Laser-proton acceleration from a cryogenic hydrogen jet at the DRACO PW laser

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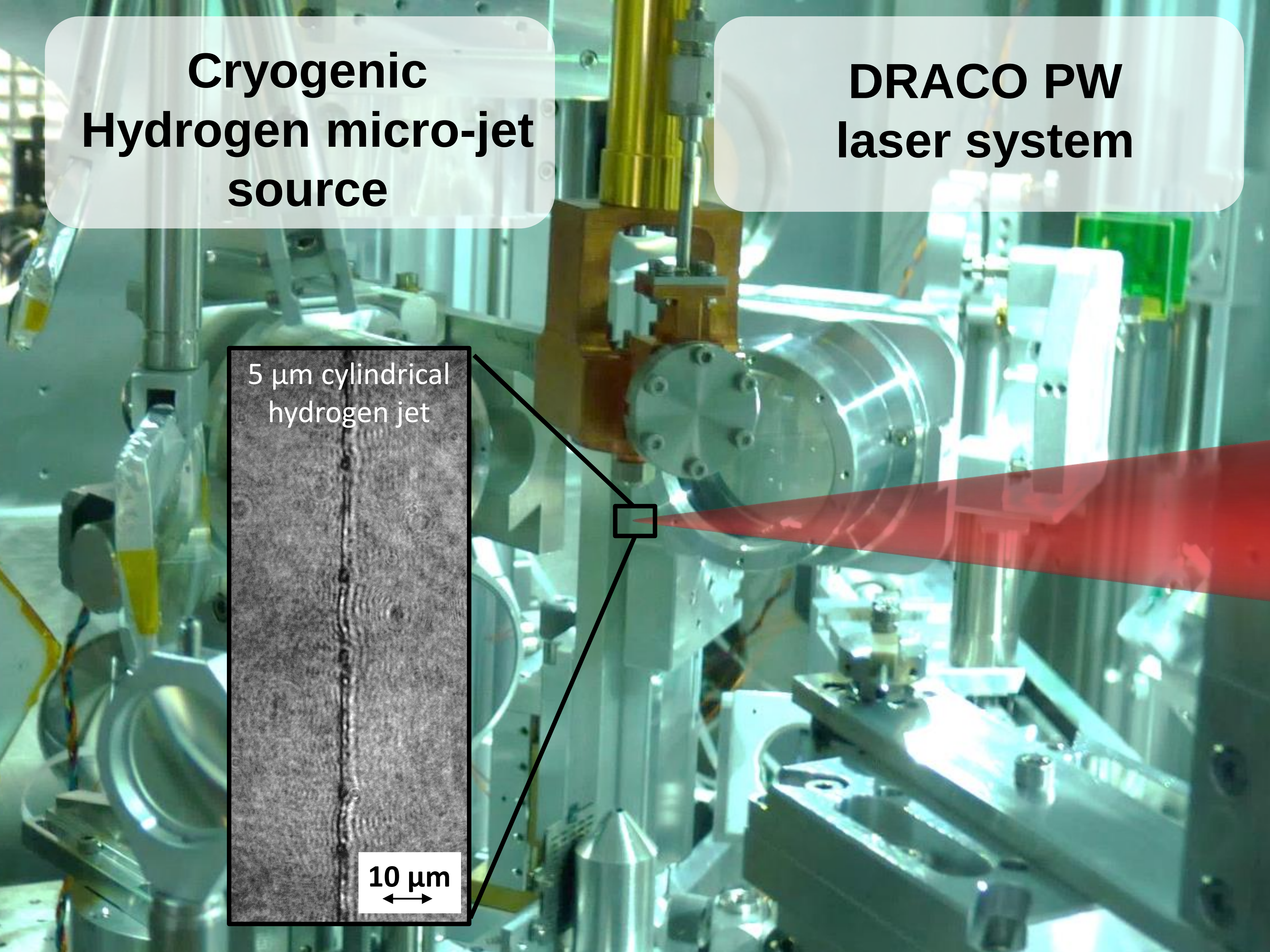
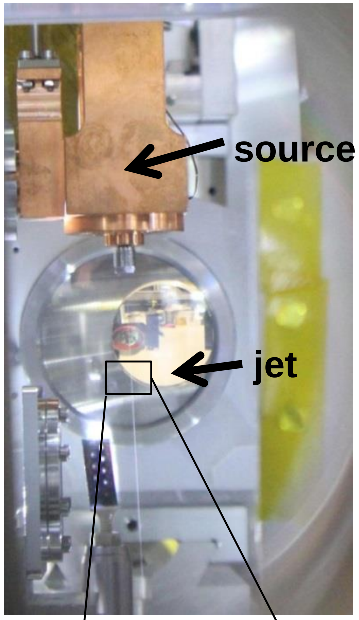
Laser Plasma Accelerator Workshop 2019

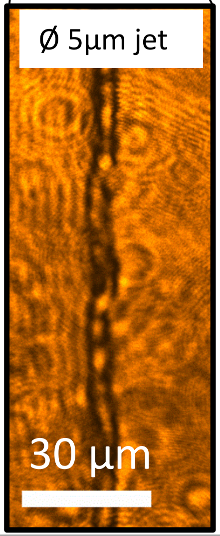
Split, Croatia – 06.05.2019


Cryogenic Hydrogen micro-jet source
DRACO PW laser system
5 µm cylindrical hydrogen jet
10 µm

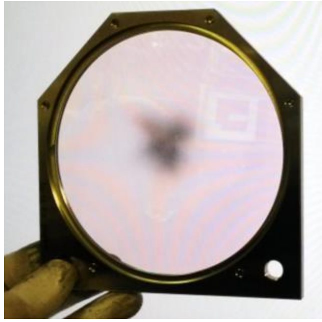
Why using a cryogenic Hydrogen jet?

