Laser proton acceleration of mass-limited-targets of different materials

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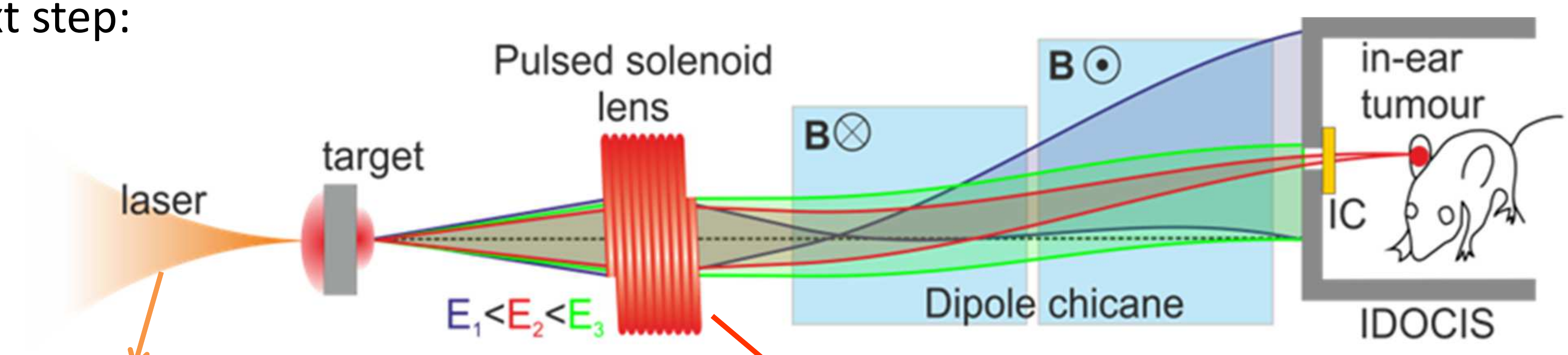
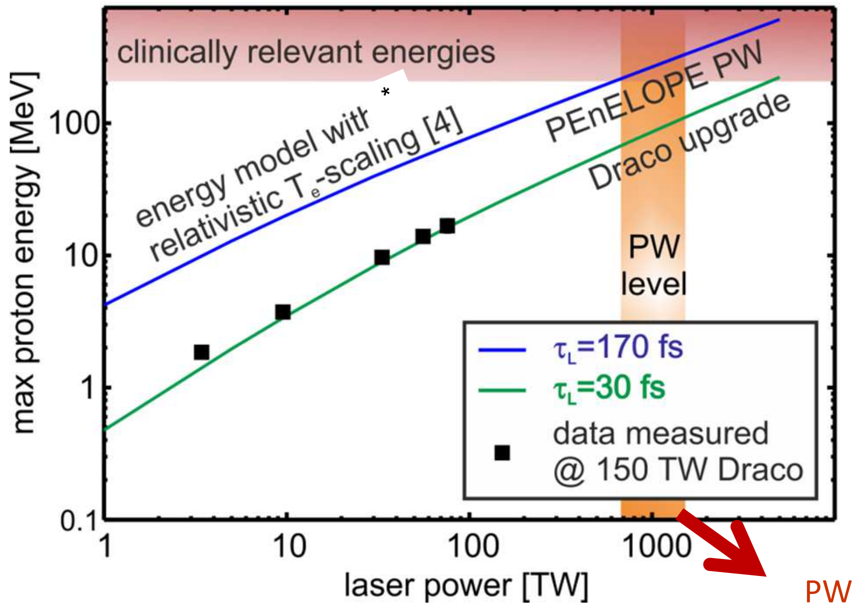
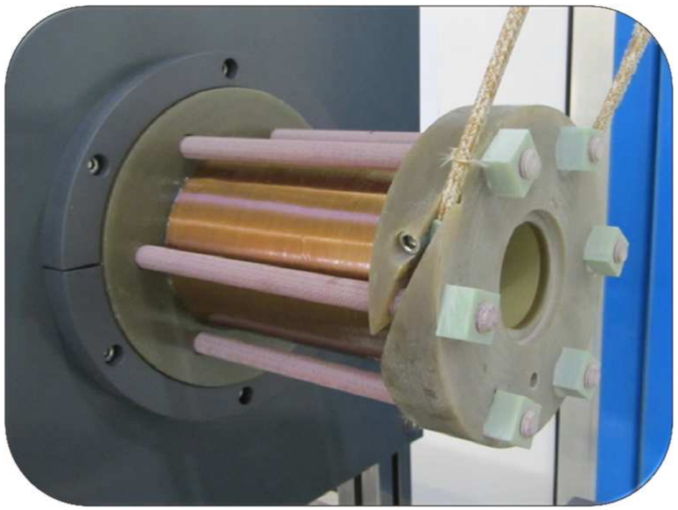
G. Becker, M. Hornung, R. Lötzsch, M. Kaluza, T. Kämpfer, J. Reislöhner, I. Uschmann

in vitro irradiations can be performed with lasers [Kraft *et al.* (2010), Yogo *et al.* (2011), Zeil *et al.* (2012)]
next step:





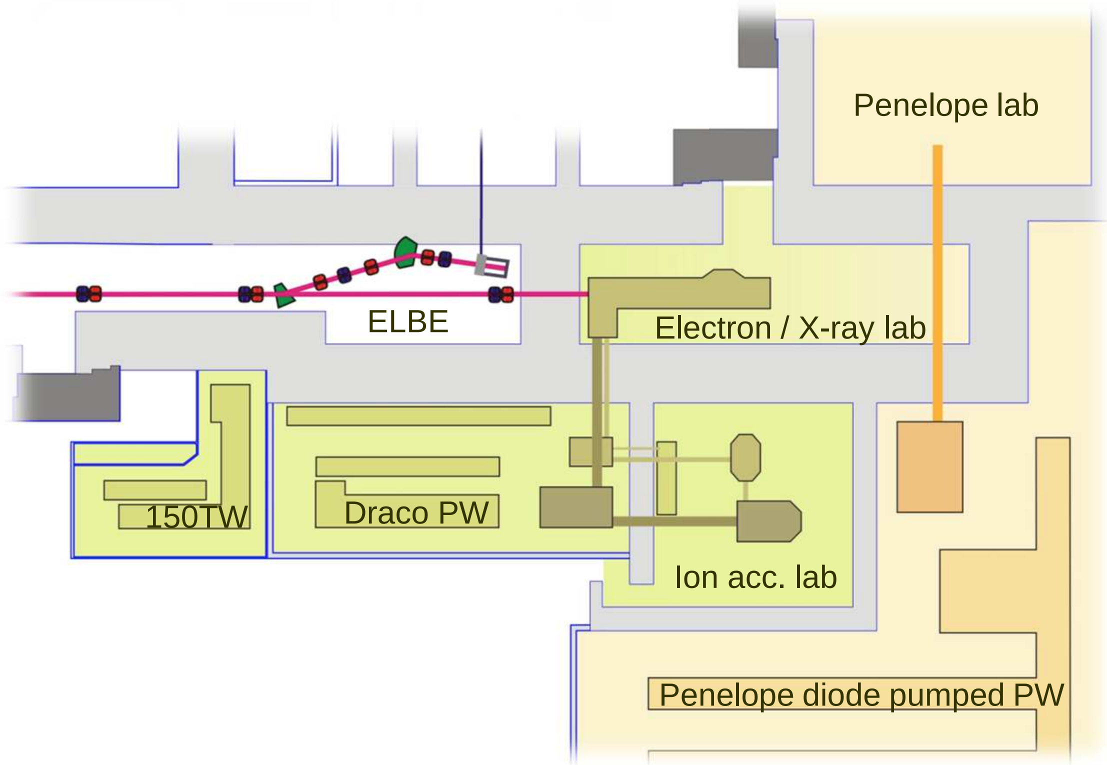
PW laser
Projects @HZDR



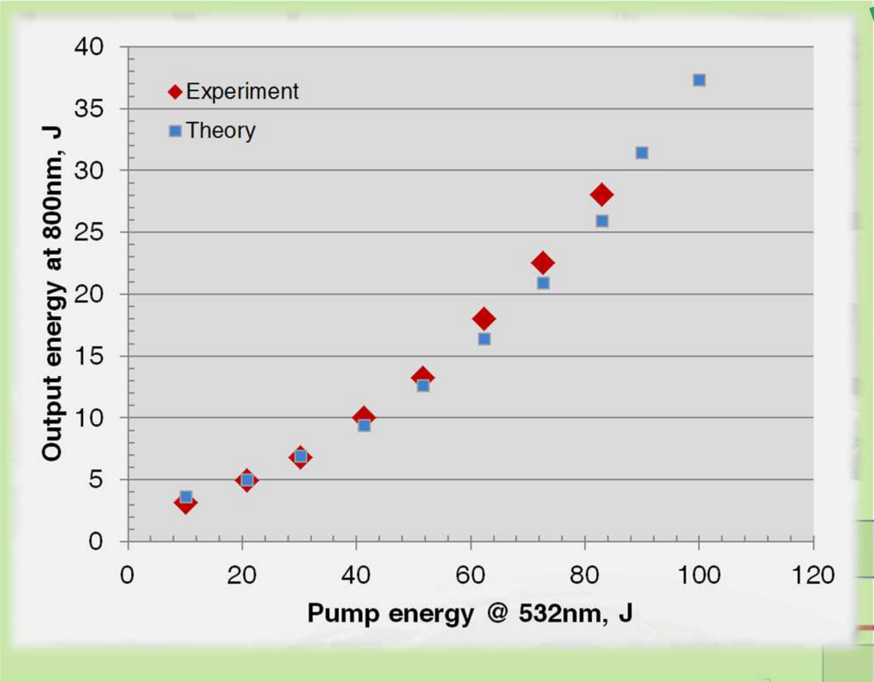
*T. Kluge et al., Phys. Rev. Lett. 107 (2011), 205003

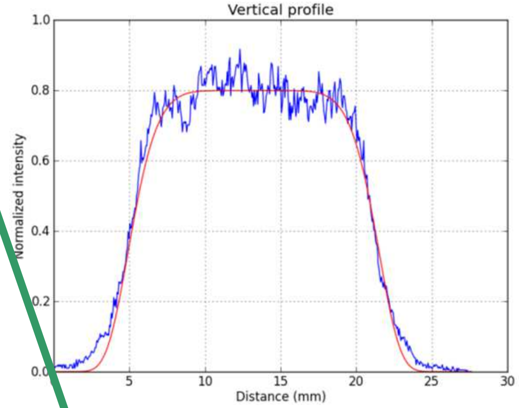
Draco dual-beam schedule:

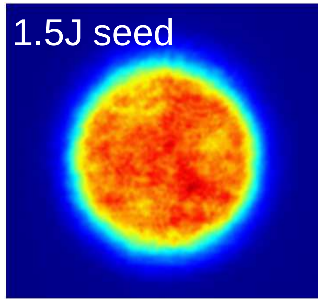
- 150TW (4J in 30fs on target) with
  - improved contrast in new target areas operational
- PW (30J / 30fs) amplifier installation running, on target summer 2015

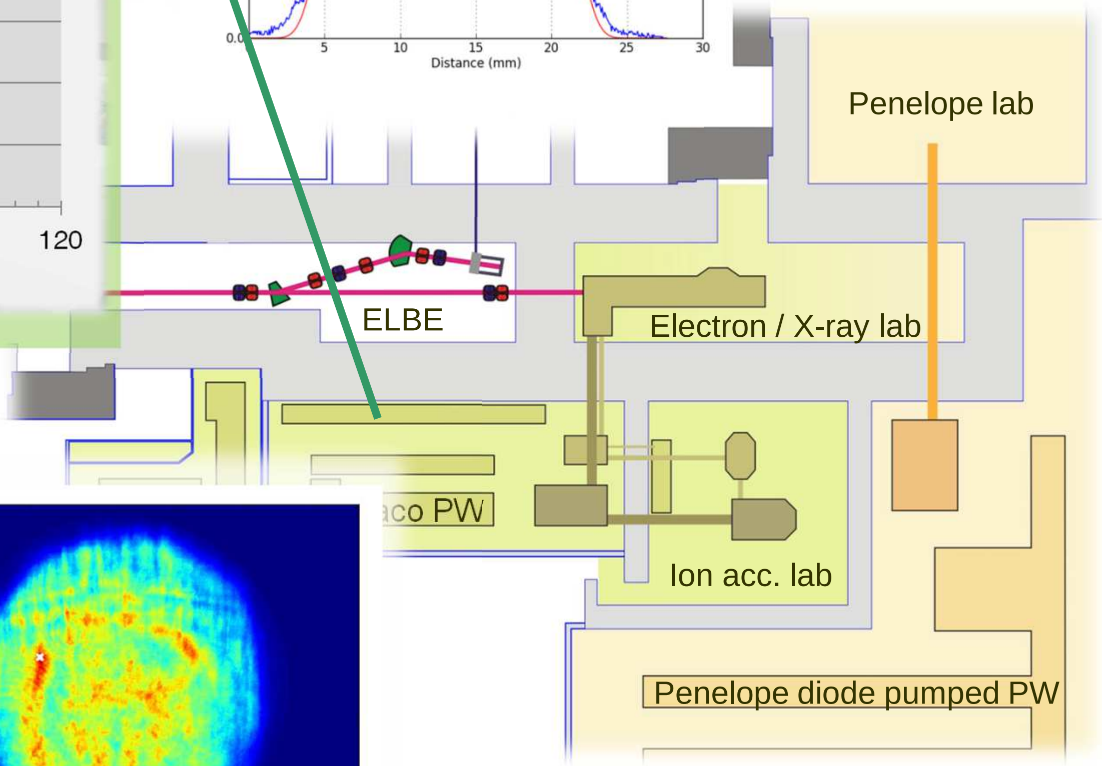


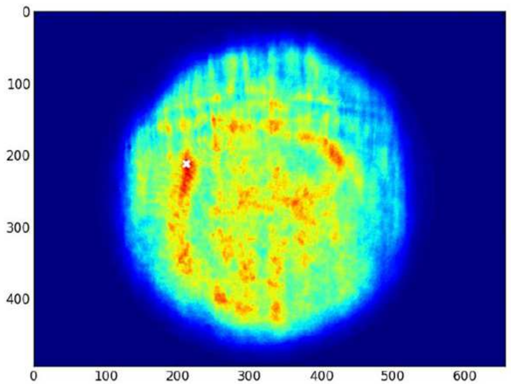
PW laser status at HZDR – Draco PW upgrade

