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# $H_2$ powered aircrafts

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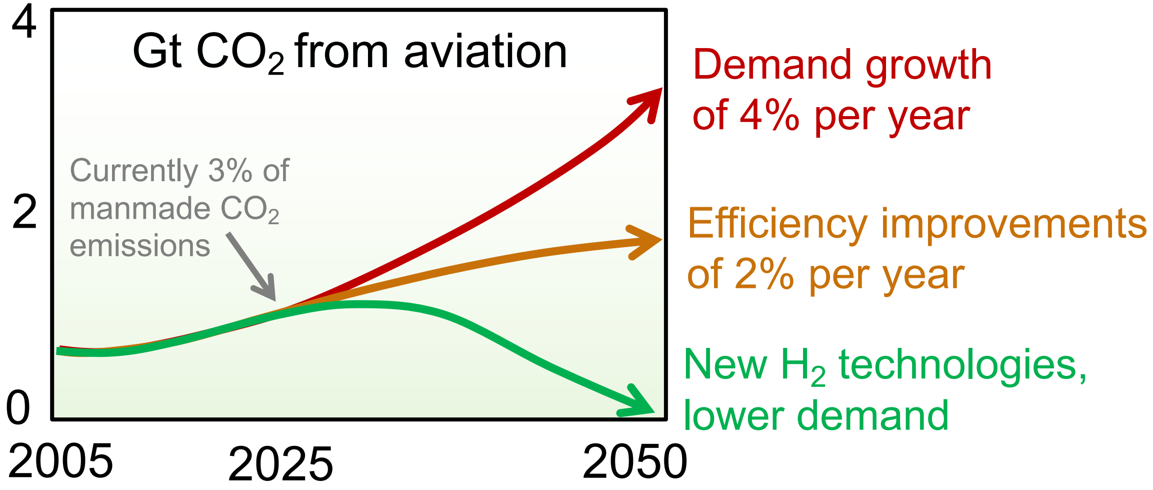
Hydrogen-powered aviation, 2020, McKinsey & Company for the EU Clean Sky 2 JU and Fuel Cells and Hydrogen 2 JU

# Decarbonizing aviation by 2050 is an extremely difficult challenge because the time scale of new technology development is long

## How to decarbonize aviation?




*Hydrogen-powered aviation, 2020*

## Why using Hydrogen ($H_2$) and not batteries for large aircrafts?

Mainly because the effective gravimetric energy density of liquified $H_2$ is **more than 36 times larger**


**> 18 kWh/kg**

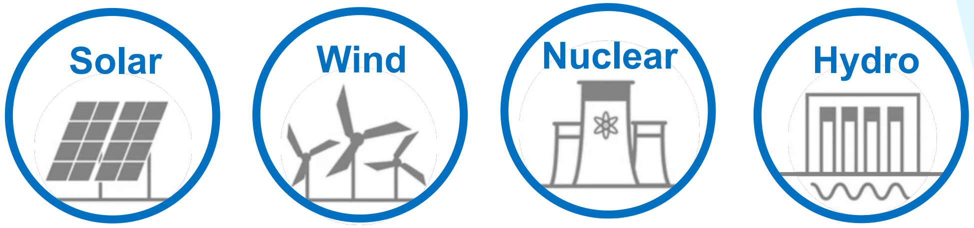
**0.5 kWh/kg**

*Hydrogen storage methods, Züttel, Naturwissenschaften 2004*

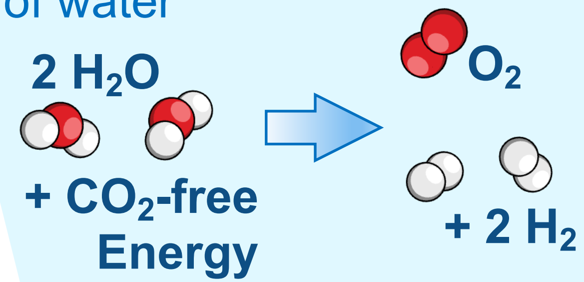
*Advanced in Li-S Batteries […] Chen et al, Advanced Materials 2021*

