Towards Accurate Modelling of Aeraulic Droplets Interactions within COMSOL Multiphysics®

Comsol European Conference:
Munich, 25-27 October 2023

F. Viry[1], M. Sturma[2], P. Namy[1], B. Barbet[2]
[1]: SIMTEC, 5 rue Felix Poulat 38000 Grenoble France
[2] : MARKEM-Imaje, Bourg-lès-Valence, France

Outline

I. Background – Motivations – Objectives

II. Modelling and Numerical Model

III. Main Results

IV. Conclusions – Perspectives

Before starting, who we are… www.simtecsolution.fr

SIMTEC : Fundamentals

- French Numerical modelling consultancy
- Leader in France of the COMSOL Certified Consultants, key partner worldwide
- 7 members Eng.D. + Ph.D.
- Main partners:
  - big international companies
  - laboratories
- Involved in the Research projects like EU FP (SHARK, SisAl)/ PhD supervision

COMSOL Certified Consultant

markem·imaje, framatome, orano, TDA THALES GROUP, NAVAL GROUP, cea, Continental, MAN, Radiall, GROUPE ADP, ALSTOM, faurecia, AIRBUS, Schlumberger, Nexans, AIR LIQUIDE, SOLVAY asking more from chemistry, ADISSEO A Bluestar Company, fives ultimate machines ultimate factory, L'ORÉAL RECHERCHE, novasep for the life sciences, SORIN GROUP, legrand, Schneider Electric, Parrot

