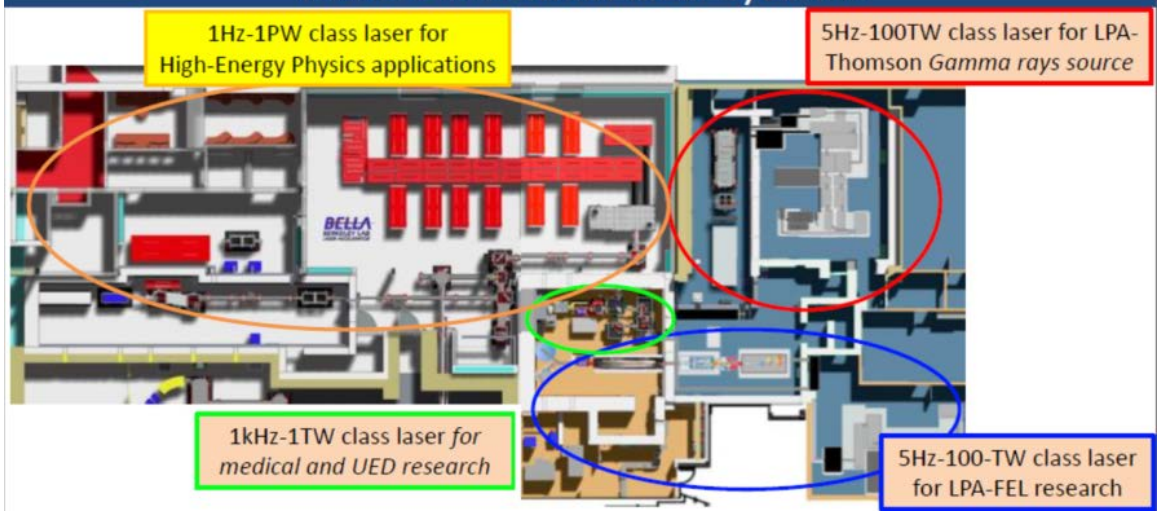
WG2: Ion Acceleration (L. Lancia, D. Margarone)

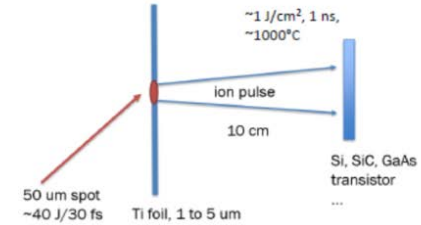
- Facilities: status, upgrades and applications
- New targetry and target manipulation
- Interaction and acceleration diagnostics
- Acceleration mechanisms and insights

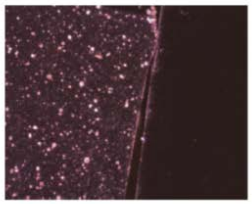
S. Steinke, BELLA, LBNL (USA)

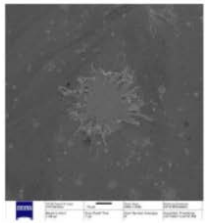
LBNL BELLA (BErkeley Lab Laser Accelerator) Center houses four main laser systems



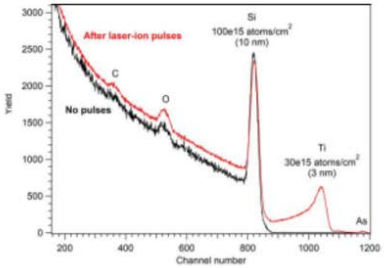
Pulsed implantation of SiC with ion pulses from BELLA – towards formation of vacancy centers



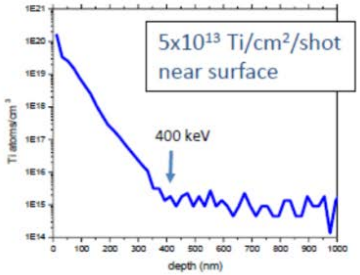




Channeling - RBS, Ryan Thorpe, Rutgers

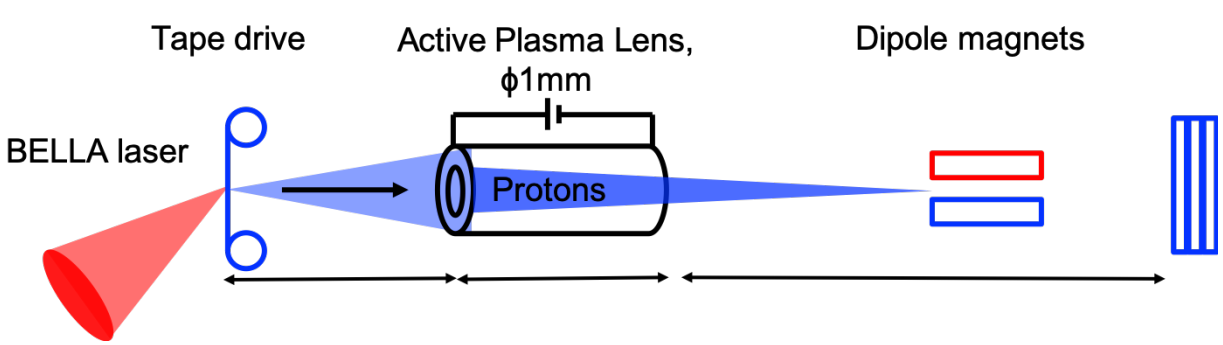


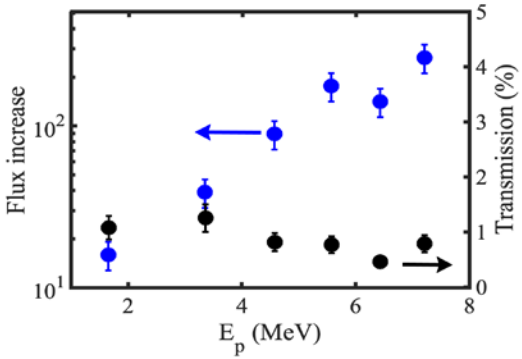
SIMS: Secondary Ion Mass Spectrometry

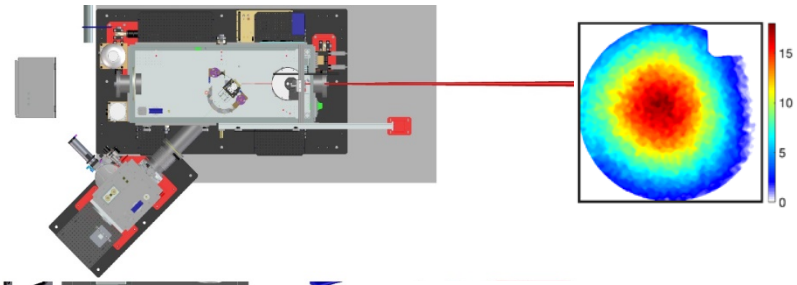


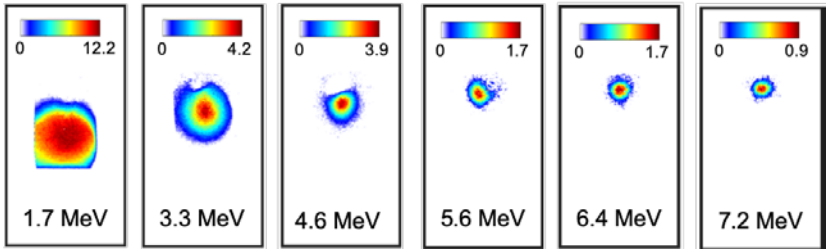
J. Bin, et al., LBNL (USA)

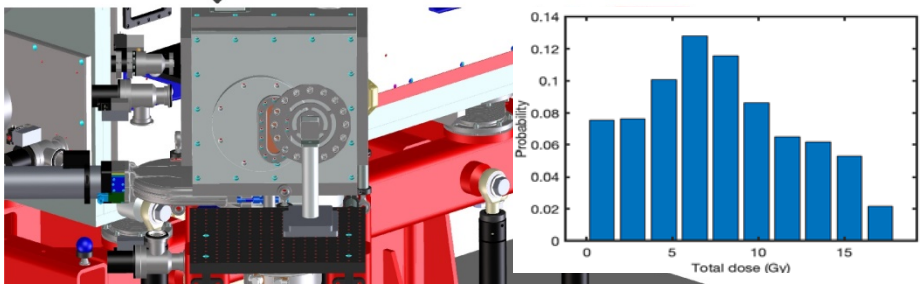
Focusing of laser-accelerated proton beams with active plasma lens





