On board ELPI measurements of PM size and numbers in vehicle aeration system to evaluate the dynamics of PM exposure in traffic flow. Implication for lung PM deposition dynamics of car drivers and passengers.

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Electrical Low Pressure Impactors allow to perform short term response (1s) measurements of both PM numbers and size distribution. The relative low sensitivity of these systems to vibrations made it possible to perform on board measurements of PM in the aeration system (incoming air) of a car inserted in traffic flow, to assess the dynamics of PM size distributions and concentrations. A number of representative situations have been analysed: urban and rural backgrounds, tunnel profiles and measurements in the wake of trucks. The use of the respiratory tract PM size deposition models from IRCC 1996 [2] coupled with the observed PM size distributions and numbers allowed us to predict the dynamics of human PM respiratory tract deposition. These calculations are made on the basis of mean human ventilation rates and epithelial surface area.

Particulate measurement in the "Grand-Mare" tunnel

The tunnel selected for our study is located in Rouen (France) suburb, under a hill and at the end of a motorway. Its structure consists in separates tubes for each circulation way. The mean traffic is equivalent to 30.000 vehicles per day. The tunnel length is about 1500 m and its slope is more than 3%. This last characteristic is very important in regard to engine load. The ventilation in the tunnel is provided by axial fans set in motion by the carbon monoxide level. During our measurements, the ventilation was natural, that is to say not forced by fans.
Two ELPI particle sizers have been employed. The first was placed in the tunnel, near the road, equidistantly from the ends. The second one was located inside a car and connected to the external air supply. The car as been used to realized a lot of crossings in the tunnel. The response of particle sizers has been compared both at the beginning and at the end of the experiment to ensure a good interpretation of results.

Particulate concentration - tunnel profile

For each tunnel crossing, a very good correspondence has been found in the results between particle sizers when the on board ELPI was opposite to the immobile one. This important result shows that we can use an on board device to obtain a good measurement of outside pollutant in confined atmosphere. This correspondence gave us the opportunity to determine the particulate concentration at each position along the tunnel. The obtained curve is the concentration profile of the tunnel. The measurement has been carried out several times in each tube (ascending and descending) to compute mean representative profiles. The typical profile obtained show that the particulate concentration regularly raises along the tube up to the exit, except in the first 200 meters subsequent to the entrance where a dilution effect has been observed. A maximum concentration is recorded at each tube exit. This regular growth can be explained by the pumping

effect due to traffic and difference in pressure between the tube extremities. We notice also that the particulate concentration level is three times higher in the ascending tube than in the descending one. This specificity is due to the engine load which is lower in the descent.

Size distributions – background and truck wake

In case of background measurement, the particulate distribution is constant whatever the distance from the entrance. Only the concentration changes. The maximum of the distribution function is obtained for in the first ELPI class (30 to 60 nm).
On the other hand, in the wake of a truck, the signature obtained is different with a maximum around 100 nm according to measurements performed on a CVS* connected to a diesel engine exhaust pipe. Moreover, the concentrations are similar.
This difference in PM size distributions when sampling is operated in or out of the wake of a truck, suggest modifications during the aging of the exhaust aerosol in confined atmosphere. Either selective deposition of largest particles or effects of dilution ratio [1] or the secondary formation of small size aerosol (30-50 nm) by exhaust gas condensation may occur during the aerosol aging.

PM respiratory tract deposition

Maximal epithelial deposition rates of 5pg/cm²/min and 100pg/cm²/min in alveolar and tracheobronchial regions of the respiratory tract respectively can be expected from atmospheres in the wake of trucks which may peak at as much as ca. 4 mg/m3 of PM2.5. In the view of PM/size lung deposition pattern, these nanoparticles may very efficiently deposit in the distal respiratory tract. Knowledge implementation concerning the nature of the background aerosol would be of major interest for health effect considerations.

Conclusion

This study has shown that it is possible to provide on board measurements with ELPI. This tool is useful to quantify external aerosols but also measure the particles inside a vehicle. The related health effects, based on the EPA PM deposition fraction model [2], can be estimated from these results.

1 **: GOURIOU F., BALMIGERE V., DIONNET F., MORIN J.P. and WEILL M.E.** « Quantitative investigation on diesel exhaust: influence of dilution, residence time and hygrometry on soot particles ». *5th international ETH conference on nanoparticle measurement, Zürich 2001.*
2 **: EPA** « Air quality criteria for particulate mater ». *EPA/600/P-001L volume2, april 1996*

* CVS : Constant Volume Sampler

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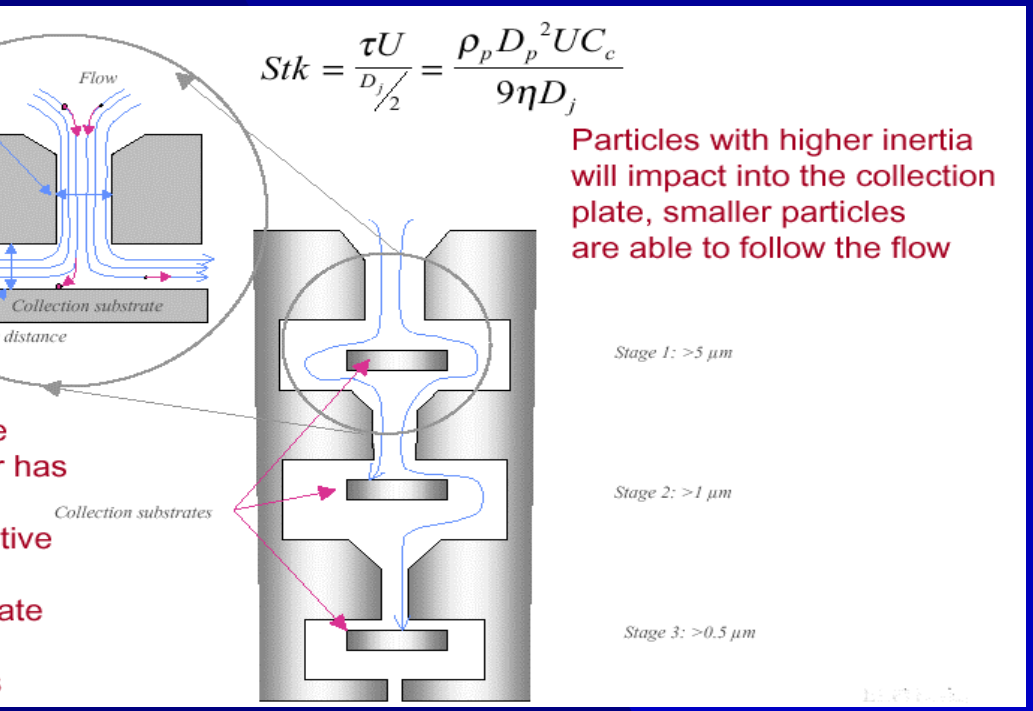
Particulate measurement device : ELPI cascade impactor



movable
dynamic (1 mes./sec)

