FROM RESEARCH TO INDUSTRY

nanoSAFE'16

DESIGN AND EVALUATION OF A DIFFUSION CHARGING DIFFERENTIAL MOBILITY CLASSIFIER TO MONITOR PERSONAL EXPOSURE TO AIRBORNE NANOPARTICLES

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Toxicologie Programme Transversal

NanoSciences Programme transversal

PNS PLATE-FORME NANO SÉCURITÉ

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OUTLINE

General information

- Context
- Project goal

Collector information

- Principle
- Description

Results

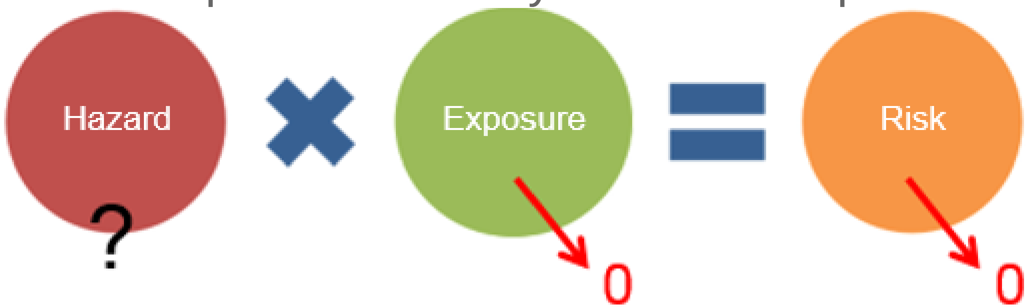
- Diffusion charging zone
- Field charging zone
- A posteriori analysis

Conclusion & Perspectives

Context

- Increase of utilization and production of nanomaterials in research and industry

- Discussions on potential health impacts caused by inhalation of particles
  - Risks?



- Current scarcity of hazard data in nanotoxicology
  - Particle capacity to reach and deposit in the deep alveolar regions of lungs
  - Exposure can be hazardous
  - Studies realized on cells or on animals but complicate to extrapolate to human

- To assess the efficiency of risk management measure, it is necessary to determine the personal exposure

GENERAL INFORMATION

Project goal

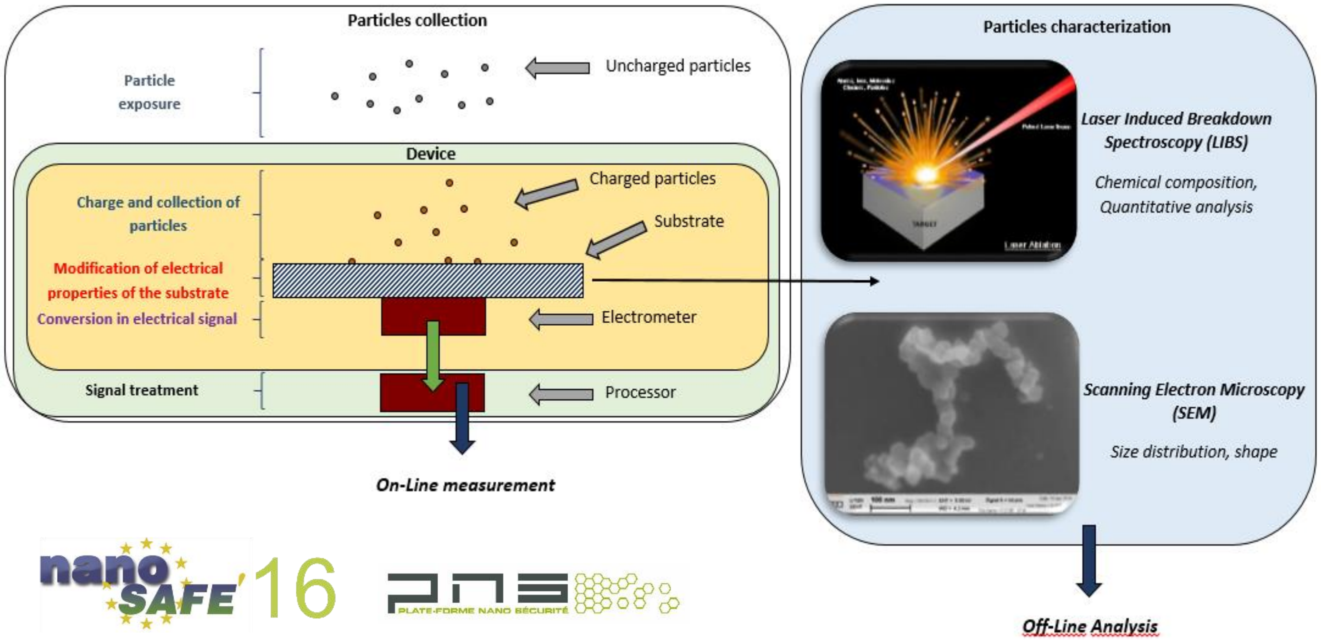
- Developing a global solution to evaluate the personal exposure to particles
- Validate a collection device based on electrostatic precipitation principle, coupled with on-line and off-line particles analysis
  - User friendly
  - Sampler (off-line analysis)
  - Monitor (on-line analysis)
  - In a broad range of size particles