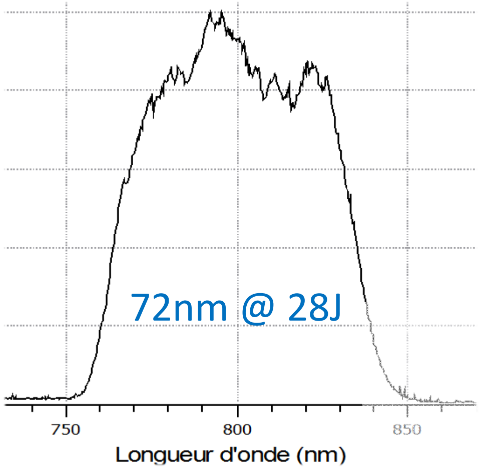




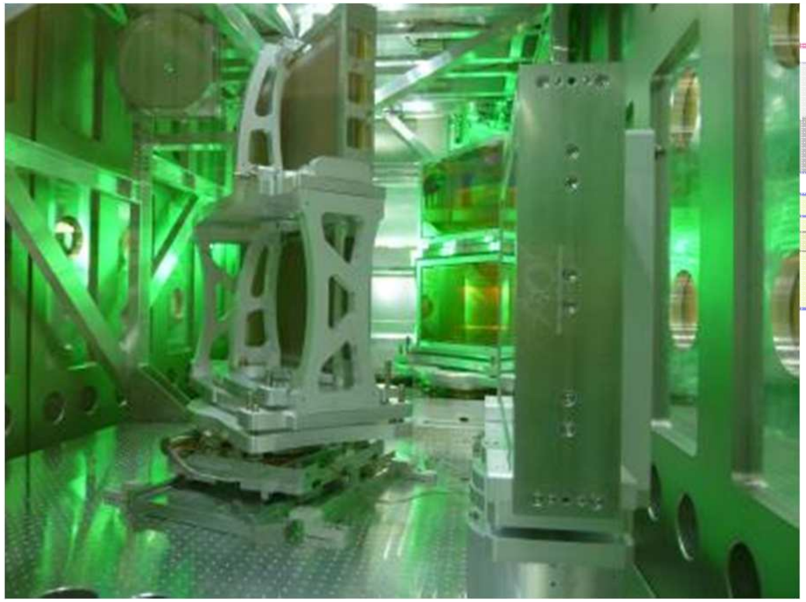


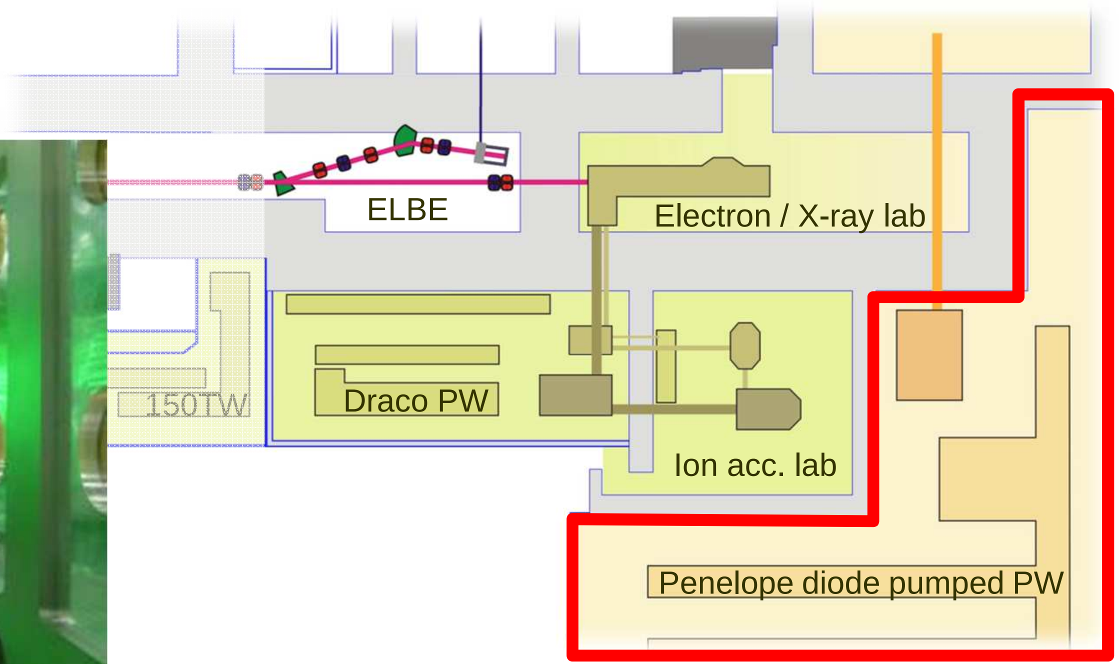






- Compressor / beamline installed
- Target areas operational



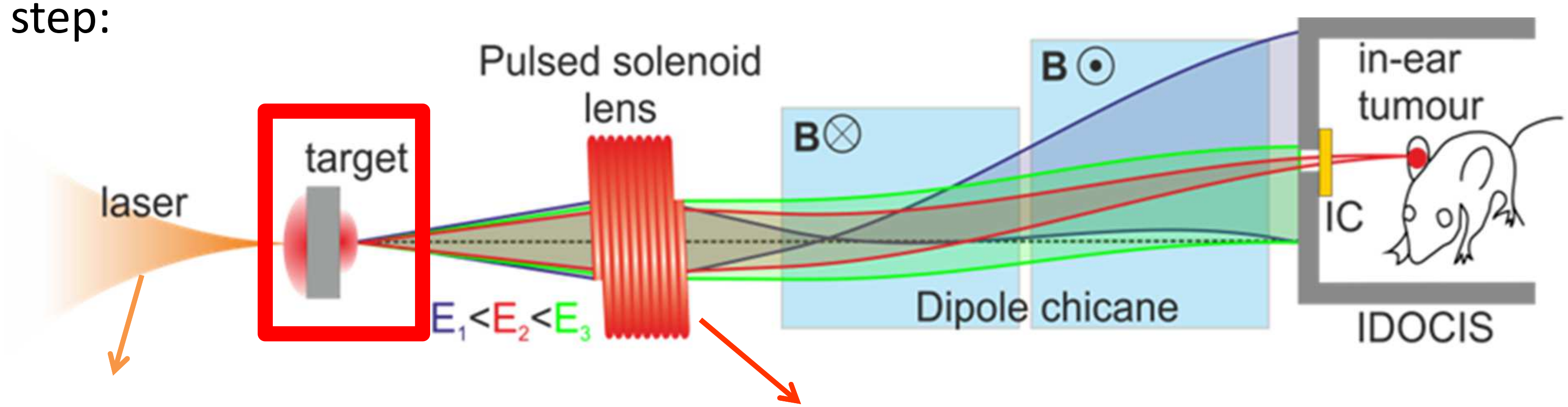


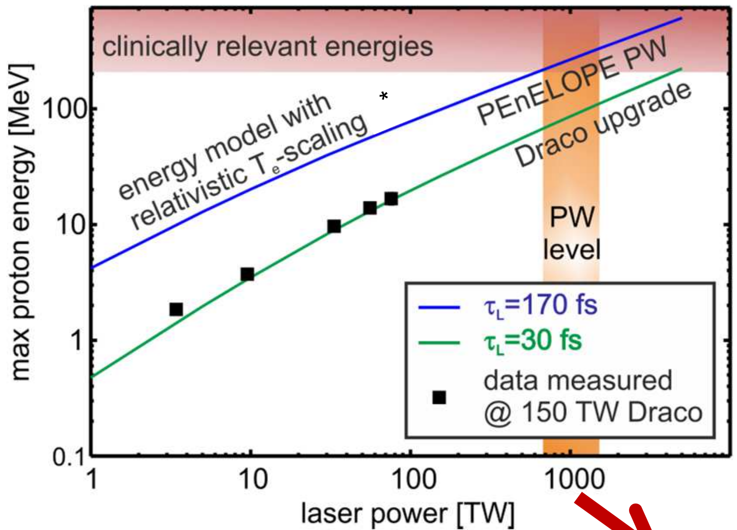
PW Laser, 150 fs

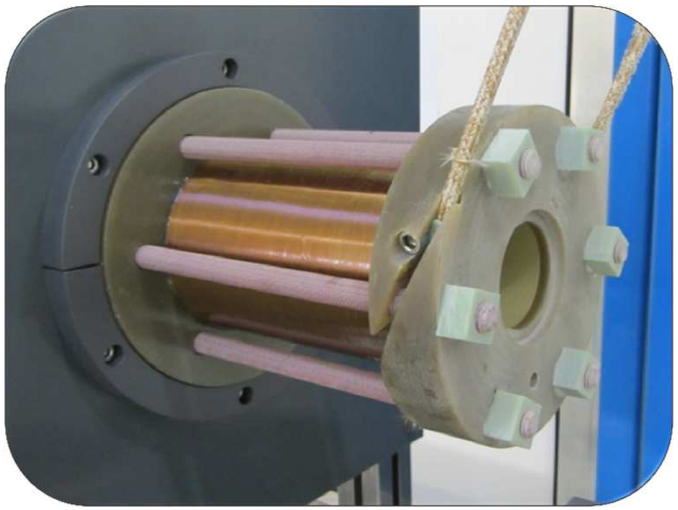
Motivation – Laser driven ion therapy

in vitro irradiations can be performed with lasers [Kraft *et al.* (2010), Yogo *et al.* (2011), Zeil *et al.* (2012)]

next step:







PW laser
Projects @HZDR