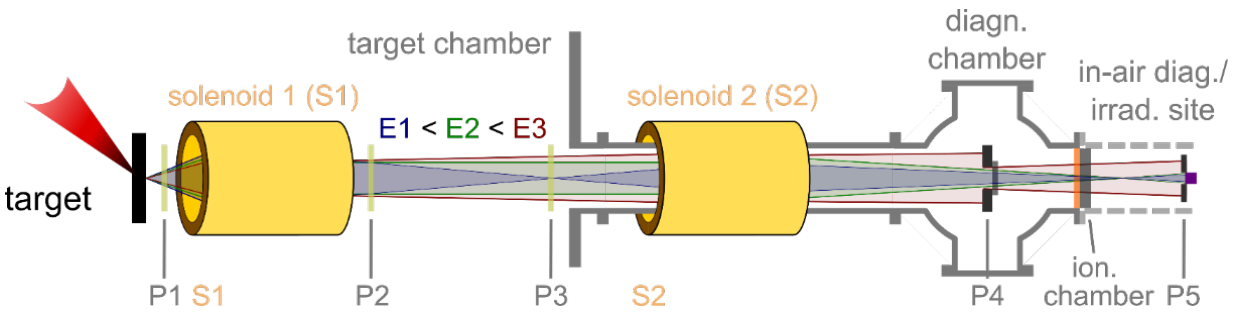


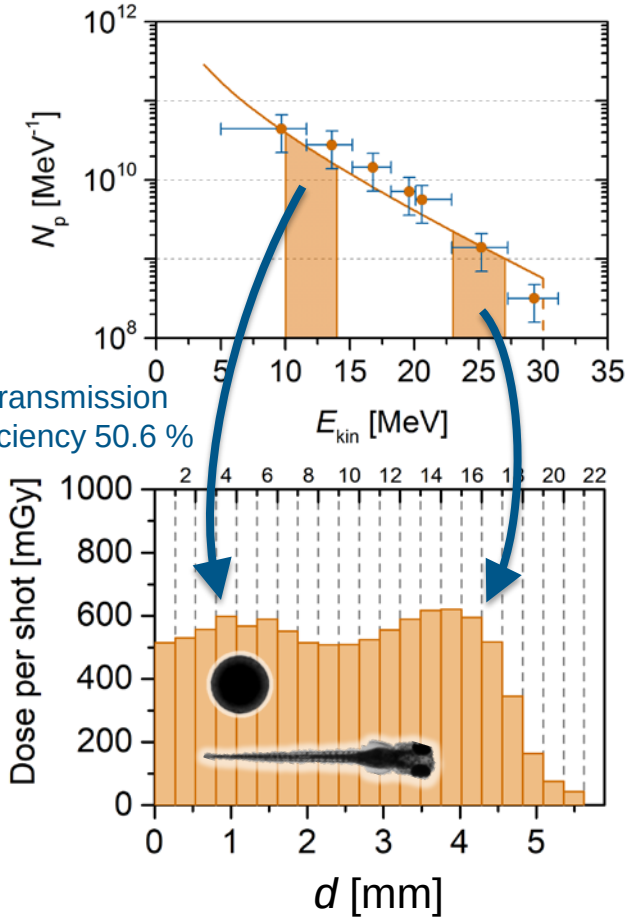




- 1st demonstration of focusing of laser driven proton beam with APL, ~mm spot size, up to ~260× flux increase
- **1st radiobiological study** @ BELLA

Dose controlled irradiation experiments with LAP @ Draco PW

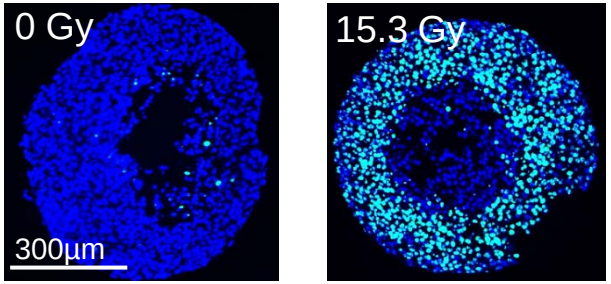




Transmission efficiency 50.6 %

- Installed tunable pulsed high-field beamline for **3D dose delivery** for radiobiological experiments at Draco PW
- Using two solenoids to focus protons of two different energies in one laser shot
- **spectral homogenisation** via two solenoids; **lateral** by overfocussing, scatter foil, apertures (both below ±8,5%)
- Dose rate of **0.7 Gy/shot** with homogenisation achieved
- First **irradition studies** with **3D tumor spheroids** (in-vitro) and **zebrafish embryos** (in-vivo) conducted