Electrostatic precipitator developed

- Wide scope
  - Environmental, Health and Safety issues
  - Worker protection
  - Inhalation toxicology

Principle

- Five stages
  - Airborne particles capture
  - Particles charge by two mechanisms (field and diffusion charging)
  - Particles collection on a metallic substrate by **size-dependent zone**
  - On line measurement of concentration
  - Off line analysis of chemical composition, spatially resolved by Laser Induced Breakdown Spectroscopy (LIBS)

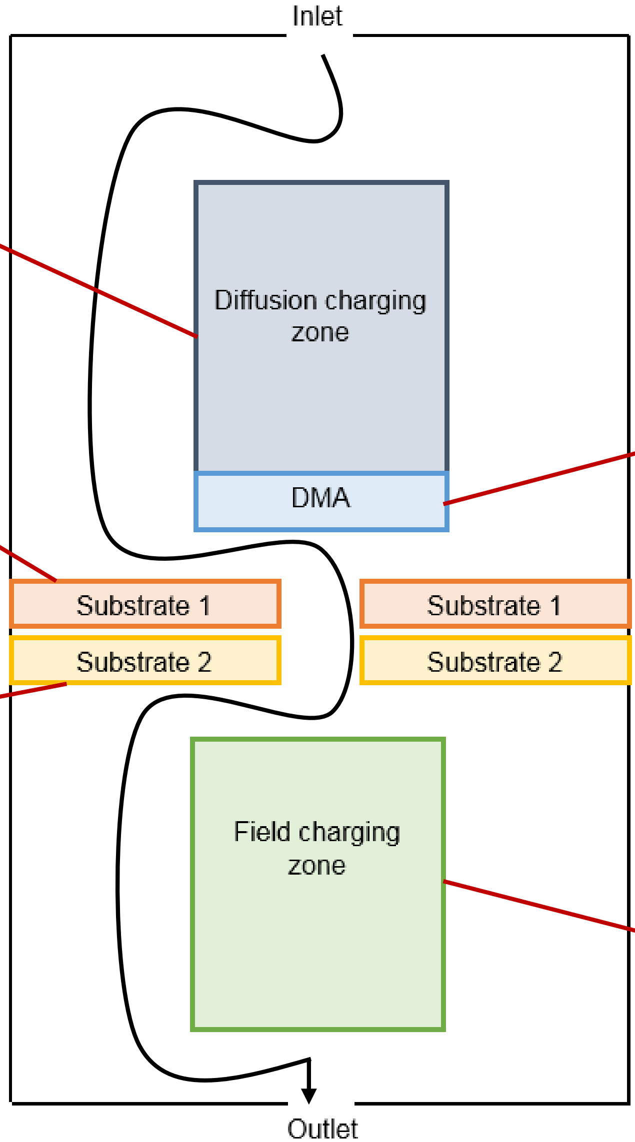


COLLECTOR INFORMATION

To preferentially charge particles between 10 and 100 nm

For nanoparticles (<100nm)

For submicro and microparticles (>100nm)



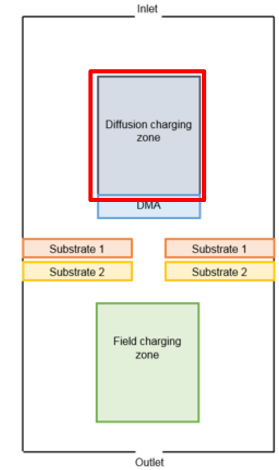
Sort of particles by their electric mobility

