SENS4ICE

SENSORS AND CERTIFIABLE HYBRID ARCHITECTURES FOR SAFER AVIATION IN ICING ENVIRONMENT

Atmospheric Hydrometeor Detector based on Electrostatics

FINAL DISSEMINATION EVENT OF SENS4ICE PROJECT

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Directorate General for Research and Innovation, Brussels, Belgium – 29 November 2023

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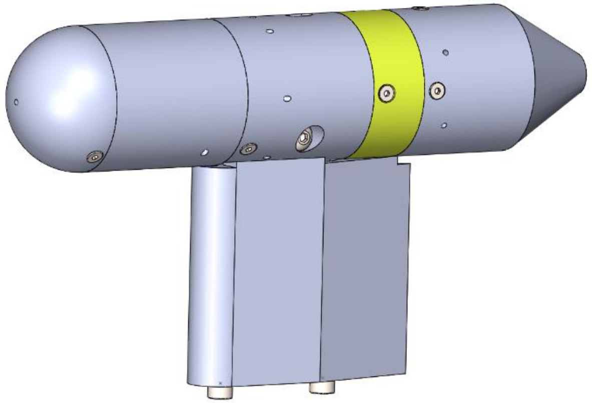
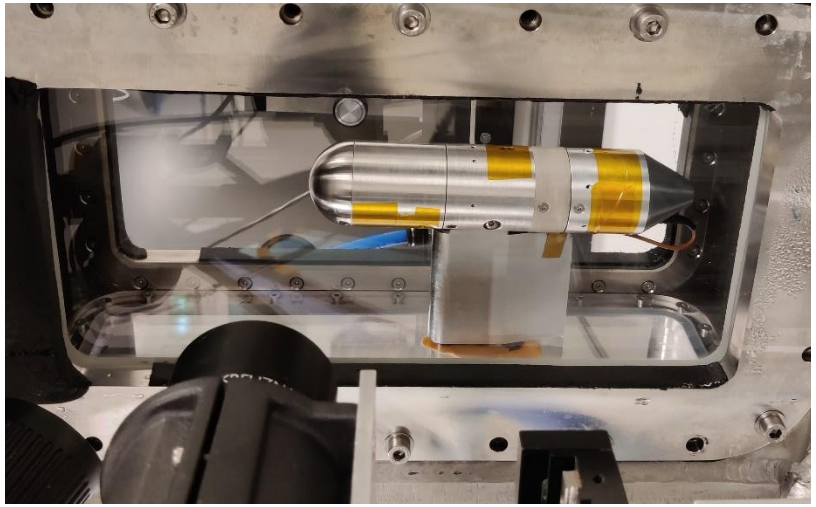
AHDEL -Atmospheric Hydrometeor Detector based on Electrostatics (ONERA)

- detection type: **atmospheric conditions**
- physical principle: electric charging and detection of particles and size distribution estimation
- sensor high-level output description: **LW ICE & App O detection, LWC, MVD, Dmax**
- main sensor specifications: **5x12x20 cm^3 / 0.9 kg / 180 W**
- TRL at project start: **1**
  TRL now: **4 (for LW, App C and App O detection and for discriminating C and O)**
- testing: IWT testing in TU Braunschweig facility





Outline

- Context and objectives
- Physical principle
- Lab tests
- IWT tests
- Conclusion and perspectives

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Context and Objectives

- EU H2020 SENS4ICE Project (DLR coordination)
  - New technologies for severe in-flight icing detection: 17 partners, different and innovating approaches and technologies
  - Objectives: Increase the **flight safety** in icing conditions, especially for the SLD conditions
  - For direct icing detector, sensors with different physical principles
    - Thermal (heat transfer/temperature)
    - Optical (laser/imaging)
    - Mechanical (wave propagation)
    - Electrical

→ **ONERA approach: AHDEL (Atmospheric Hydrometeor Detector based on Electrostatics)**