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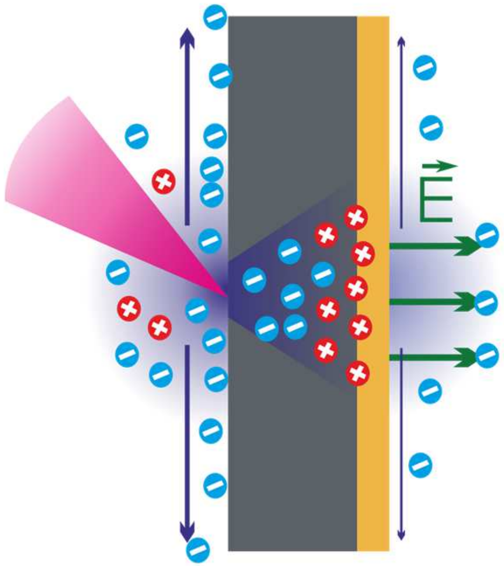
LiGht Laser Ion Generation, Handling and Transport

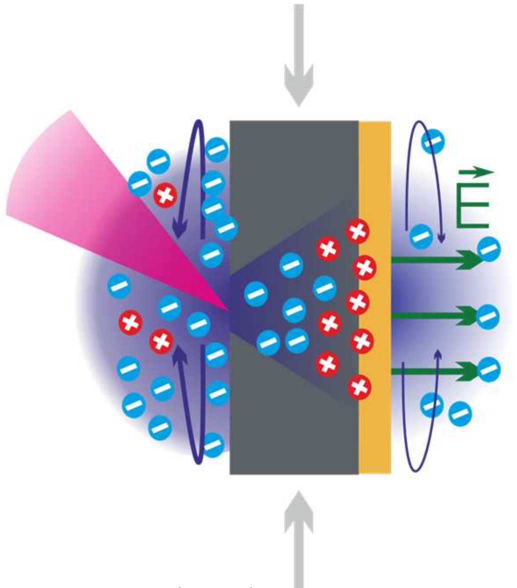
oncooptics

TNSA from Reduced Mass Targets



TNSA at large foil

- electrons laterally spread along the target surface



RMT

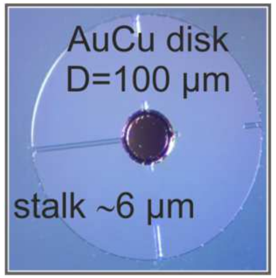
- electron reflection at target edges
- T_e and n_e increased
- time averaged hotter and denser sheath

→ **increased proton energies**

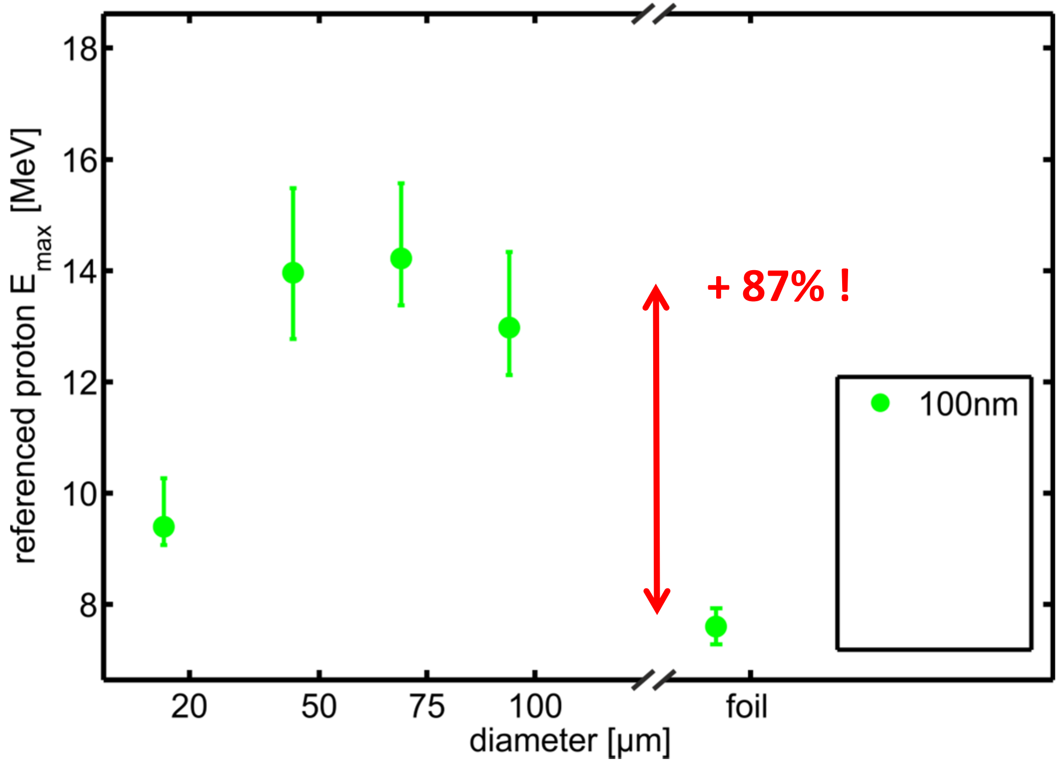
Psikal Phys. Plasm. 15 (2008), Kluge Phys. Plasm. 17 (2010)