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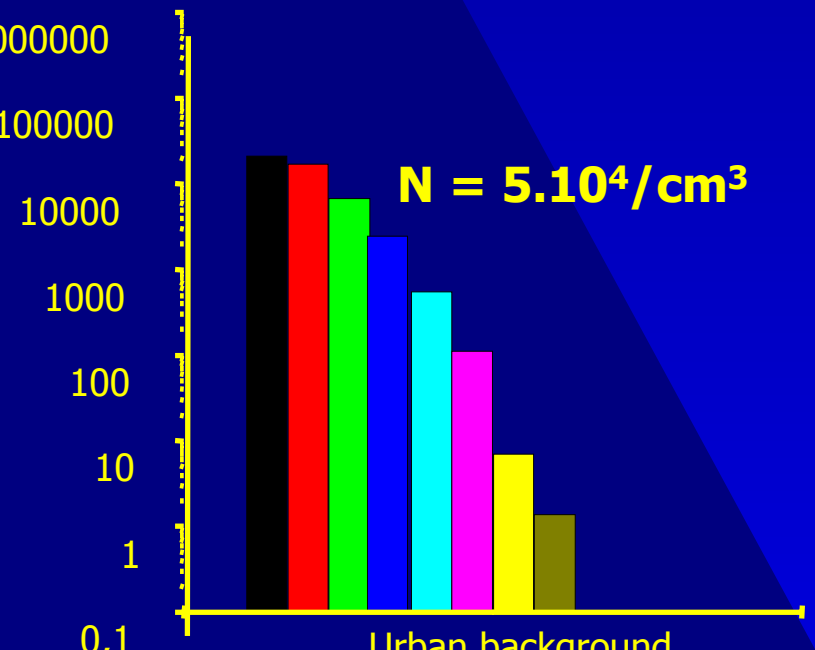
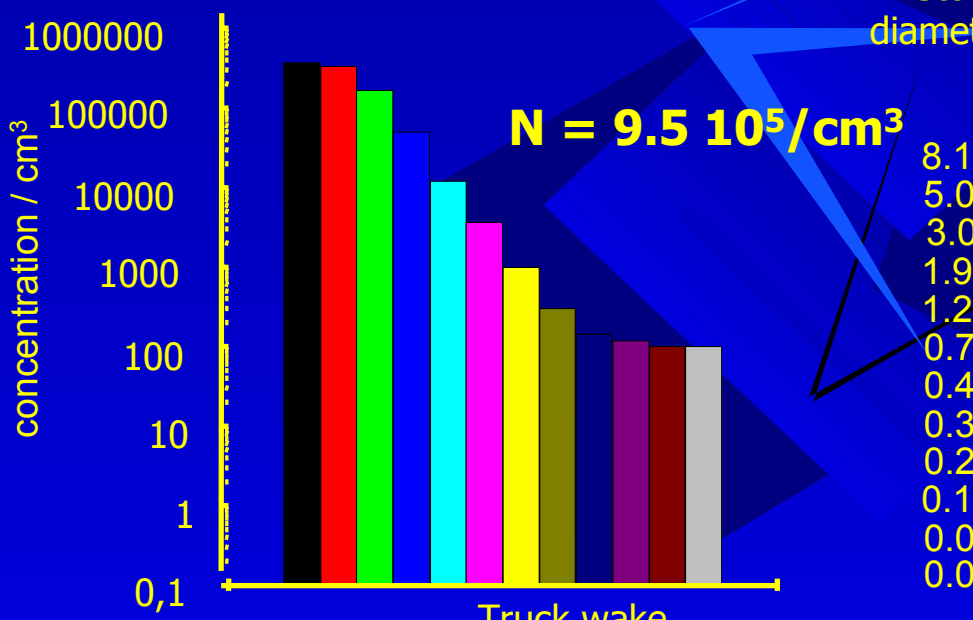
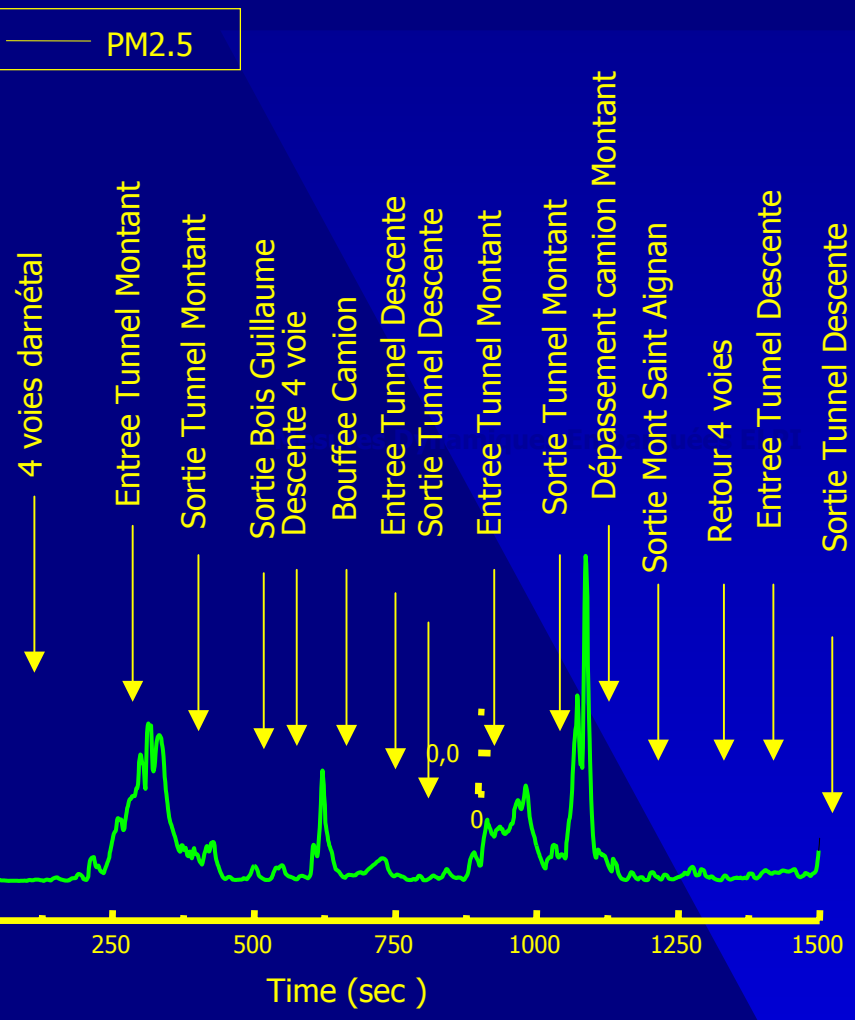
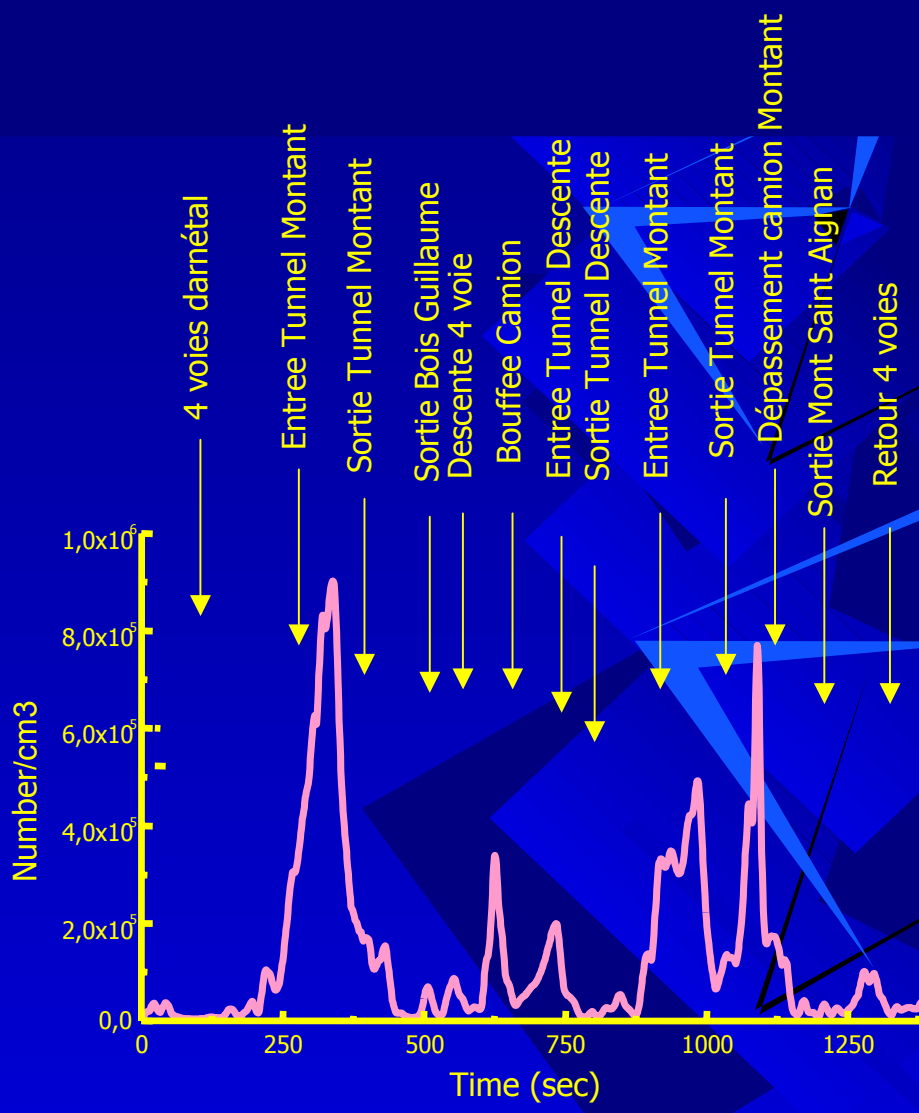
On board ELPI measurement