1. Target development for applications (e.g. ion therapy)





- Debris-free target → long term operation
- Pure proton target
  → mono species particle acceleration
- Flow speed: ~ 100 m/s
  → repetition rate > 1 Hz
- Different geometries: e.g. cylindrical (2, 5, 10 µm diameter) or planar (e.g. 2 x 20 µm^2)
- Multiple gases and mixtures: H_2, D_2, Ar, Ne, He



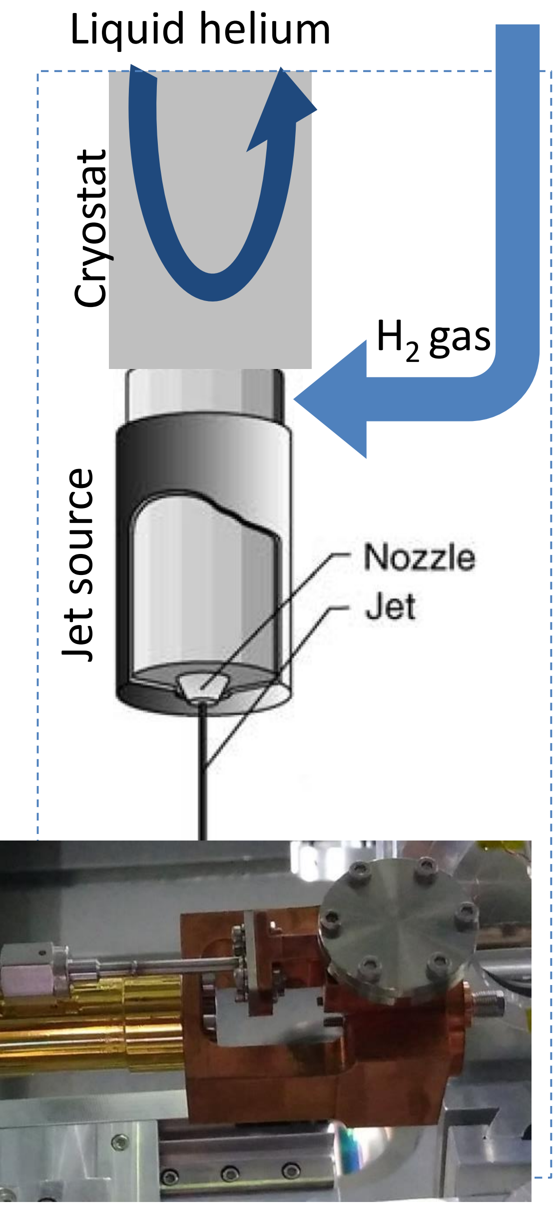
Poster: A. Huebl

- Requirement: stable and reliable target

2. Acceleration from near critical density target, enhanced TNSA schemes or shocks

- Plasma density: 30 n_c @ 800 nm ~ 5x10^{22} e$^-$/cm^3
- Target can get relativistically transparent
- Comparison with PIC-simulations
- Study plasma dynamics with optical probing

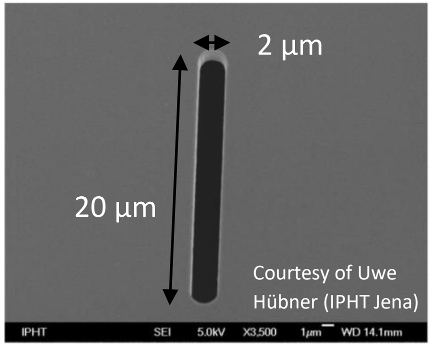
Basic operation principle (exemplary for H_2)



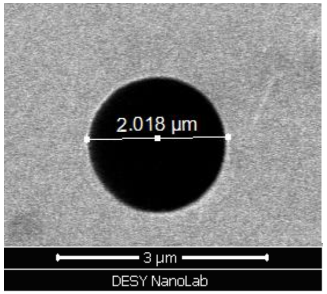
- Cryostat and source cooled down by using liquid helium (16-20 K)
- Hydrogen liquefied inside source
- Liquid hydrogen pressed through the nozzle
- Evaporative cooling causes freezing in vaccum

