

Unexpected Ultrafine Particle Emissions from Hook-and-Loop Fasteners



Julian Wehrle, Tobias Rüggeberg, Ernest Weingartner
Institute for Sensors and Electronics (ISE), FHNW, Switzerland

nw University of Applied Sciences and Arts Northwestern Switzerland
School of Engineering and Environment

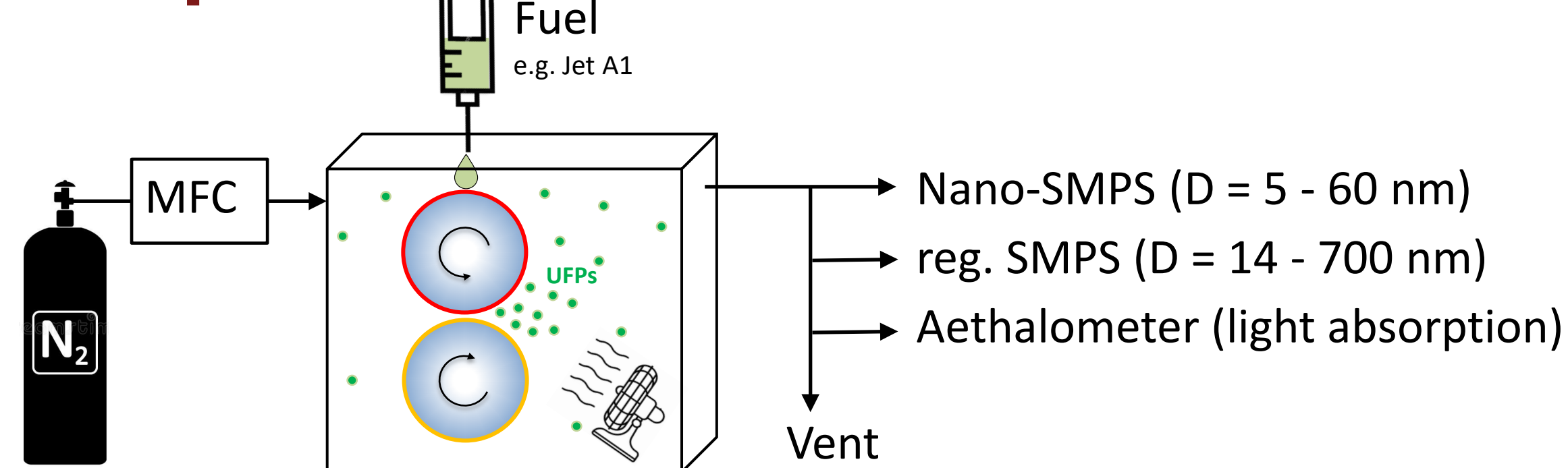
Background

The simple mechanical opening of commercial **hook-and-loop fasteners** (Velcro®) produces **large amounts of UltraFine Particles (UFPs, $D < 100$ nm)**.



This is unexpected and scientifically intriguing as UFPs are typically associated with high-temperature combustion, gas-phase nucleation, or condensation processes rather than macroscopic mechanical actions.