On road comparison of Mass and Number PM2.5 profiles





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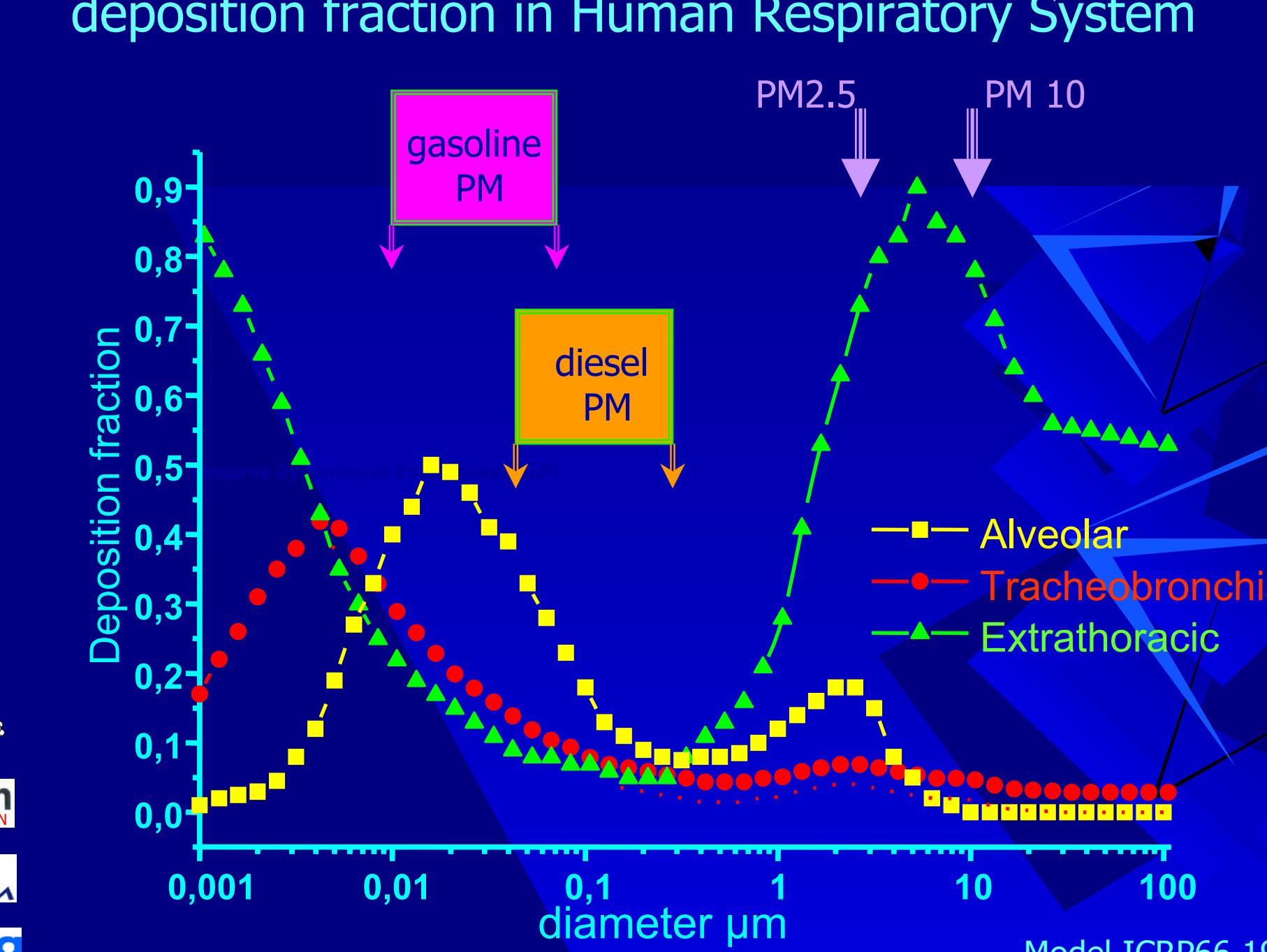

deposition fraction in Human Respiratory System
PM2.5
PM 10
gasoline PM
diesel PM
Deposition fraction
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
0,001
0,01
0,1
1
10
100
diameter µm
Alveolar
Tracheobronchi
Extrathoracic