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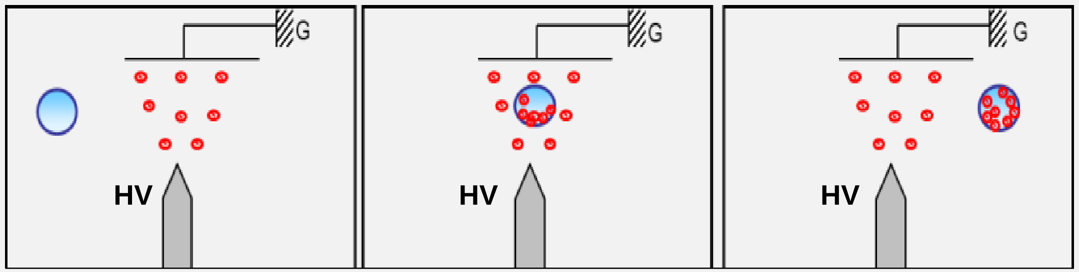
AHDEL physical principle : two main subsystems

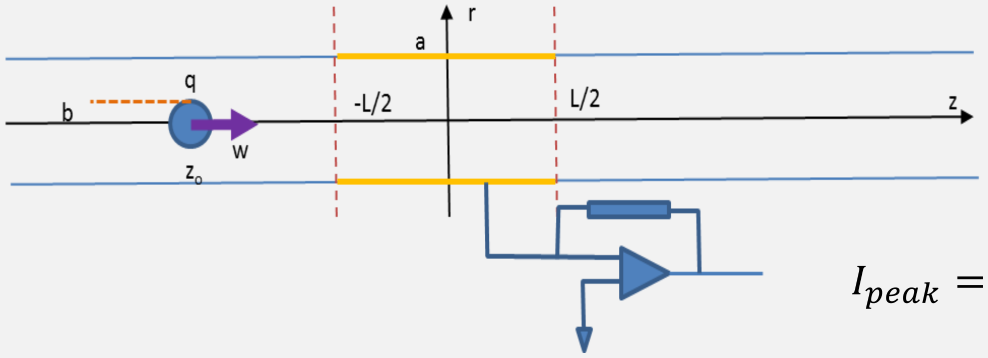
Charging subsystem



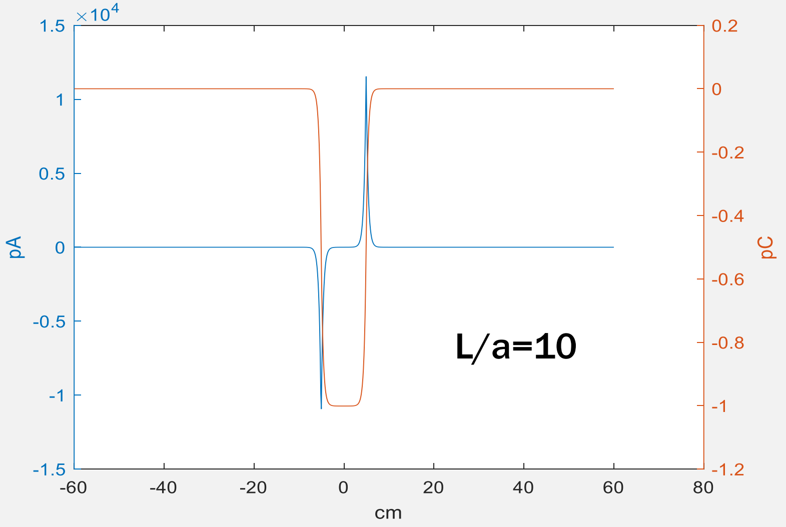
Saturation charge from electric field effect

$$\begin{cases} n_c = \frac{1}{e}\left(\frac{3\pi\varepsilon_0\varepsilon_r}{\varepsilon_r + 2}\right).E_r.d^2 \\ \tau = \frac{\varepsilon_o}{e\mu_i N_i} \end{cases}$$