< 100 nm on the first substrate

> 100 nm transported on the field charging zone

To charge larger particles

RESULTS



Diffusion charging zone

- Determination of the number of charges acquired by particle
  - Corona wire + 4000 V
  - Grid + 50 V

- Experimental set up

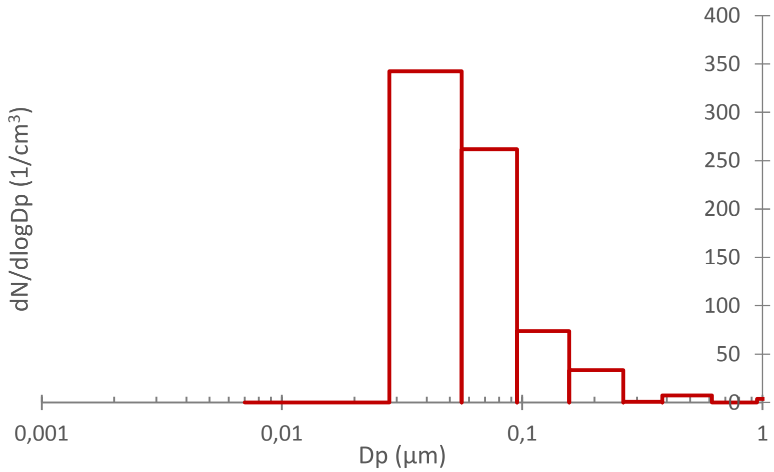
NPs Suspension — Atomizer — DMA *(SMPS TSI 3080)* — Neutralizer *(^{85}Kr)* — Diffusion charging zone — ELPI *(Dekati)*

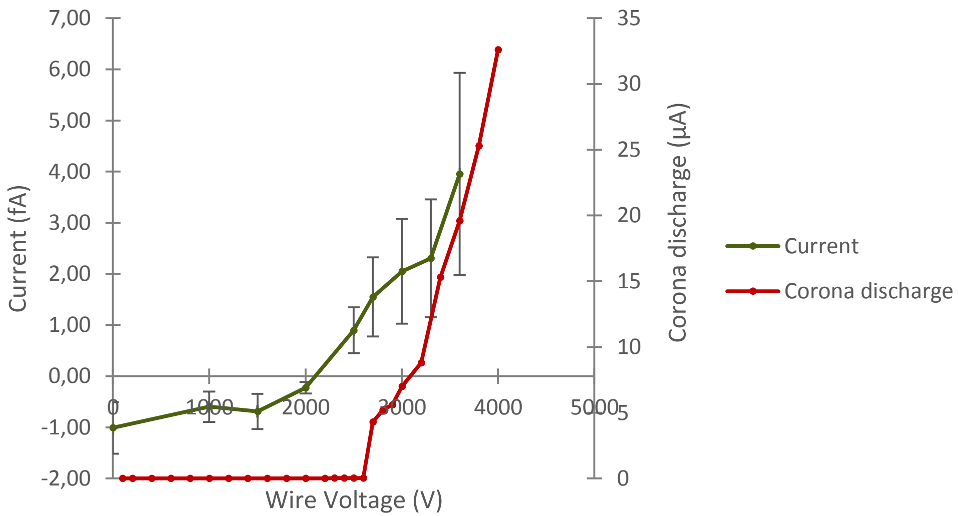
- Two ELPI configurations
  - Charger ON / Trap ON / Device OFF → Determination particle number
  - Charger OFF / Trap OFF / Device ON → Measurement of current

- Two samples
  - Nano SiO_2 50 nm
  - PSL 100 nm

Diffusion charging zone

Nano SiO_2 50 nm





ELPI stages 1 & 2 (40-70 nm)

