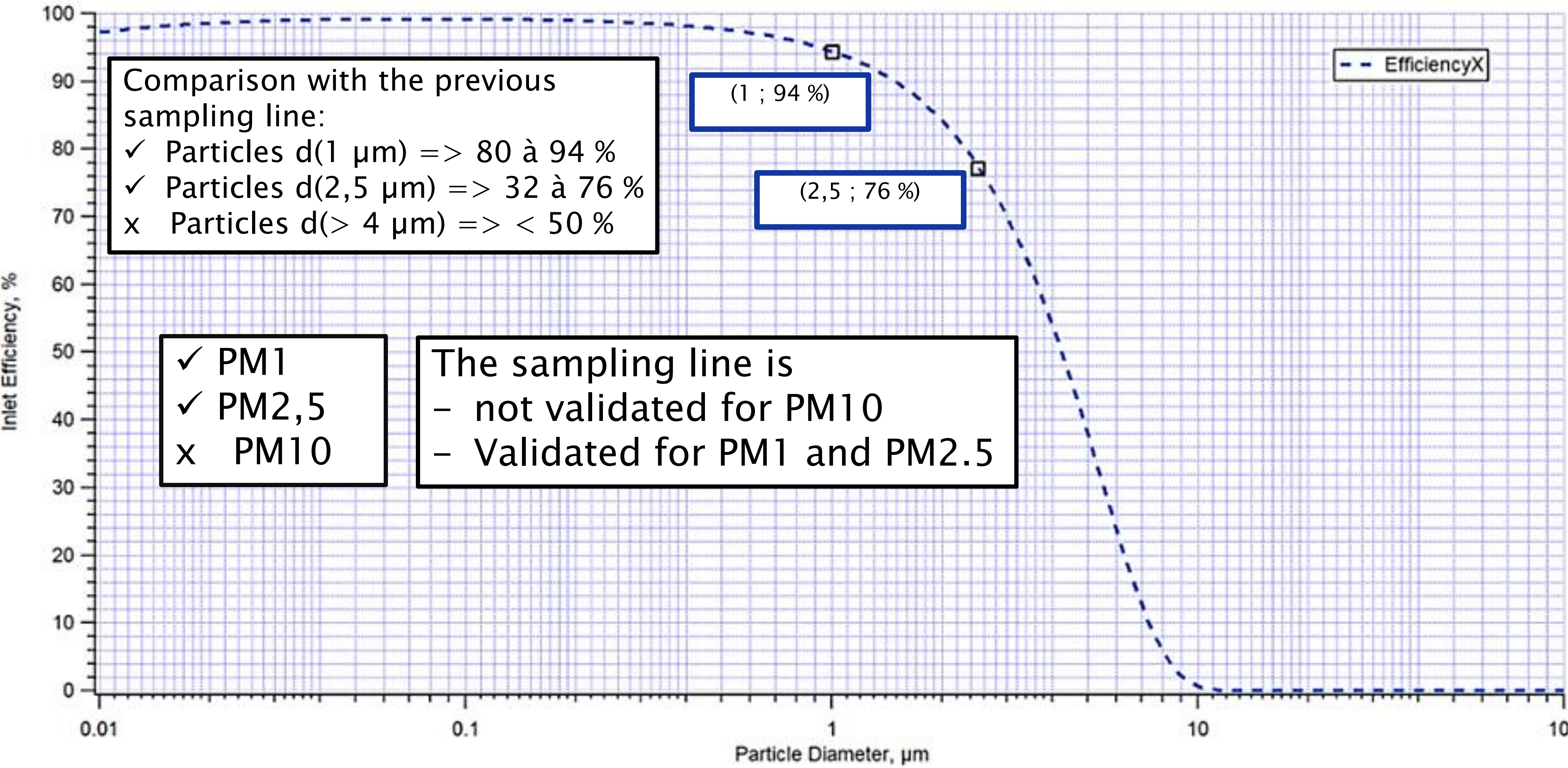
Challenge 4: definition/optimisation of the sampling line

Efficiency versus diameter for the optimized sampling line



Comparison with the previous sampling line:

- ✓ Particles d(1 µm) => 80 à 94 %
- ✓ Particles d(2,5 µm) => 32 à 76 %
- x Particles d(> 4 µm) => < 50 %