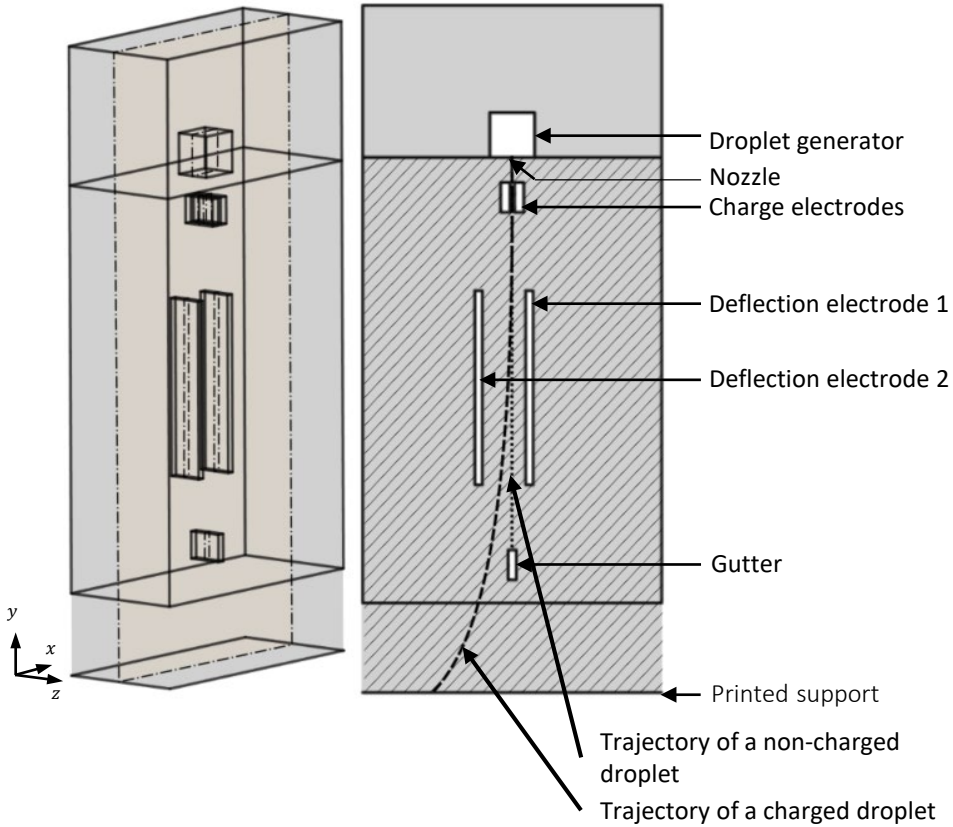
INNOVATION RADAR, European Commission

SHARK INDUSTRIALISING LASER FUNCTIONAL TEXTURING

SisAl Pilot

I. Background – Motivations – Objectives

- Collaboration with MARKEM-IMAJE
- Continuous Inkjet printing (CIJ) : high speed printing for marking and coding
- How does CIJ work?
  - High speed emission of droplets ($\approx 100\ \mathrm{kHz}$ at $\approx 20\ \mathrm{m/s}$)
  - Charge of particular droplets ($\approx 1\ \mathrm{pC}$)
  - Deflection of charged droplets in an electric field ($\approx 1\ \mathrm{kV/mm}$)
  - Impact of charged droplets on the printed support
- Goal : maximizing printing quality
- Printing quality depends on:
  - Breakoff quality at generation
  - Charge control
  - Deflection
  - Interactions during flight



Schematic representation of a print head

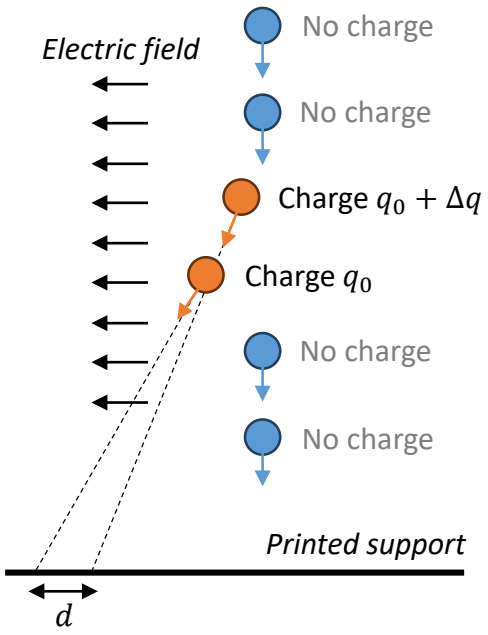
Accurate numerical tool to predict the final position of the droplets