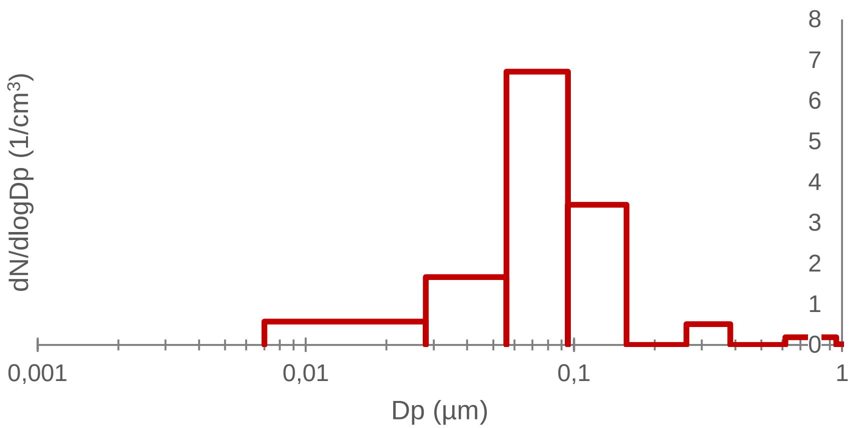
- Charger ON / Trap ON / Device OFF
  - N = 49.3 ± 4.8 p/cm³
- Charger OFF / Trap OFF / Device ON
  - I = 2.74 ± 0.8 fA

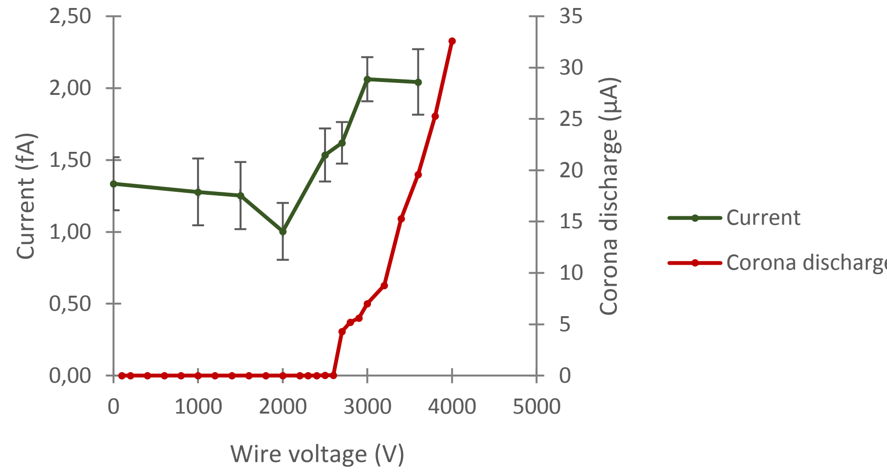
$N_{charge} = I / (N.e.Q)$

$\mathbf{N_{charge} = 2.1}$

Diffusion charging zone

PSL 100 nm



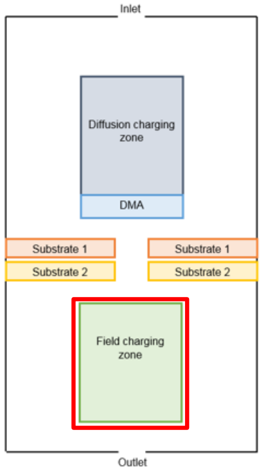


ELPI stages 2 & 3 (70-120 nm)

- Charger ON / Trap ON / Device OFF
  - N = 18.1 ± 2.0 p/cm^3
- Charger OFF / Trap OFF / Device ON
  - I = 1.4 ± 0.2 fA

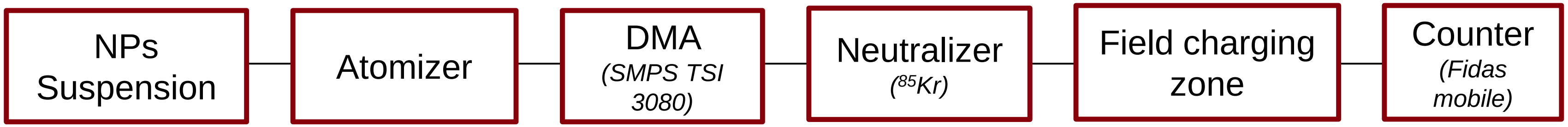
N_{charge} = I / (N.e.Q)