AuCu disks and ultra-short pulses

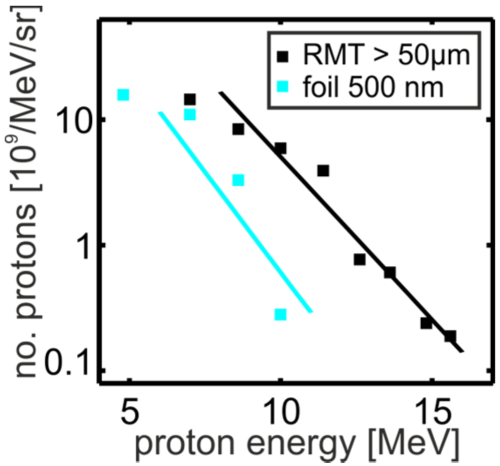
Laser: 3 J, 30 fs, 10^{21}W/cm^2
Diameters: 20 – 100 µm
Thicknesses: 100 nm – 1 µm



- maximum proton energy



- proton yield

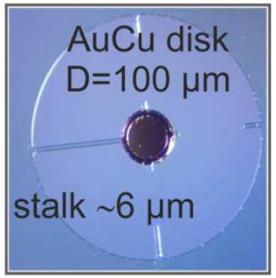


K. Zeil, et al., PPCF 56, 084004 (2014)

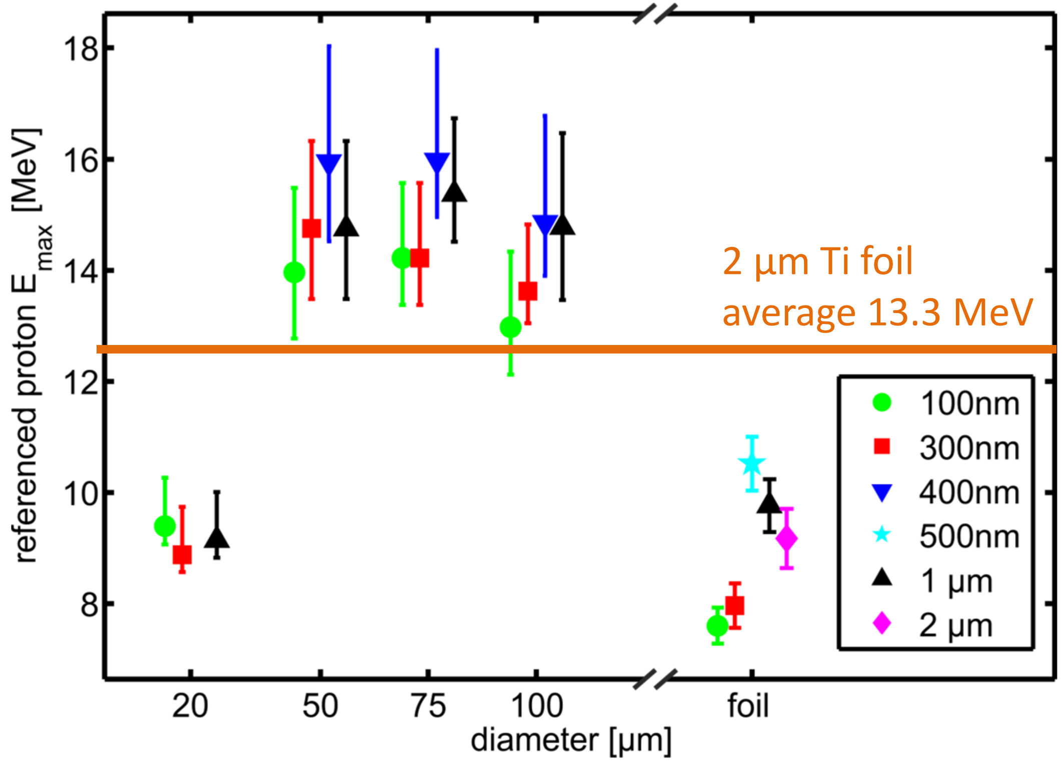
- absolute gain in proton energy and yield for given laser parameters !!
- time averaged hotter, denser and more homogenous sheath

AuCu disks and ultra-short pulses

Laser: 3 J, 30 fs, 10^{21}W/cm^2
Diameters: 20 – 100 µm
Thicknesses: 100 nm – 1 µm



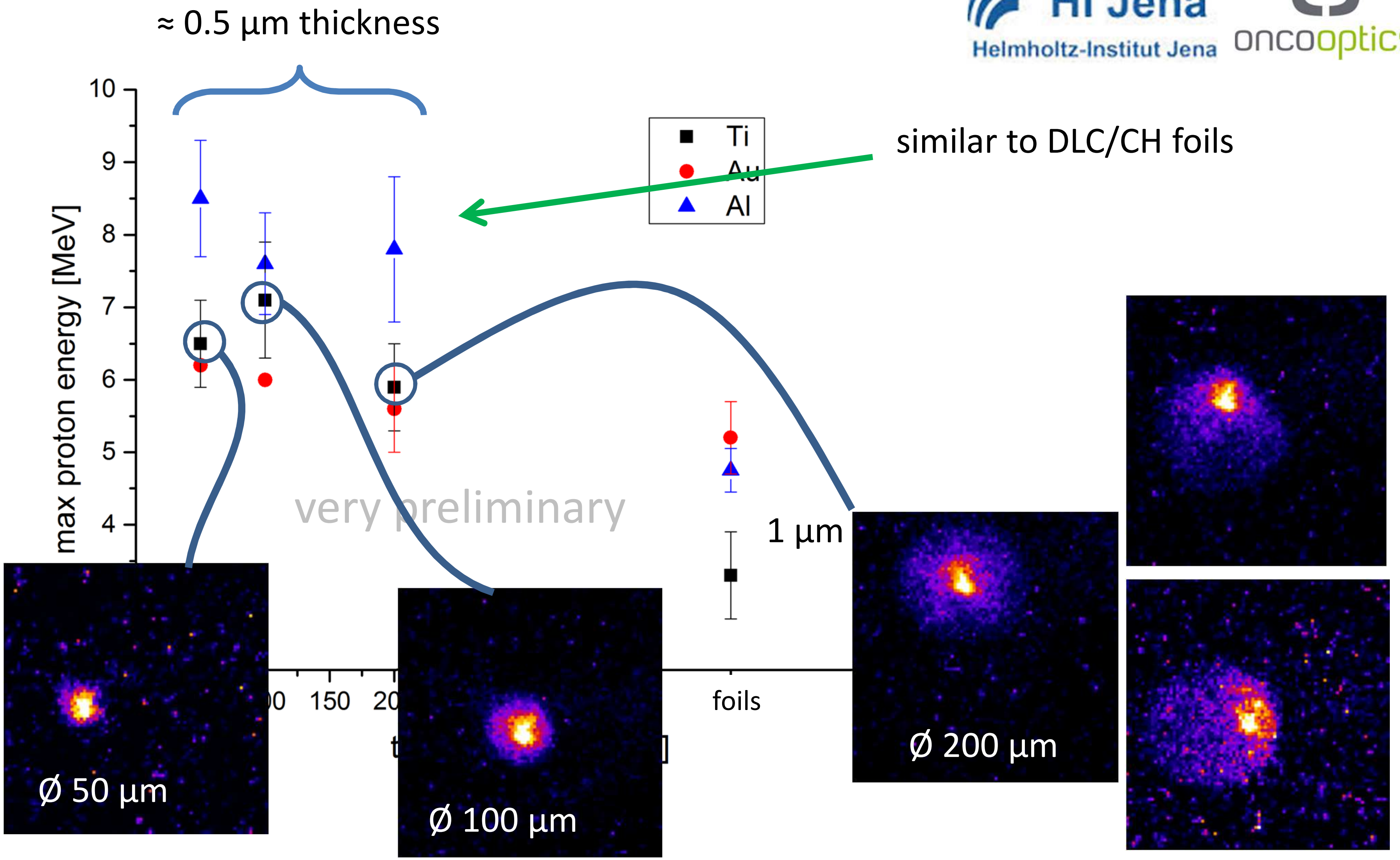
- maximum proton energy



K. Zeil, et al., PPCF 56, 084004 (2014)

- Obvious target material dependence
- Complex interplay between target parameters relevant for TNSA

