# HYDROGEN DETECTION FROM DISTANCE

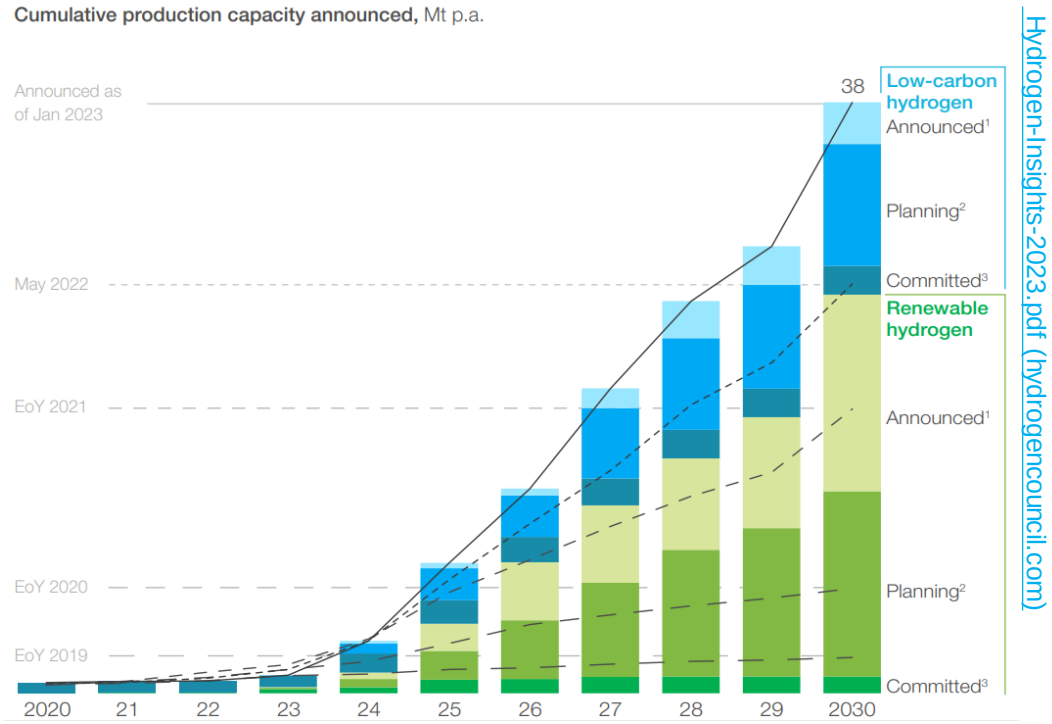
**UV Raman LIDAR for detection of hydrogen in air**

Matthias Hollmann, Institute of Technical Physics, 22.10.2024

# Project overview

## Motivation

- Important resource for decarbonisation
- Reliable leak detection is essential
- Standoff detection of hydrogen with:
  - Replication and detection of a leak
  - Discussion of effects caused by hard targets near a hydrogen leak