→ produce solid and continuous jet

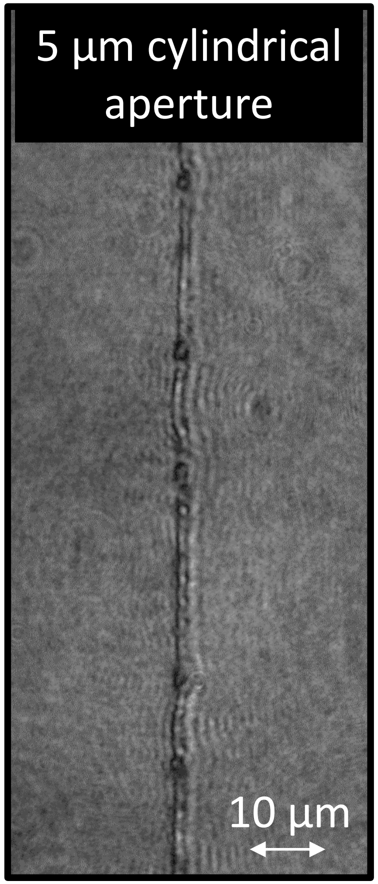
Slit aperture

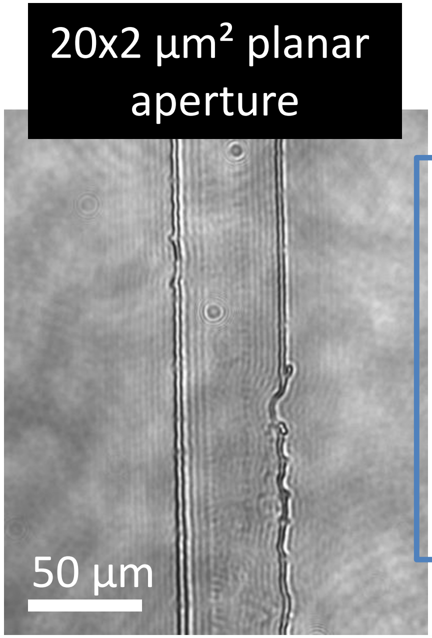


Cylindrical aperture

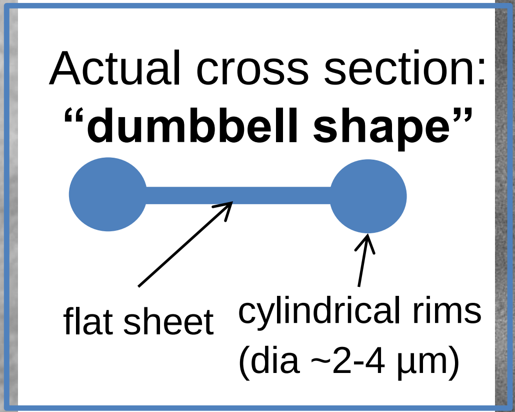


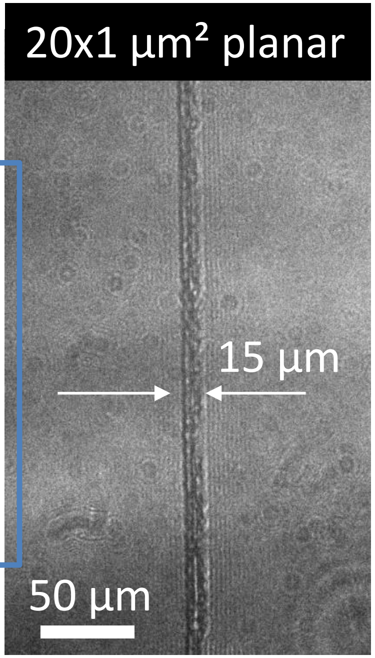
Shape and size of cryogenic jets





< 250 nm thick (upper limit)



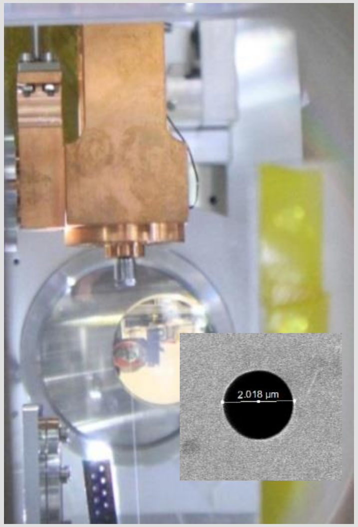


Tunable target characteristics (e.g. thickness, length) by controlling operation parameters

Implementation in target area is challenging → robust cylindrical jet to begin with

Collaboration with HED group from SLAC

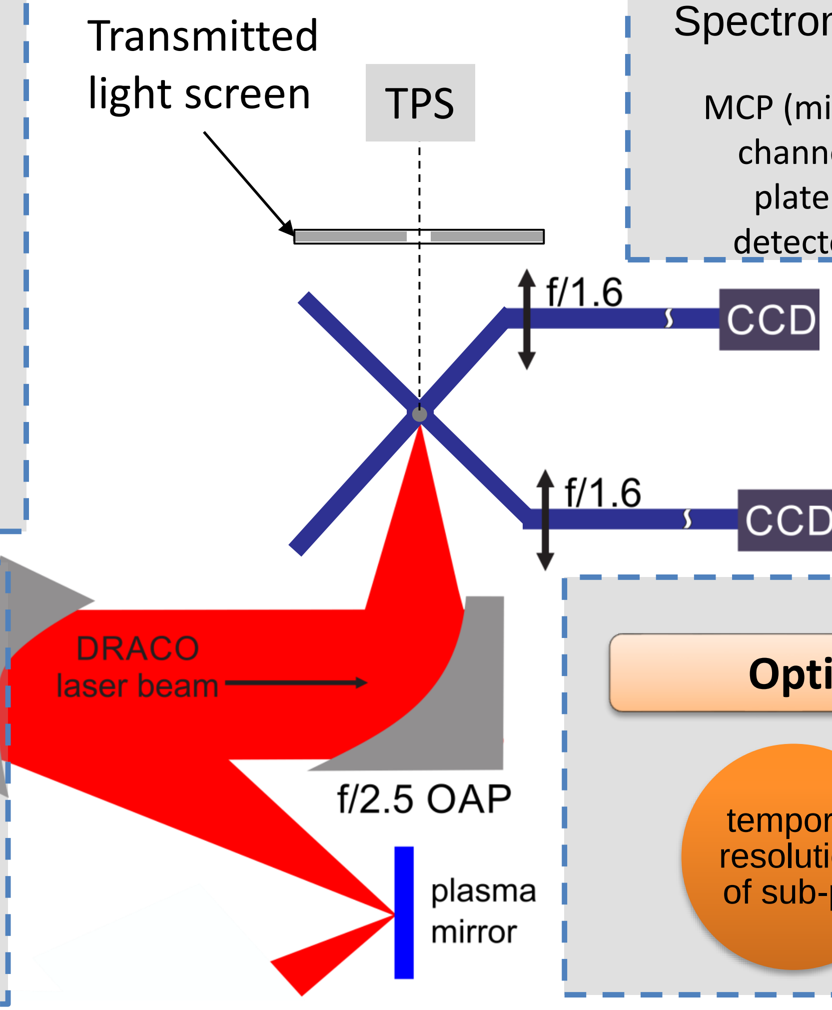
5 µm cylindrical cryogenic H2 jet



J. Kim, S. Göde and S. Glenzer, Rev. Sci. Instr., (2016)

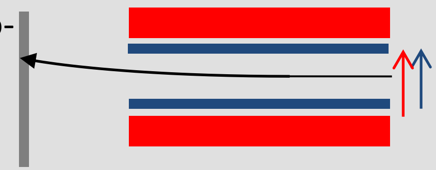
Ti:Sapphir Draco

- Up to 23 J on target,
- 30 fs pulse duration
- Focused to a spot size of ~ 3 µm



Proton beam diagnostics:

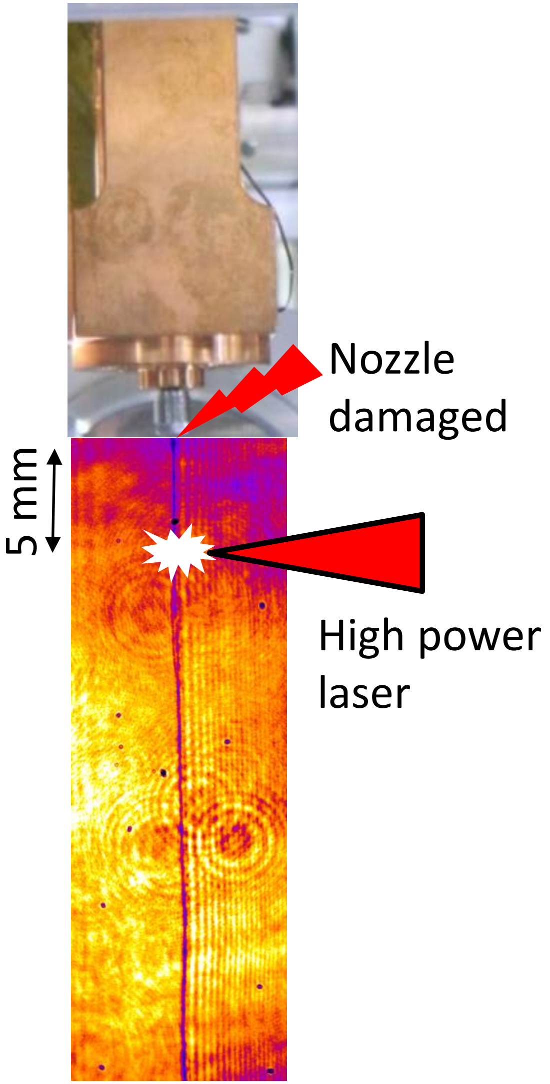
Proton beam spectra:
Thomson Parabola Spectrometers



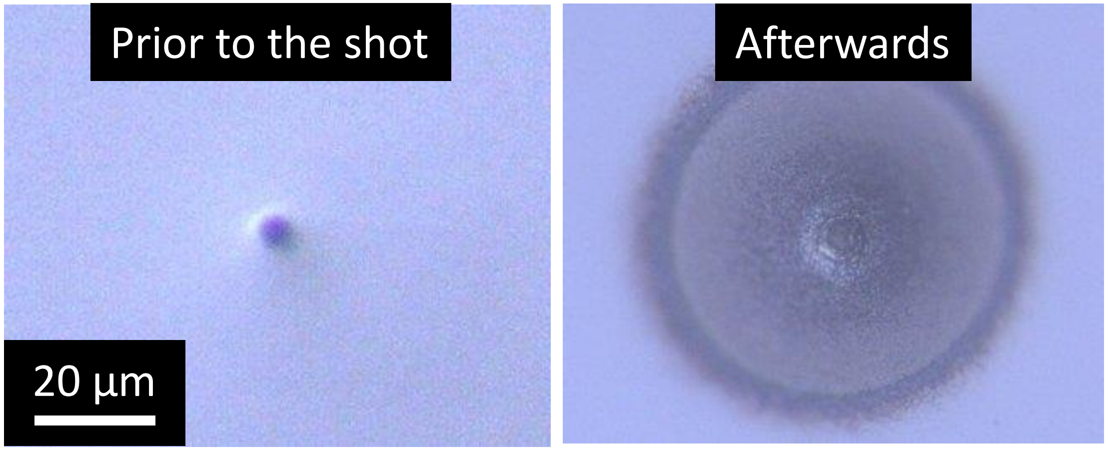
Optical probe setup

temporal resolution of sub-ps + spatial resolution of µm

Implementation in the experiment



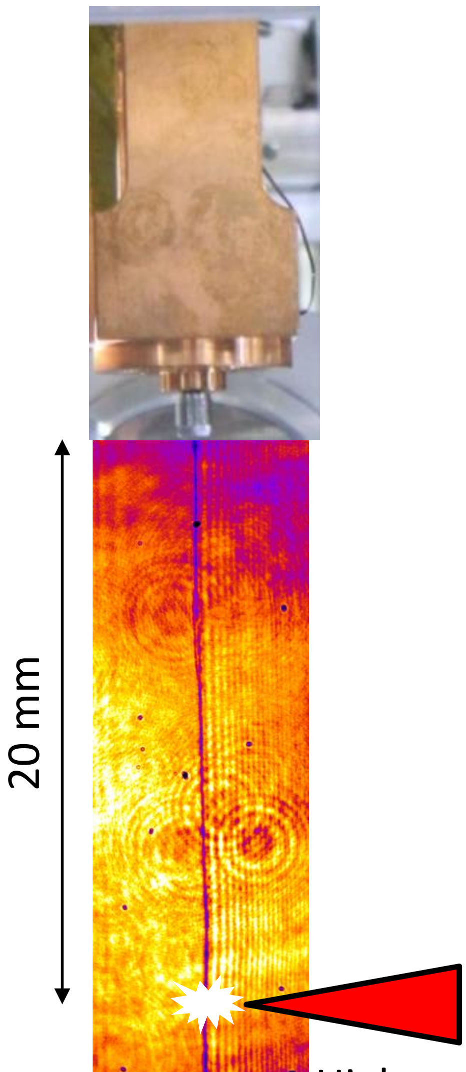
- Requirement: stable and reliable target
- Continuous flow -> spatial jitter increasing with distance from nozzle
- Microscopic images of cylindrical 5 µm Nozzle