## How do we make Hydrogen?

1) Take some decarbonized energy



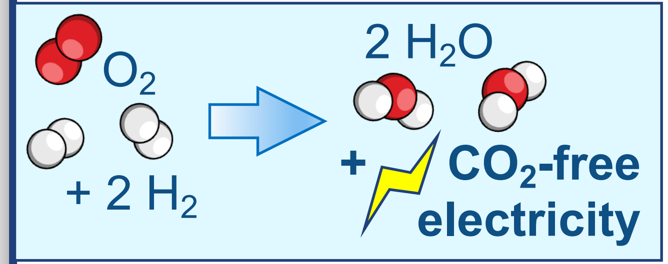

2) Use it to split molecules of water




3) Store the resulting $H_2$. This is challenging because of its low volumetric energy density → cryogenic cooling at ambient pressure, or high compression at ambient temperature

# $H_2$ turbines are cost-effective propulsion systems which can enable a significant positive effect on the climate

**Commuters and regional segment**
~ 50 passengers, 700 kilometers, 450 km/h

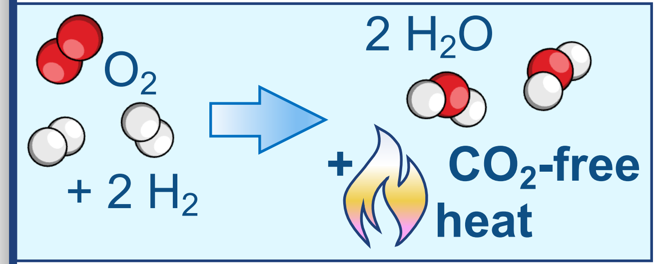



**$H_2$ fuel cells**

Weight of cooling system of $H_2$ fuel cells prevents cost-effective scale-up to larger segments


**Small segment** → **Minor climate impact reduction**

**Medium-range segment**
~ 250 passengers, 7000 kilometers, 900 km/h




**$H_2$ gas turbines**

$H_2$ turbines technology does not exist and must be developed in record time


**Large segment** → **Significant climate impact reduction**

Source: **Hydrogen-powered aviation, 2020,**
McKinsey & Company for the EU Clean Sky 2 JU and FCH 2 JU

# ETH significantly contributes to the pioneering HYDEA project: HYdrogen DEmonstrator for Aviation

**HYDEA will holistically demonstrate the feasibility of hydrogen propulsion on an aircraft engine in a compacted timeframe (2023-2026) up to Ground test.**

The project aims to address fundamental questions related to the use of hydrogen as an aviation fuel, including **emission** studies and technologies, such as **NOx optimization studies**, potential **contrails** emissions and further optimization of the **integration of all the subsystems**, with the **propulsion** system and the **aircraft**.

CLEAN AVIATION · Avio Aero (a GE Aerospace company) · GE Aerospace · DLR · SAFRAN · AIRBUS · ETH zürich