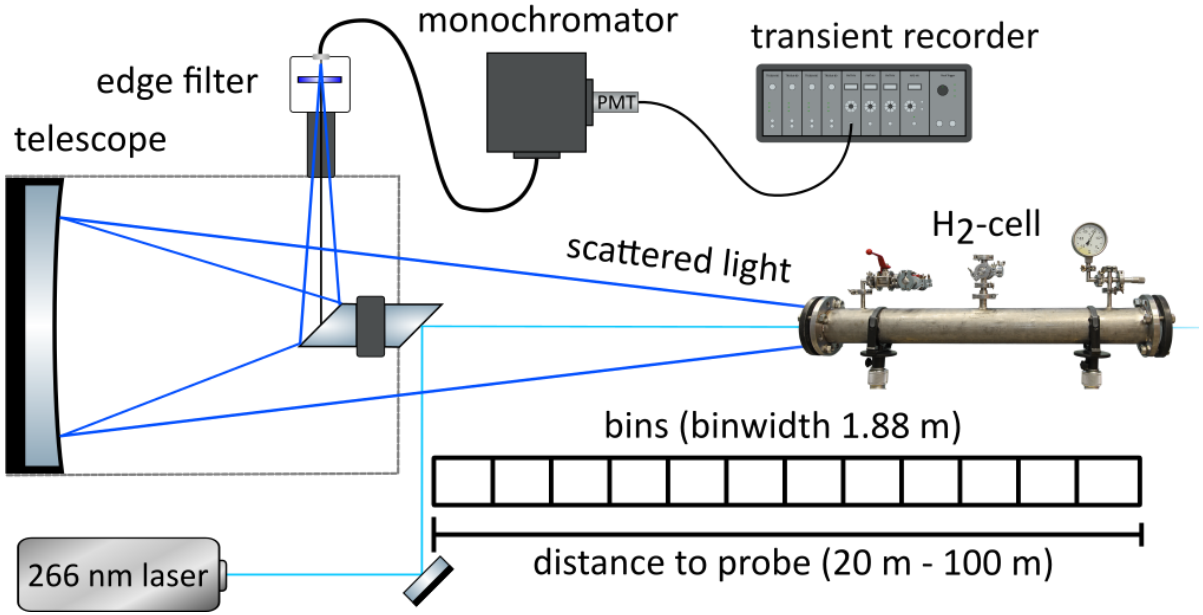



## Approach & advantages

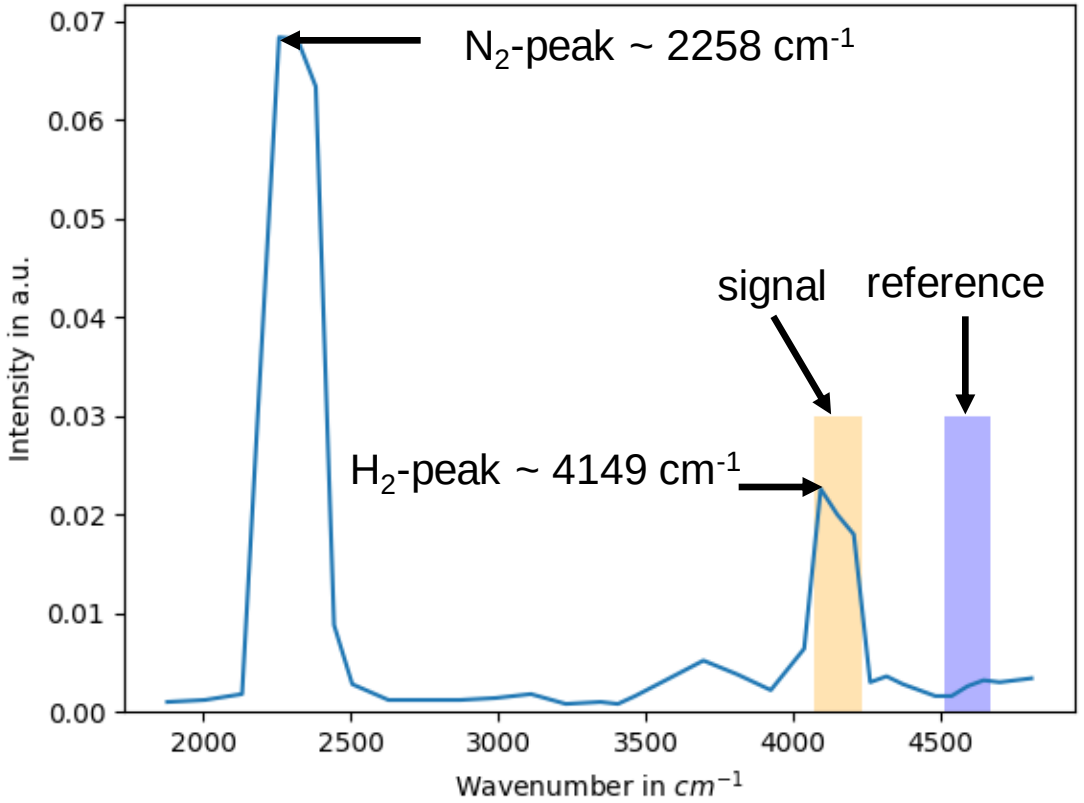
- LIDAR system to cover a large area
- Raman as an active detection method
- Usage of a UV laser to reduce influence of environmental light