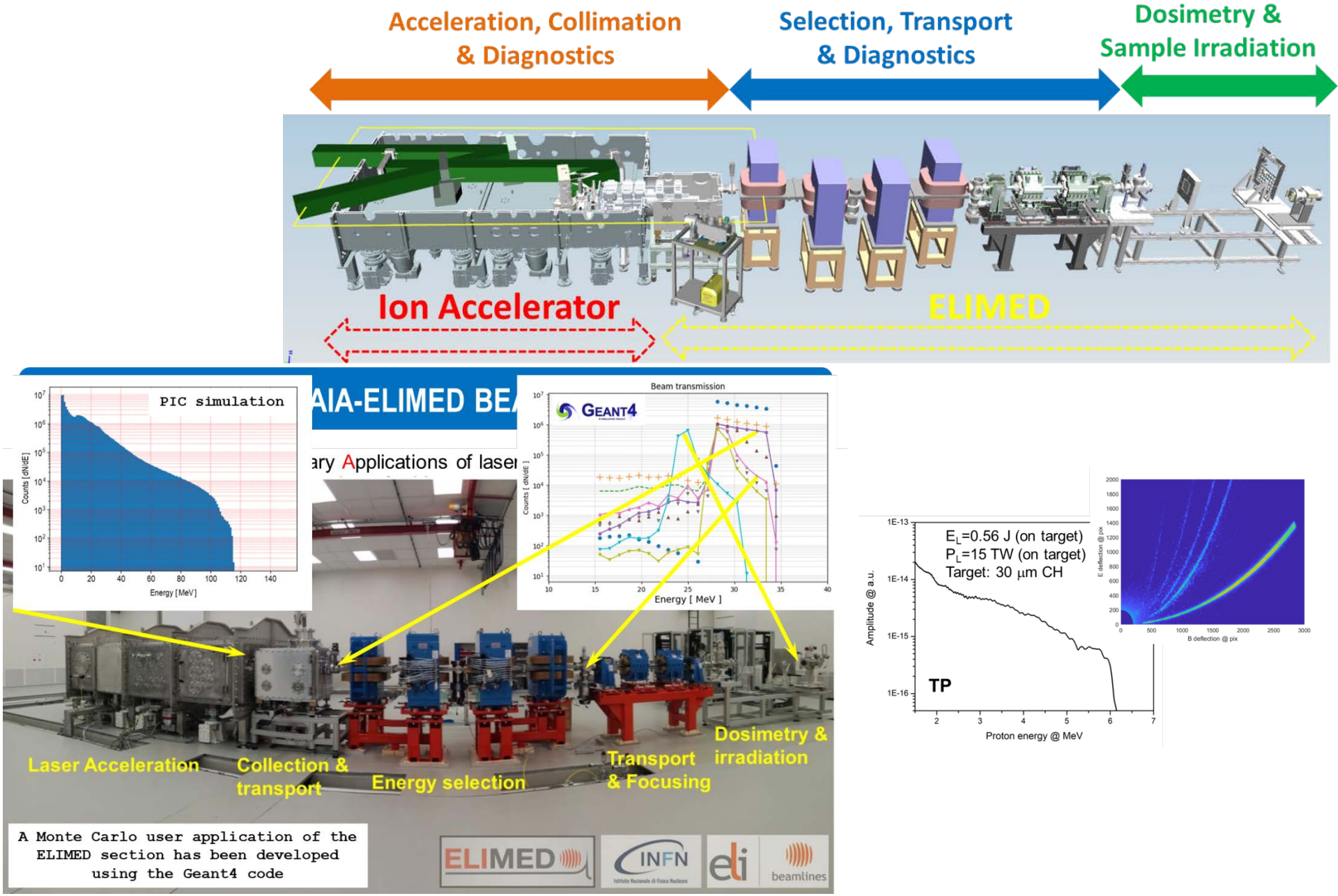
3D tumor spheroids



HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

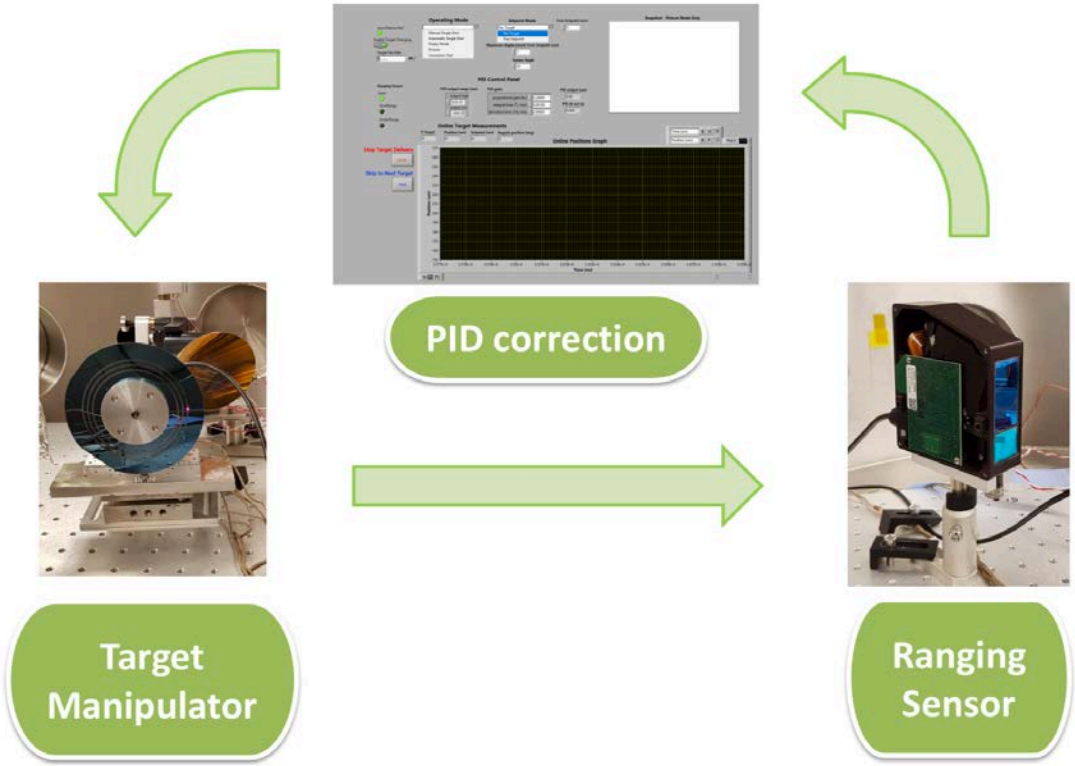
F. Brack, HZDR, Dresden

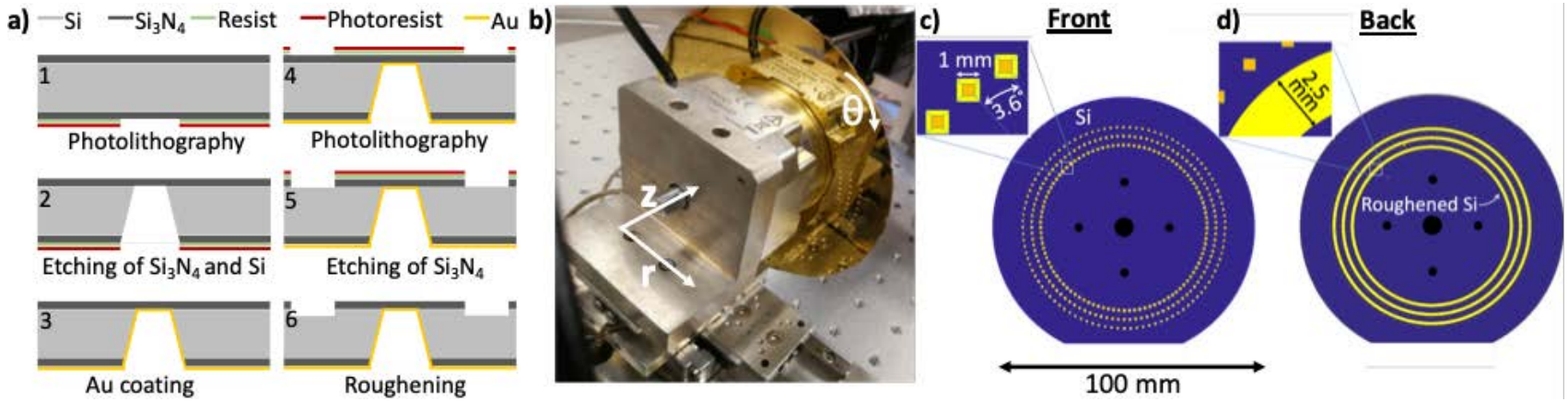
D. Margarone,ELI-BL (Prague)
F. Catalano, INFN-LNS (Italy)



I. Pomerantz, Tel Aviv Un. (Israel)

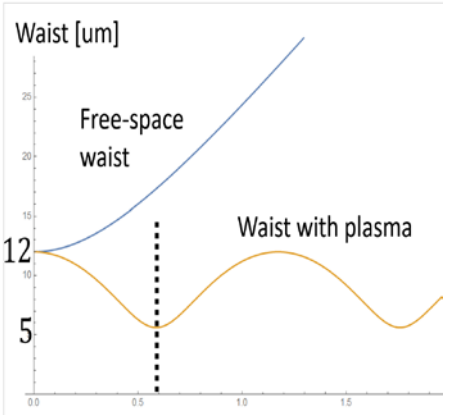
gatling gun target delivery system

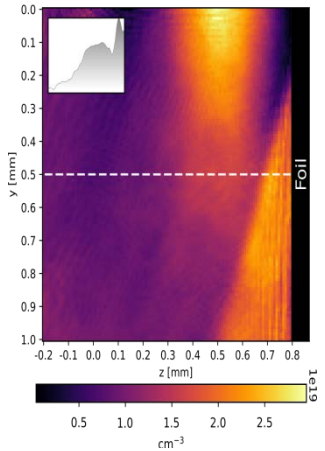




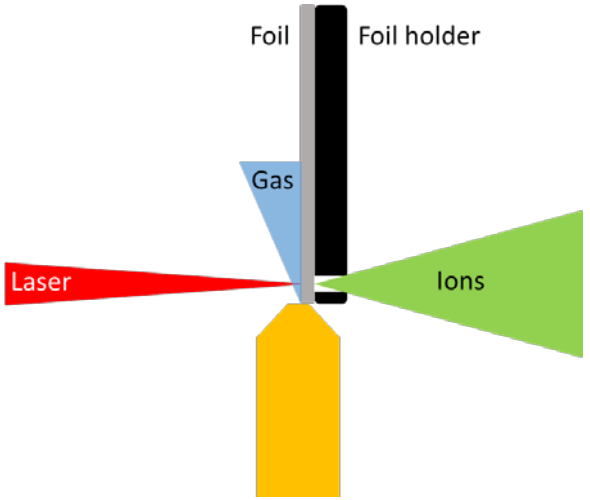
D. Levy, Weizmann (Israel)