Human Respiratory Tract PM Deposition

Human Lung Data

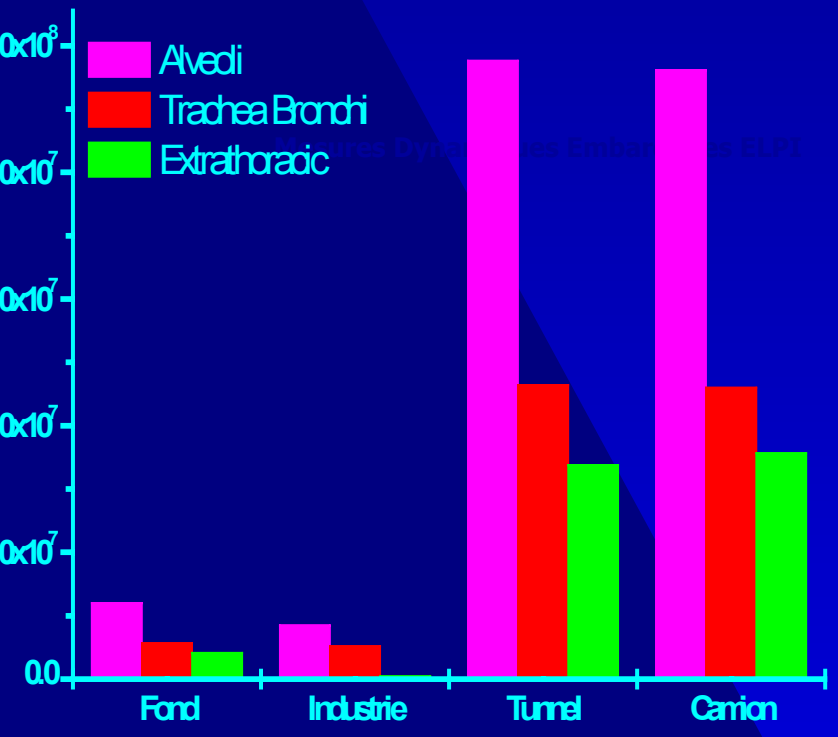
300.16⁶ alveoli (surface area 100m²)

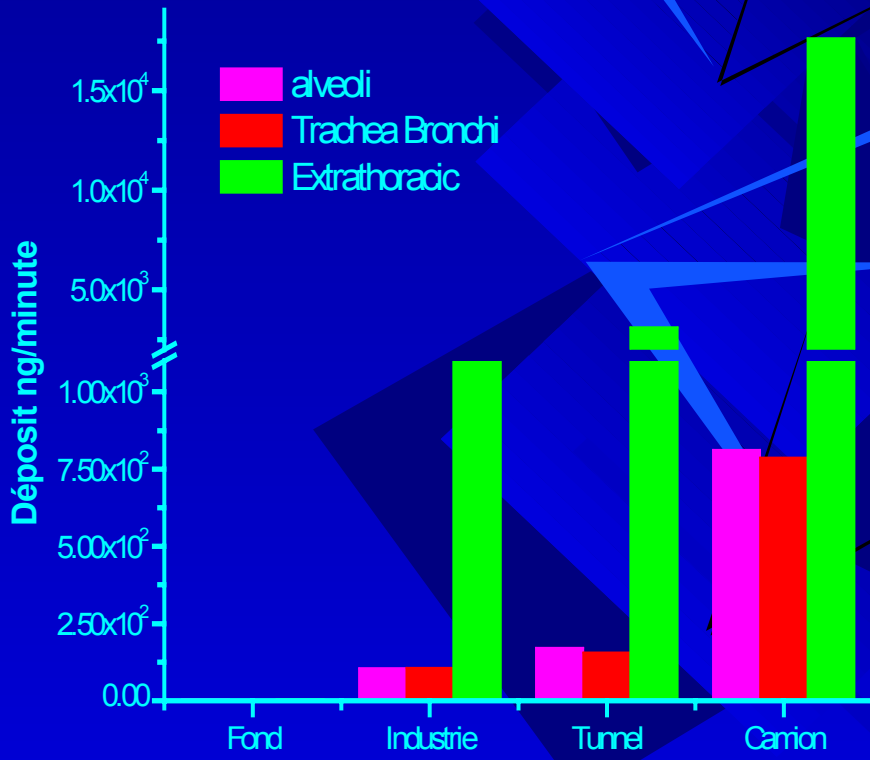
deposition rate 1ng/cm²/min

Terminal Bronchi Surface Area 4m²

deposition rate 25ng/cm²/min

lveoli
racheoBronchial
xtrathoracic





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Particulate Measurement in the «Grand Mare» Tunnel (ROUEN – France)

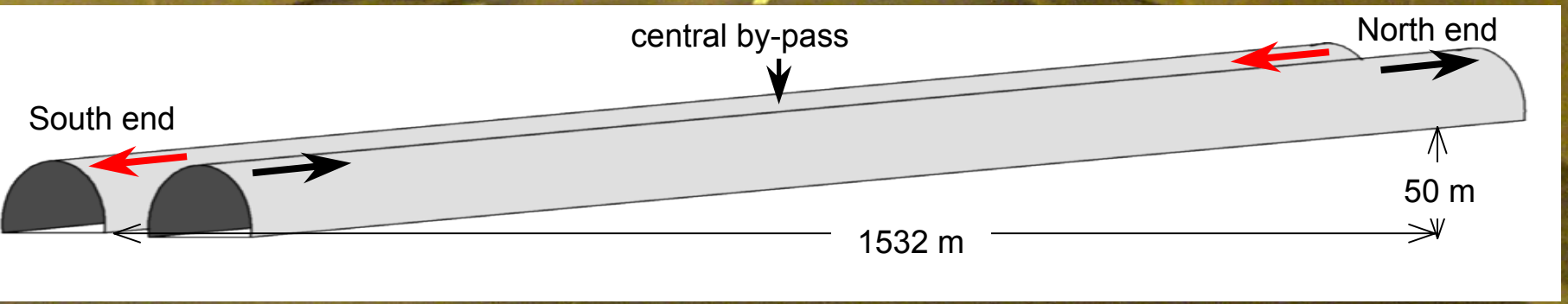
ell determined experimental conditions (closed space)

nowledge of traffic rate and quality

000 vehicles/day

petitive experimental conditions (more than in opened area)

nnel has a constant slope with two independent tubes for ascending and scending Traffics