# Setup

- Pulsed 266 nm laser:
  - 700 ps pulse duration
  - Spectral width < 140 $cm^{-1}$
- Newton telescope
  - Ø 40 cm, focused on the sample
- Transient recorder
  - resolution of 12.5 ns or 1.88 m
- Outdoor measurements
  - 130 m long test facility



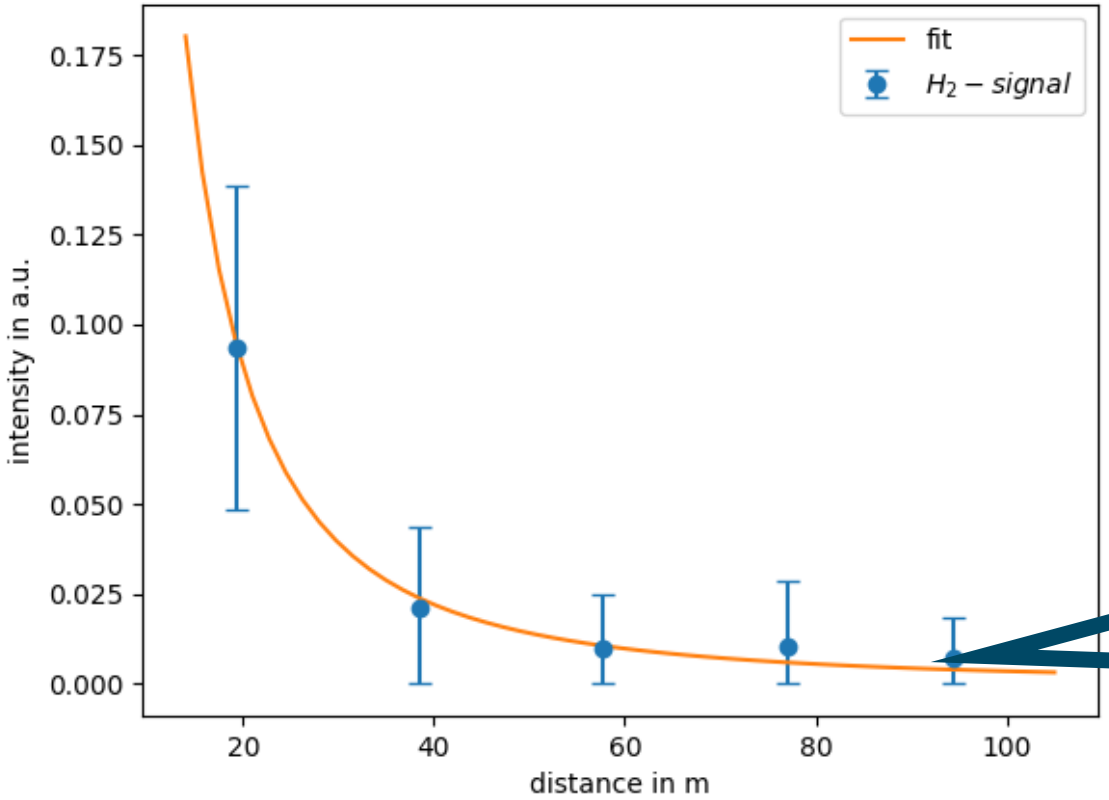

# Spectrum of $H_2$-$N_2$ mixture




- 200 mbar $H_2$, 800 mbar $N_2$
- 20 m distance
- 50 µJ pulse energy and 50 s integration time