Detection subsystem



$$I_{peak} = f(a, L).w.q$$



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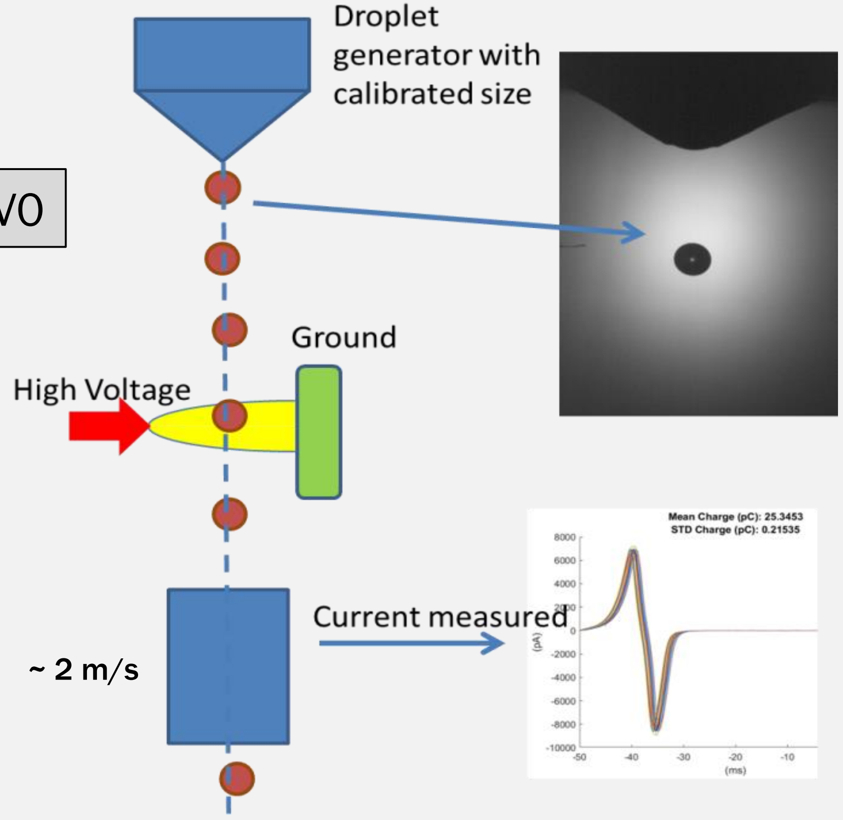
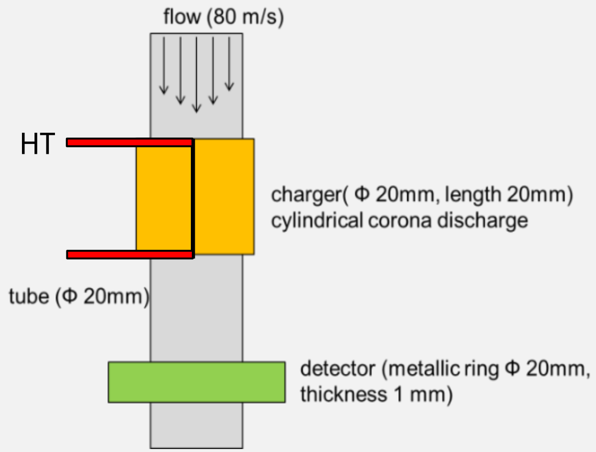
Lab tests: principle demonstration