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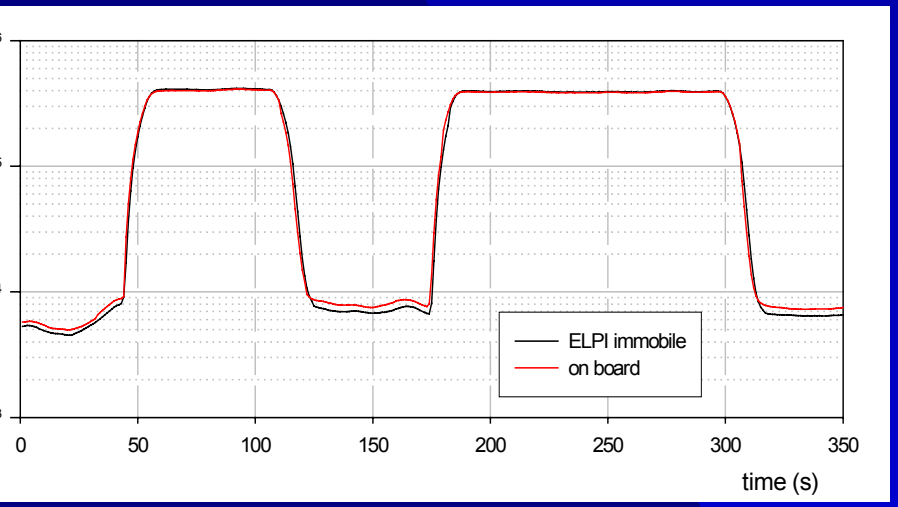
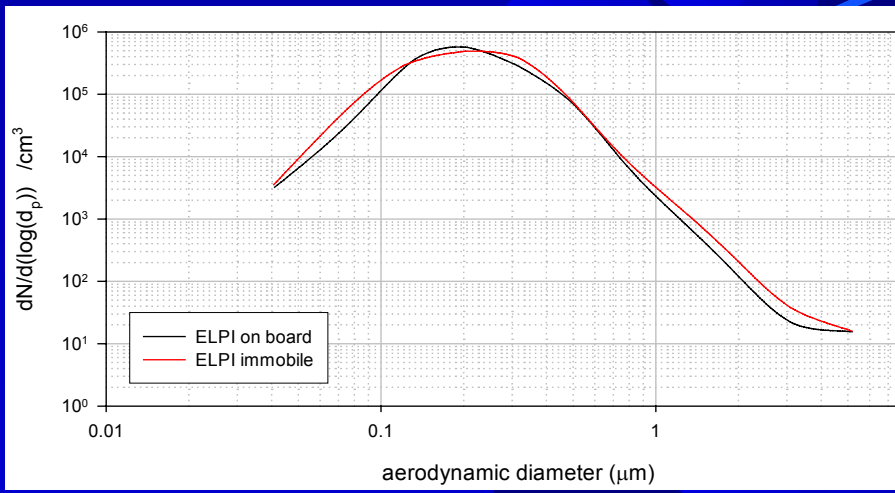
Comparison of ELPI n°1 et 2