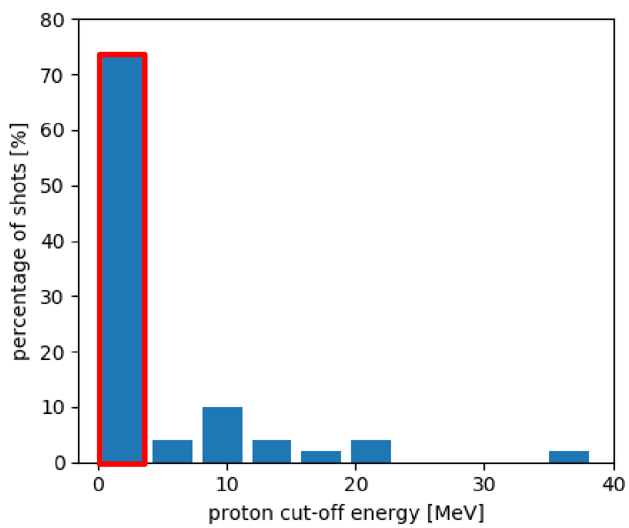
Implementation in the experiment

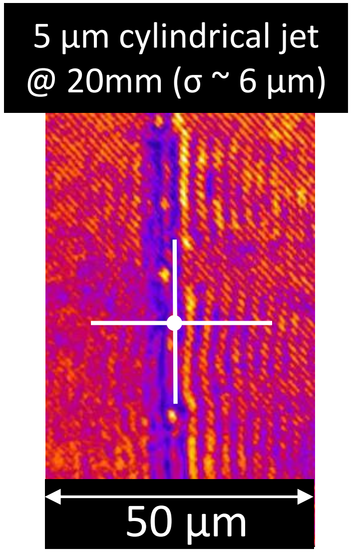
Prevent damaging the nozzle

Solution 1:
Increase distance
→ hit propability is ~ 30%



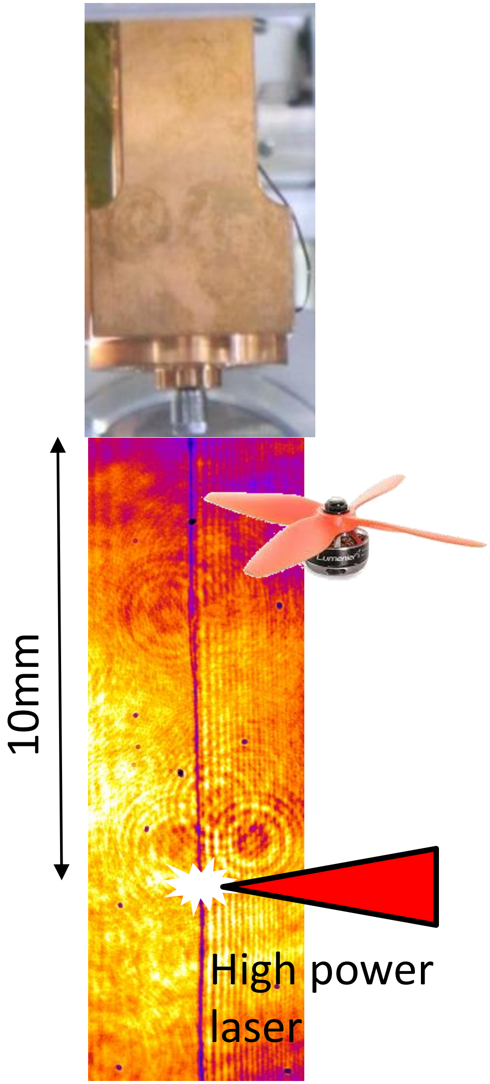
High power laser





Prevent damaging the nozzle