Charging and detection

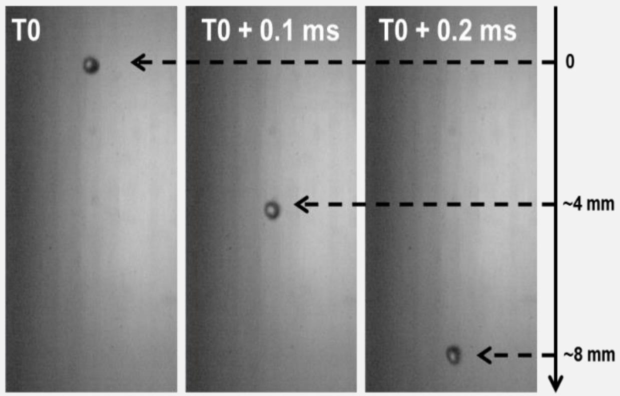


Size and electric charge dependency

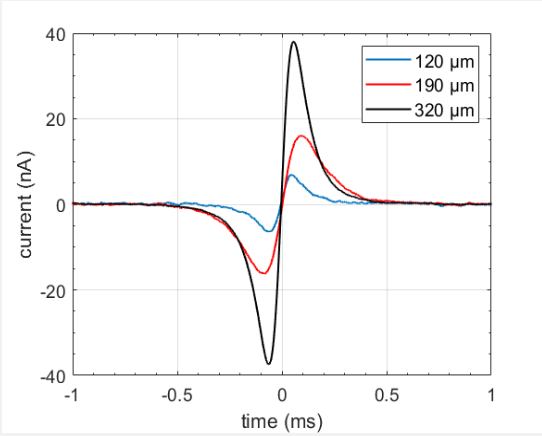
AHDEL V1



Droplet size and charge measurements



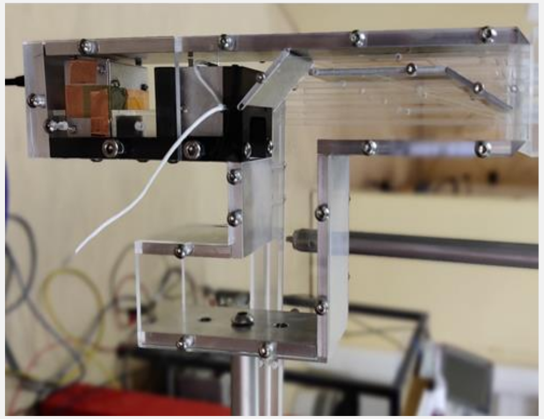
320μm ~ 40 m/s



Lab tests: preparation of IWT versions

Inertial and Electrostatic discrimination versions

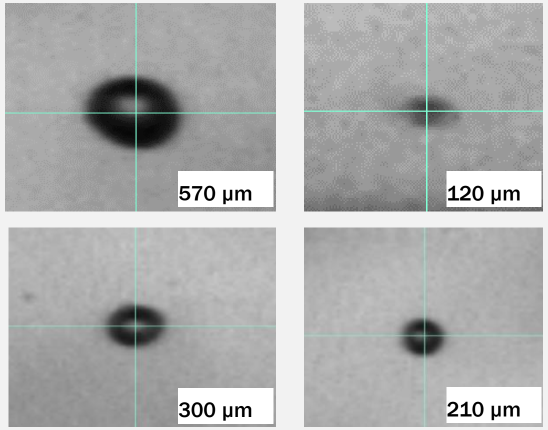
AHDEL V2



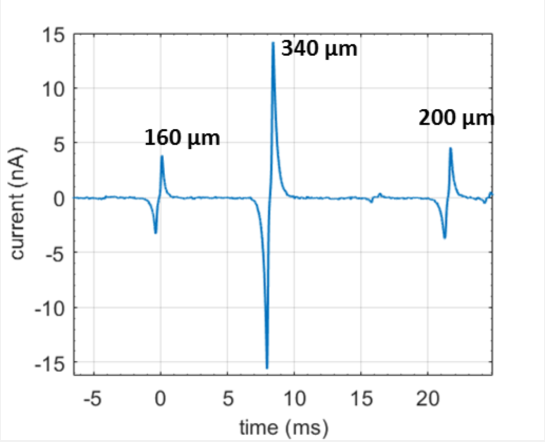
AHDEL V3

Droplet charge versus size evaluation

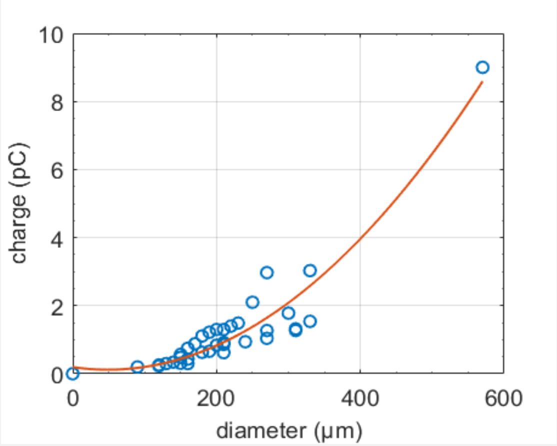
Droplet visualization (20 µm/pixel)