Disk targets of different material



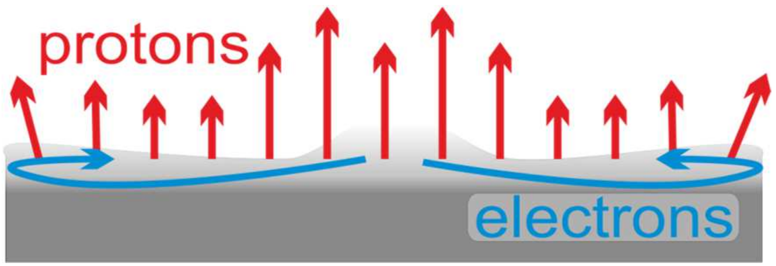
Ti Kα Images at backward direction (near OAP)

Disk targets of different material

HI Jena Helmholtz-Institut Jena
oncooptics

≈ 0.5 µm thickness

- Similar performance for difference in size, thickness, material
- Robustness against laser contrast fluctuations
- Profit from robust acceleration performance and enhanced proton number
- Very small targets (focus size) ?



→ Electron recirculation during acceleration

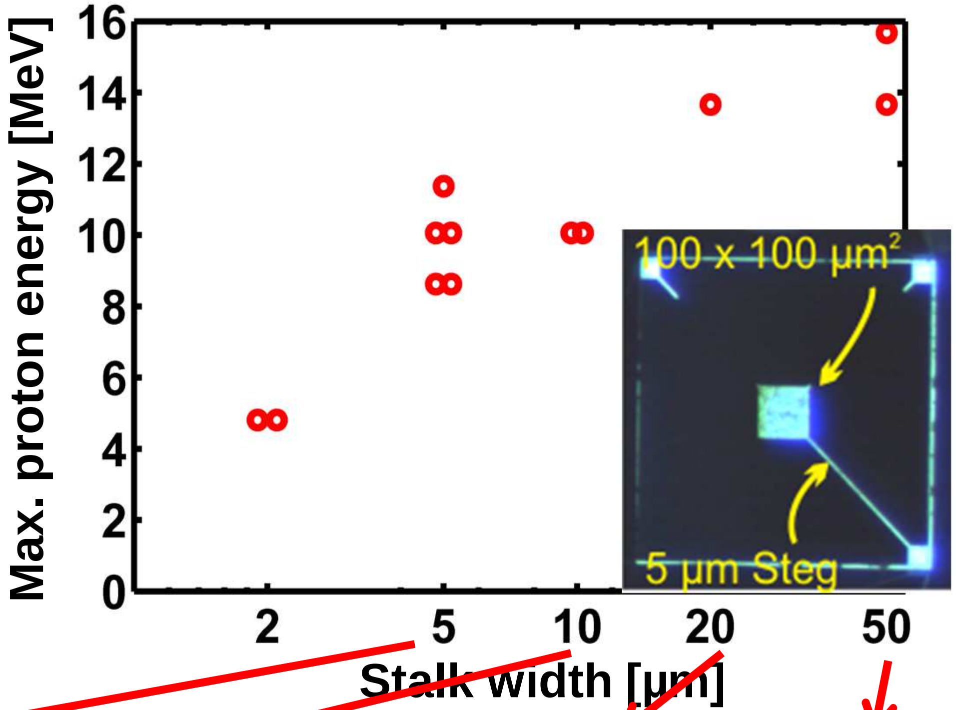
Ø 50 µm

Ø 100 µm

Ø 200 µm

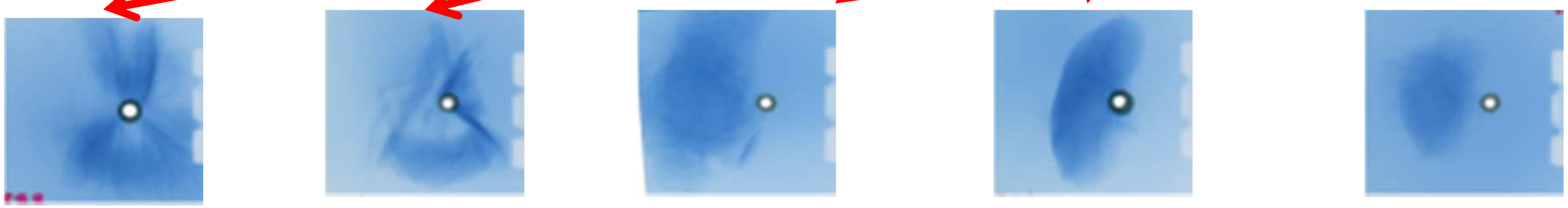
Ti Kα Images at backward direction (near OAP)

Target edge & stalk effects at DRACO



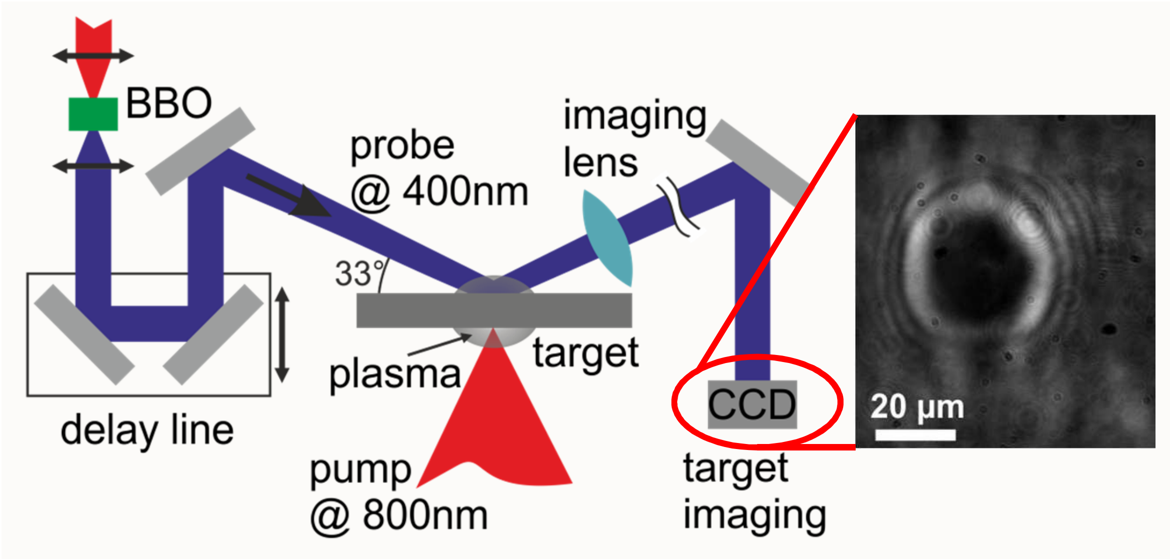
Folie

Proton beam profiles, E ≈ 9 MeV



- similar field strength at edges as in focal region
- edge fields prevent efficient plasma expansion
- further investigation using 3D PIC simulations required

Accessing target dynamics at critical density?