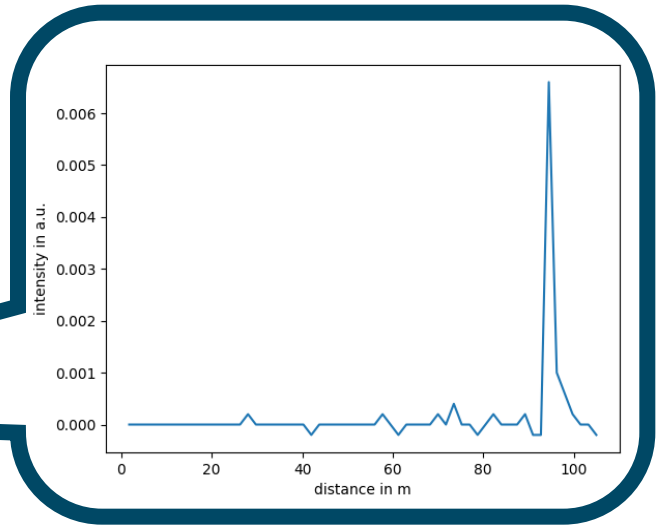
- Spectrum recordet for system validation
- 0.5 nm resolution
- Reference measurement needed to correct for elastic scattering
- Intensity of $H_2$-peak and reference used in further measurements