$\mathbf{N_{charge}}$ **= 2.9**



Field charging zone

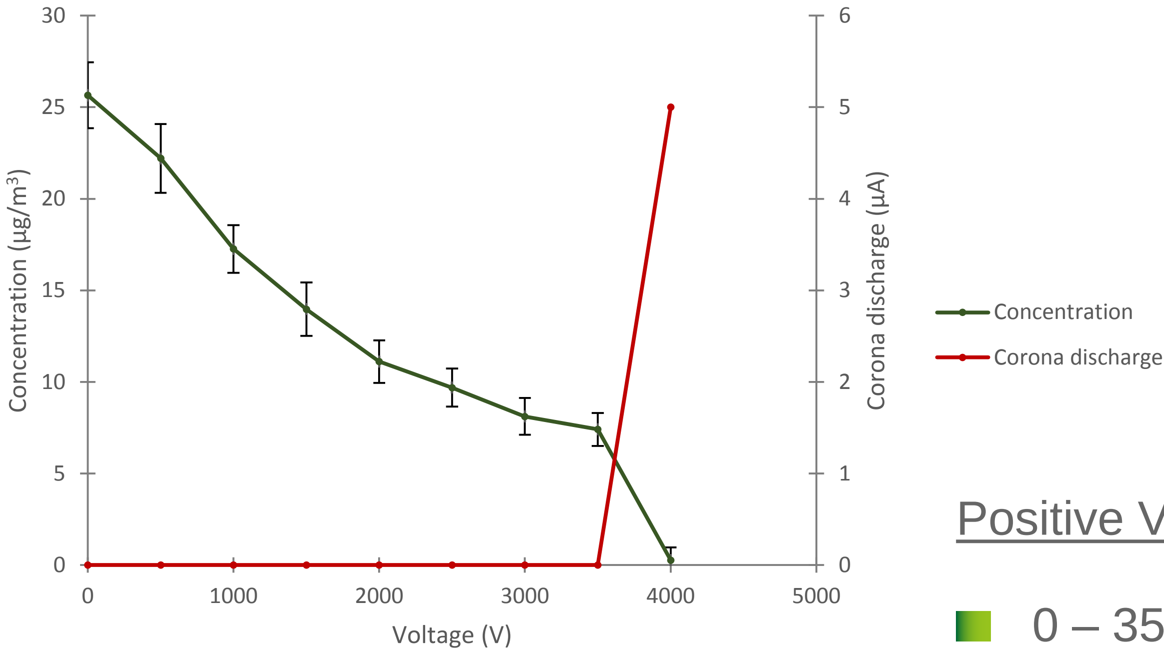
- Evaluation of particles collection
  - Corona needle 4000 V
- Experimental set up



- Device configurations
  - Positive voltage
  - Different flowrates
- Three samples
  - PSL 190 nm
  - PSL 490 nm
  - PSL 900 nm

RESULTS

Field charging zone



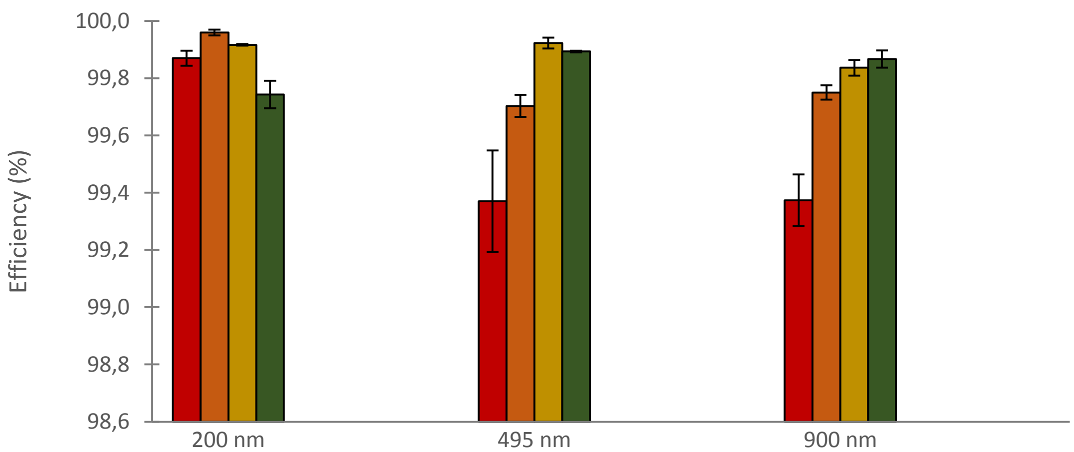
Positive Voltage – PSL 900 nm

- 0 – 3500 V
  - Collection of di, tricharged particles
- 3500 – 4000 V
  - Collection of initially neutral or monocharged particles
- Final concentration : 0 µg/m3 (100%)

RESULTS

Field charging zone

- Evaluation of particles collection
  - Positive voltage
  - Three sizes (200, 495, 900 nm)
  - Four flowrates (0.25, 0.5, 1, 2.5 L/min)