Setup and Instrumentation

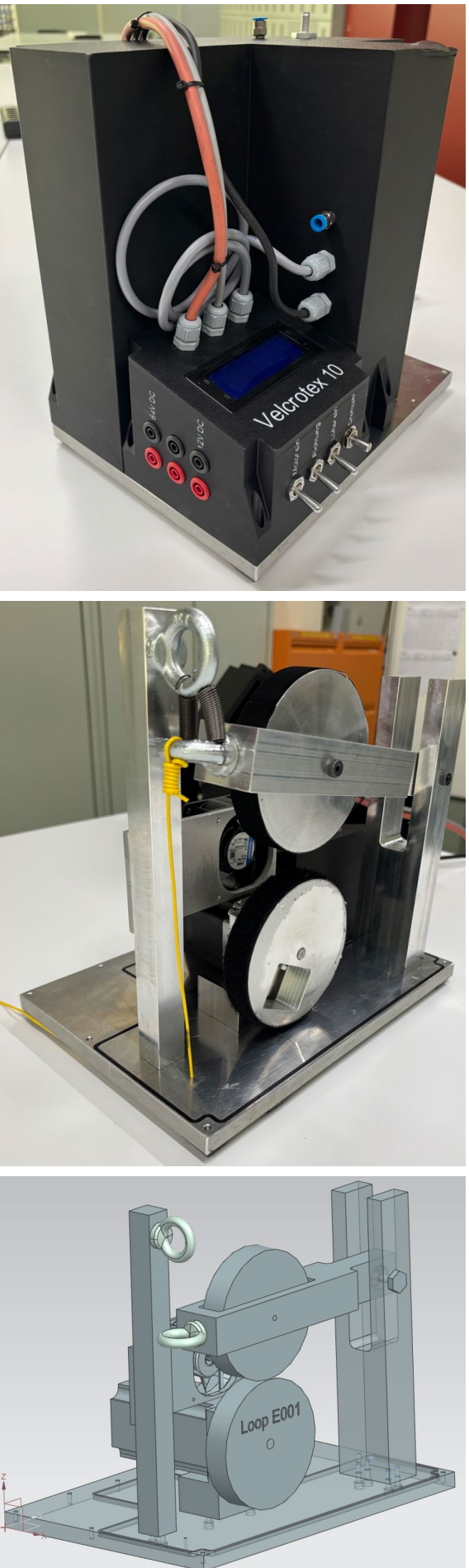


Velcrotex 10 is an automated particle-generation system for continuous cyclic disengagement of hook-and-loop fasteners under defined conditions.

Controlled parameters:

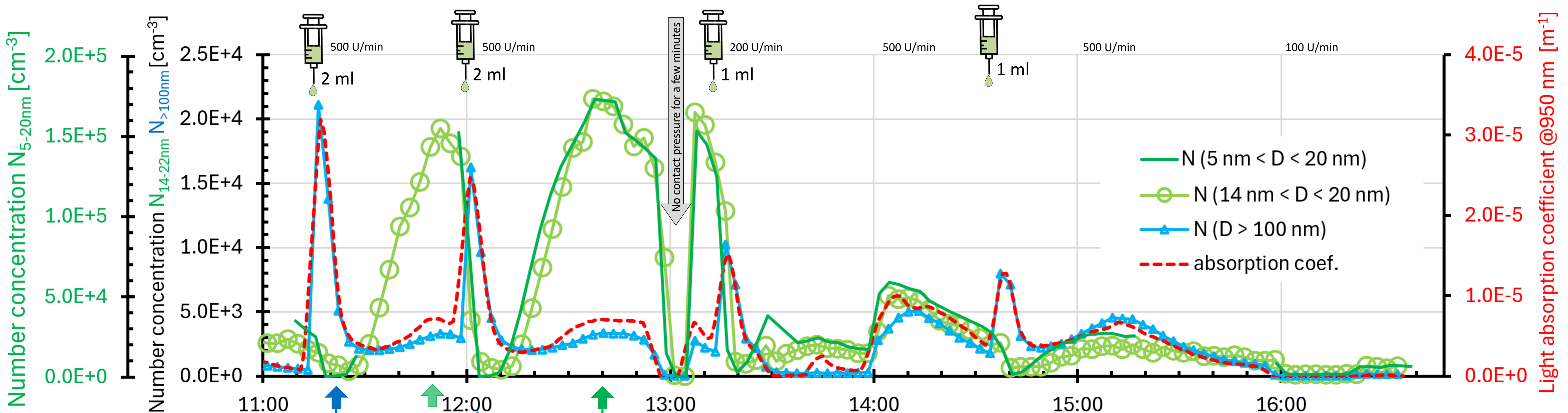
- organic additives (liquids as VOC precursors)
- peeling velocity (10–1500 rpm), contact pressure, wear state
- gas flow and atmosphere (e.g. N_2 , air)

Electrically conductive chamber with minimized parasitic particle sources.