Gas-foil target for Ion acceleration

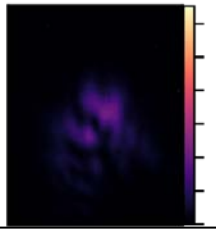




1. Novel target: underdense gas followed by a thin foil.

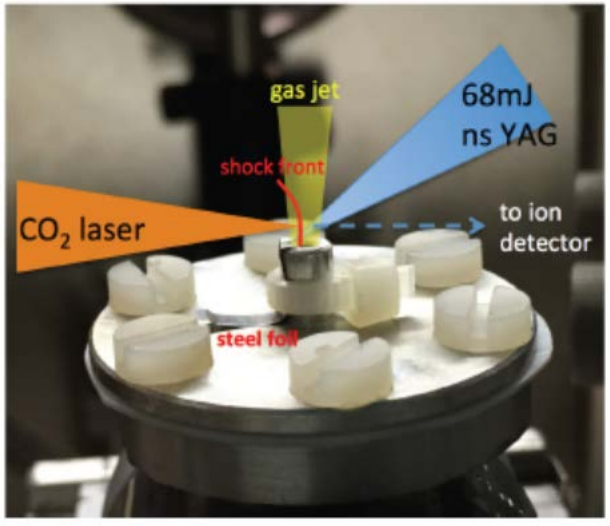


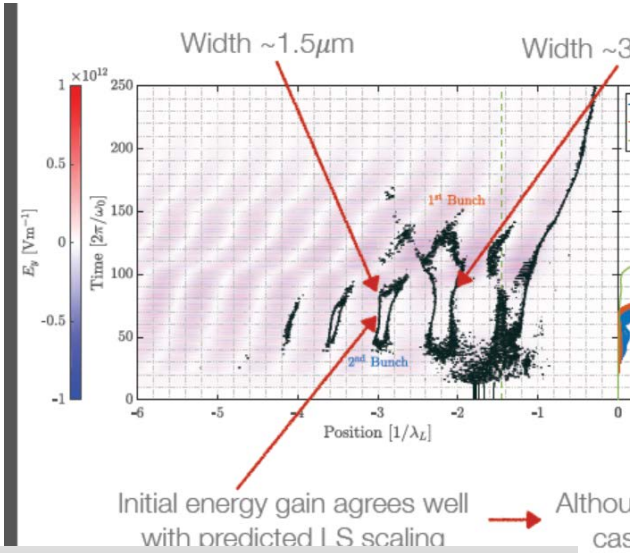
2. Self-focusing and temporal compression/steepening expected to increase intensity up to 10 times.



Already at $1.5 \times 10^{19}\ cm^{-3}$

O. Ettlinger, Imperial College (UK)

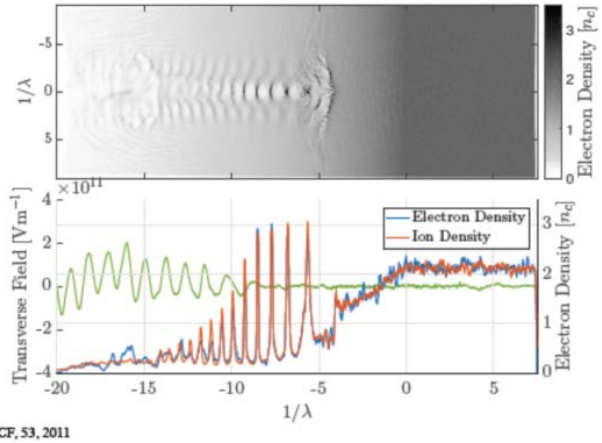




Imperial College London

Plasma Gratings

- In the presence of an under-dense plasma, the ponderomotive force leads to grating formation



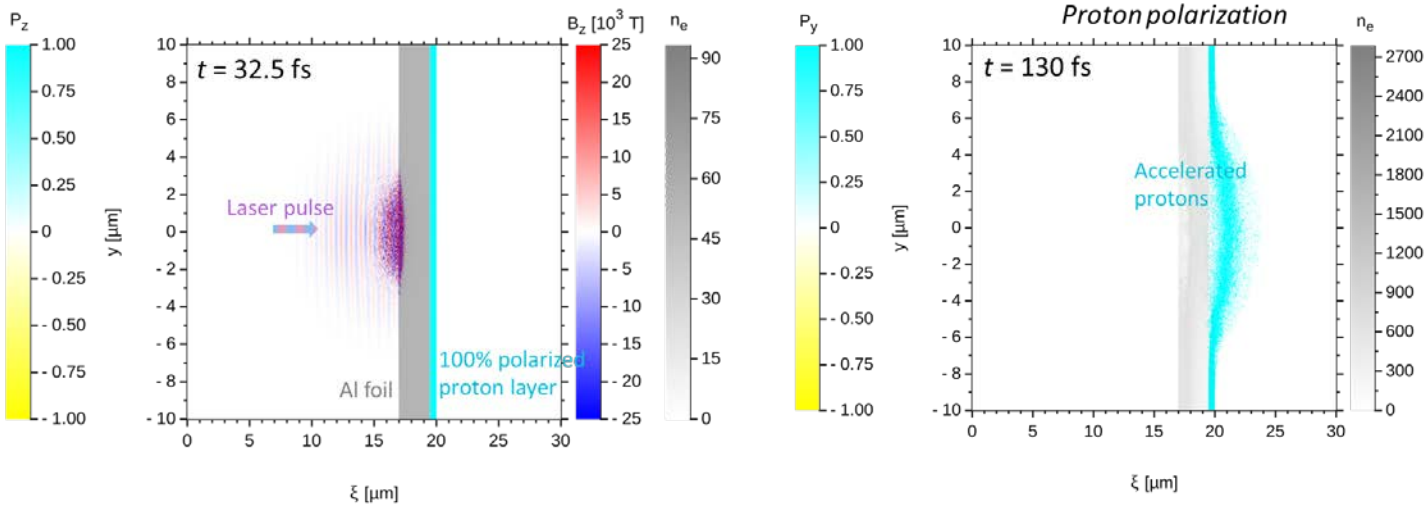
EPOCH

C. S. Brady and T. D. Arber, PPCF, 53, 2011

A. Lehrach, Julich (Germany)

3D VLPL simulation (λ = 800 nm, normalized laser amplitude a_0 = 12, 25 fs duration, 5 µm focal spot size)

