



HAL
open science

Influence of water vapour on the propagation speed and mean energy of an atmospheric non-equilibrium diffuse discharge in air under very high electric fields

Alexandra Brisset, Pierre Tardiveau, Kristaq Gazeli, B. Bournonville, P. Jeanney, K. Ouaras, L. Magne, Stéphane Pasquiers

► To cite this version:

Alexandra Brisset, Pierre Tardiveau, Kristaq Gazeli, B. Bournonville, P. Jeanney, et al.. Influence of water vapour on the propagation speed and mean energy of an atmospheric non-equilibrium diffuse discharge in air under very high electric fields. 23rd International Symposium on Plasma Chemistry, Jul 2017, Montréal, Canada. hal-04917314

HAL Id: hal-04917314

<https://hal.science/hal-04917314v1>

Submitted on 28 Jan 2025

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Influence of water vapour on the propagation speed and mean energy of an atmospheric non-equilibrium diffuse discharge in air under very high electric fields

A. Brisset¹, P. Tardiveau¹, K. Gazeli¹, B. Bournonville¹, P. Jeanney¹, K. Ouaras¹, L. Magne¹, S. Pasquiers¹



¹ LPGP, CNRS, University Paris-Saclay, 91405 Orsay, France

Summary: We report results on the influence of relative humidity (RH) on the propagation, temperature and the energy of a pin-to-plane nanosecond pulse discharge at atmospheric pressure. Water vapour only impacts discharges after a given relative humidity threshold, for which propagation is first **slowed down**, but accelerates faster than usual close to the plane. Energy is unchanged.