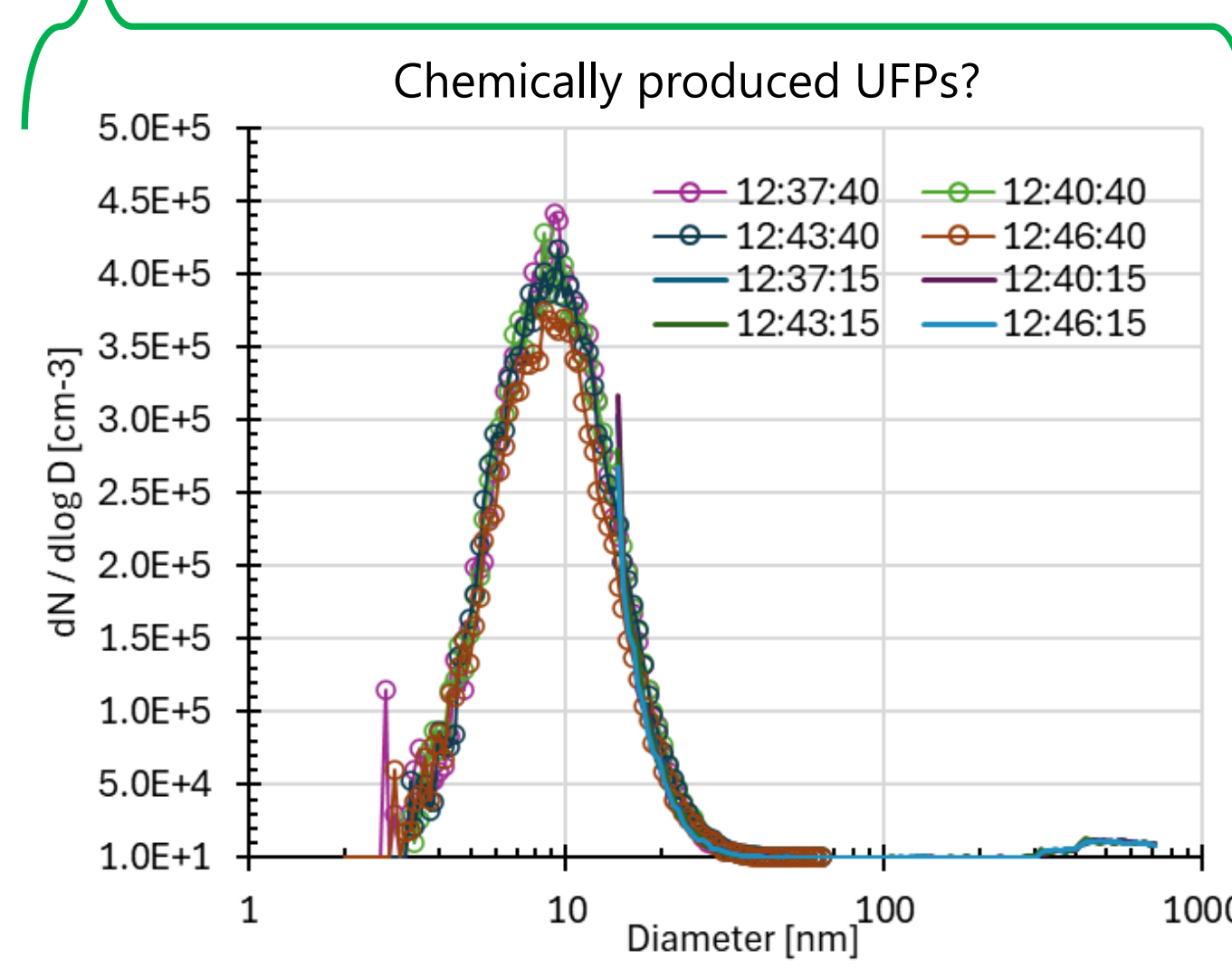