Laser acceleration via TNSA mechanism

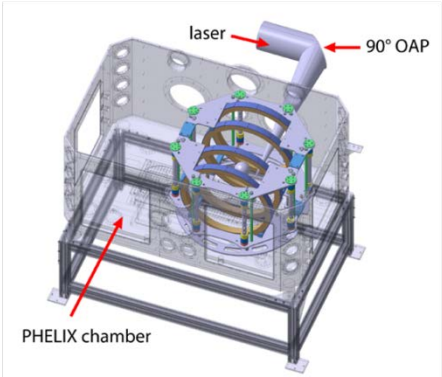


➡ Proton polarization is conserved during acceleration

Possible experimental realization: Polarized ^{3}He target

Start of measurements @ PHELIX GSI

Unpolarized ^{3}He already accelerated up to 4.65 MeV



➡ New approach with two atomic pre-polarized target

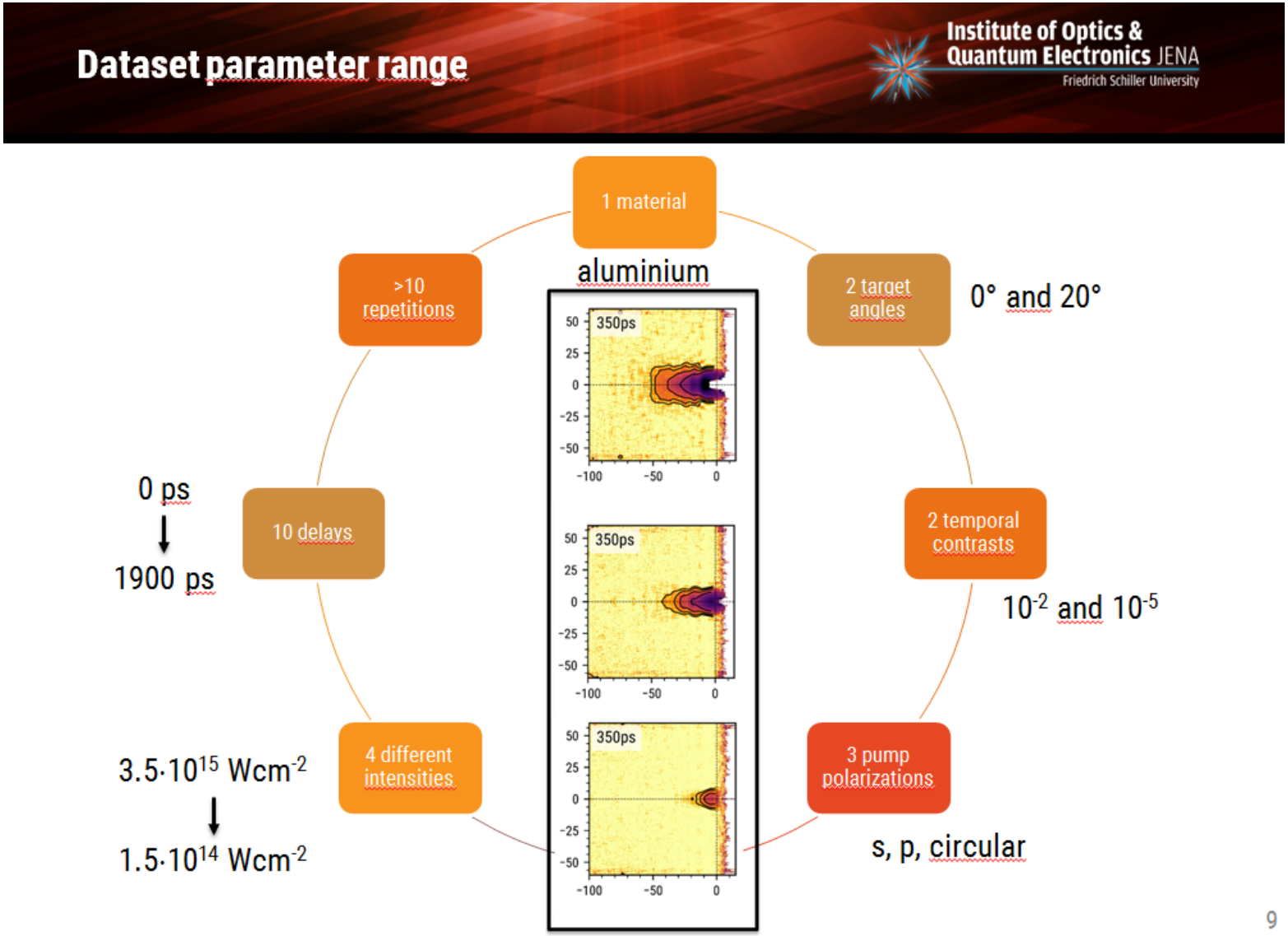
WG2: Ion Acceleration (L. Lancia, D. Margarone)

- Facilities: status, upgrades and applications
- New targetry and target manipulation
- Interaction and acceleration diagnostics
- Acceleration mechanisms and insights

M. Maeusezahl, Jena Un.

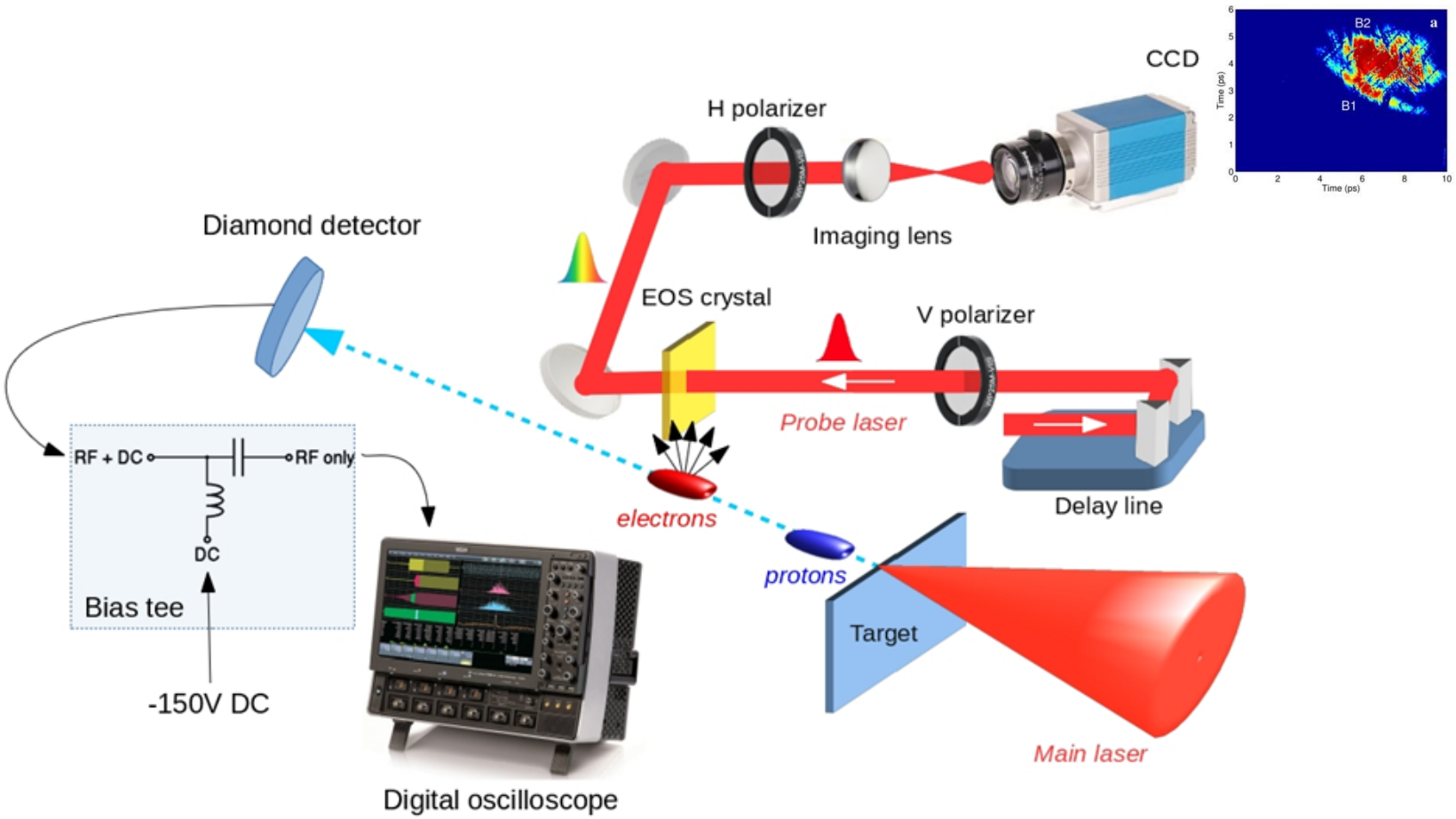
pre-plasma-probing setup

Measurement of aluminium pre-plasma for a **wide parameter range** (angle of incidence, intensity, polarization…)



F. Bisesto, INFN-LNF, Italy

Experimental setup: particle diagnostics



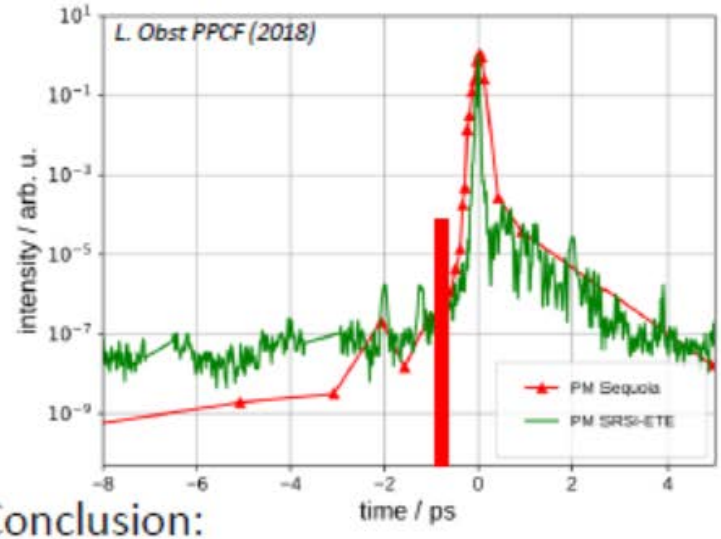
Bisesto, F., et al. "Single-shot electrons and protons time-resolved detection from high-intensity laser–solid matter interactions at SPARC_LAB.", High Power Lasers, 7 (2019)