Sensor measurements



Q versus D function



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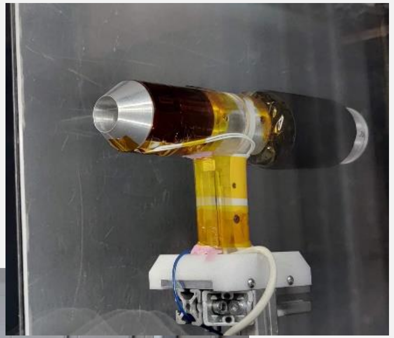
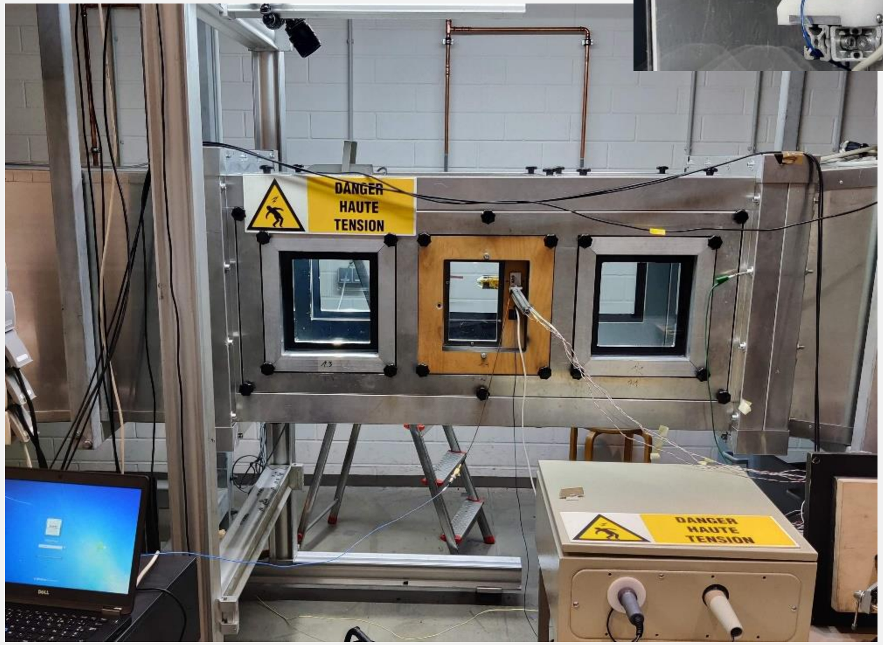
IWT tests: TU Braunschweig IWT facility

- Inertial (V2) and electrostatic (V3) discriminator principles tested
- 8 points of the SENS4ICE test matrix performed

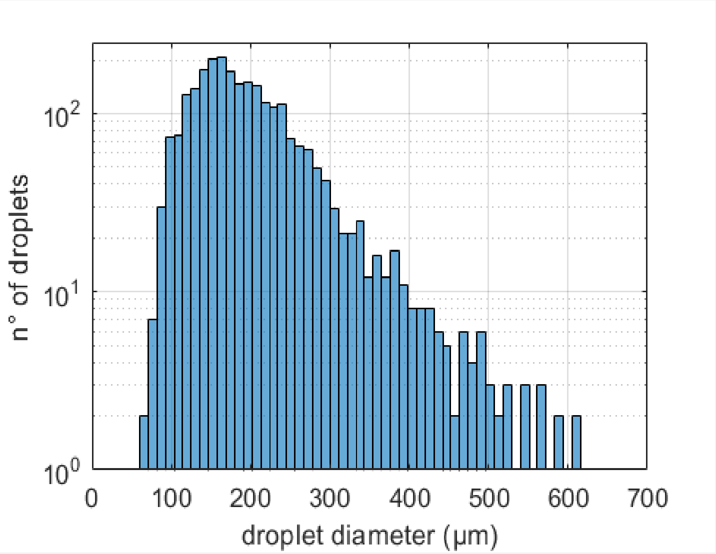




- Unforeseen technical problems observed at high concentration (>0.6 g/m3):
  - Charging system → water accumulation in unexpected zones
  - Ice accretion in internal parts
- 20 additional points tested: varying LWC, MVD, T and Flow speed
- Response time (spray ON & spray OFF) → 0.3 to 3s for both models