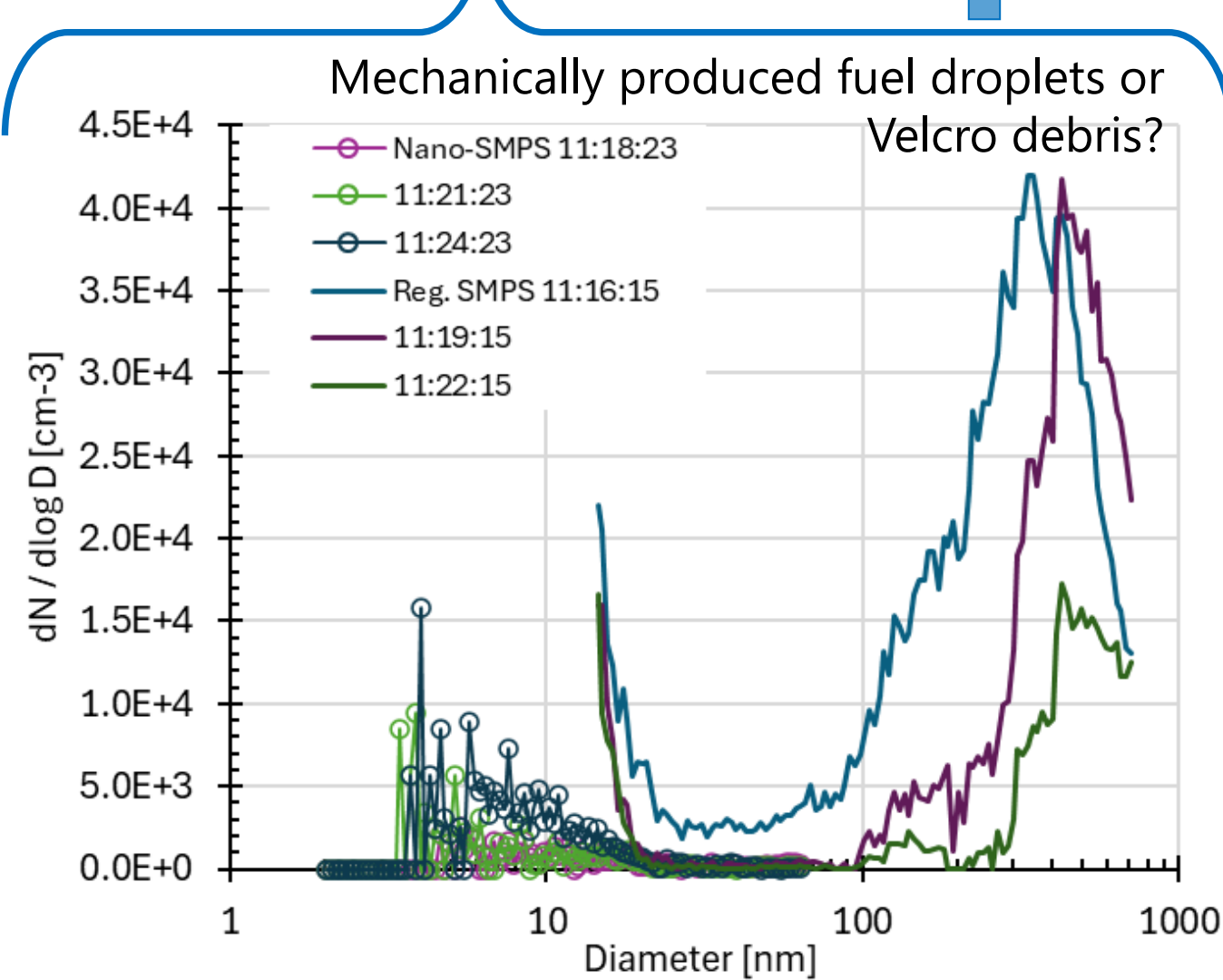