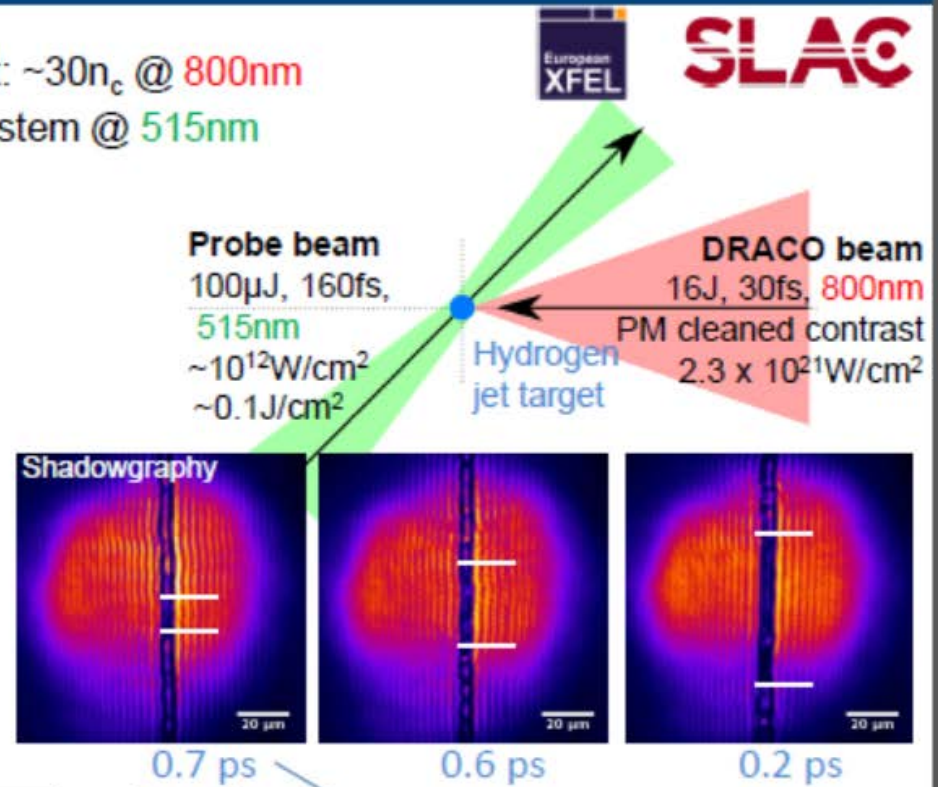
F. Bernert, HZDR, Dresden

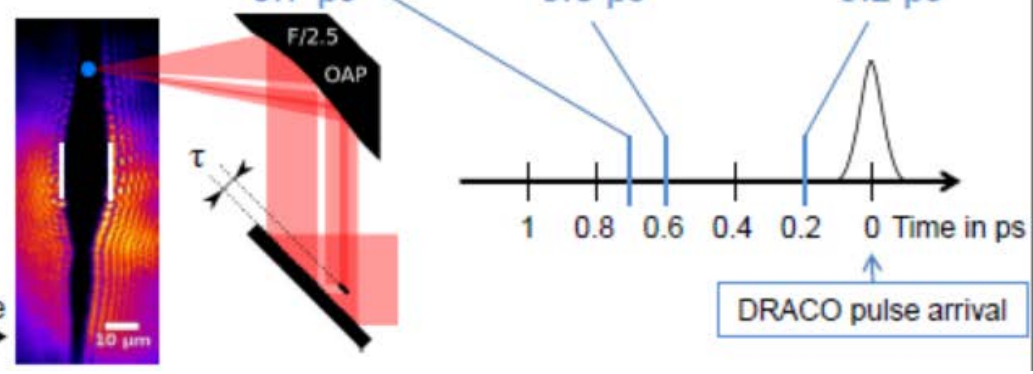
Off-harmonic probing of hydrogen jets

HZDR

- Cylindrical Ø 5µm cryogenic hydrogen jet: ~30n_c @ 800nm
- Synchronized stand-alone probe laser system @ 515nm

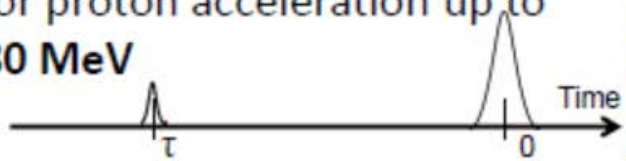






Conclusion:

- PW-laser induced target evolution effect at **full energy** can be studied
- Target pre-expansion beneficial for proton acceleration up to **80 MeV**



S. Keppler, Un. Jena (Germany)

6.5 µm - Al

Current status of POLARIS:

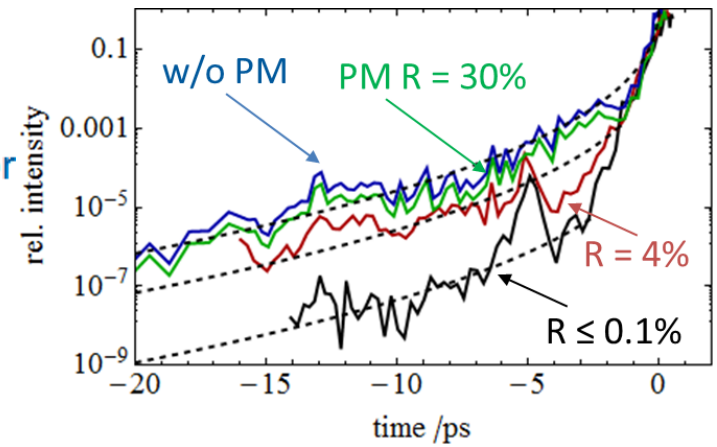
- high-power, high-contrast laser system, well suited for experimental program
- variable contrast settings possible

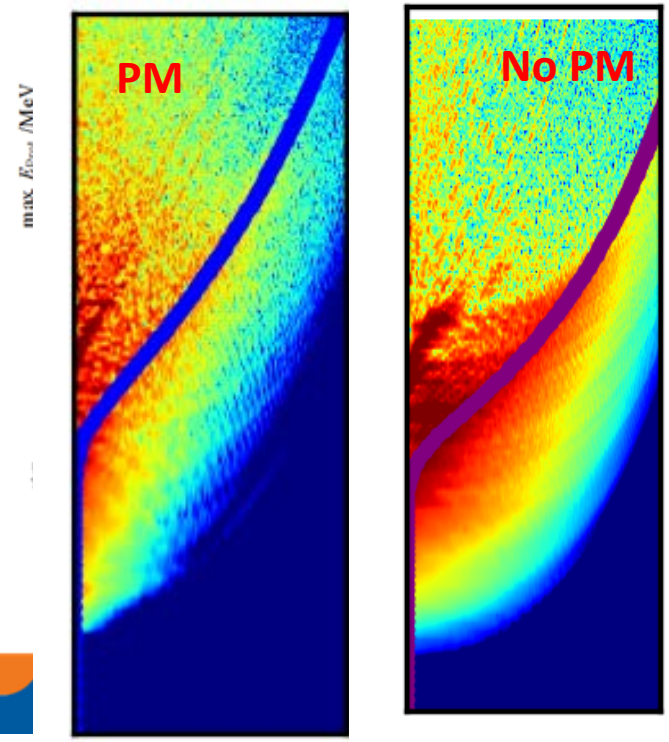
Experimental results from campaign on laser-driven proton acceleration:

- characterization of the scaling (from $I_L^{0.5}$...I_L^{1}) of TNSA-protons with different plasma scale length
- observed a change in scaling at high intensities