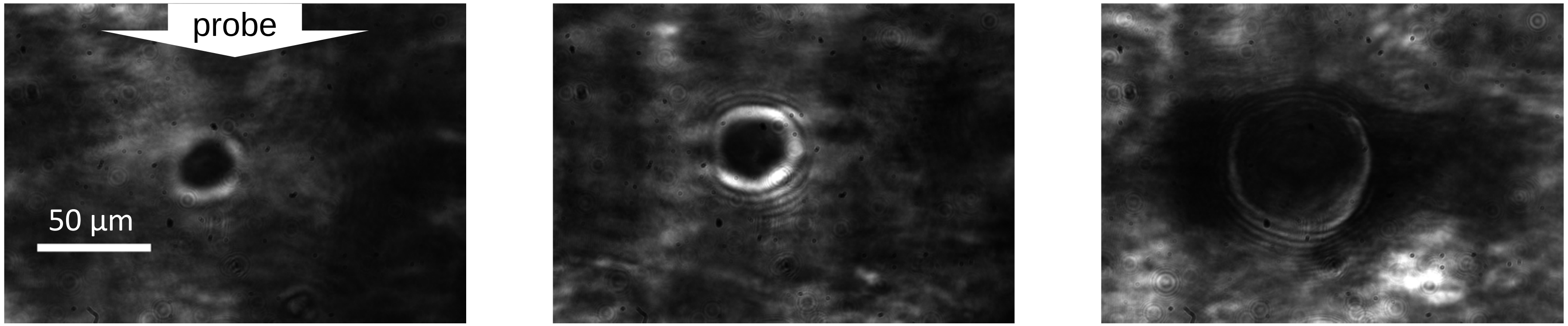
Pump

- ✓ t_p = 30 fs
- ✓ E_L = 40 – 220 mJ
- ✓ $I_{max} = 4 \cdot 10^{19} W/cm^2$

Probe

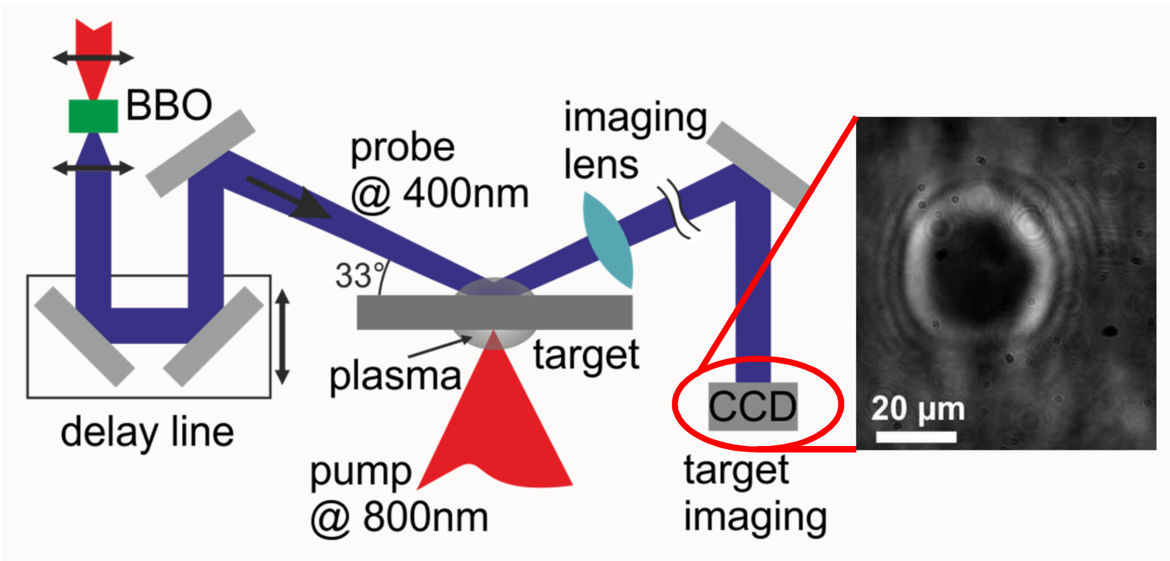
- ✓ $t_p \approx$ 130 fs
- ✓ E_L = 0.1% of pump
- ✓ $I < 3 \cdot 10^{12} W/cm^2$

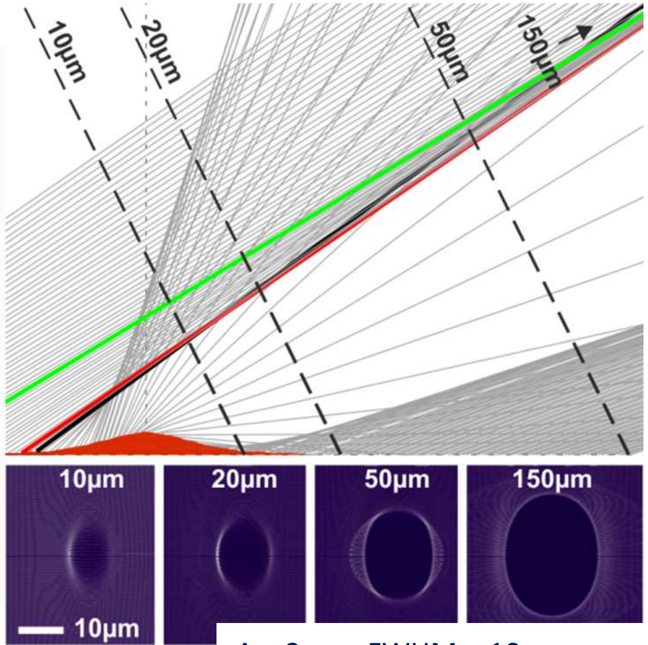
2 µm Ti foil with ≈ 1 µm of photo resist, $E_L \approx$ 84 mJ



-3.5 ps | ≈ pump pulse arrival | +23 ps

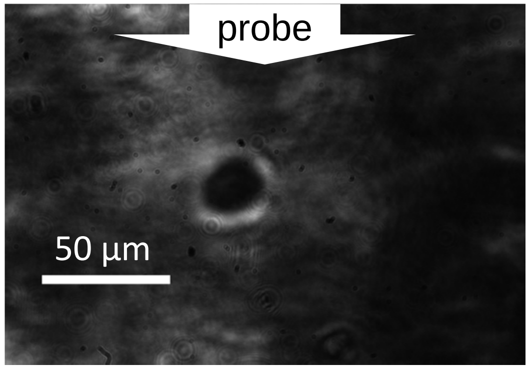
Accessing target dynamics at critical density?



