OPTIMIZATION OF PROTON BEAM FOCUSING THROUGH A TARGET MODULAR APPROACH IN THE CONTEXT OF PROTON FAST IGNITION

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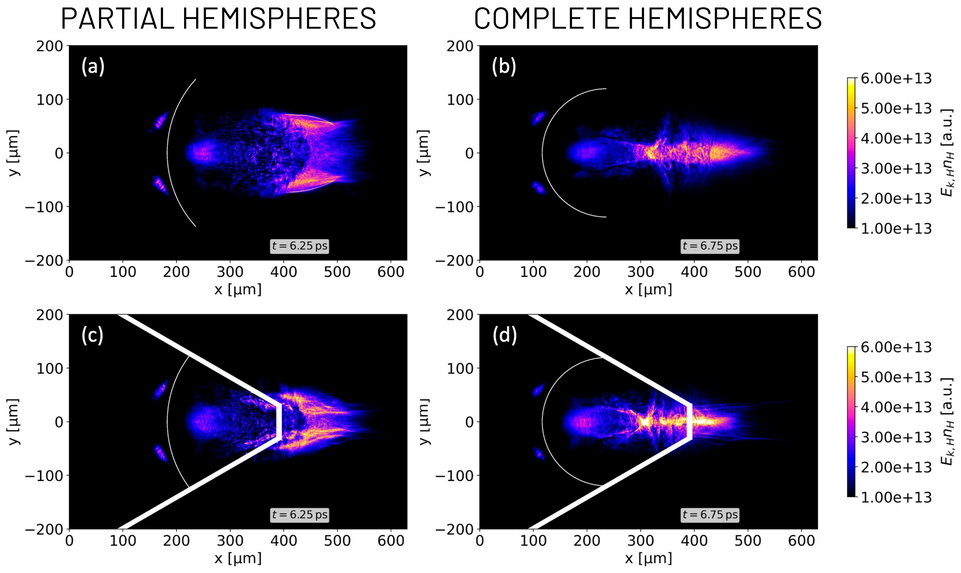
We performed a set of *down-scaled* simulations* following a target modular approach to understand the individual effect of each target component on proton focusing.

PROTON ENERGY DENSITY MAPS

EPOCH

PARTIAL HEMISPHERES | COMPLETE HEMISPHERES

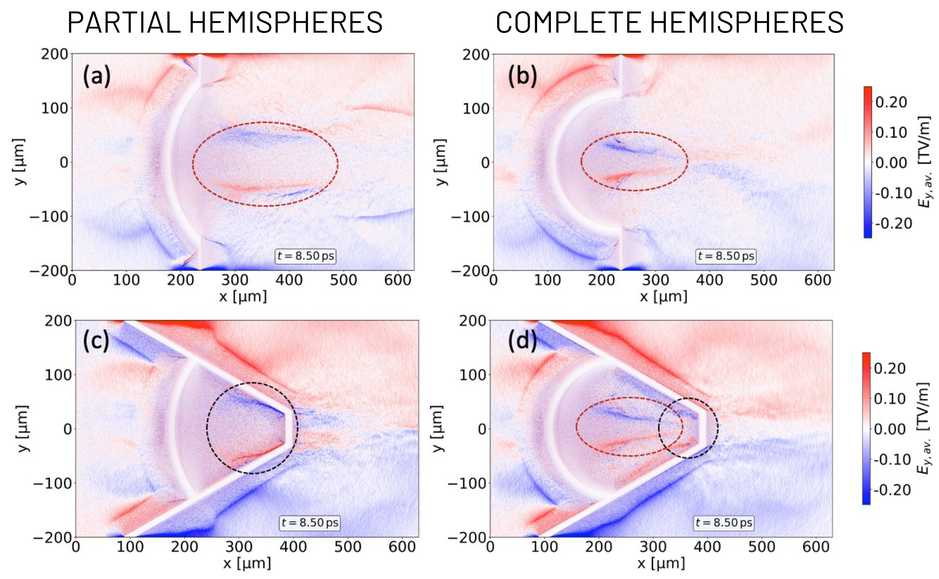


* Simulations performed for OMEGA-EP parameters: $7{\times}10^{19}$ W · cm^{-2}, 700 fs, $D_L = 35$ μm