	200 nm	495 nm	900 nm
0.25 L/min	99,9	99,4	99,4
0.5 L/min	100,0	99,7	99,8
1 L/min	99,9	99,9	99,8
2.5 L/min	99,7	99,9	99,9

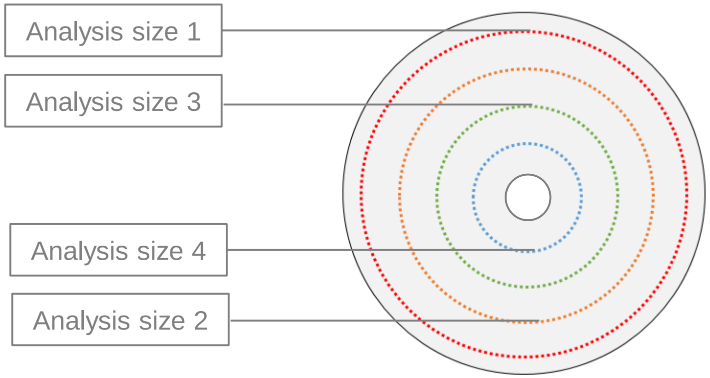
- Very good results of collection efficiency
- But collection on substrate? Loss to walls?
- Optimization of field charging zone by numerical calculation (COMSOL Multiphysics™)
  - To improve ratio :

$$\frac{\text{Particles on substrate}}{\text{Particles collected}}$$

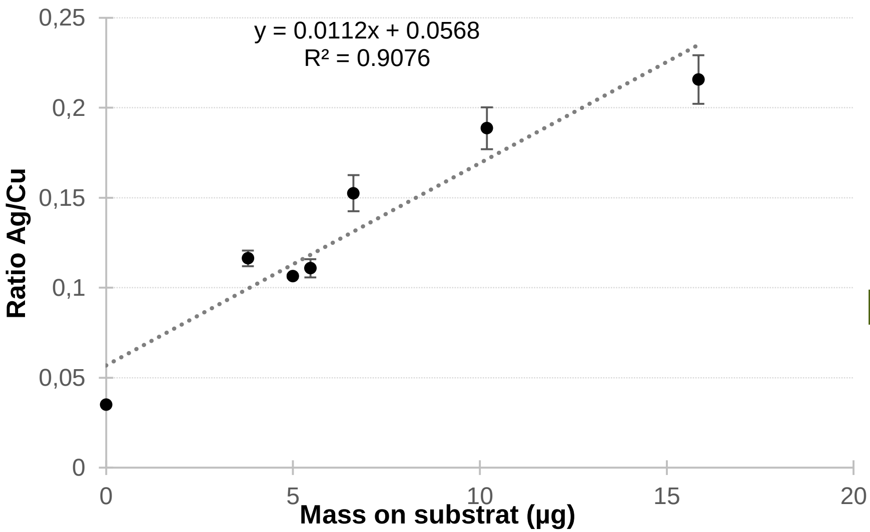
RESULTS

Collection zone – A posteriori analysis

- Substrate analysis by LIBS (Laser Induced Breakdown Spectroscopy)
  - Analysis spatially resolved
  - Rapid analysis
  - Analysis for each size zone
  - Possibility to map the substrate



Envisaged shot matrix



Estimation of airborne concentration :
During a **8h** sample at **1L/min**, it is possible **to detect** an particle aerosol of **0.6 µg/m³** and **to quantify** an aerosol of **1.9 µg/m³**

CONCLUSIONS

Conclusions

Diffusion charging zone
- Characterization of the aerosol electric state

Collection zone
- Possible particle sorting knowing the aerosol electric state – DMA principle

Field Charging zone
- Collection efficiency > 95%
- Optimization of this part by numerical calculation

Off line analysis to aerosol estimation
- Spatially resolved analysis
- LOD & LOQ for Ag in µg/m^3

Promising and encouraging results for future

Perspectives

On line measurement
- Current measurement at the substrate surface (fA range)
- High sensitivity electrometers integration in our device

Calibration base for LIBS analysis
- Best conditions (min SNR)
- Standard calibration

Innovation

- Sampler and monitor
- Coupling on line measurement and chemical analysis
- Discrimination between nanoparticle exposure and submicro, microparticle exposure

Thank you for your attention !

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