I. Background – Motivations – Objectives

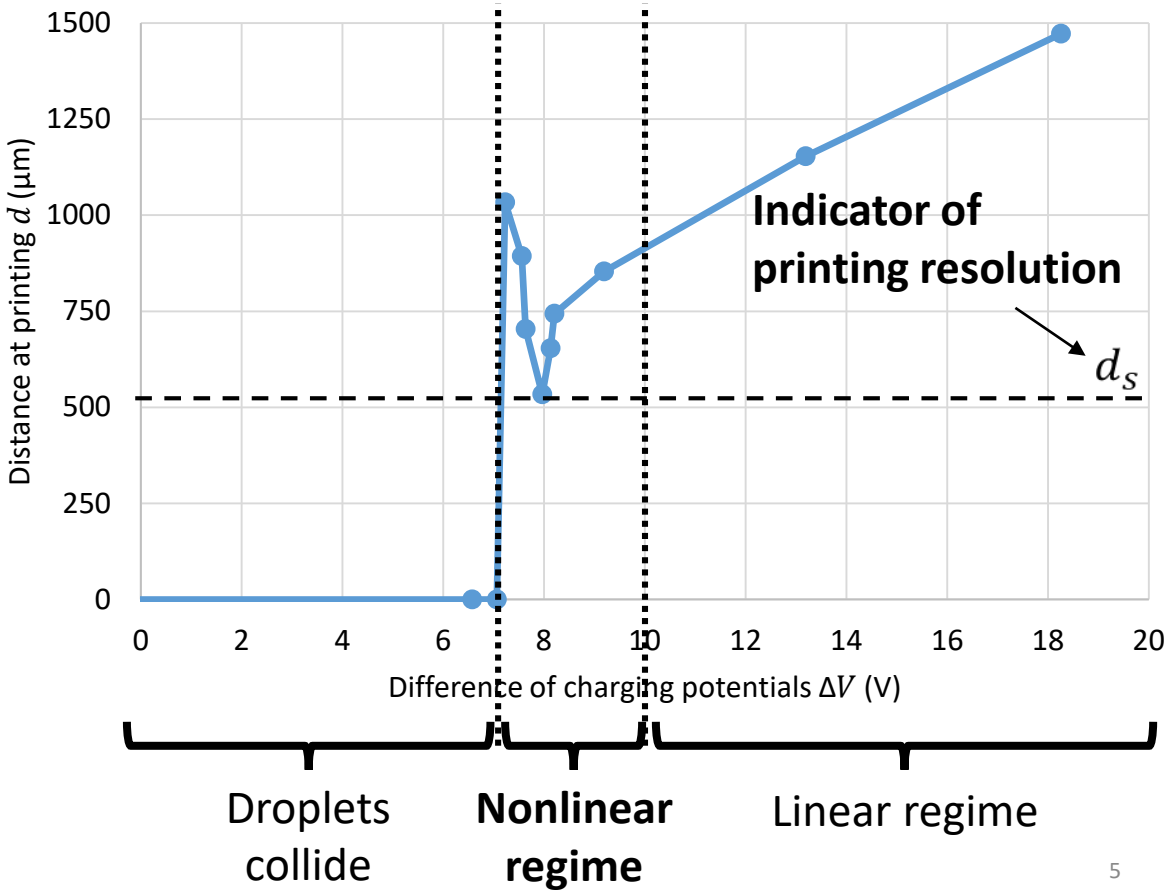
Goal: understanding and predicting this kind of nonlinear behavior

→ Printing two droplets

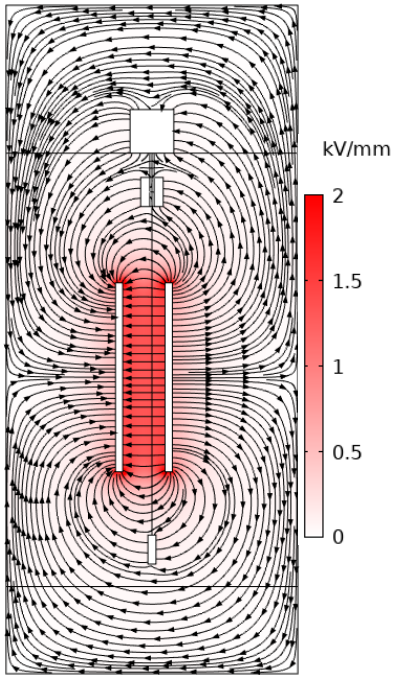
→ With small charge difference



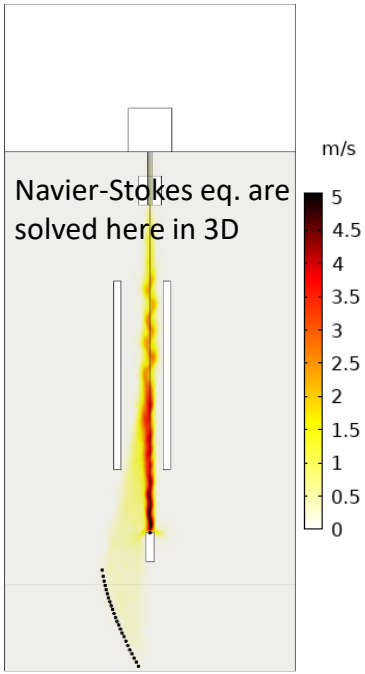
Experimental distance between droplets at printing