Solution 2:
Blocking the line of sight



Implementation in the experiment

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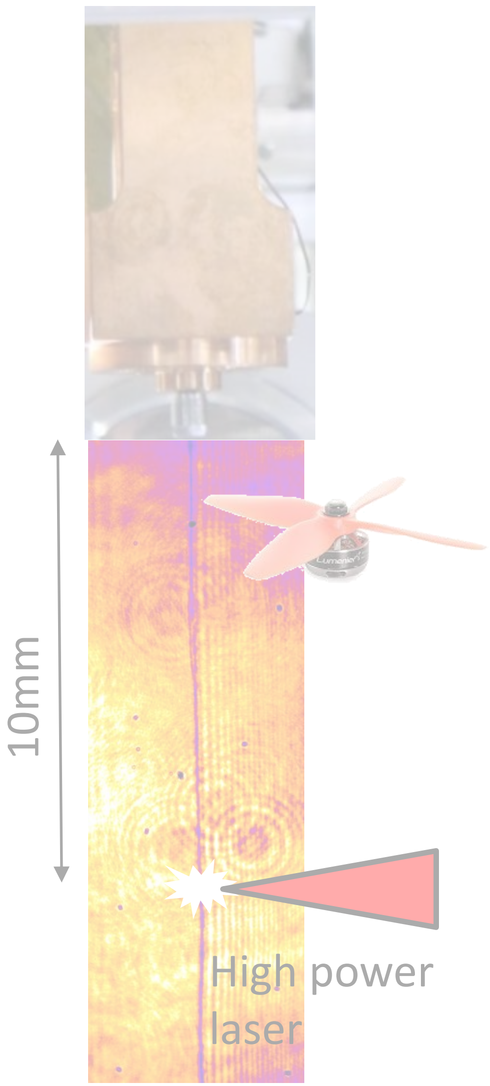
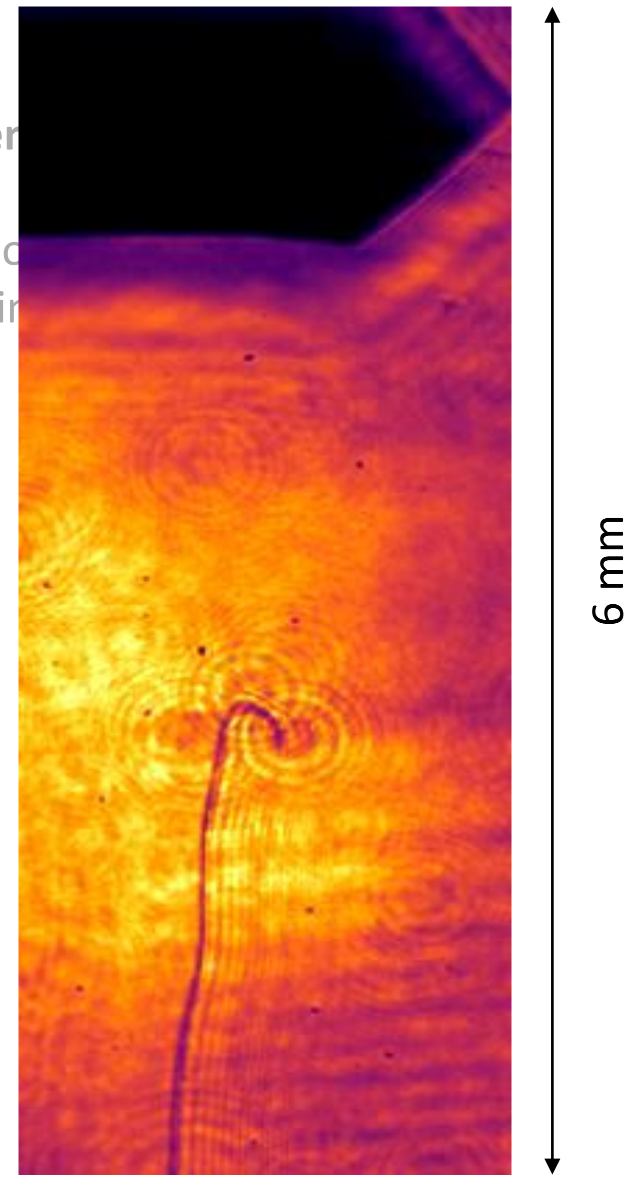
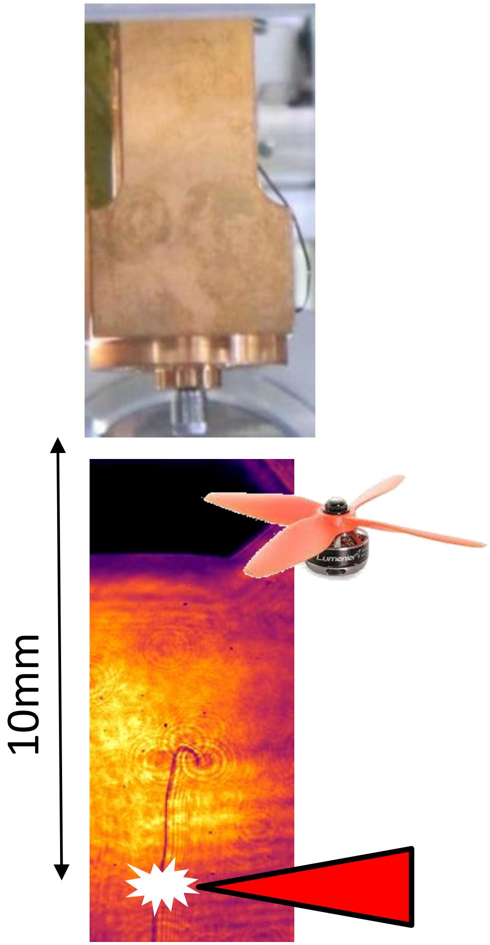
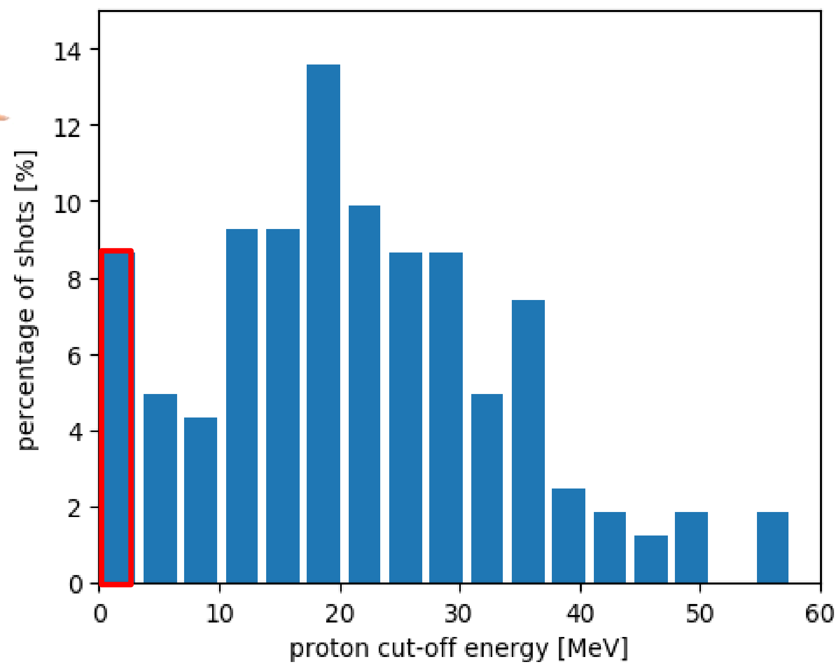