# Detection of $H_2$ in up to 100 m distance



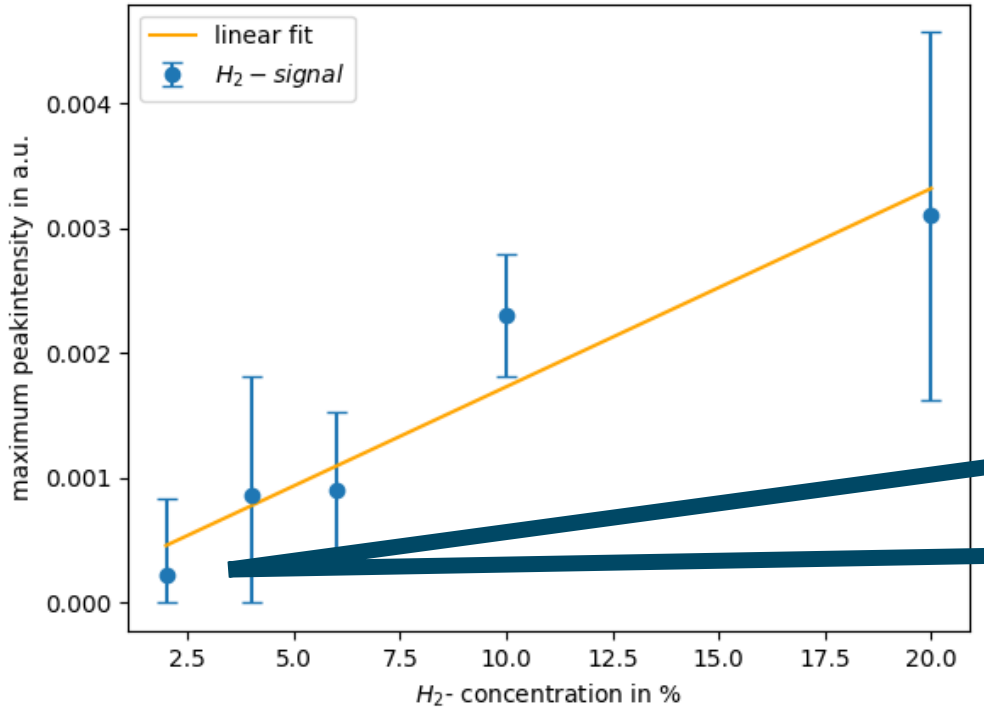

- 100 mbar $H_2$
- 300 µJ pulse energy
- 50 s integration time

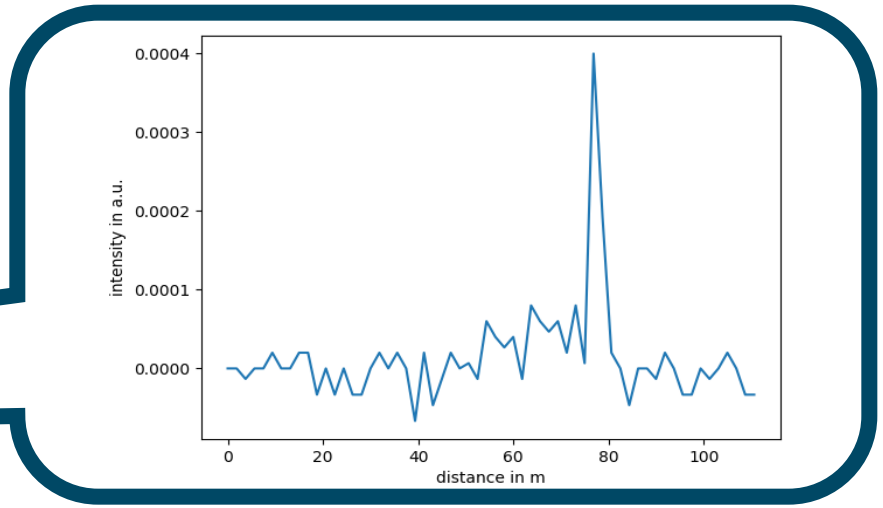
- Fit according to isotropic scattering: $intensty \sim 1/r^2$




- Clear peak in the timeresolved measurement

# Dependencies on $H_2$ concentrations




- Linear dependency expected

- 20 mbar $H_2$ at 80 m distance
- 200 µJ pulse energy
- 50 s integration time

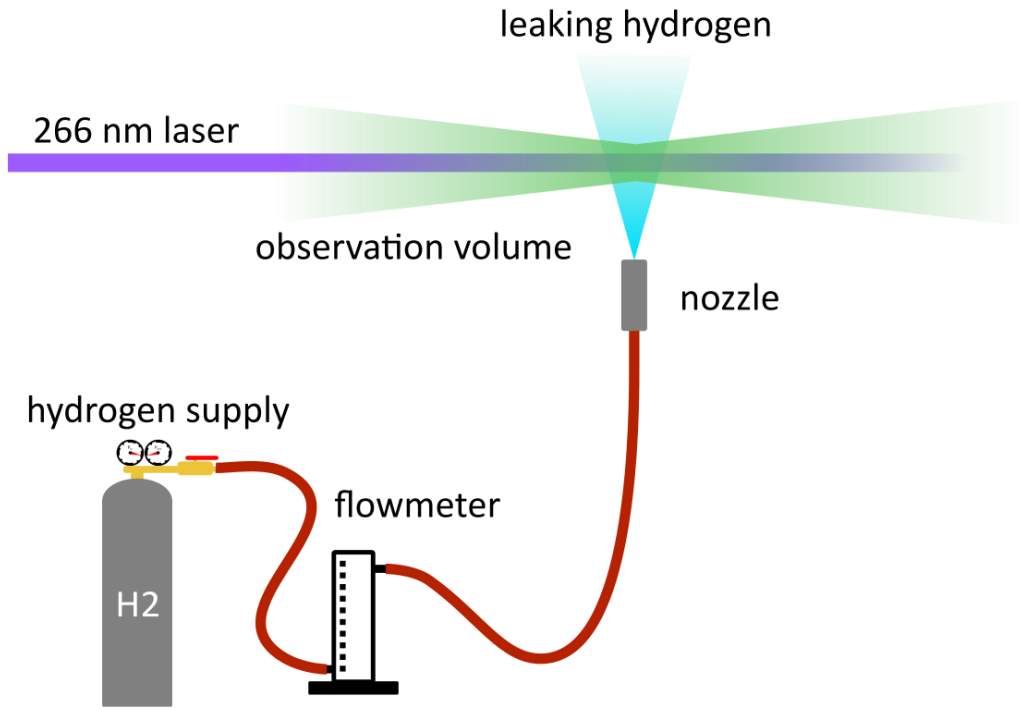
- Calculate the dependency of countrate on the amount of $H_2$ with known observation volume

- In simplified scenario detection of 20 mbar $H_2$ in up to 80 m distance possible
- More realistic testing needed >>> replication of a $H_2$ leak

# Replication of a $H_2$ leak

- More realistic testscenario
- $H_2$ leaks through nozzle with 1 mm diameter
- Control $H_2$ flow with a valve and the flowmeter
- Smaller intersection of observation volume, $H_2$ and excitation volume