- Examining proton energy density distributions for various target shapes revealed that focusability strongly depends on geometry.
- Partial hemispheres, whether free-standing or within a cone, show poor focusability, while complete hemispherical foils exhibit good focusability in both scenarios, as already noted by Bartal *et al.* [1].
- Notably, the ability to focus protons seems to be inherent to the hemispherical foil.

AVERAGED TRANSVERSE ELECTROSTATIC FIELD Ey MAPS

PARTIAL HEMISPHERES | COMPLETE HEMISPHERES

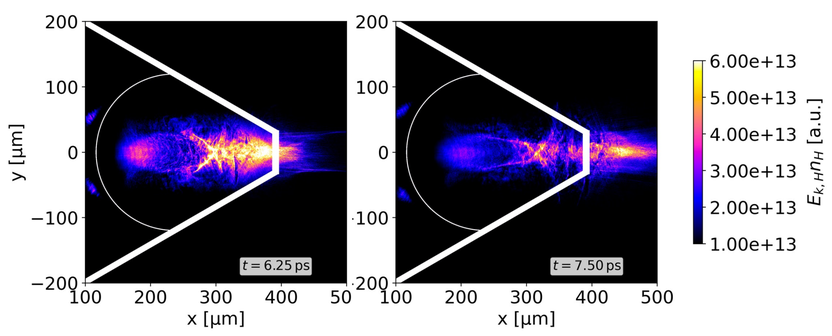


- The enhanced proton focusing observed in complete hemispheres arises both from the natural trajectories of the ion beam (red dashed oval) and from the fields due to electron charge accumulation at the cone tip (black dashed circle).
- The first effect effect is diluted in the partial hemisphere given its larger radius with respect to the constant laser focal spot.
- In partial hemispheres, the only transverse electrostatic fields contributing to proton focusing (black dashed circle) originate in the cone walls due to electron charge accumulation near the tip.

Complete hemispheres inserted inside cones show promising focusing dynamics when extrapolated to full scale targets**.

PROTON ENERGY DENSITY MAPS

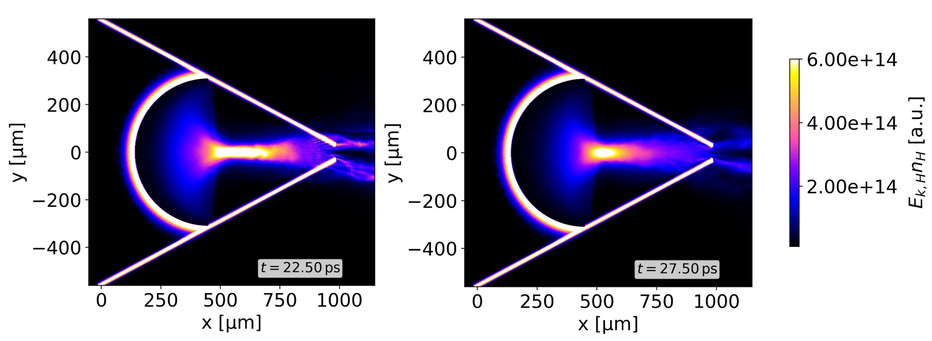
DOWN-SCALED TARGETS



* Simulations performed for OMEGA-EP parameters: $7{\times}10^{19}$ W · cm^{-2}, 700 fs, $D_L = 35$ μm