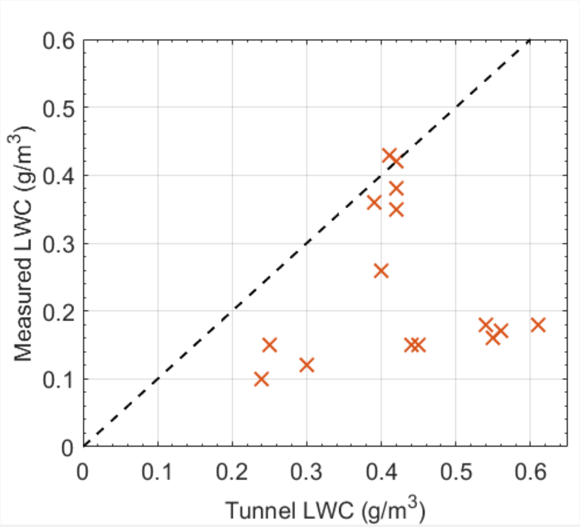
IWT tests: TU Braunschweig IWT facility

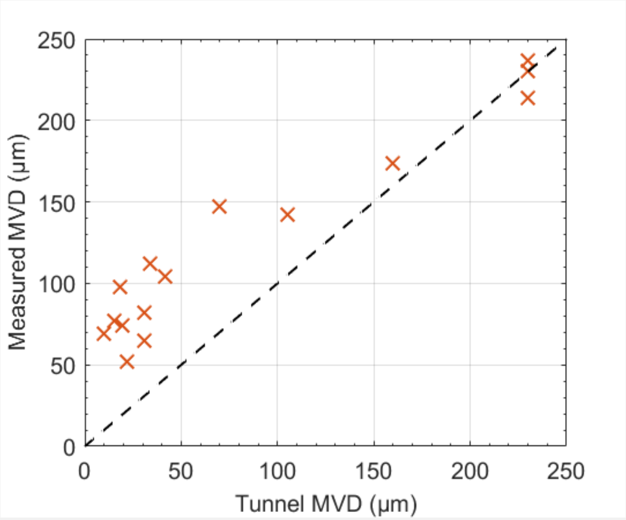
- First measurement of droplet distribution



- **30s acquisition**
- **Detector volume 0.08 cm^3**
- **Flow speed 40 m/s**
- **Air temperature -10 °C**
- **MVD 230 µm**
- **LWC 0.42 g/m^3**

- Results and analysis : MVD and LWC computed from distributions
- LWC underestimated and MVD overestimated → filtering @ 40µm
- **Good accuracy** for high MVD conditions → within 20% error

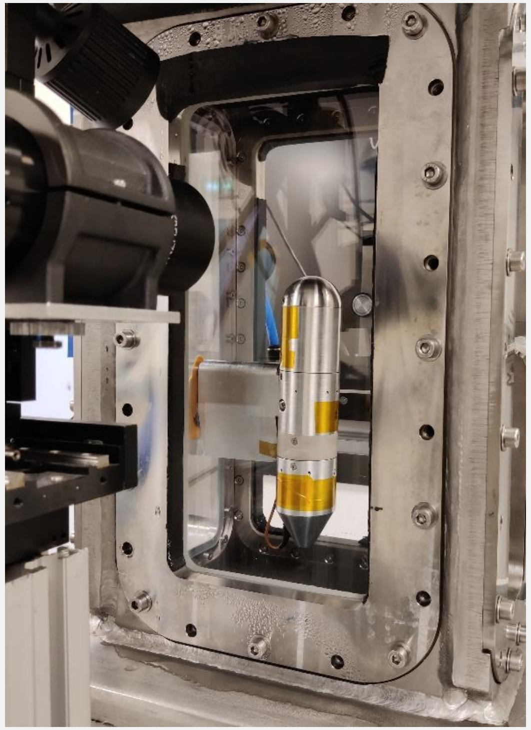




- IWT test outcome: **great achievement** in SENS4ICE and important understanding and ideas for next AHDEL versions
- AHDEL **withdrawn** from SENS4ICE **flight testing** (available time and resources)