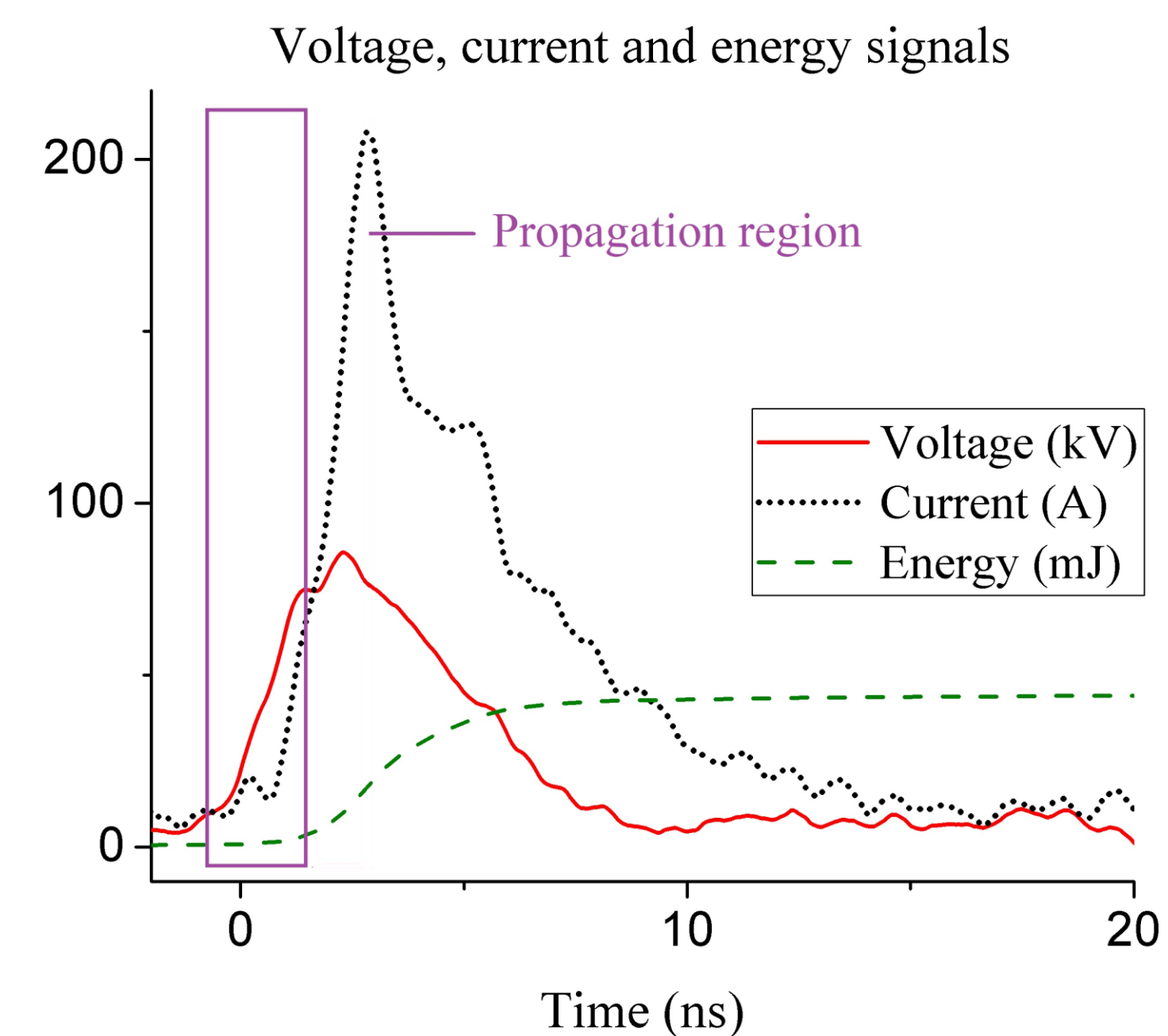
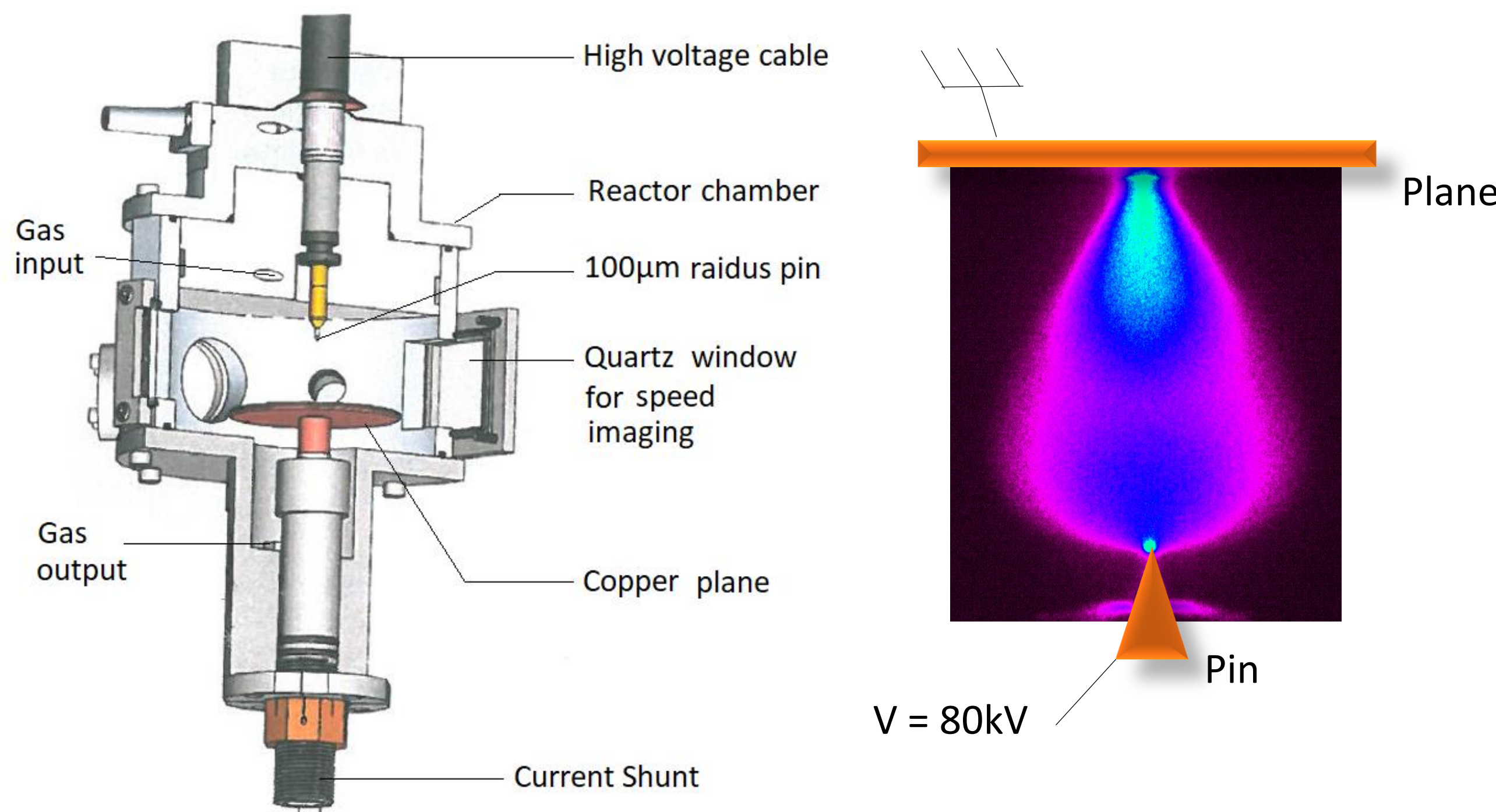
Introduction: This work comes within a research on the fundamental mechanisms of diffuse electric discharges under very high electric fields and the associated non-