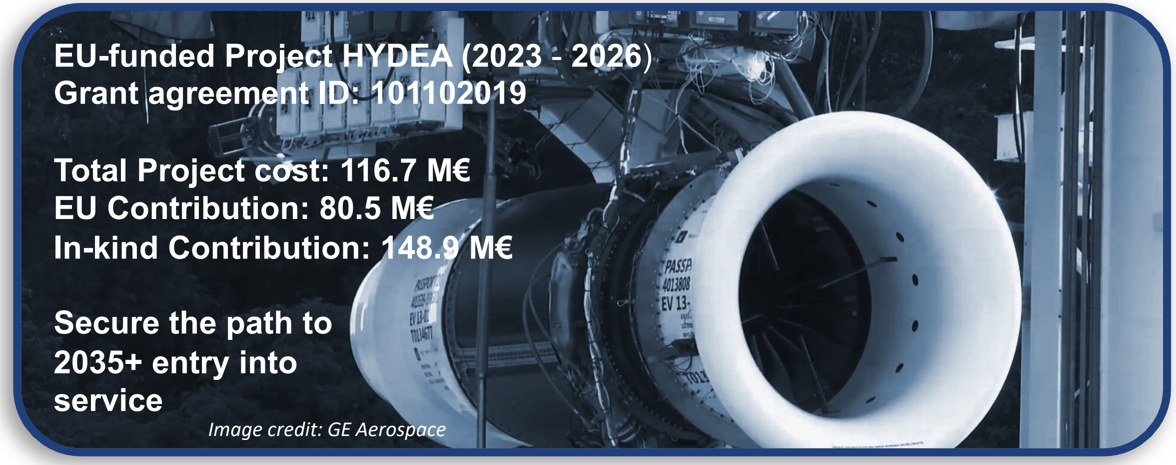
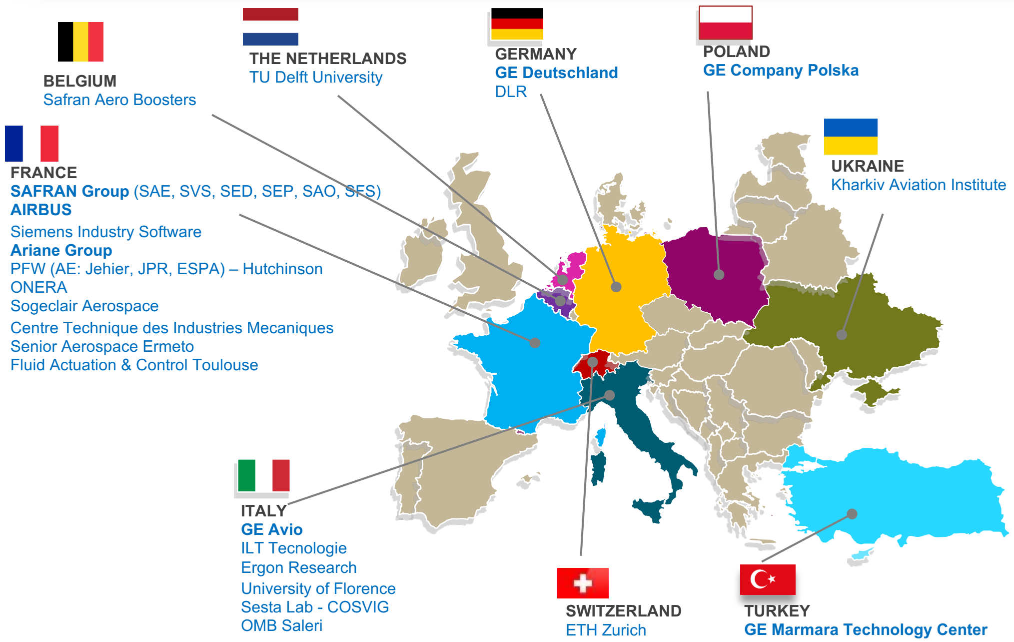


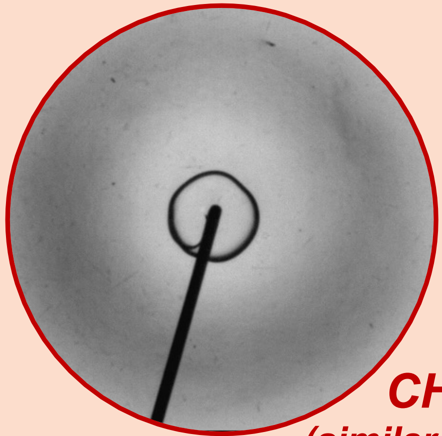

*Image credit: GE Aerospace*



# Hydrogen and kerosene are a radically different fuels with different combustion physics → challenging technology development

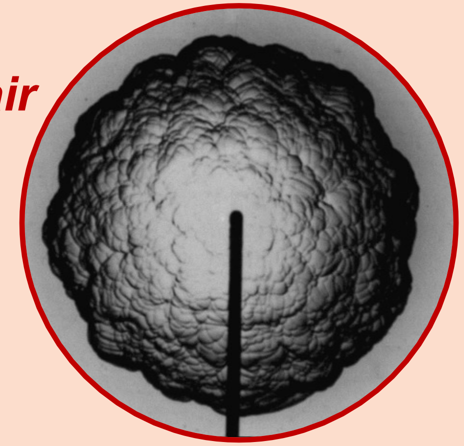
## *It is very challenging to switch combustor technologies from kerosene to $H_2$ because*

- $H_2$-air flames burn **much faster** and they are **severely wrinkled** by thermo-diffusive instabilities
- These differences significantly impact the flame stability, the risk of flashback and the $NO_x$ emissions
- **There are no models yet to predict the coupling between reaction rate, diffusion, and turbulence**