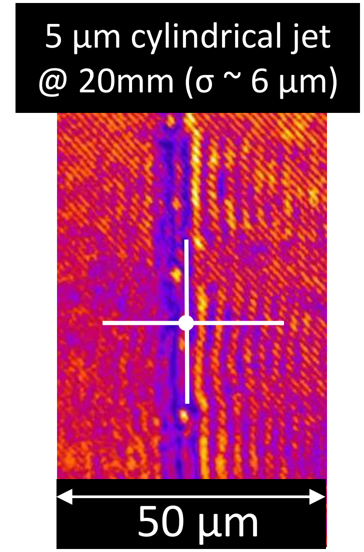


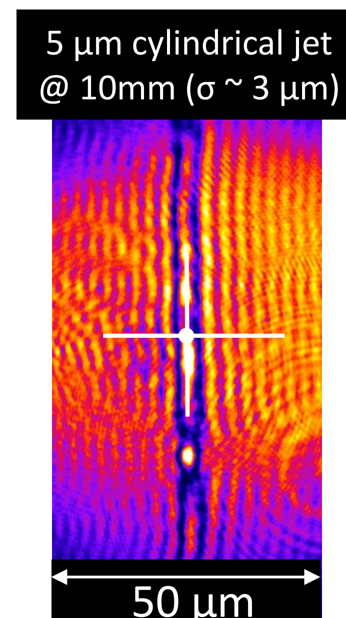


Prevent damaging the nozzle

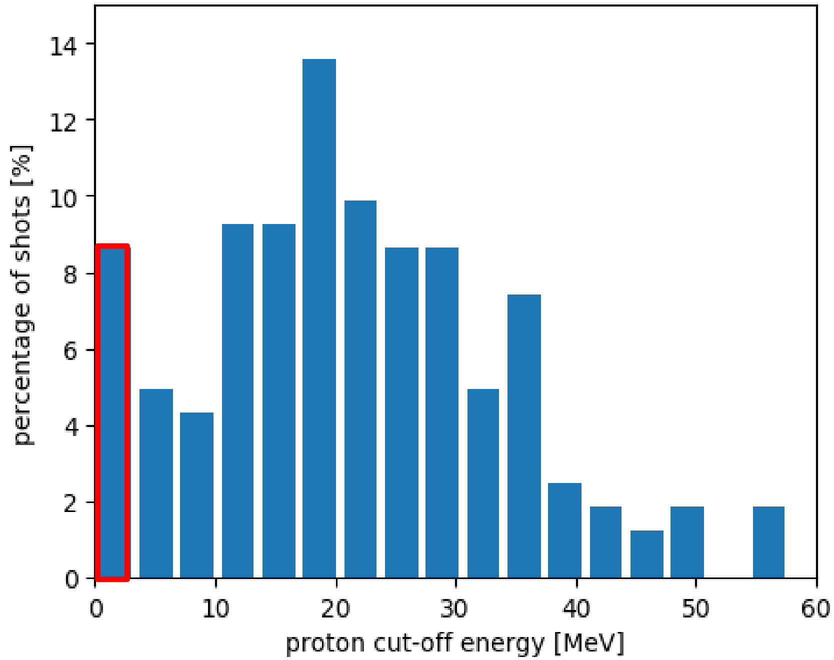
Solution 2:
Blocking the line of sight
→ hit propability > 90%