PROTON ENERGY DENSITY MAPS

FULL SCALE TARGETS

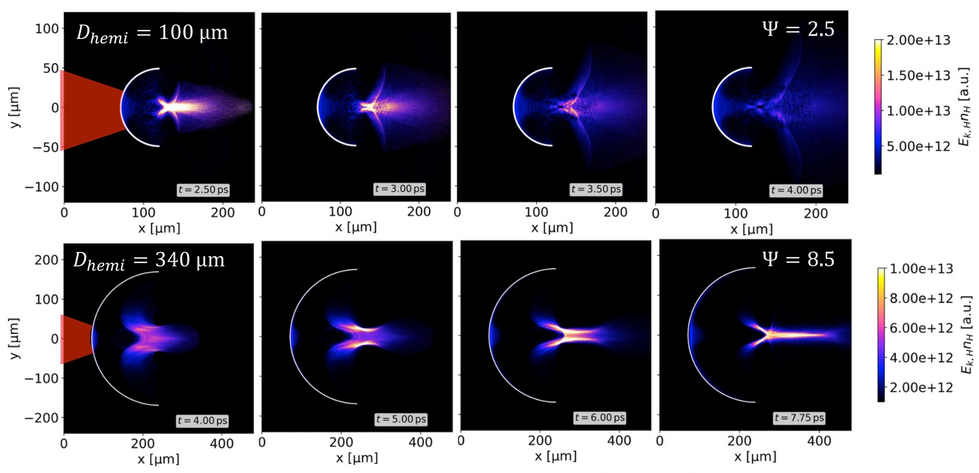


** Simulations performed in pFI conditions: $2{\times}10^{19}$ W · cm^{-2}, 1.8 ps, $D_L = 640$ μm

Matching the hemisphere diameter with the laser focal spot seems essential for optimizing proton focusing [2]. To further understand this feature, we performed a set of simulations*** of *down-scaled* free-standing hemispherical foils.

PROTON ENERGY DENSITY MAPS

FREE-STANDING COMPLETE HEMISPHERES

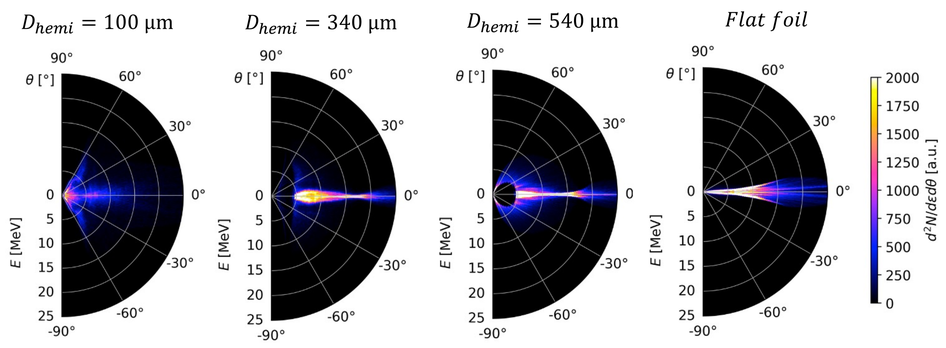


* *Simulations performed for CSU ALEPH parameters: $4{\times}10^{19}$ W · cm^{-2}, 40 fs, $D_L = 40$ μm

- Optimally illuminated hemispheres are characterized by a Ψ parameter $\Psi = D_{hemi}/D_L$ between 6 and 8.5, corresponding to hemisphere diameters of 240 μm ≤ D_{hemi} ≤ 340 μm in our down-scaled conditions. In these cases, strong proton focusing of all energies with a small divergence half-angle of $\theta_p \pm 10°$ is observed.

PROTON DENSITY DISTRIBUTIONS RESOLVED IN ENERGY/ANGLE

FREE-STANDING COMPLETE HEMISPHERES



- Hence, in down-scaled experiments with laser focal spots of around 40 μm (OMEGA-EP, CSU, etc.), studying proton focusing from large pFI-scale hemispherical foils is not optimal and scaled-down targets should be used.

References:
[1] Bartal et al., Nature Phys. ***8****, (2012)*
[2] Kemp et al., Phys. Plasmas. ***31****, (2024)*

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