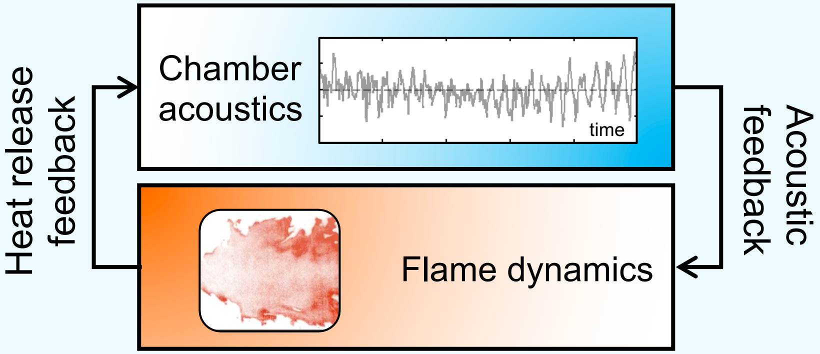
*$CH_4$ – air*
*(similar flame speed as kerosene)*

*$H_2$ – air*



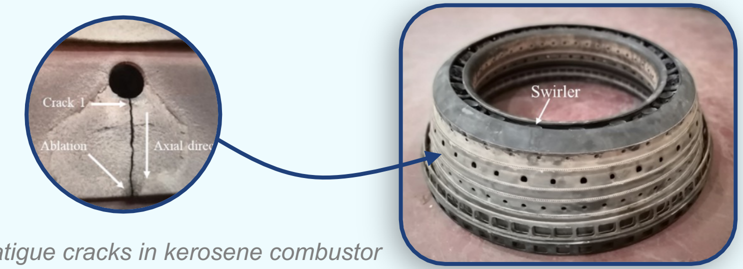
Movies courtesy of H. Pitsch: J. Beeckmann, et al, *Proc. Combustion Institute 2017*

## Predictive tools of thermoacoustic instabilities are not available yet



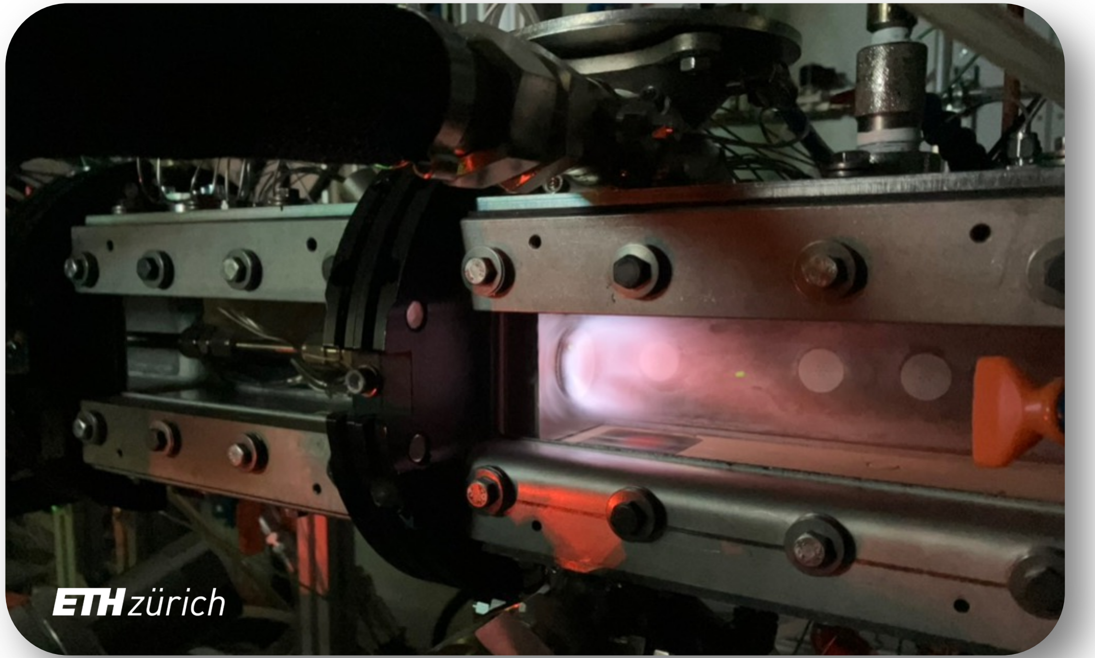

*Laser induced fluorescence of OH radicals (Bonciolini et al., Proc. Combustion Institute 2019)*