equilibrium plasmas in atmospheric air. Such discharges are created at very high over-voltages, several tens of kilovolts, with **sub-nanosecond rise times** and without any pre-ionizing system [1].

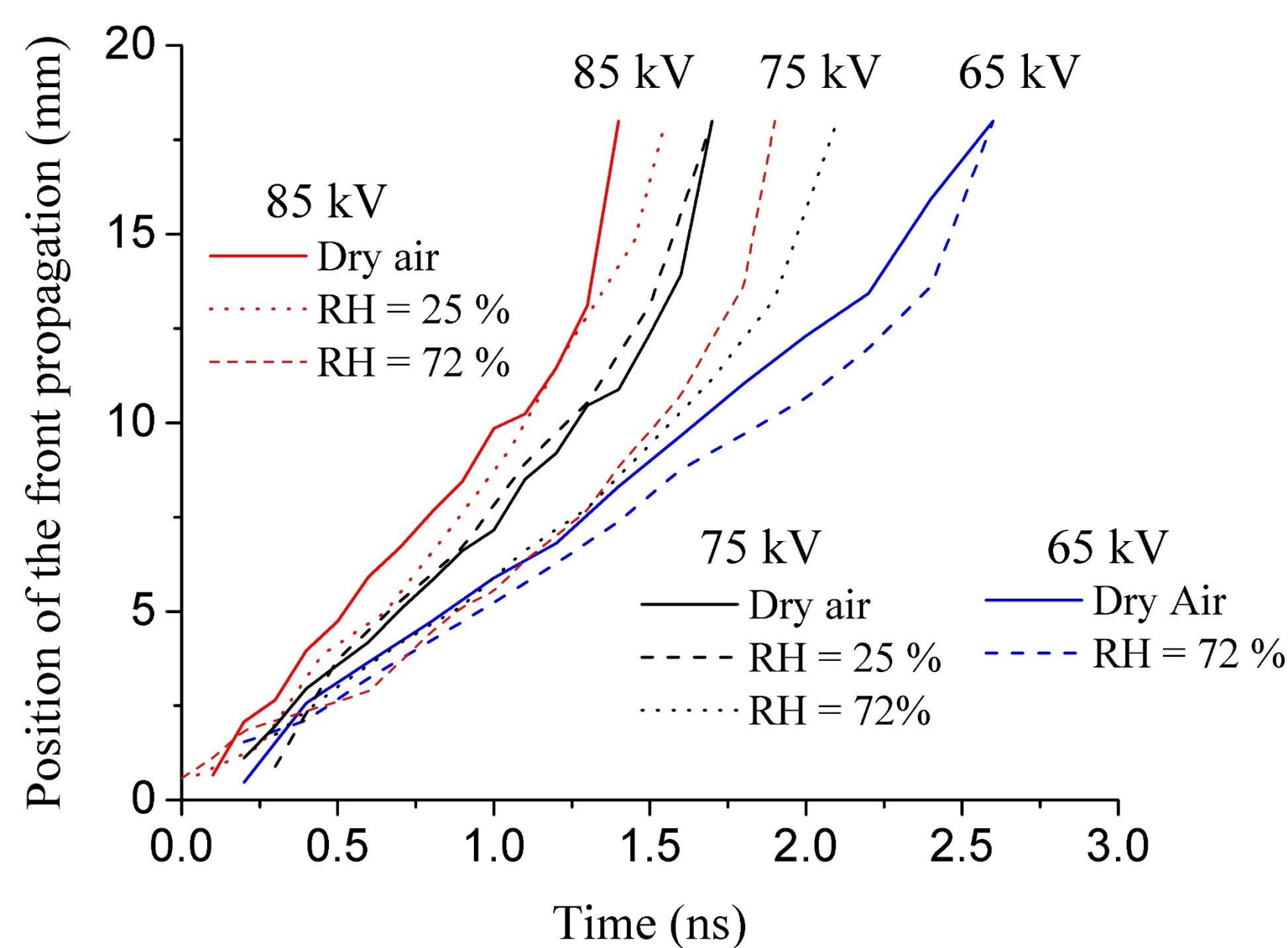
In the context of air treatment research, better understanding of the physical and chemical processes of these discharges helps to develop advanced and high energy efficiency reactors. The **high field** values that make **large volume discharges**, should enable the design of plasma reactors presenting more homogeneous properties than current ones.