0.9% relative difference on concentration

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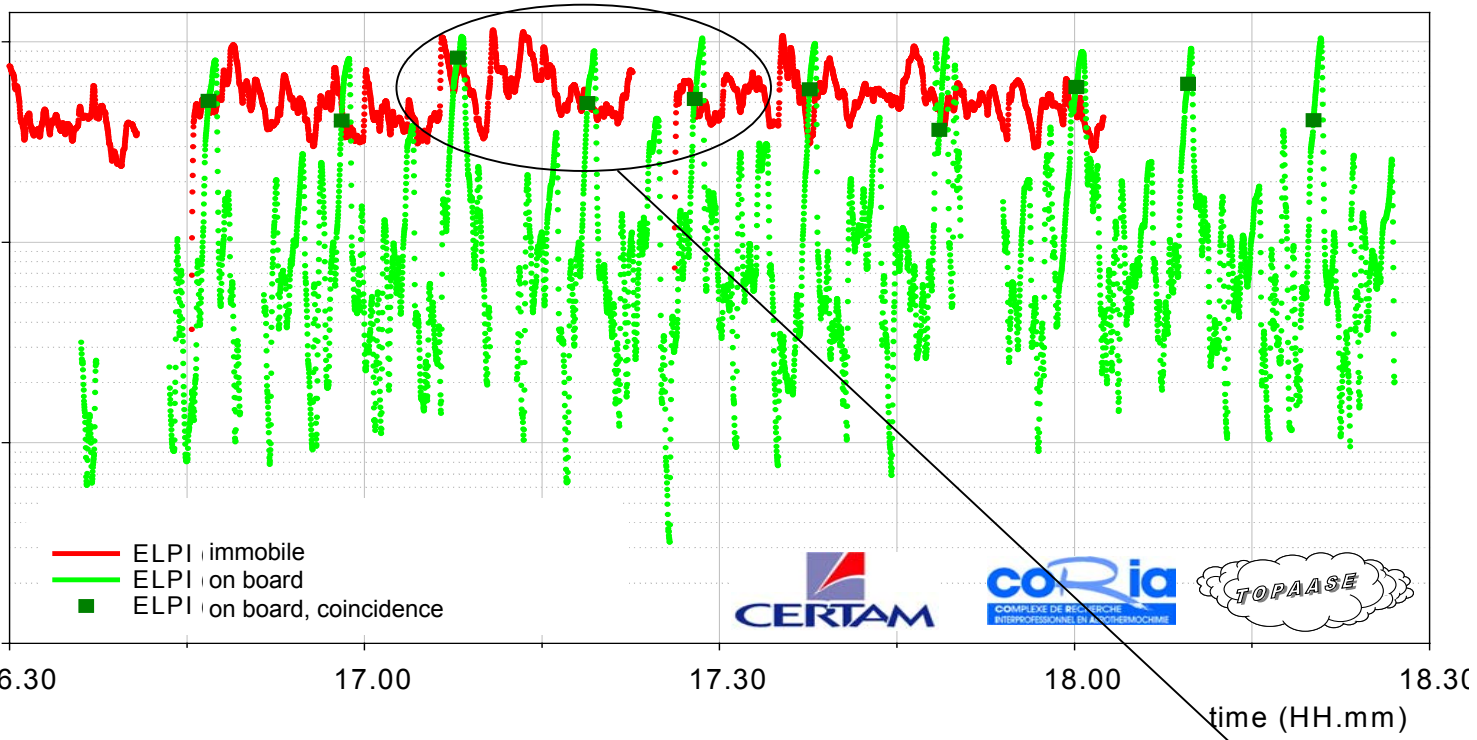
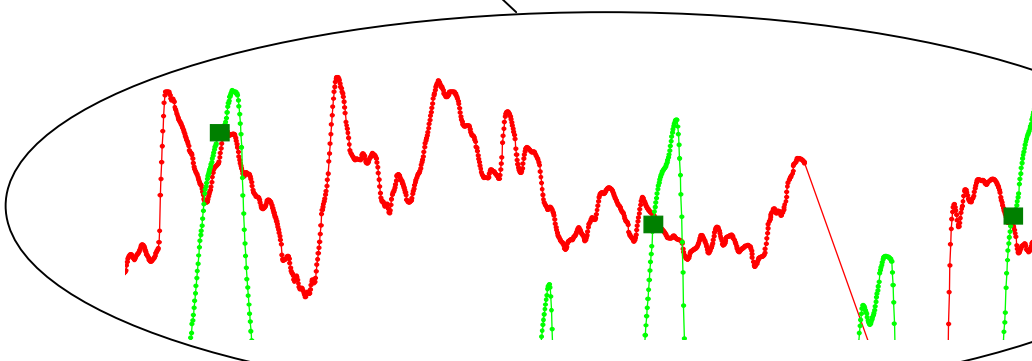
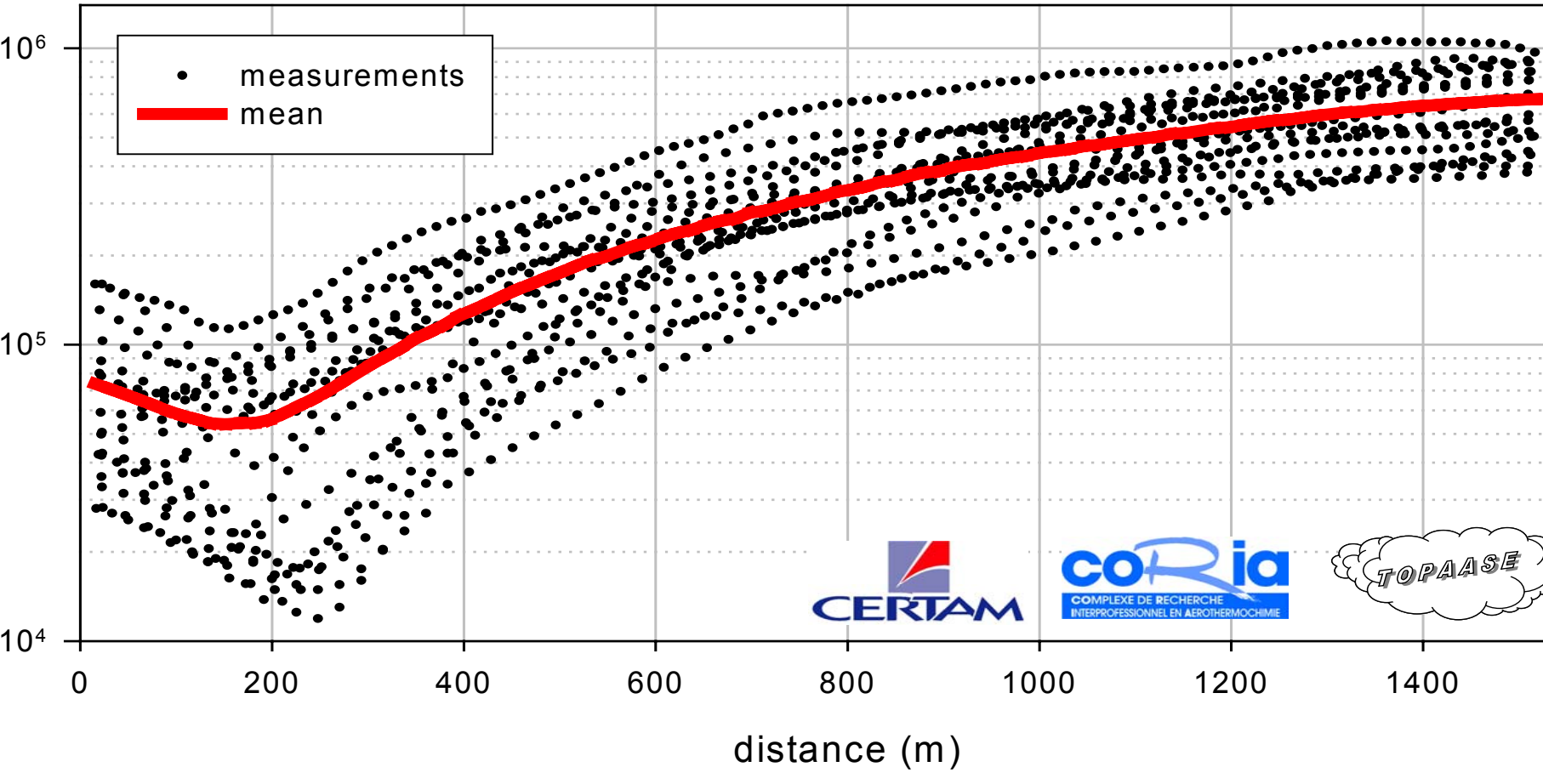
immobile ELPI (central bypass) / on board ELPI (ca