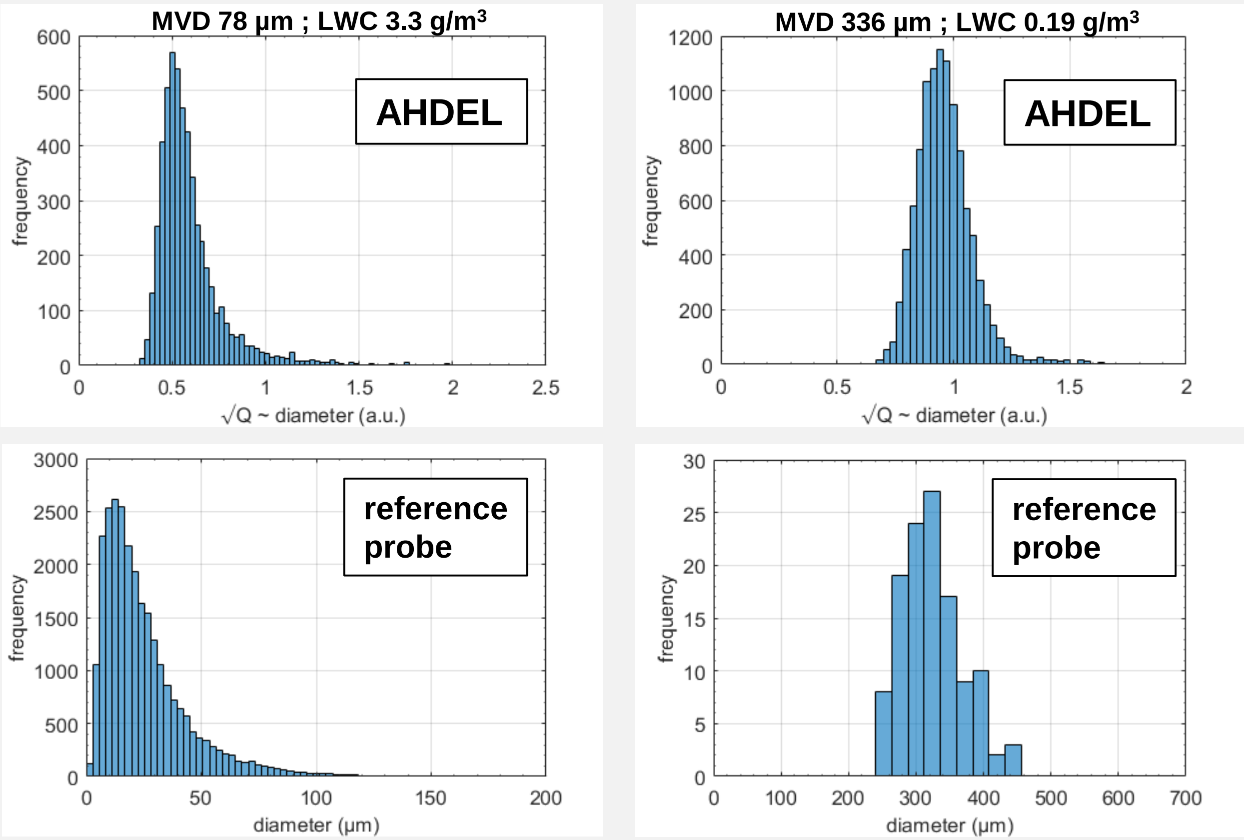
IWT tests: ONERA Research vertical IWT facility

Test of a new improved AHDEL version



- Tested on velocities from 50 to 150 m/s, MVD up to 570 µm, LWC up to 5 g/m^3
- 60 test points with successful operation
- High-Voltage and anti-icing system very robust (significant improvement compared to previous version)
- Droplet size distribution estimation

Droplet distribution computation and comparison with reference probe



- Successful IWT tests with new sensor version
- The sensor development will continue with more IWT tests scheduled for 2024

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Conclusion

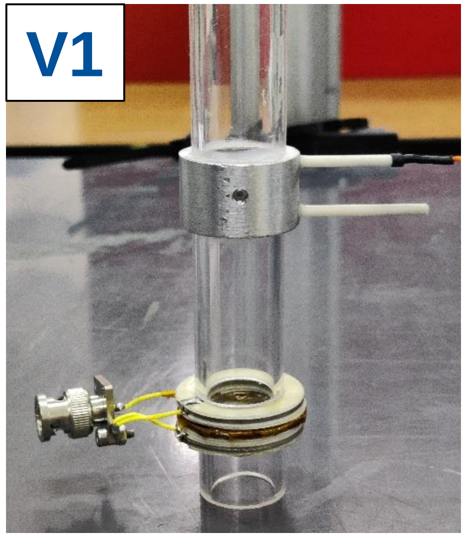
- Innovative principle of icing detection → electrical based
- Start from a very low TRL
- Development of prototypes validated in lab and tested in IWT facilities
- Very interesting results obtained in IWT tests
- Great achievement for the sensor technology in the scope of SENS4ICE project