Experimental setup:

- Nanosecond air discharge, P = 1atm
- 1L/min flow of synthetic air
- Relative humidity addition up to <2%, 18%, 25%, 34%, 47%, 57% and 72% through a controlled temperature water evaporator coupled to a dilution system
- Pin-to-plane electrodes, 19mm gap
- 100 μm pin radius
- Voltage peaks at 65kV, 75kV and 85kV
- Repetition frequency : 5Hz
- Propagation speed uncertainties range from ±0.1 to ±0.3 mm/ns using linear regression or repeatability measurements methods.

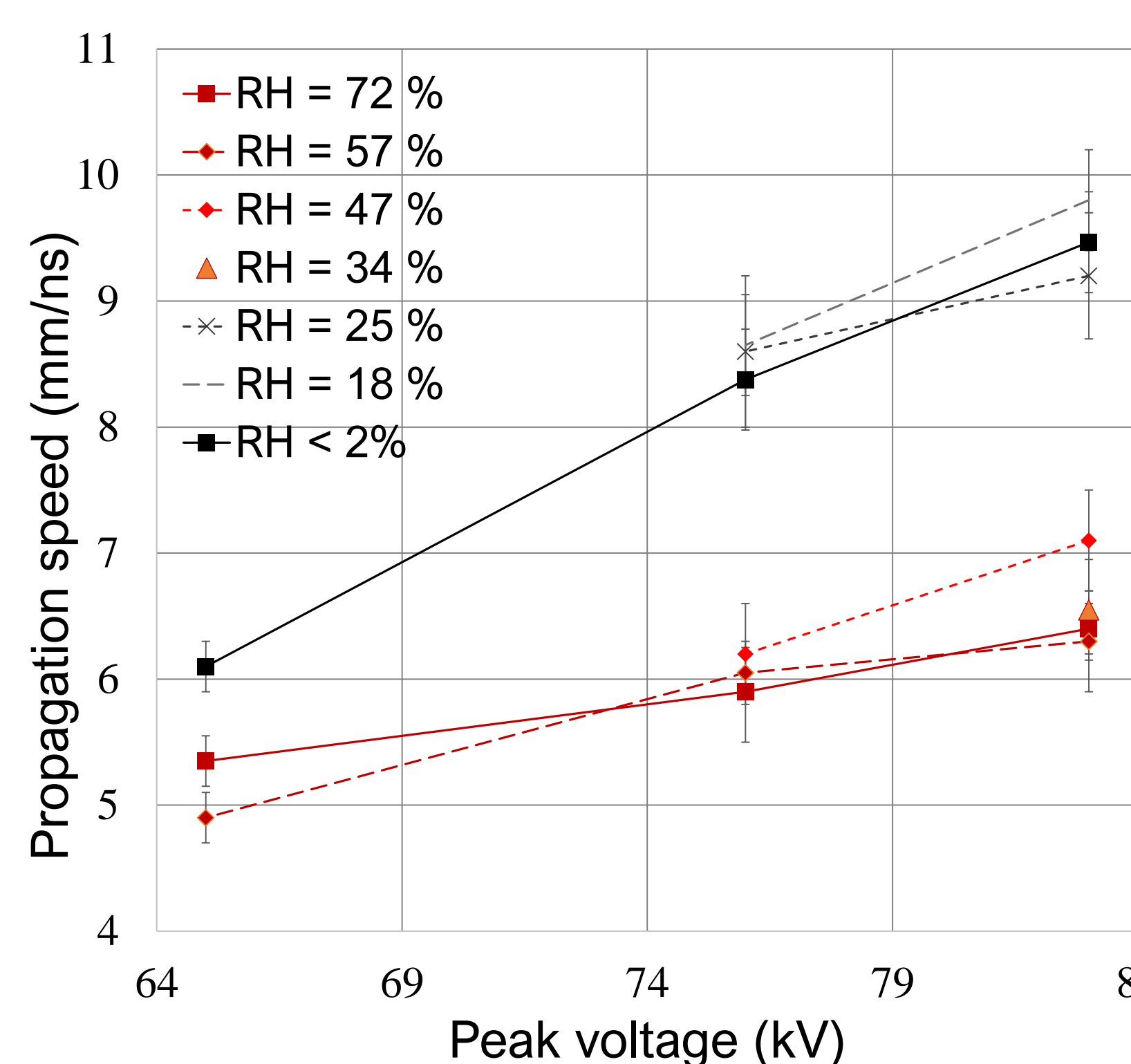


Results on propagation speed:



- * **Faster propagation as voltage increases.**
- * **Linear propagation** until the discharge reaches about 3/4 of the gap.
- * **Acceleration** close to the plane, **Stronger acceleration** in humid air.

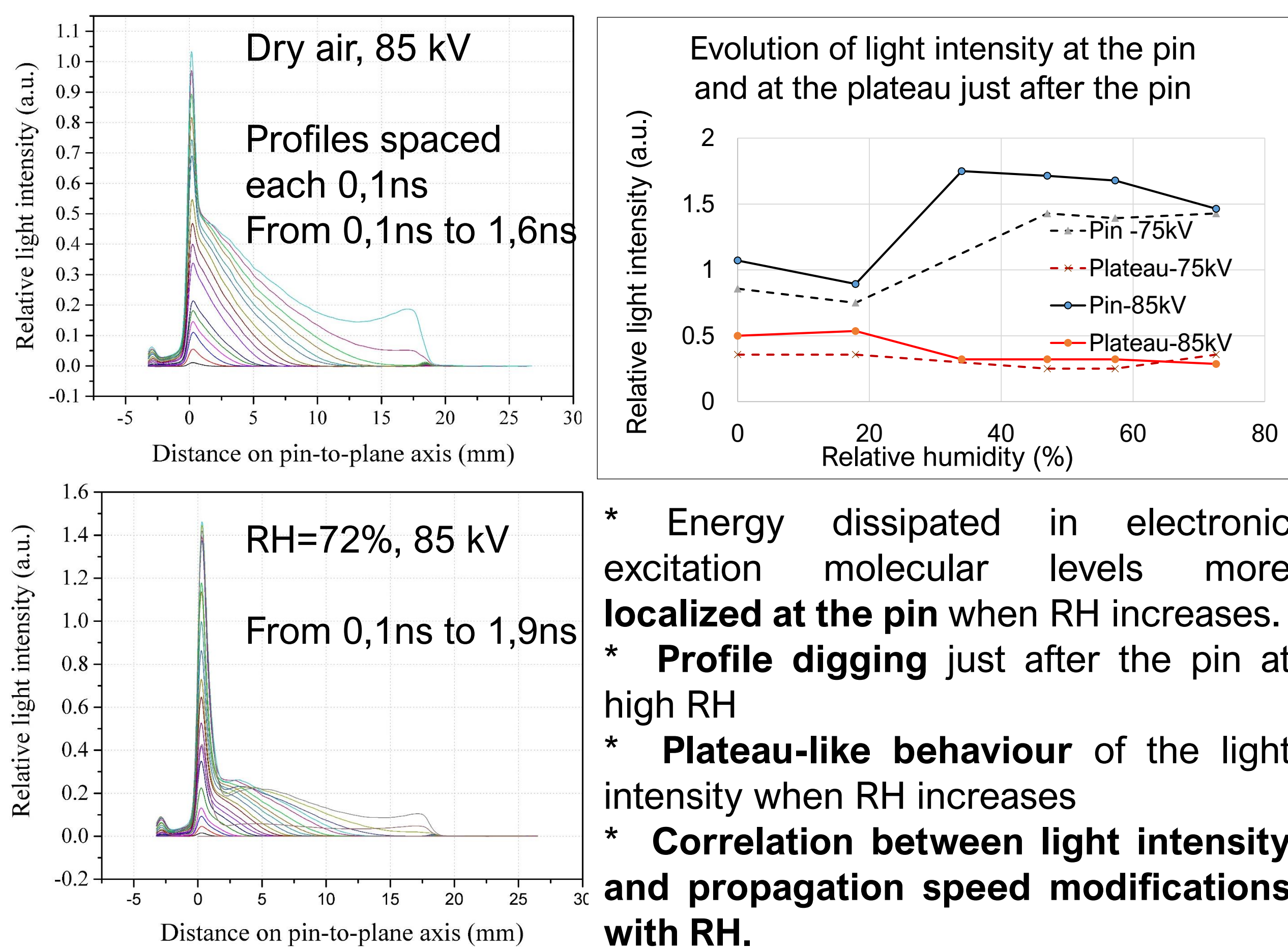
Results on propagation speed versus voltage:



- * Existence of a **threshold of relative humidity (RH) around 30%** above which the propagation speed is affected.
- * Significant **slowing down effect** on propagation speed for voltages **>65kV**.
- * **Non-linear** evolution of the propagation speed for RH beyond this threshold.
- * **Linear** evolution of propagation speed for high RH

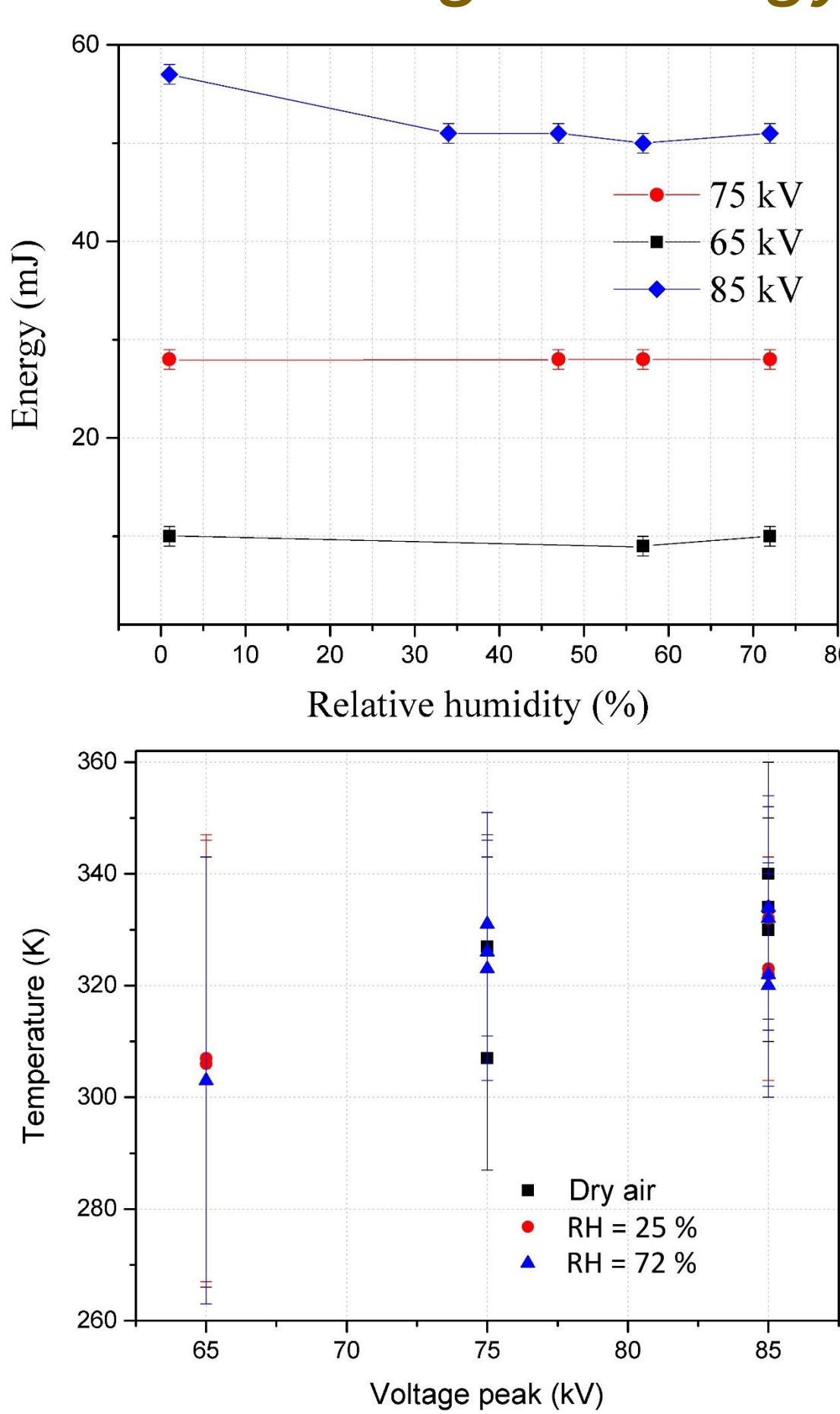
At high humidity, possible influence of **water molecular aggregates** on the propagation speed maybe through electronic attachment, electronic fragmentation, photon absorption...