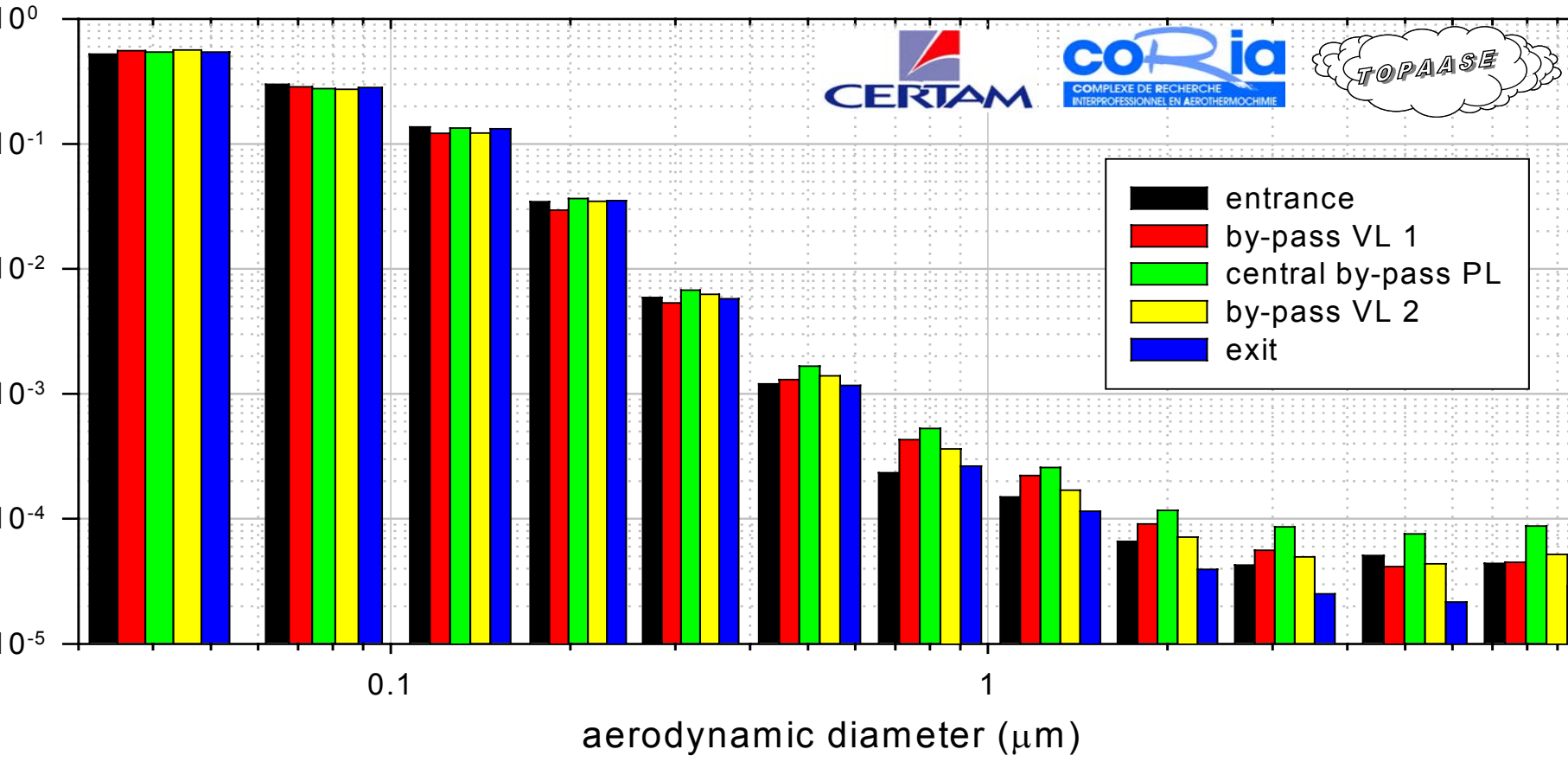




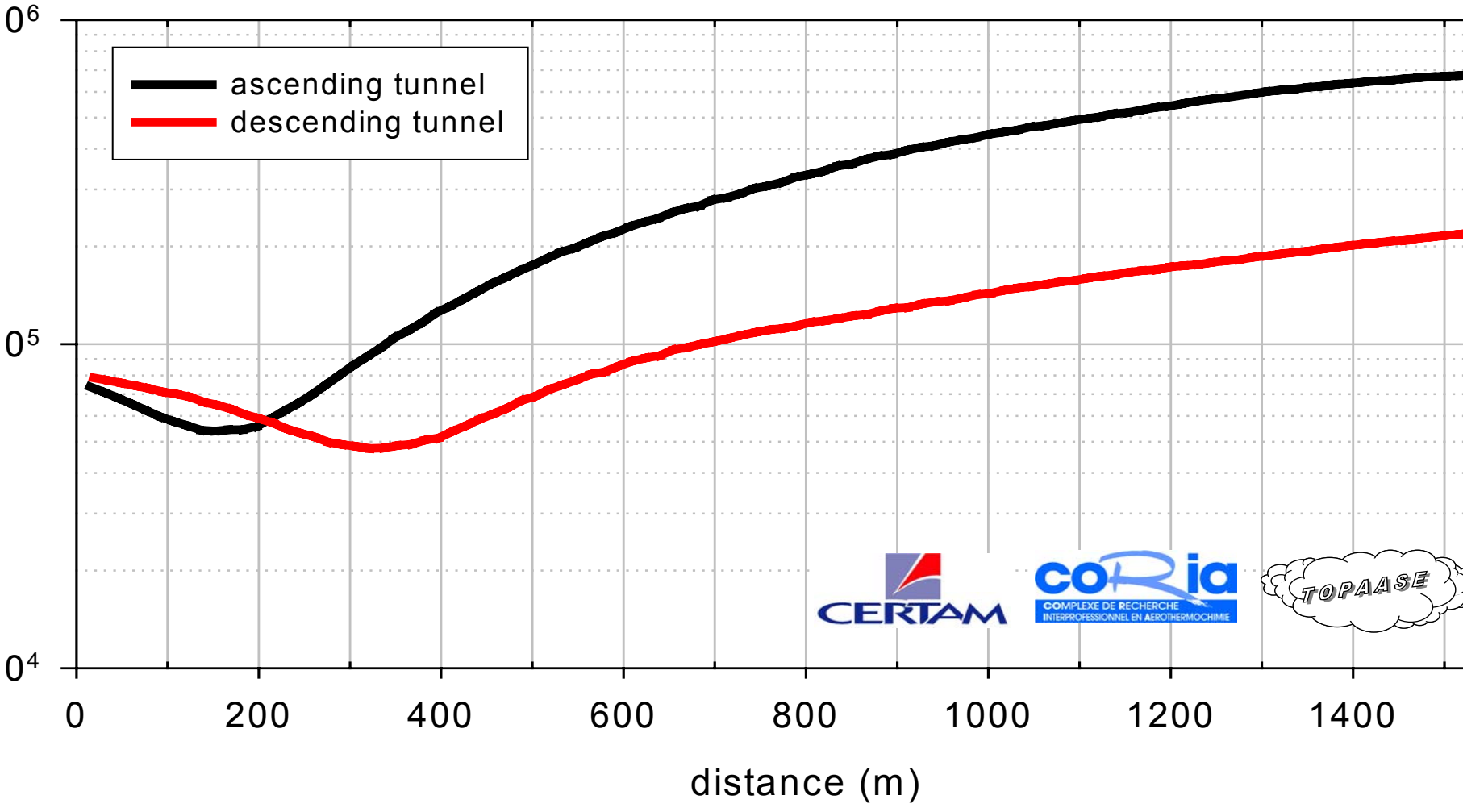
PM concentrations : ascending tunnel



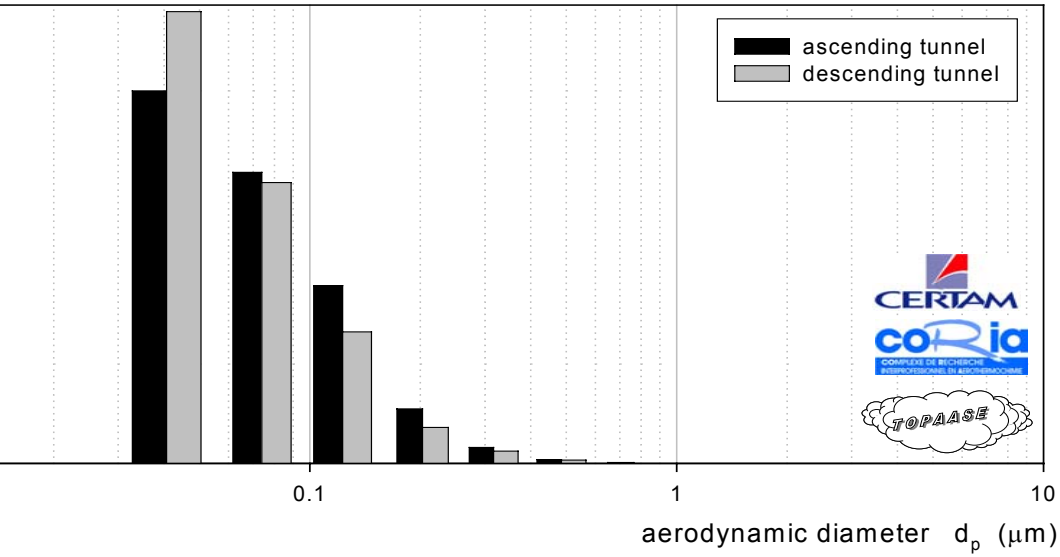
ize Distribution Patterns / Distance in Ascendant Tunn

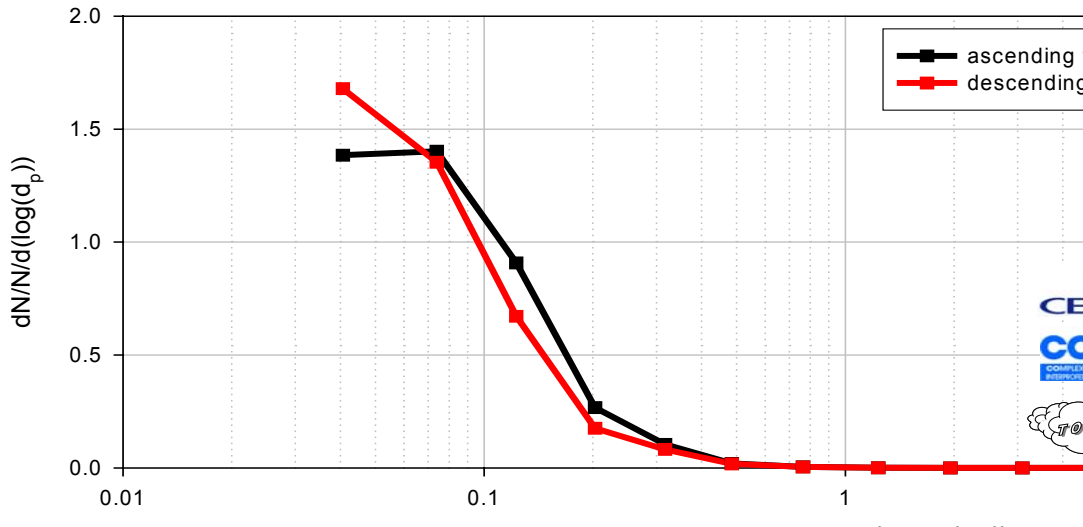


PM concentration profiles : ascending tunnel / descending tunnel



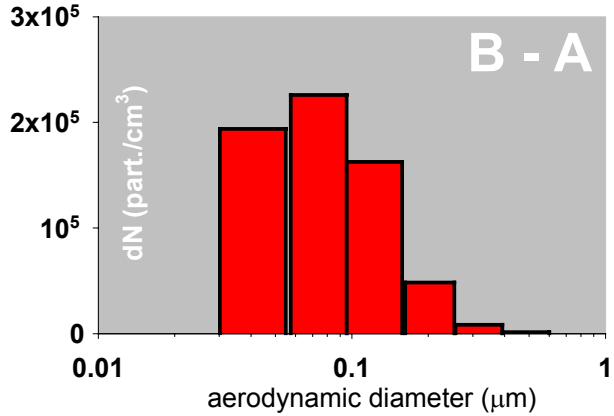
PM size distribution patterns: ascending tunnel / descending tunnel



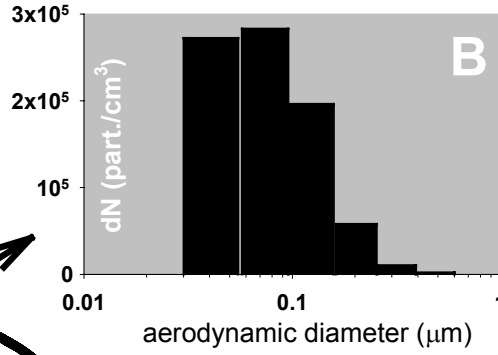


PM Size Distribution wake / background

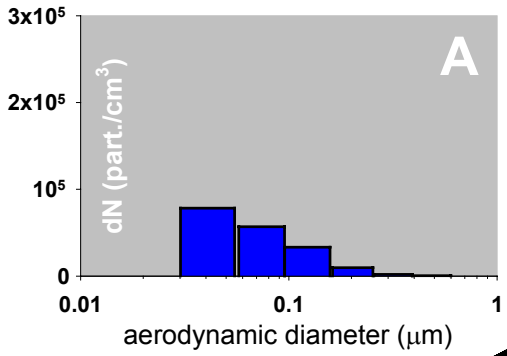
typical diesel distribution equivalent to mesurement on CVS with *10 < dilution ratio < 100*



in the wake measurement *(PM 2.5 = 1.17 mg/m3)*



background distribution *(PM 2.5 = 320 µg/m3)*



Conclusion (1) - tunnel

- ore particles in ascending tunnel (x3)
- xcellent concordance (on road / on board ELPI)
- e concentration increases along the tube with pumping
- d/or chimney effects
- o difference size distribution between entrance and exit
- gnificant difference between descending and ascending
- nel (both PM number and size distribution)
- nportant difference between tunnel atmosphere and wa
- tributions (both PM number and size distribution)

Conclusion (3)

Difference background / truck wake :

- Deposition ?
- Secondary Aerosol (Condensation or solid PM) ?

Further analytical knowledge is required

conclusion (3)
Human Lung Deposition Rate and Particulate Concentration

PM 2.5 concentration :

- urban zone : 30 $\mu g/m^3$
- tunnel : 300 $\mu g/m^3$
- truck wake : 1 to 5 mg/m^3

Mesures Dynamiques Embarquées ELPI

Maximal epithelial PM deposition rate :

- 5 $pg/cm^2/min$ in alveolar region
- 25 pg/cm2/min in TB Region

Important Considerations for Exposure quantification and Health Effects Considerations

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