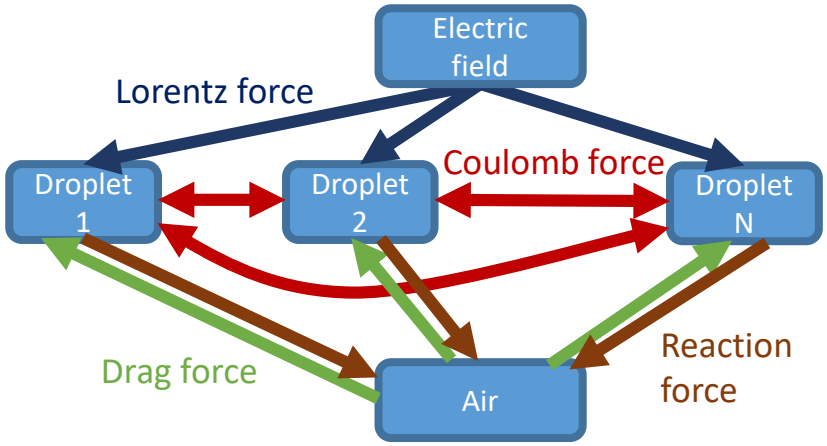
I. Background – Motivations – Objectives



Electric field



Snapshot of the trajectory of the droplets and air flow



→ Hypothesis: aeraulic aspiration *vs.* electrostatic repulsion?
→ Too coarse mesh in CFD to quantify…
→ … Refining the mesh is not feasible!

→ How to fix this?

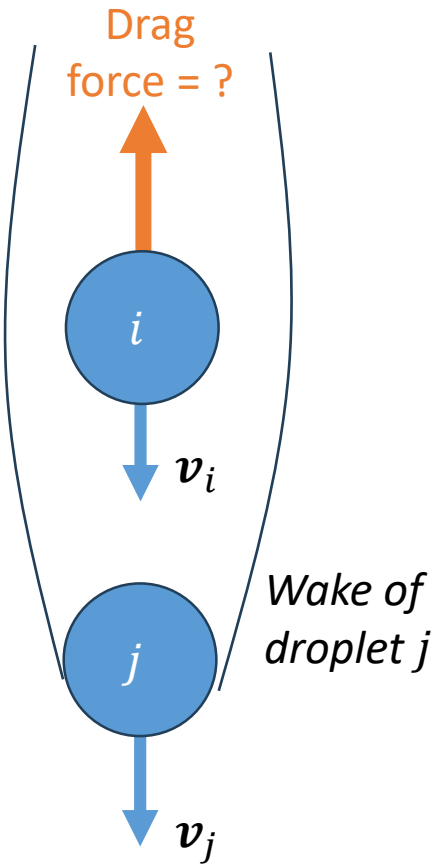
M. Sturma, P. Namy, V. Bruyère and B. Barbet, "Modeling of charged droplet dynamics in an Electric Field using COMSOL Multiphysics®," in COMSOL Conference 2020 Europe, 2020.

F. Viry, M. Sturma, P. Namy and B. Barbet, "Electrostatic and Aerodynamic Modelling of the Charged Droplet Trajectories thanks to a Lagrangian-Eulerian Model in COMSOL Multiphysics®," in 19th International Multidisciplinary Modeling & Simulation Multiconference, Rome, 2022.

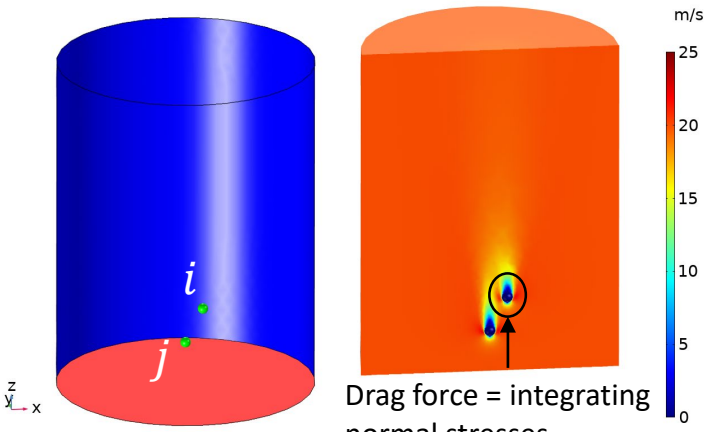
II. Modelling and Numerical Model

Drag force experienced by a droplet in the wake of another one

→ It is sufficient to know the air flow around droplet j?