Results on light intensity profiles:



- * Energy dissipated in electronic excitation molecular levels more **localized at the pin** when RH increases.
- * **Profile digging** just after the pin at high RH
- * **Plateau-like behaviour** of the light intensity when RH increases
- * **Correlation between light intensity and propagation speed modifications with RH.**

Results on gas energy and temperature:



- * **Constant mean energy** with water vapour.
- * At voltages close to 65kV, the mean energy is about 4mJ (±1mJ). At 75kV, it reaches at 16mJ (±1mJ) and at 85kV, 32mJ (±4mJ).
- The light emission of N₂(C-B) dominates the spectrum and temperature is determined by analysing the rotational distribution of some N₂(C-B) transitions by optical emission spectroscopy. Spectroscopic method is described in [2] and confirmation of some assumptions in [3].
- Spectroscopic parameters :
 - * Spatial integration over all the discharge volume
 - * 10 ns time average
 - * 2400 gr/mm for good spectral resolution
 - * **Low temperature around 300K ± 40K** at 65kV, around 320K ± 20K at 75kV and around 330K at 85kV
 - * Little **temperature increase with voltage peak.**
 - * **No influence** of the presence of **water vapour** on the gas temperature

Conclusion:

When **relative humidity exceeds 30%** and if **voltage peaks higher than 65kV**, the **propagation speed is significantly lowered**, while the energy remains similar. Also, the distribution of the **light intensity axial profiles is stronger at the pin** but lower beyond. Below this threshold, no significant modification is observed on neither speed propagation nor energy, and light emission profiles are less affected. Hypothesis about the modification of the electronic attachment in such cases, or the possibility of modified energy transfer during electron or photon collisions with possible **water aggregates for instance**, can be mentioned. This condensation effect could be enhanced **at the pin** which is expected to be **colder**, and where the light intensity profiles are the most affected. At last, the acceleration of the propagation at the end of the discharge, seems to be faster under high relative humidity conditions.

Acknowledgments:

This work is supported by the Agence Nationale de la Recherche in the frame of the ANR-13-BS09-0014 research program.

Outlook:

The interaction of photons and electrons with water aggregates depends a lot on the size of the aggregates. For micrometric size dielectric-like aggregates, it was shown that the reconfiguration of the electric field at the proximity of the droplet would accelerate a streamer. For nanometre size aggregates, no detailed work was done on streamer propagation to our knowledge but electronic attachment is much higher than for isolated molecules. Granulometry experiments are considered to help assert in which size range the possible discharge water aggregates stand.

References:

- [1] P. Tardiveau, L. Magne, E. Marode, K. Ouaras, P. Jeanney and B. Bournonville, Plasma Sources Sci. Technol. 00 (2016) 000000 (16pp)
- [2] D. L. Rusterholtz, D. A. Lacoste, G. D. Stancu, D. Z. Pai and C. O. Laux, J. Phys. D: Appl. Phys. 46(2013)464010(21pp)
- [3] N. A. Popov, J. Phys. D: Appl. Phys. 44 285201 (2011)