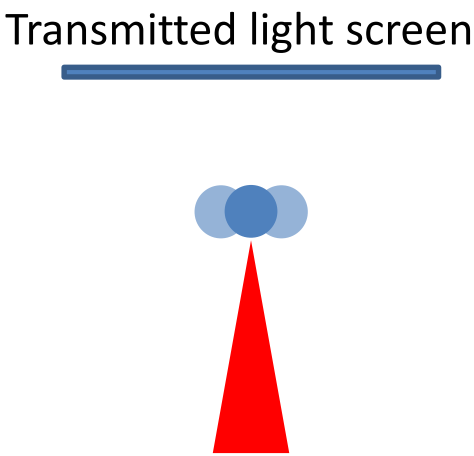


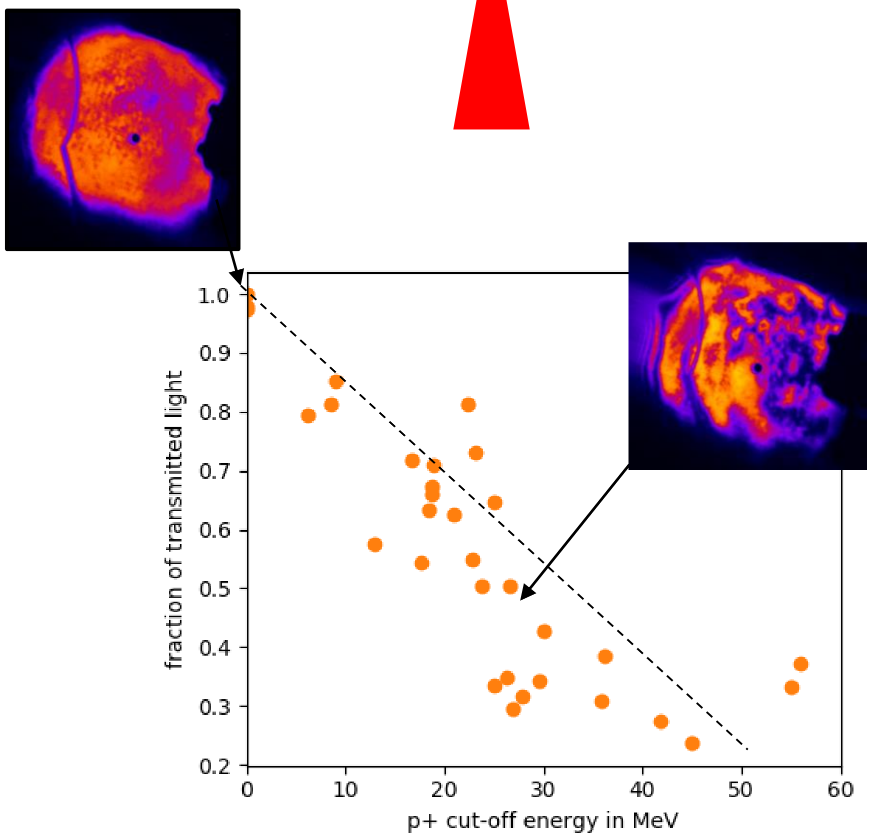




Preliminar experimental results

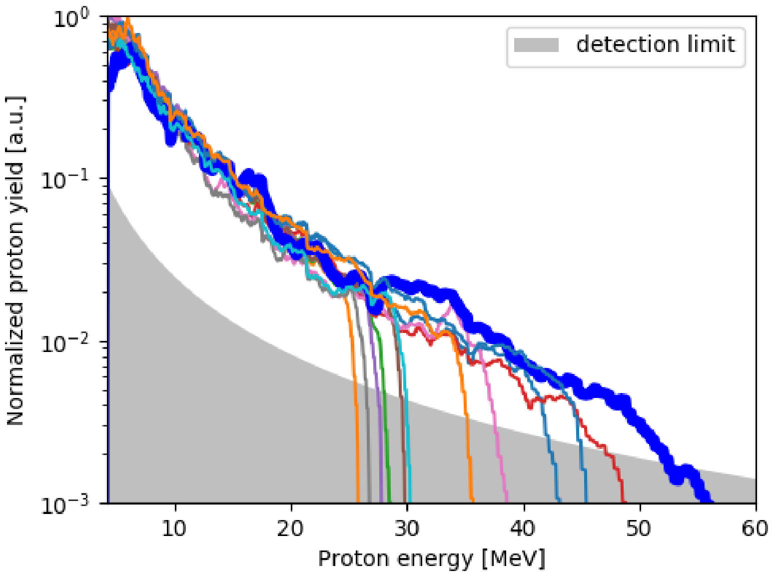


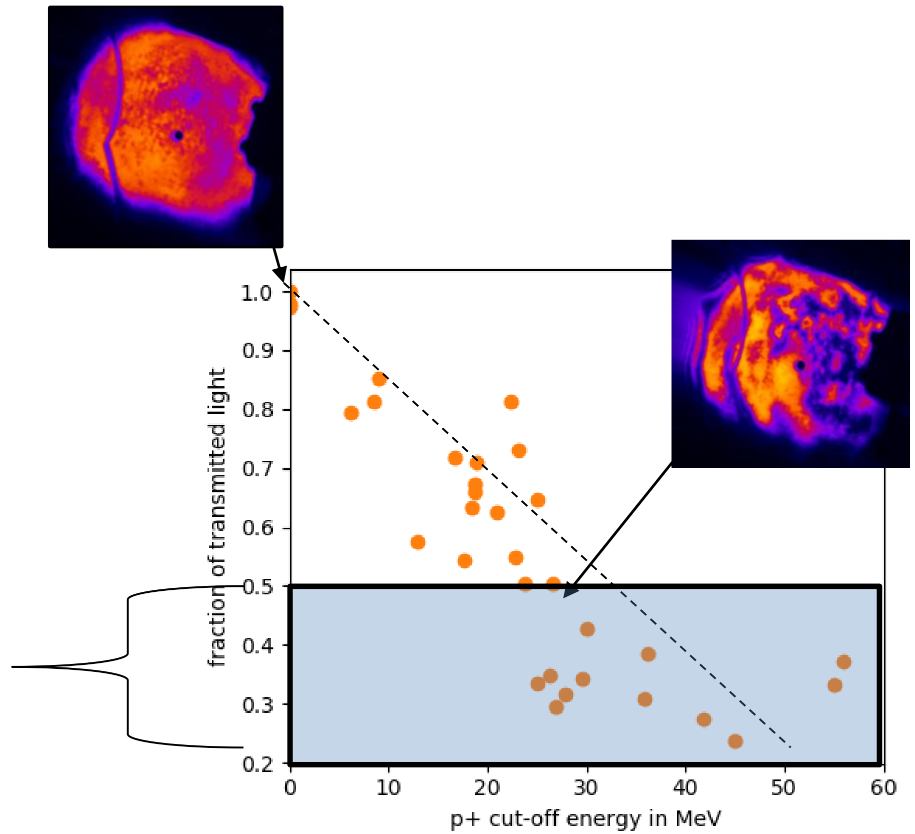




Preliminar experimental results

- For significant laser target overlapp
  → proton cut-off energies > 25 MeV
  → stable particle numbers up to 25 MeV
- Selected shots with 50-60 MeV cut-off energy





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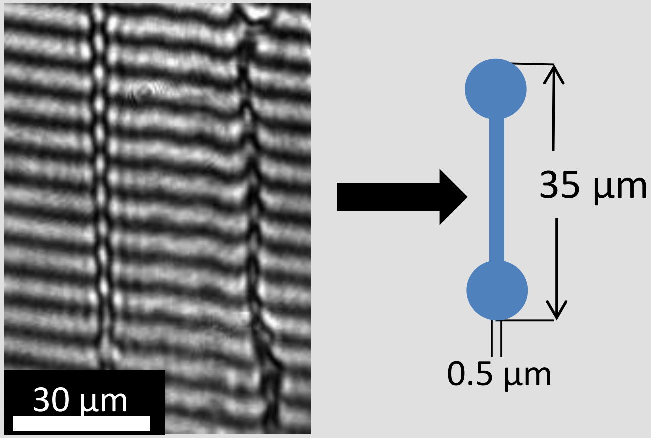
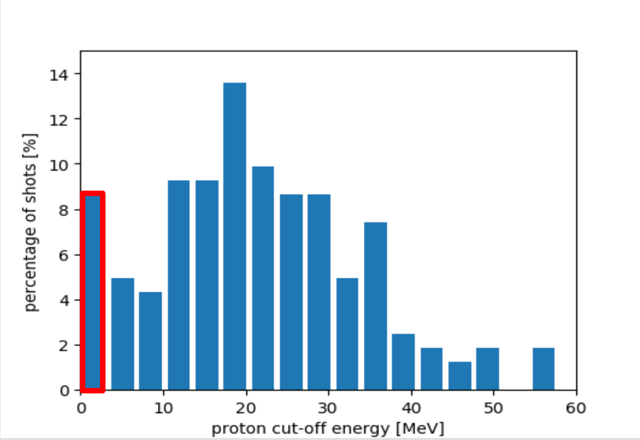
Conclusion

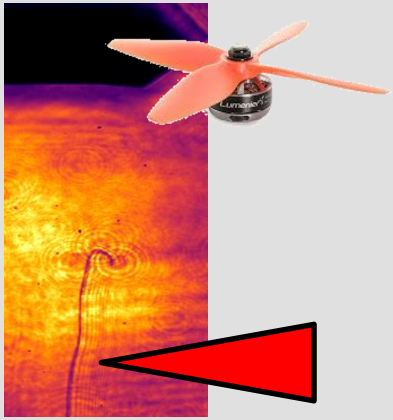
- Target characterization: e.g. size and shape of a planar jet:



- Implementation at the DRACO PW Laser

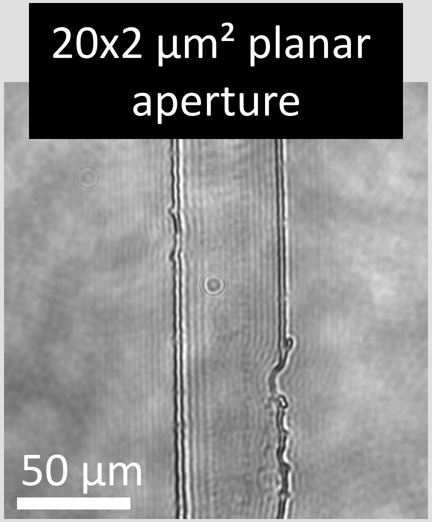


- Stability improvements



- Outlook:

Planar jets
- Thin and width target



multiple filamentation of freely propagating 100 TW beam in air

Thank you for your attention