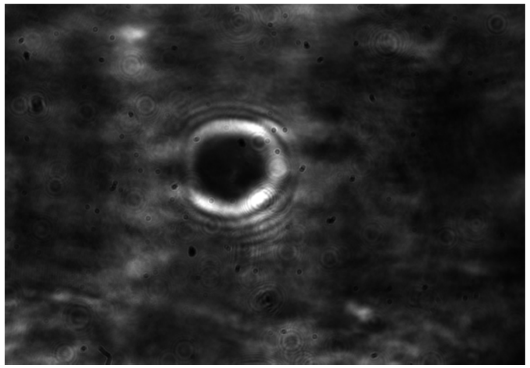


A = 2 µm, FWHM = 10 µm

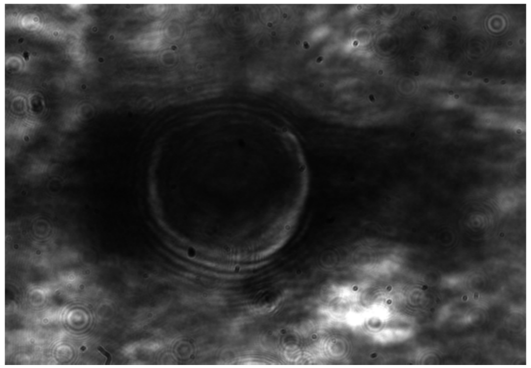
2 µm Ti foil with ≈ 1 µm of photo resist, E_L ≈ 84 mJ



-3.5 ps

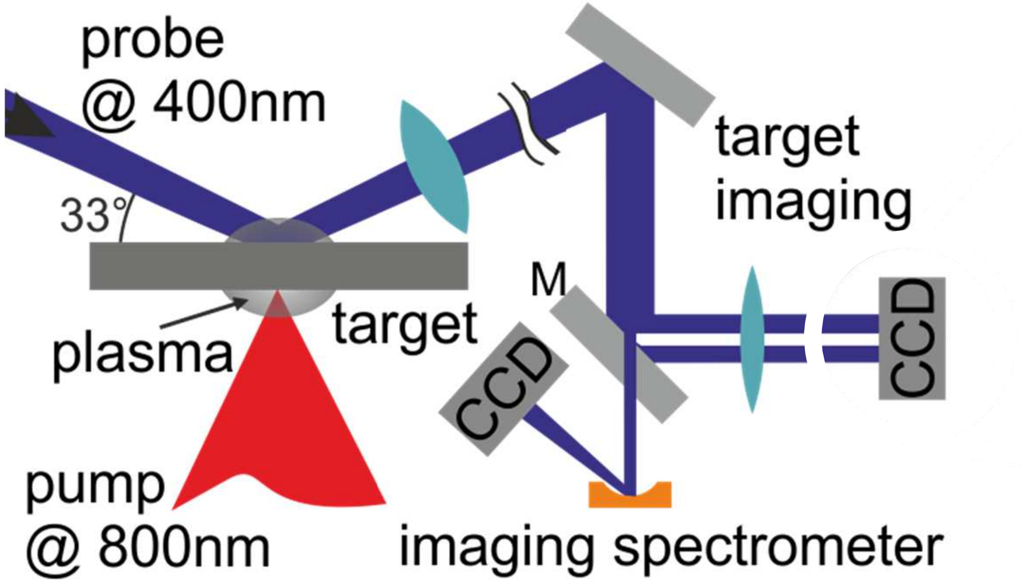


≈ pump pulse arrival

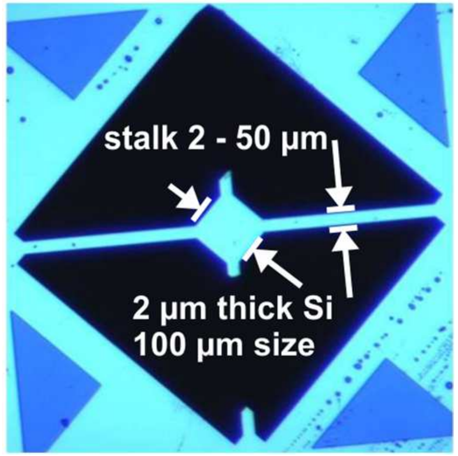


+23 ps

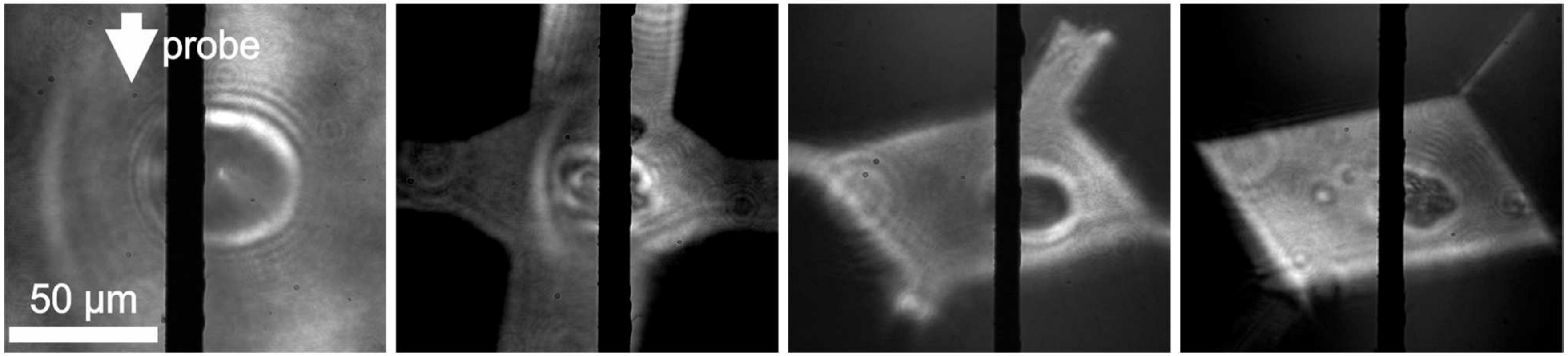
Optical probing – influence of the geometry



Si RMT target design

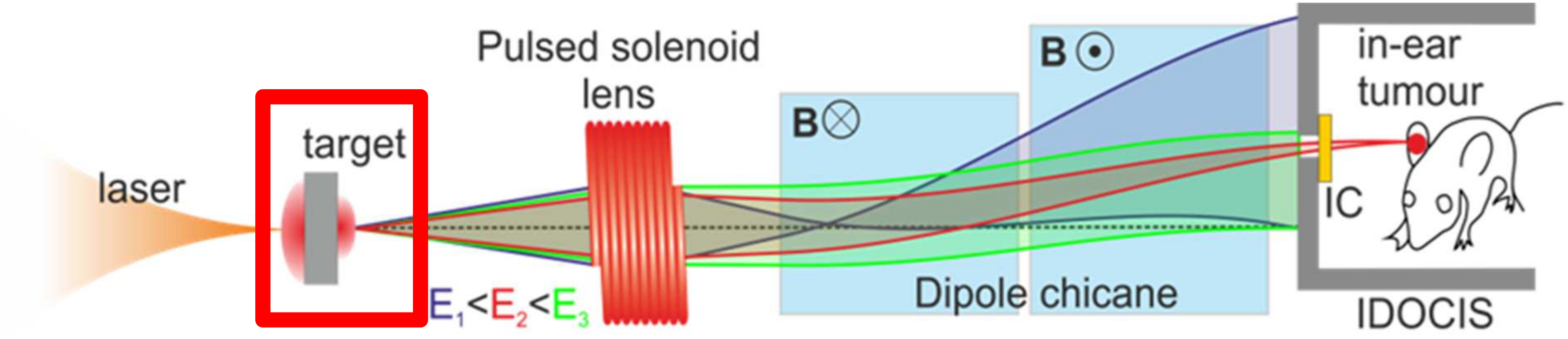


target imaging



1) Si membrane @ +1.9 ps 2) Si RMT 50 µm @ +1.9 ps 3) Si RMT 20 µm @ +1.9 ps 4) Si RMT 20 µm @ +1.9 ps

Profit for application



- Similar performance for difference in size, thickness, material
- Profit from robust performance enhancement (energy and proton number)
- next: material test at DRACO, optical probing (at high intensity)

Thank you for your attention

multiple filamentation of freely propagating 100 TW beam in air