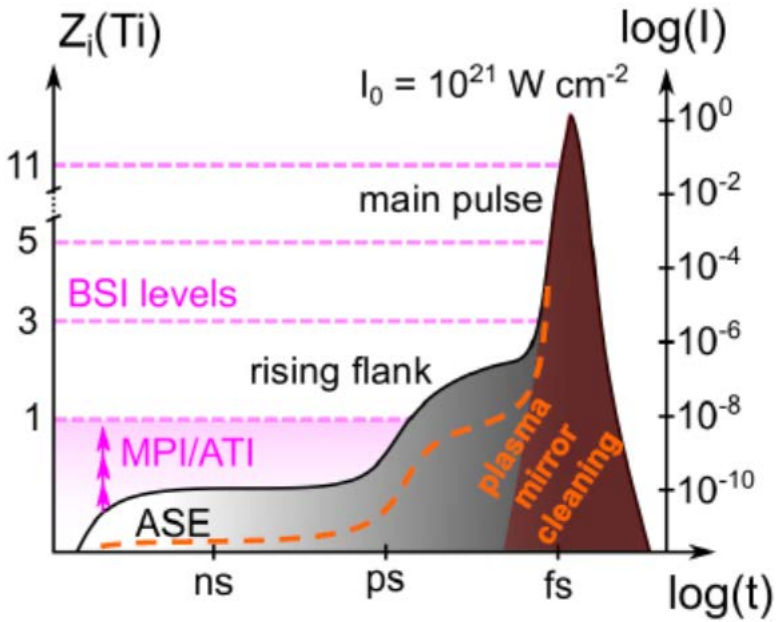
Extensive Numerical Simulations with the ANTARES code:

- scaling depends on E_{max}(t) and x(t) of protons
- protons don't experience highest field at higher intensities anymore
- laser contrast affects peak/length ratio of E_x
- p^+ are accelerated longer for higher scale-length