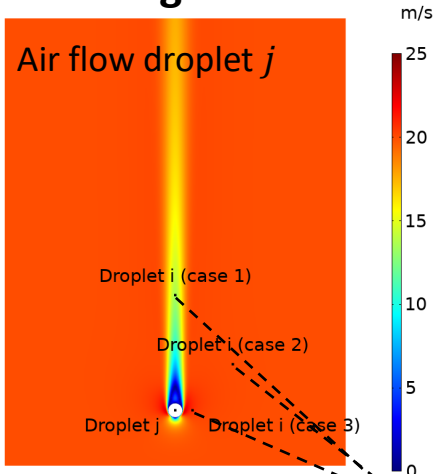


Reference drag force



Drag force = integrating normal stresses

New drag model



Drag force = Schiller-Naumann$(\boldsymbol{u}_j - \boldsymbol{v}_i)$

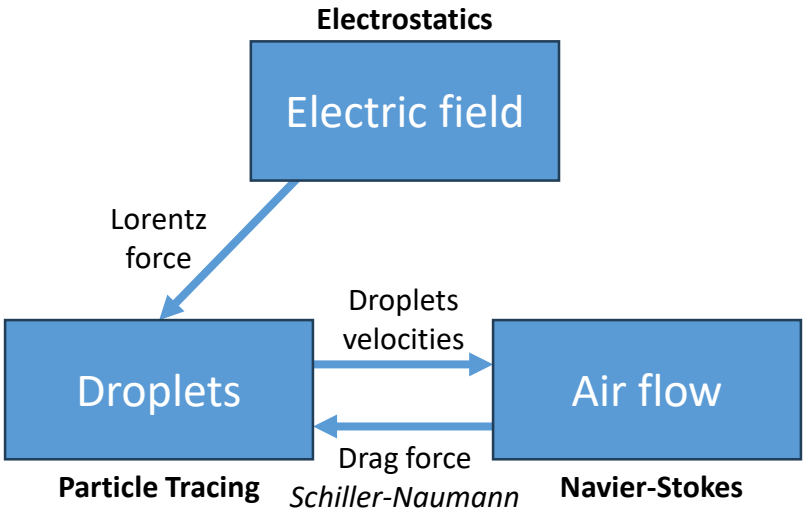
Case		Reference (µN)	Model (µN)
1	Radial	0	0
	Vertical	1.88	1.31
2	Radial	0	0
	Vertical	2.45	2.43
3	Radial	0.31	0.03
	Vertical	2.75	2.57