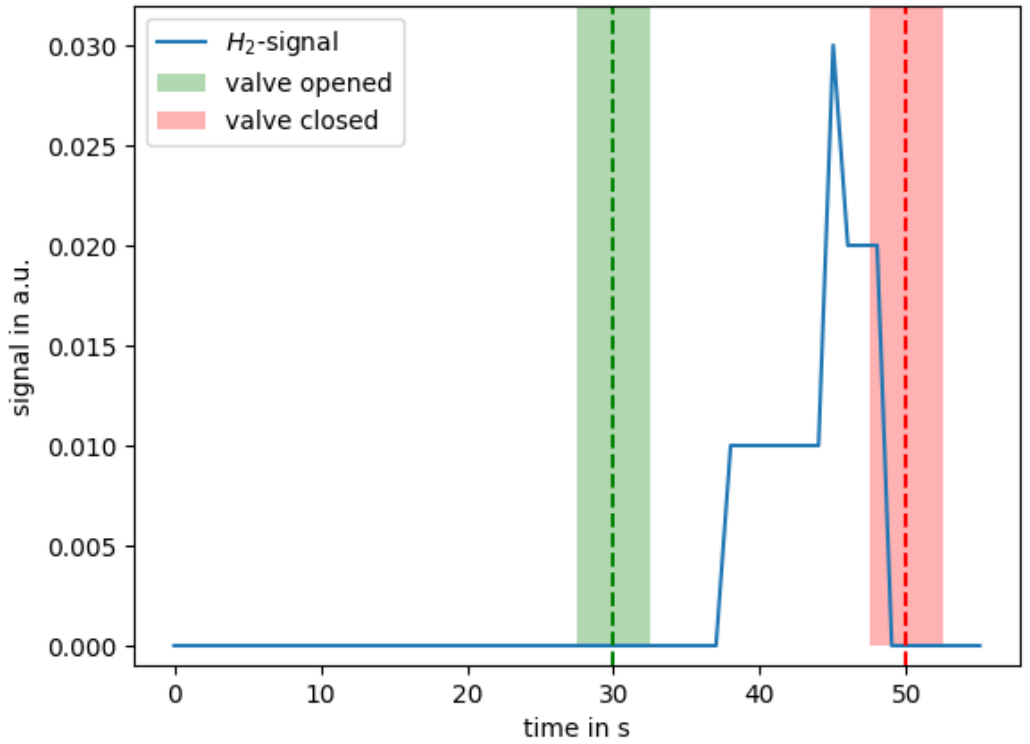
## Setup



# Replication of a $H_2$ leak

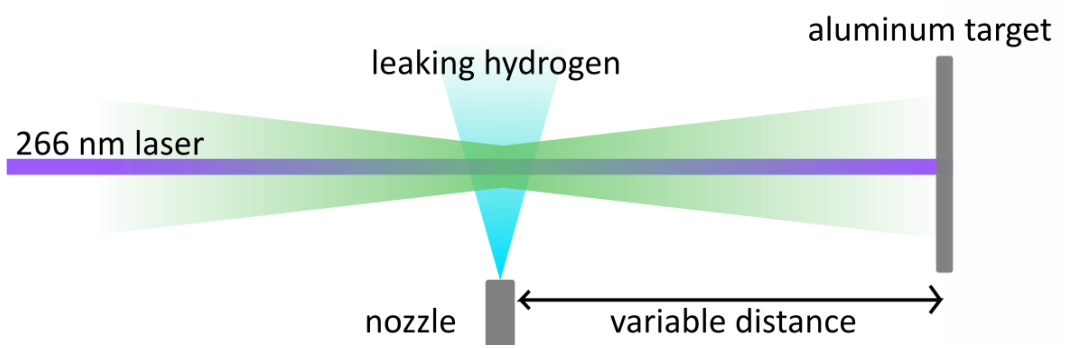
## Measurement procedure

- Nozzle placed in 20 m distance
- $H_2$ flow set to 0.5 l/s and turned off
- Live monitoring of a $H_2$ leak
- Valve opened after 30 s and closed again 20 s later