→ Possible high-amplitude self-oscillations leading to vibrations and cracks



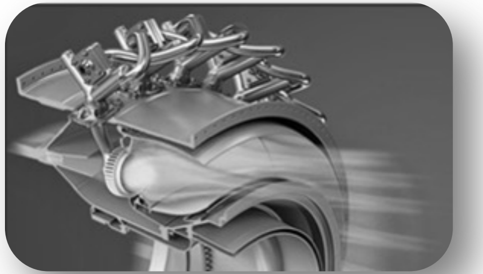

*Fatigue cracks in kerosene combustor (Zhang et al., Engineering Failure Analysis 2020)*

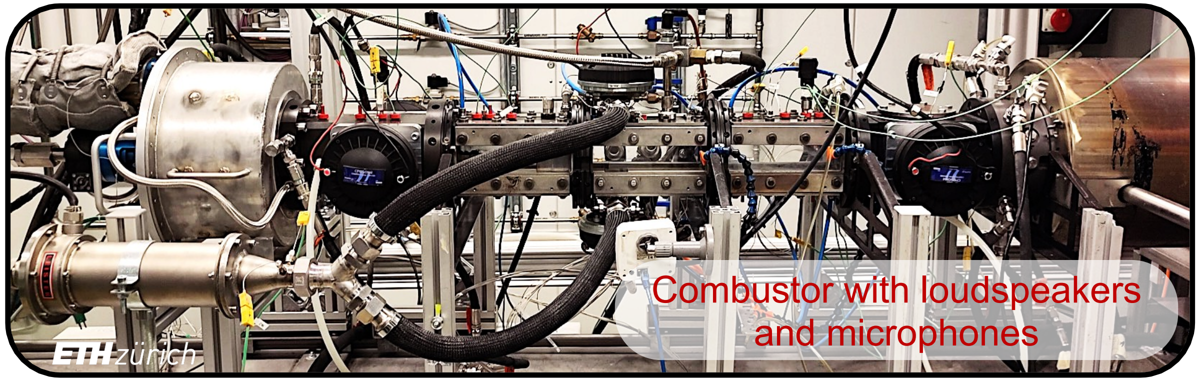
# Our task at ETH is to assess the combustion dynamics at elevated pressure using our unique facility for thermoacoustic research



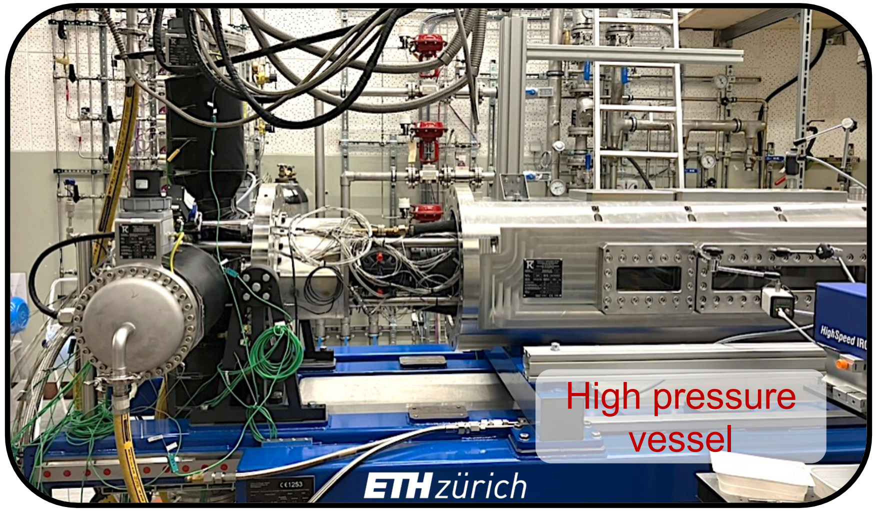

We investigate one single flame to understand and model its coherent dynamics

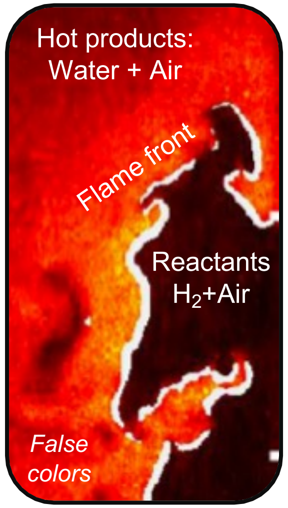
We will then predict the collective dynamics of the distribution of flames around the annular combustor