→ Slight underestimation of the drag force

→ **… Still a good estimation** ✓

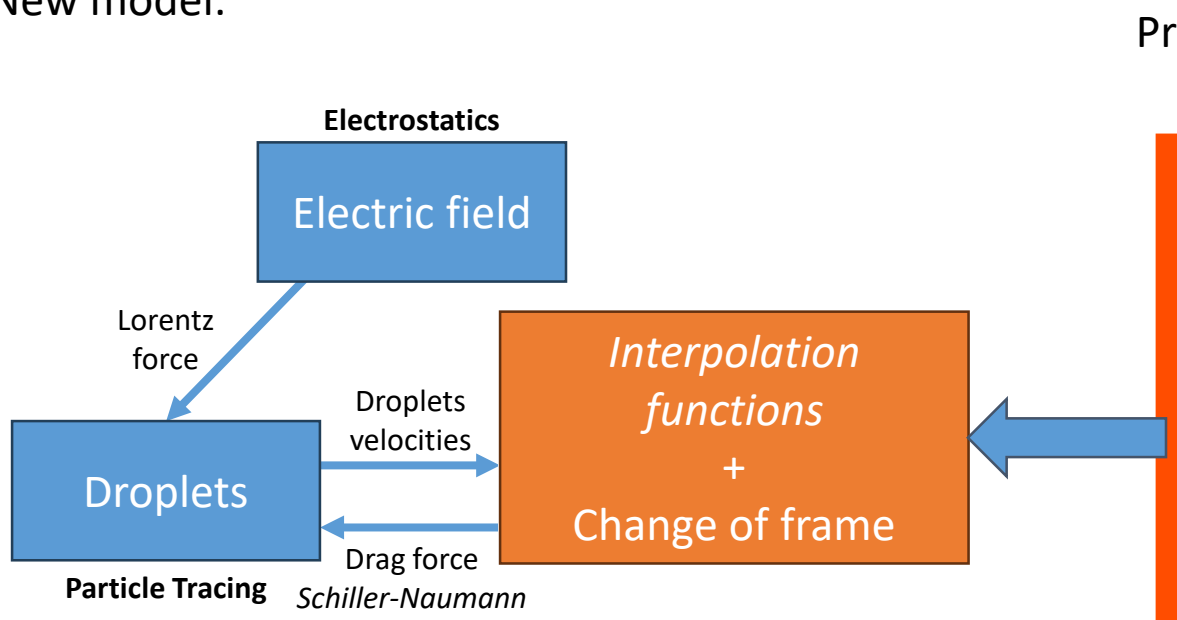
II. Modelling and Numerical Model

Former model:

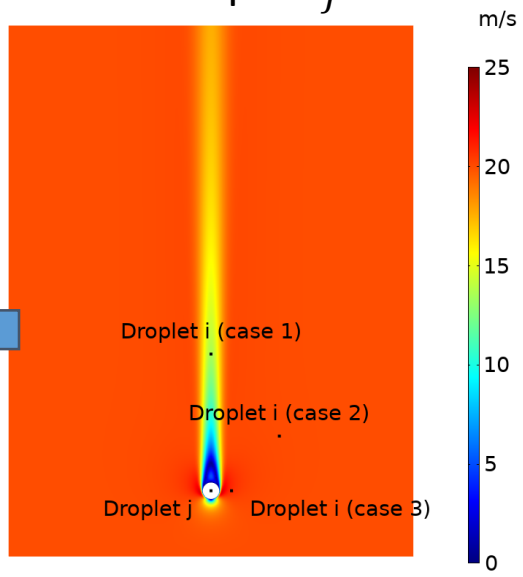


II. Modelling and Numerical Model

New model:



Precomputed air flow for multiple v_j

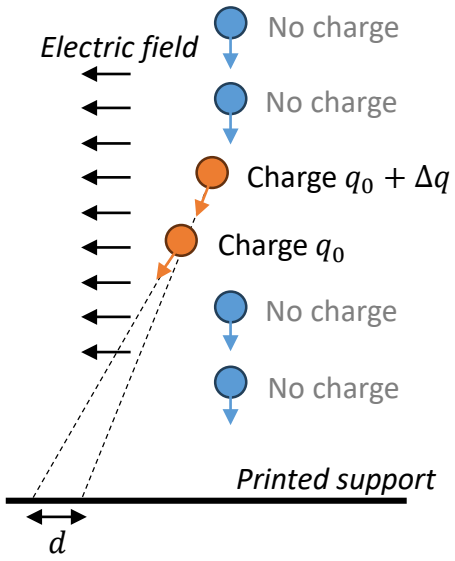


→ **Lower complexity** : precomputation of 2D-axisymetric laminar flows ✓
1 day → a few minutes (excluding precomputations)