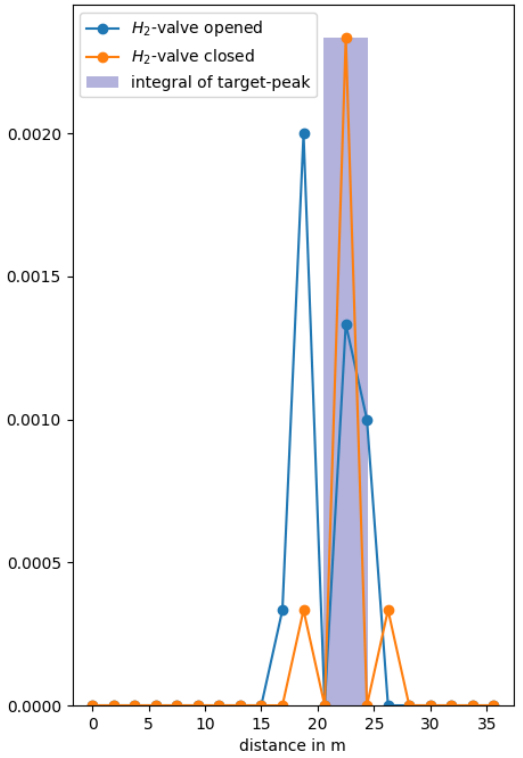

- leaking $H_2$ in 20 m distance
- pulse energy of 100 µJ
- Data averaged over 100 shots by transient recorder and afterwards integrated over 5 s

# Hard target behind the nozzle

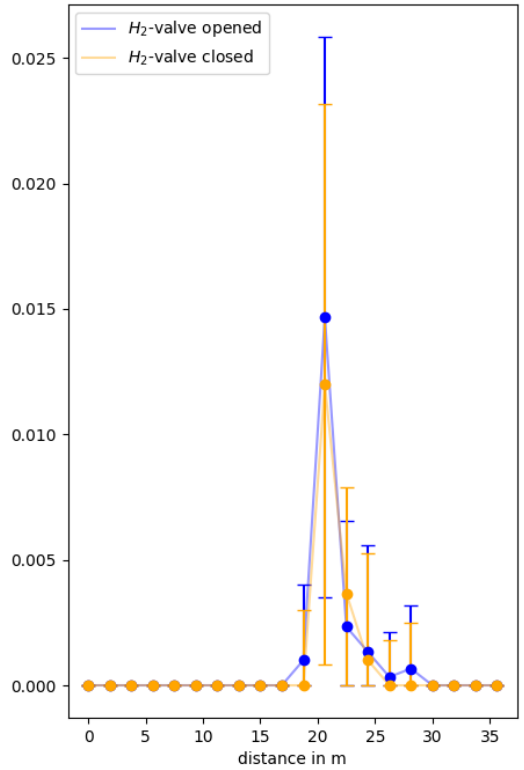



- Target and leak can be identified with 3 m distance
- Identification difficult with 1.5 m:
  - No simultaneous measurement
  - Drift in pulse energy has influence
- Estimated amount of hydrogen based on previous measurements: $n_{H_2} \approx 630\ \mu mol$ corresponding to 15.3 ml $H_2$ at atmospheric pressure