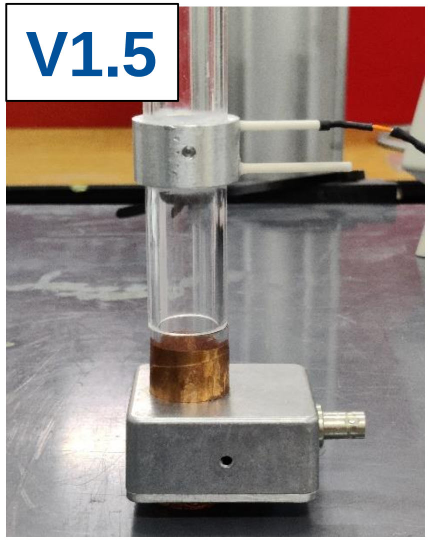
Perspectives and research gaps

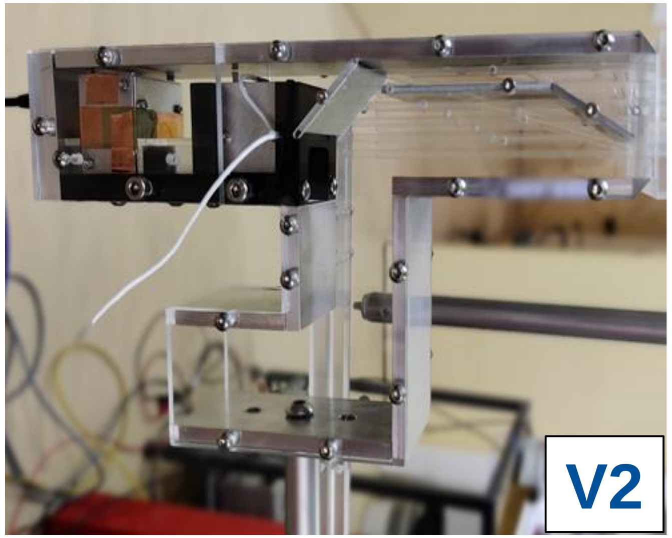
- Need to increase endurance of charging system (High-voltage design)
- Enhancement of de-icing / anti-icing systems for power consumption reduction
- Modelling and 3D simulation of the sensor internal parts → understanding & optimization
- New wind tunnel tests planned in 2024
- Flight tests for in-situ atmospheric electricity characterization expected from 2025 (IFAR research project)

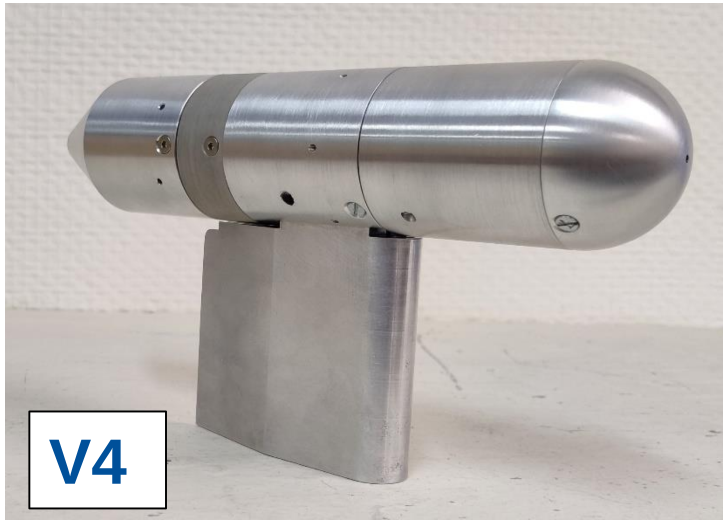
Thank you for your attention!

Progression of AHDEL versions









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If not acknowledged, images courtesy of the consortium partners.

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