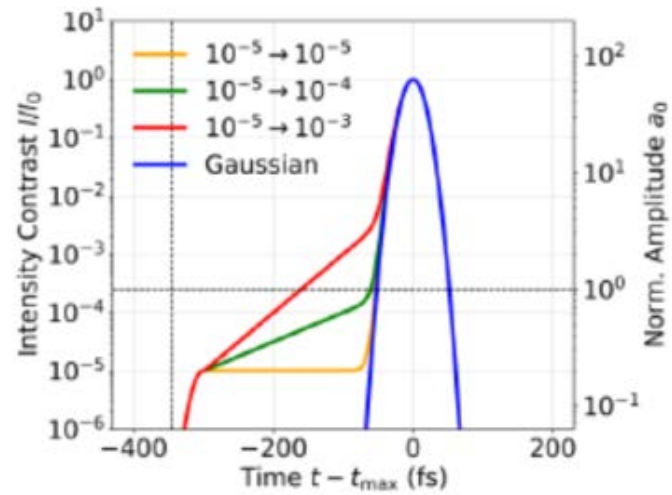


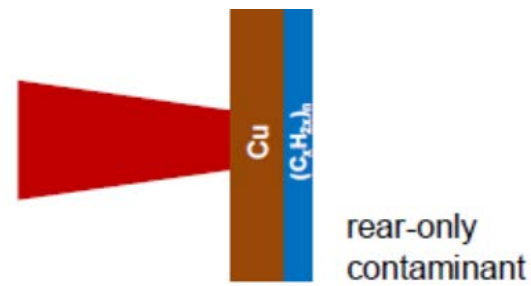


M. Garten, HZDR, Dresden



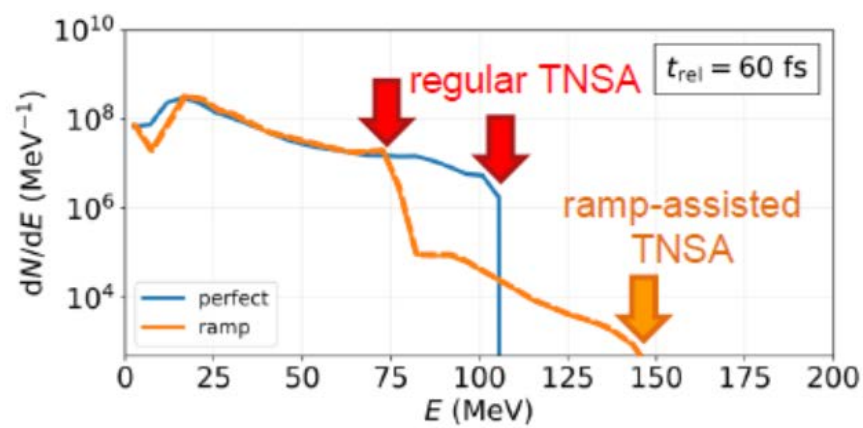
simulation





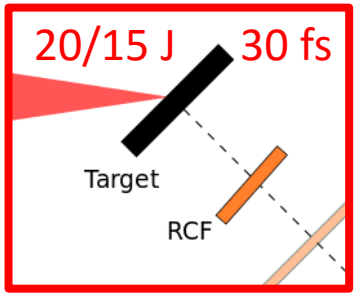
10-100 nm

Enhanced TNSA

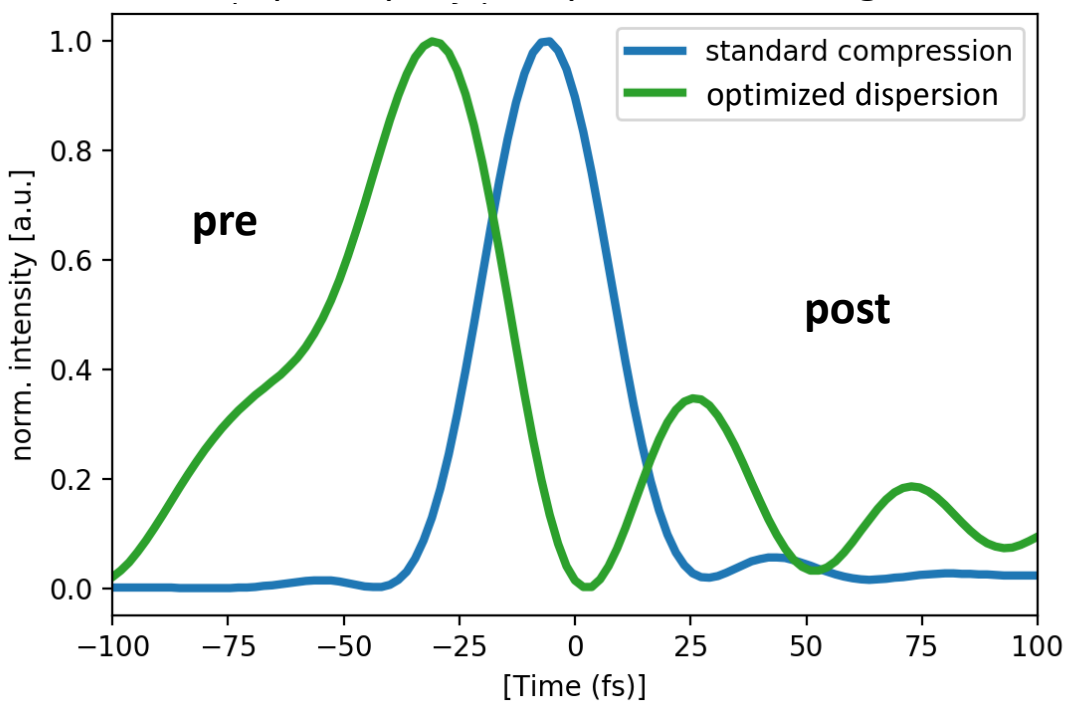


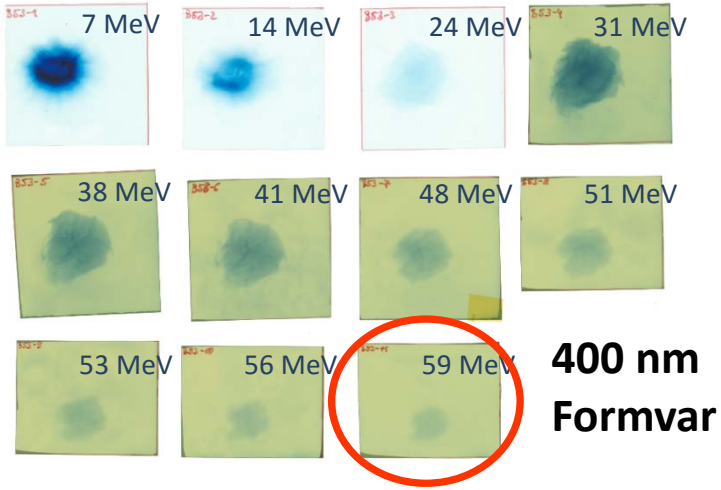
K. Zeil, HZDR, Dresden

- Proton acceleration experiments at the Draco-PW laser



temporal pulse shape near the target

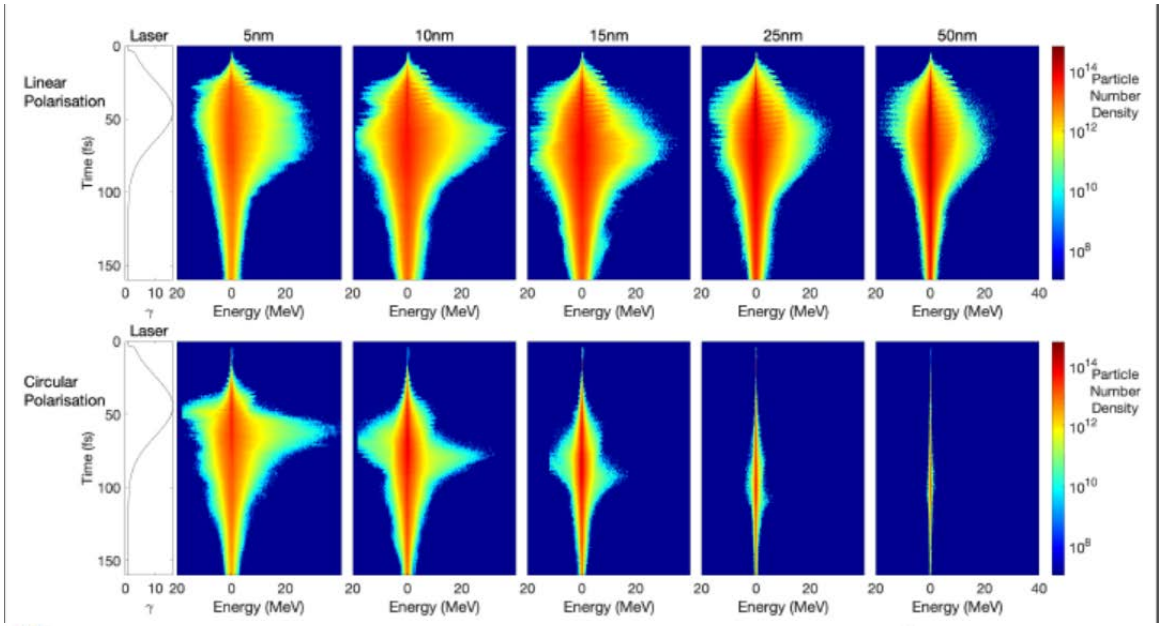




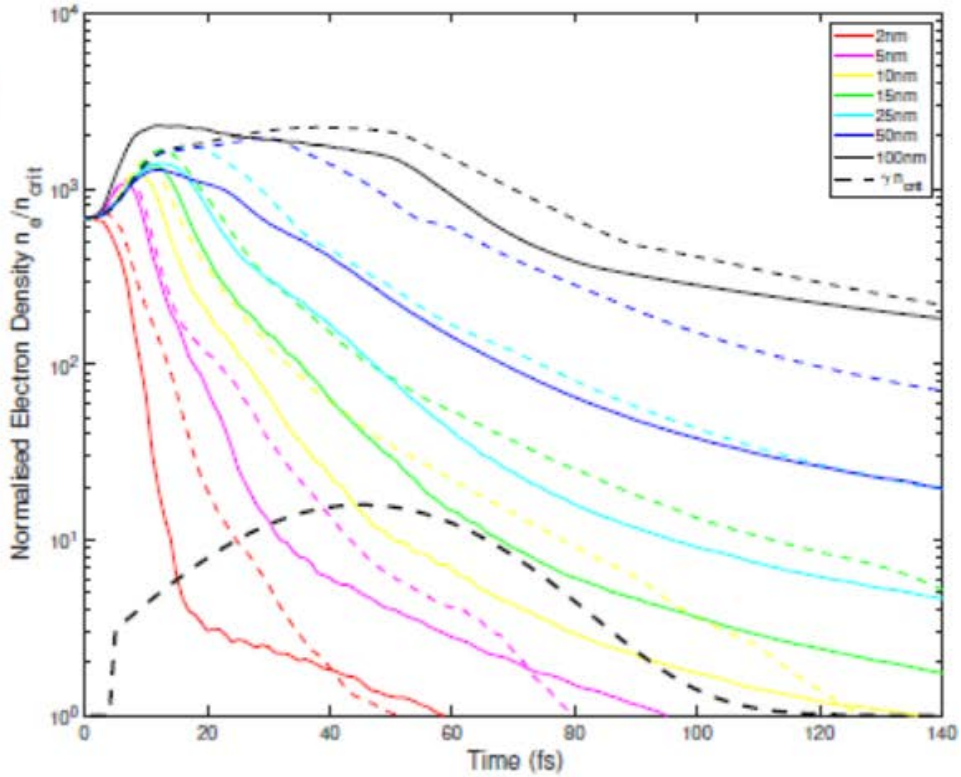
- **third order dispersion** dependence for different **contrast** conditions at target
- twofold increase in proton energy (up to 60 MeV) for optimized dispersion settings
- differences in pulse shape on linear (asymmetry) and logarithmic scale (contrast) need to be considered

E.J. Ditter, Imperial College (UK)

Ultrathin target: 2-100 nm
PIC simulations

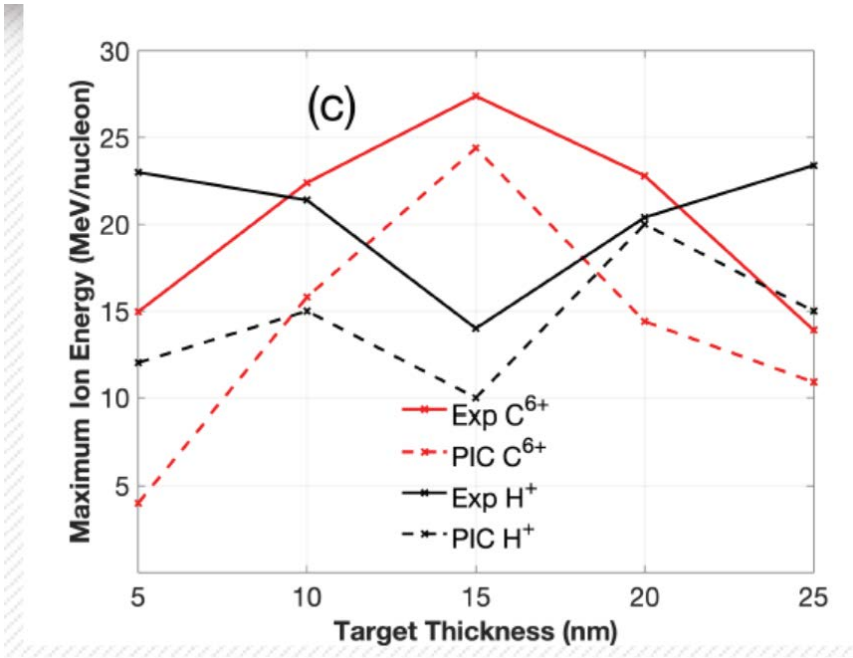


- Average electron density in focal spot
- —— Linear Polarisation
- - - - Circular Polarisation
- 2 - 10nm go transparent
- Targets ≥ 25nm remain overdense



A. McIlvenny, Queen's Un. Belfast (UK)

Ultrathin target: 5-25 nm
Hybrid RPA-TNSA



Multi-species acceleration

A-SAIL
ADVANCED STRATEGIES FOR ACCELERATING IONS WITH LASERS
QUEEN'S UNIVERSITY BELFAST

- Protons are mostly accelerated by the plasma expansion (few MeV) / sheath effects
- Carbon is initially accelerated by RPA
- Target (optimum thickness) goes transparent just after the peak of the pulse as the density drops
- RPA shuts off , enhanced acceleration takes place with transparency effects
- Followed by sheath effects