**3 m distance**



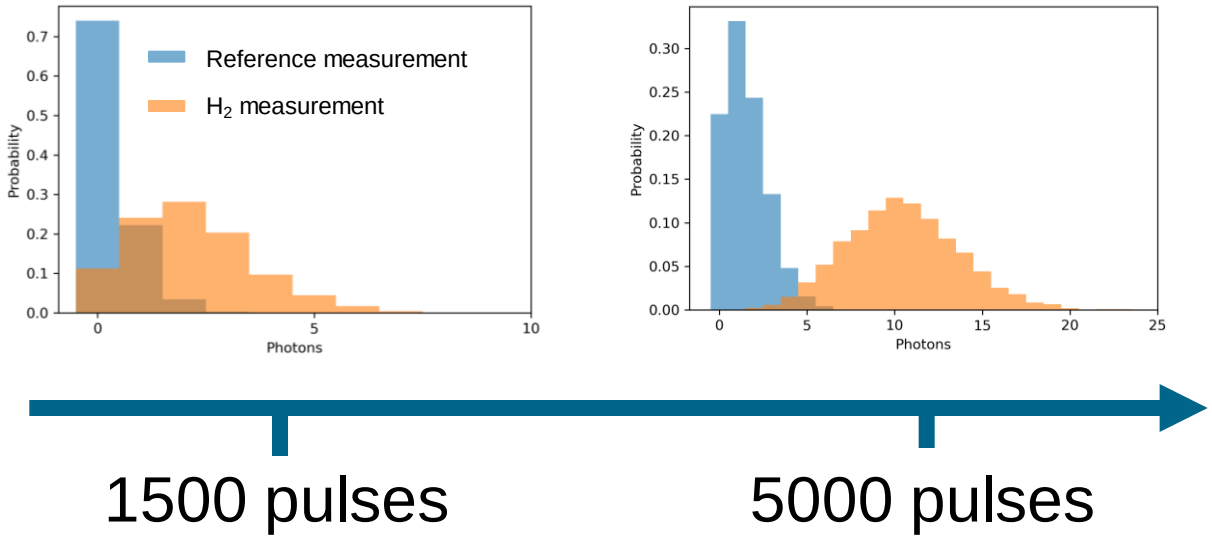

**1.5 m distance**

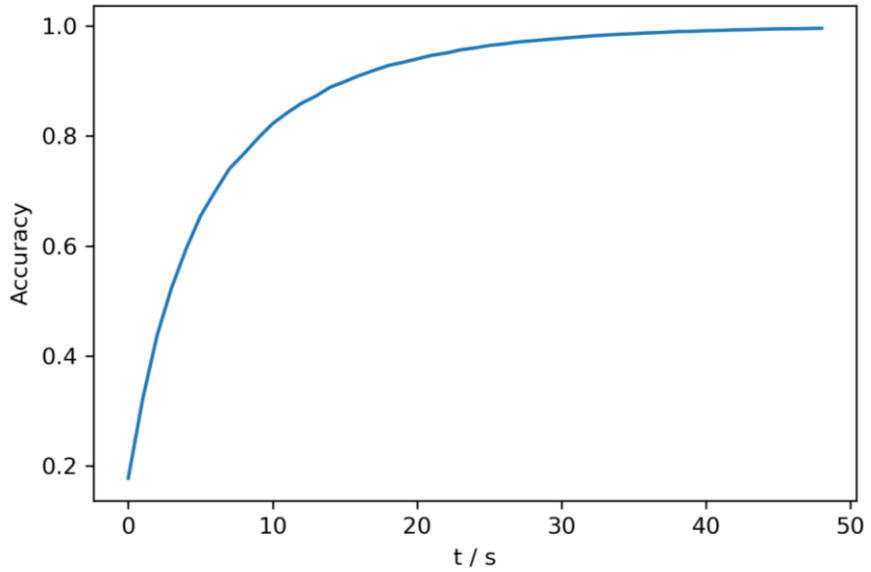



- $H_2$ nozzle in 20 m distance with 0.5 l/s
- Aluminum target 1.5 m or 3 m behind the nozzle
- 100 µJ pulse energy
- 30 s integration time

# Estimation of necessary acquisition time

## Poisson distribution




## Caculating accuracy

$$\text{Acc} = \frac{true\ positive\ counts}{true\ positive\ counts + false\ negative\ counts}$$

- Estimate acquisition time for:
  - 60 m distance
  - 50 µJ pulse energy
  - 2.1 mmol $H_2$ in obersvation volume
- For 95 % accuracy 23 s needed

# Summary & Outlook

We showed succesfully:

- Detection of hydrogen in up to 100 m distance
- Detection of low hydrogen concentrations (2 vol.% in 80 m distance)
- Live detection of a hydrogen leak

- Hard targets can affect the measurement if the distance is smaller than the resolution limit
- Estimation of minimum needed integration time due to poisson distribution
- Next steps:
  - Design of a compact system
  - Afocal sytem to get a ‚real‘ LIDAR
  - Simultaneous measurement of signal and reference

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