We measure the acoustic scattering matrix of the $H_2$ flame at atmospheric condition …




… and then at high pressure. We also perform laser-induced fluorescence for obtaining cuts of the flame, and other optical diagnostics to validate computational fluid dynamic models

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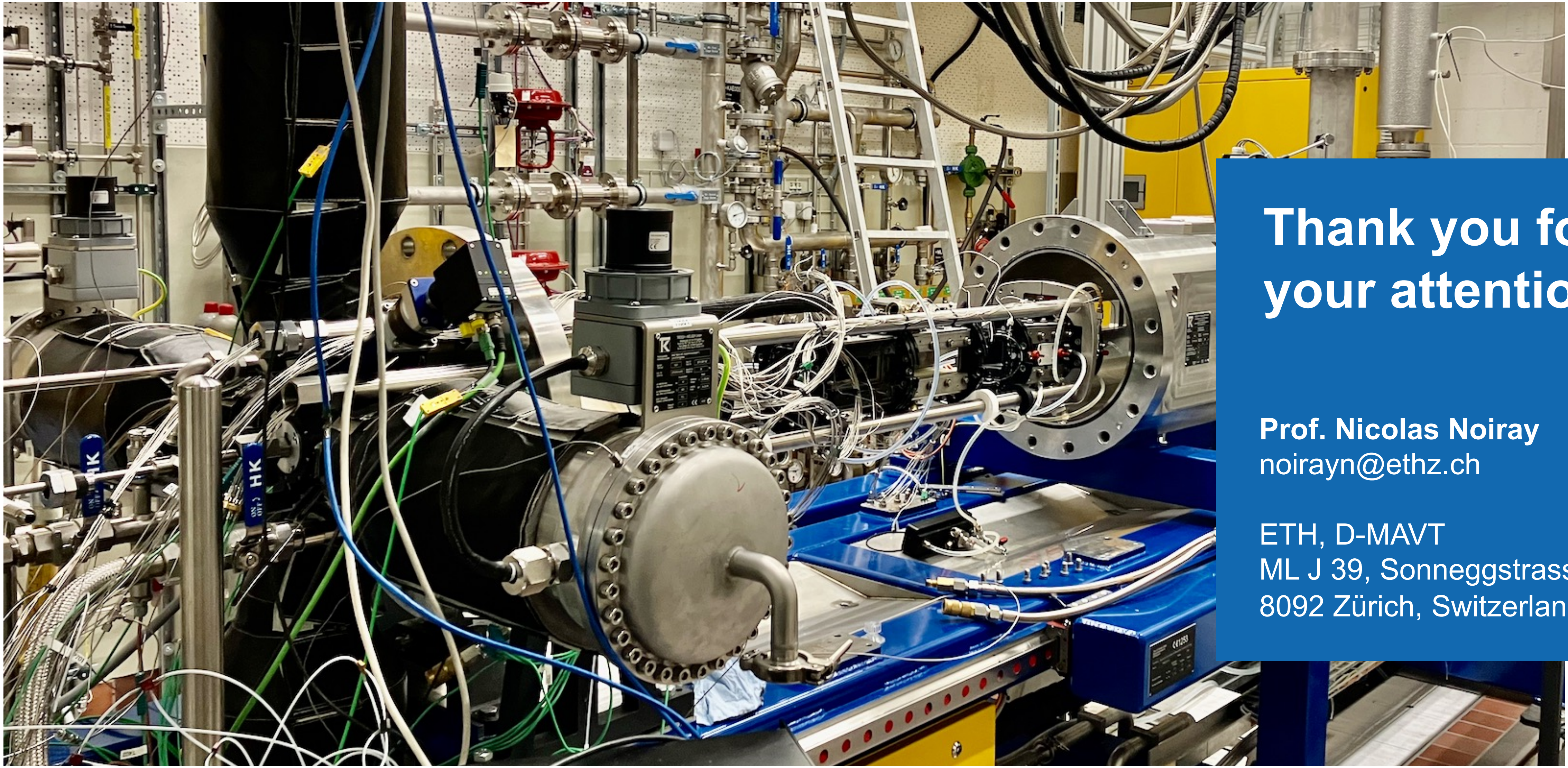

# Thank you for your attention!

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