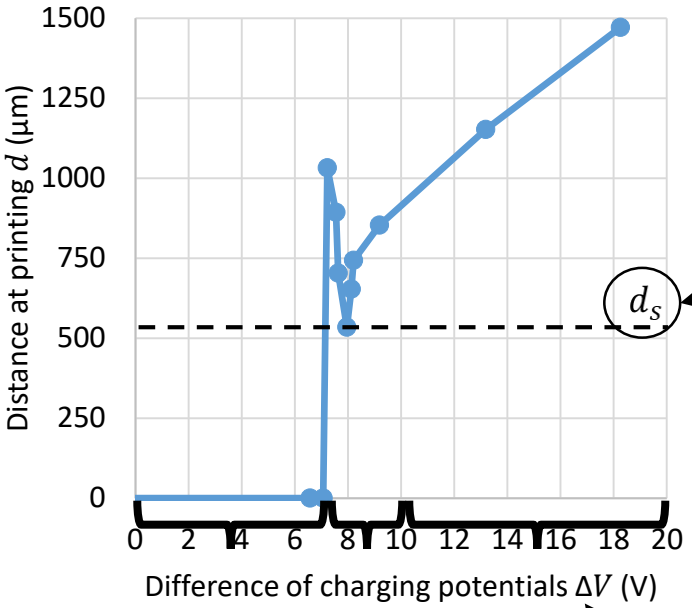
→ **Better accuracy** : 2D-axisymetry makes finer meshes practicable ✓

Main drawback : difficulty to generalize to more than two droplets – **but sufficient here!**

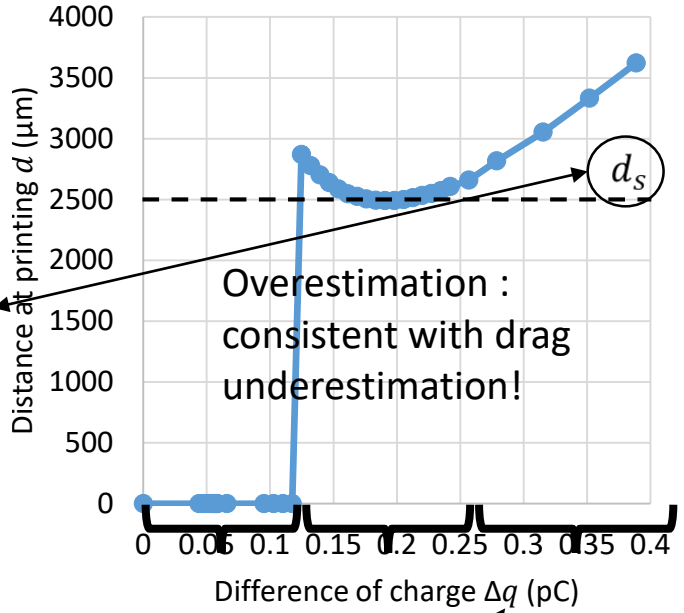
III. Main Results



Experimental results



Numerical results



Linear relationship

Low Δq	Medium Δq	Large Δq
≈ same trajectory ⇒ aeraulic aspiration ⇒ probable collision	low deviation ⇒ aeraulic aspiration vs. ES repulsion ⇒ nonlinear behavior	large deviation ⇒ no interactions ⇒ linear behavior

→ The numerical model reproduces qualitatively the experimental behavior ✓

IV. Conclusions - Perspectives

→ Ability to quantify interactions between droplets is important to ensure printing quality in CIJ

→ Focus on interactions between two droplets: revelator of the printing resolution

→ **Major contribution** : improving the **estimation of aeraulic interactions** thanks to
- ❑ Precomputed velocity fields (wakes) of a flying droplet
- ❑ Schiller-Naumann drag law

→ What about next steps?
- ❑ Model already used to understand levers affecting the printing quality
- ❑ Extending this work to more than two droplets

To finish…

Thank you!

Q&A?

Our question: What about a coffee to discuss your topic? ☺







Frédéric Viry
SIMTEC (+33) (0)9 53 51 45 60
frederic.viry@simtecsolution.fr

COMSOL CONFERENCE 2023 MUNICH