Results

Release of fine particles during several hours of continuous operation of a Velcro fastener, with 4 injections of Jet A1 fuel in N_2 :



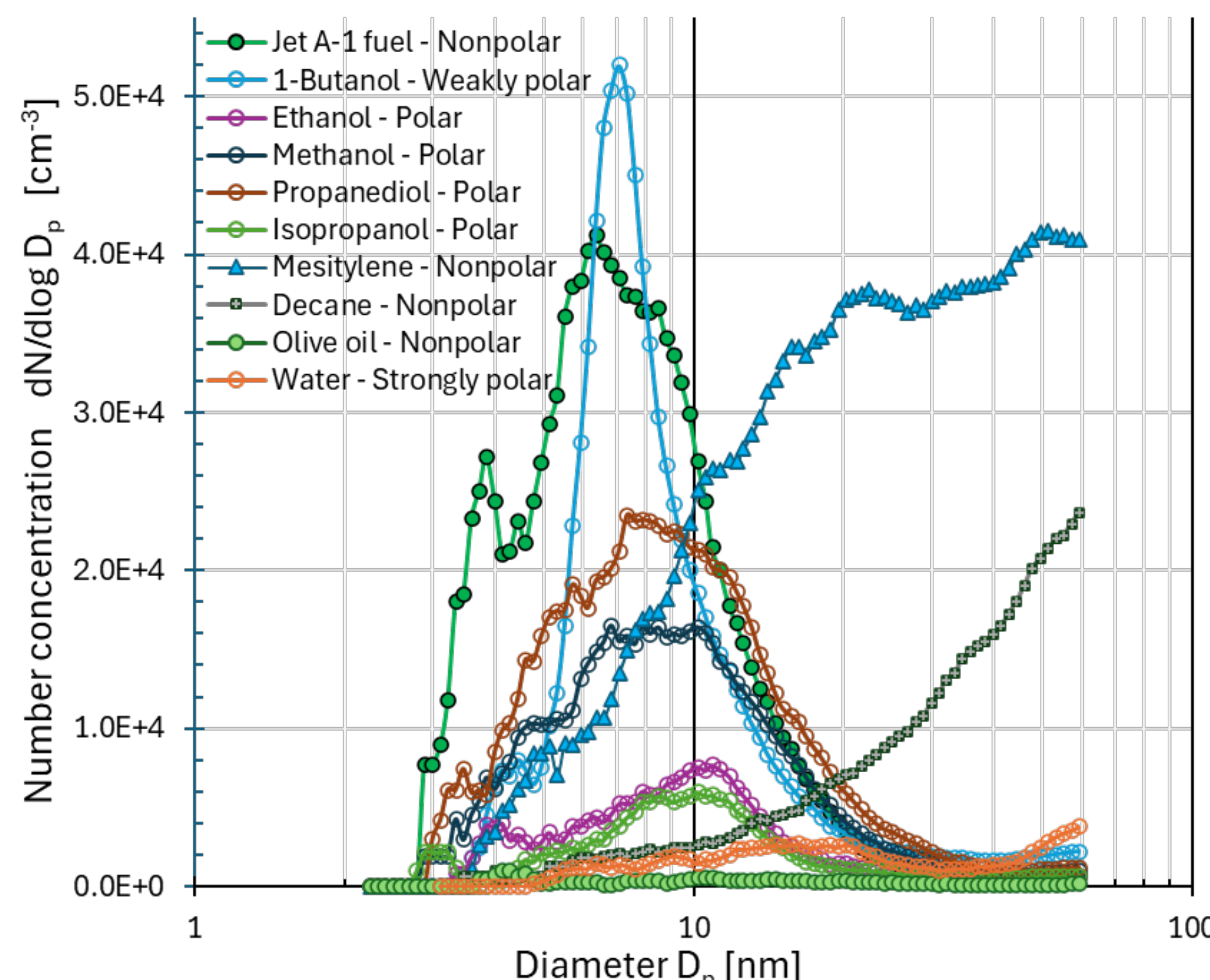
Why first release of larger particles, then emission of UFPs?



Immediately after adding 1–2 ml of liquid organic material (Jet-A1 fuel), the formation of particles **larger than 100 nm** can be observed. Their concentration correlates strongly with measured **light absorption**. After a few minutes, the formation of these “large” particles declines, and a high number of **UFPs with a size of ~10 nm** are formed.

UFP emissions for different organic additives

We investigated the formation of UFPs for a wide range of different liquid additives. The particle size distributions were measured a few minutes after the substances were added. All experiments were carried out in an O_2 -free atmosphere (N_2).



- **Jet A1 fuel and butanol** produce high UFP emissions.
- **Oil and water** almost completely suppress particle emissions
- Certain non-polar additives shift the size distribution towards larger particles: **Release of debris > 100nm** due to the disintegration of the Velcro structure?

Open questions

- What causes the initial release of large particles?
- Why does UFP formation occur with a delay?

Mechanisms

- Conventional combustion involving oxygen is rather unlikely
- Localized high shear stresses at micro-scale contact points likely lead to pyrolysis reactions: Polymer chain scission followed by nucleation or condensation?

Significance and Outlook

This **phenomenon** opens up the possibility of a simple, cost-effective **UFP generator**.

Future work will focus on the chemical & morphological particle characterization (SEM/TEM), analysis of their volatility, the investigation of alternative materials (metallic Velcro). Experiments using only VOCs (gaseous precursors, no liquids) are of interest for future work.