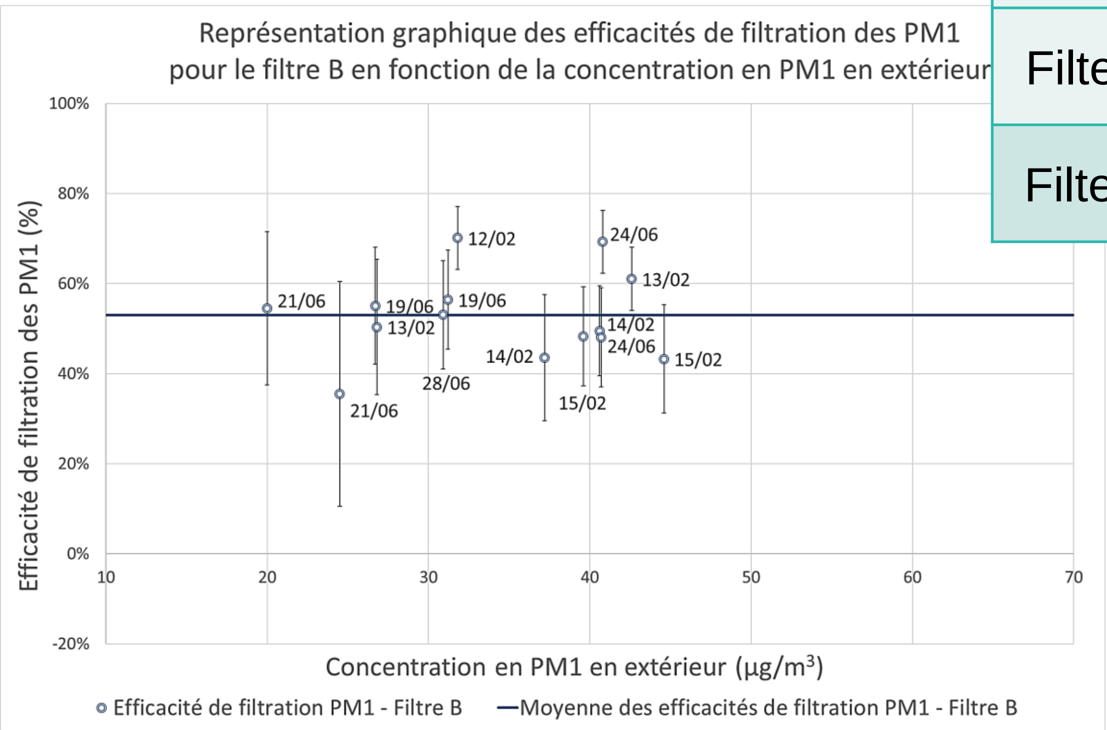
- ✓ PM1
- ✓ PM2,5
- x PM10

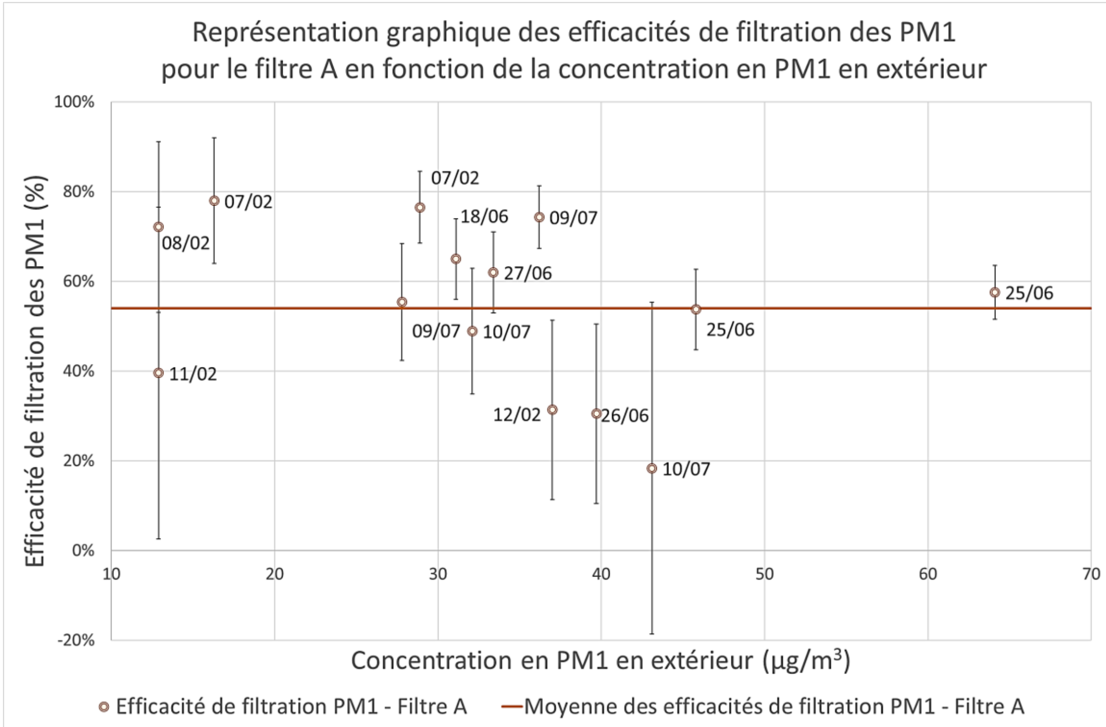
The sampling line is
- not validated for PM10
- Validated for PM1 and PM2.5

Challenge 5: *in situ* testing

Particle losses - calculation

	Average of the filtration efficiency		Number of validated experiments	
	PM1	PM2,5	PM1	PM2,5
Filter A	54 %	59 %	n = 14	n = 6
Filter B	53 %	55 %	n = 14	n = 7





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Conclusion and Perspectives

Objective: Conception of a sampling line for the assessment of the filtration efficiency of the filter

Results: Methodology
- PLC Study + wind tunnel + CFD + car changes
- Validated for PM1 and PM2.5
- Tested on 2 filters

Limitations:
- Car changes => Professionnal
- method not validated for PM10
- PM2.5: uncorrected values
- Downstream sampling point: not at the outlet
- Upstream point: dedicated to filter efficiency meas., not to ambient air characterisation

Perspectives:
- To develop a specific downstream sampling point

Thanks for your attention!

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