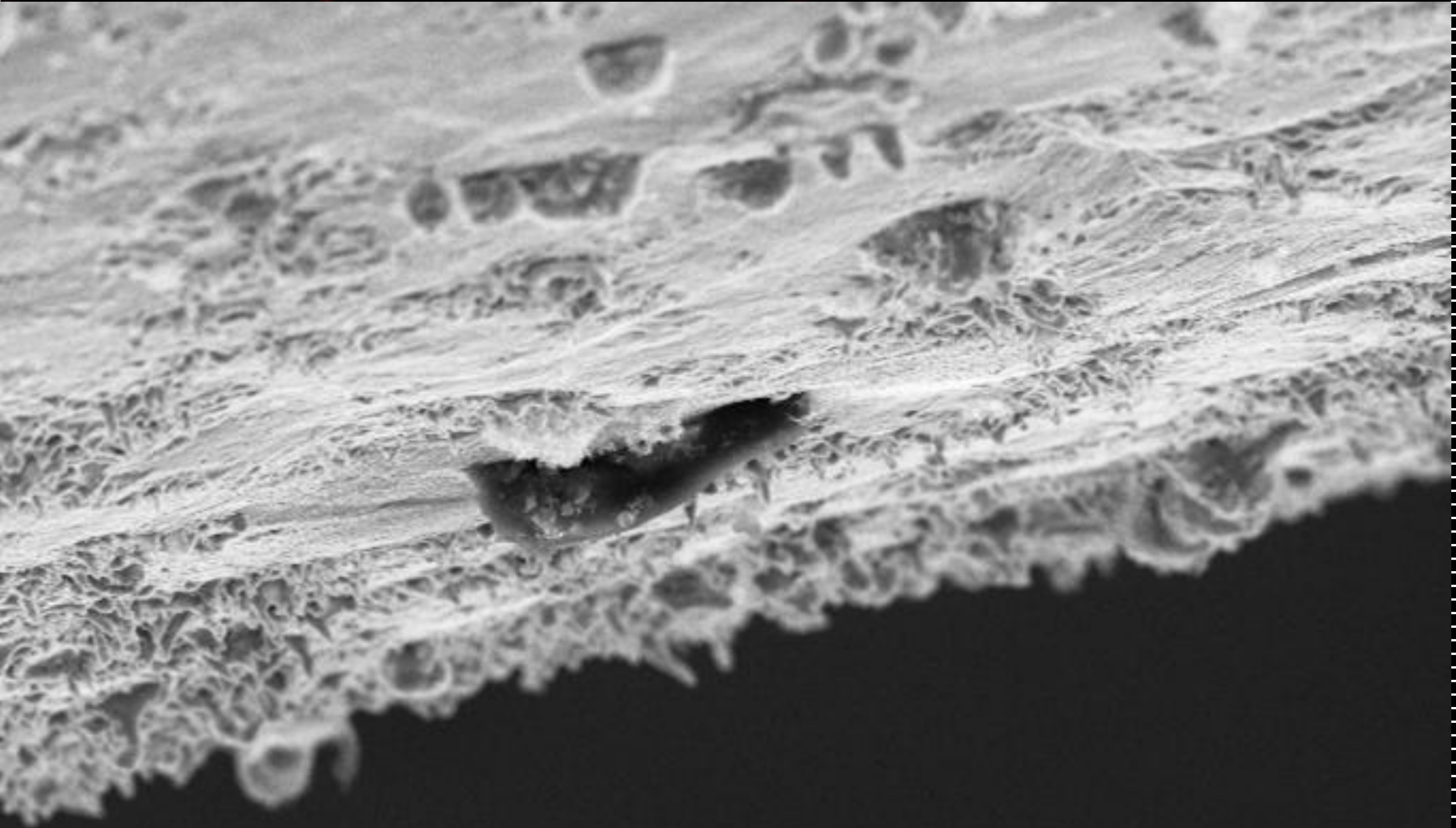


Nanofoam based double layer targets for laser-plasma interaction experiments

Matteo Iaccarino

17/03/2026

ELIMED
2 0 2 6

16 - 18 March 2026
ELI Beamlines Facility
Dolní Břežany, Czech Republic

- Activities performed within the framework of a collaboration between:

- Our group from POLITECNICO MILANO 1863

M. Passoni
Principal Investigator

A. Maffini

F. Mirani

M. Galbiati

D. Vavassori

M. Iaccarino

M.S. De Magistris

K. Ambrogioni

D. Orecchia

D. Dellasega

V. Russo

- The eli **beamlines** team

D. Margarone

L. Giuffrida

V. Kantarelou

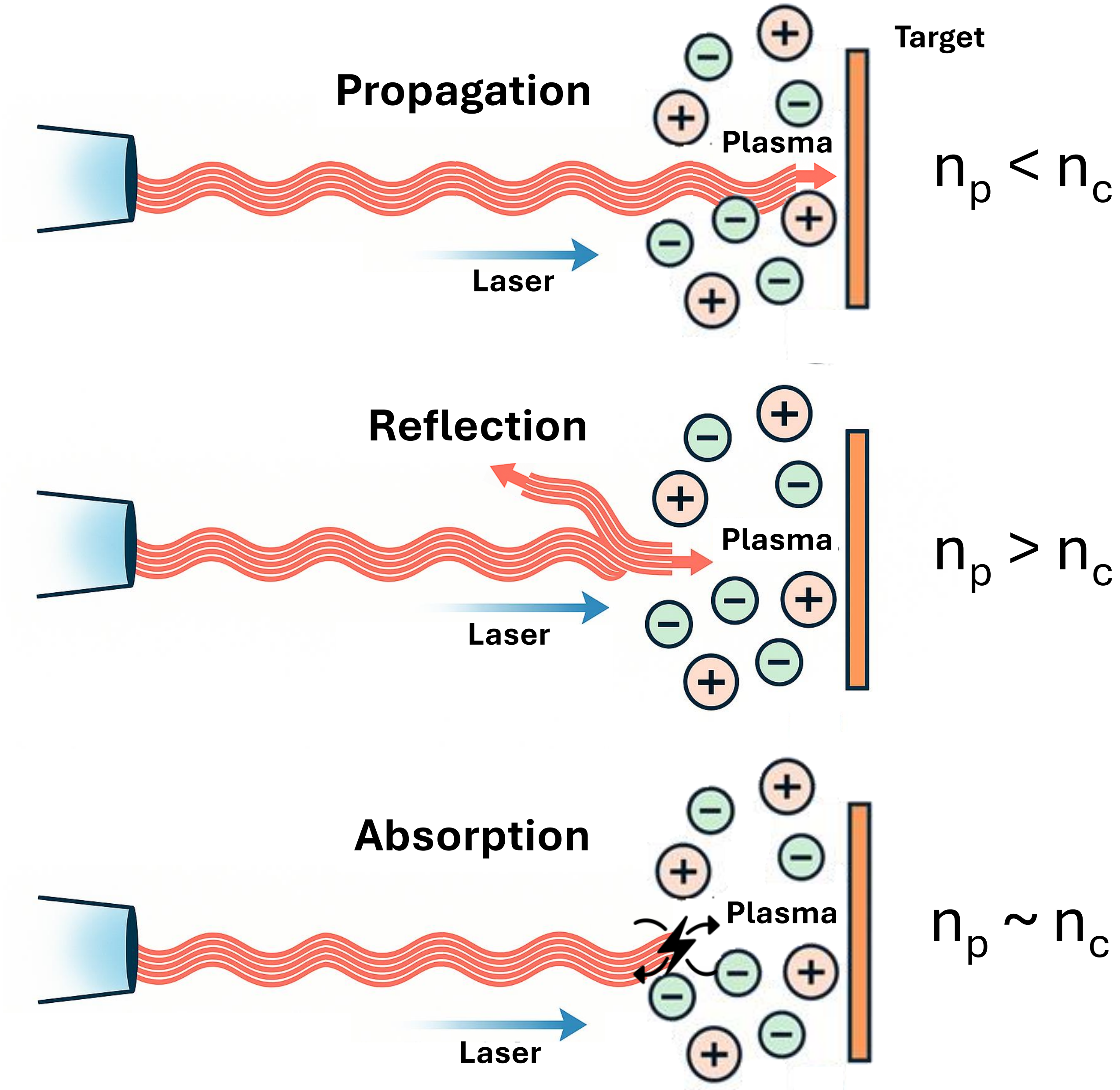
...and the ELIMAIA team (F. Schillaci, etc.)

- And ...

QUEEN'S UNIVERSITY BELFAST

Apollon

Laser-plasma interaction



Laser

- Intensity ($I > 10^{13}$ W/cm^2)
- Duration (*fs – ns*)
- Wavelength
- Energy (*mJ – MJ*)
- Repetition Rate

Target

- Density
- Thickness
- Composition

Plasma formation

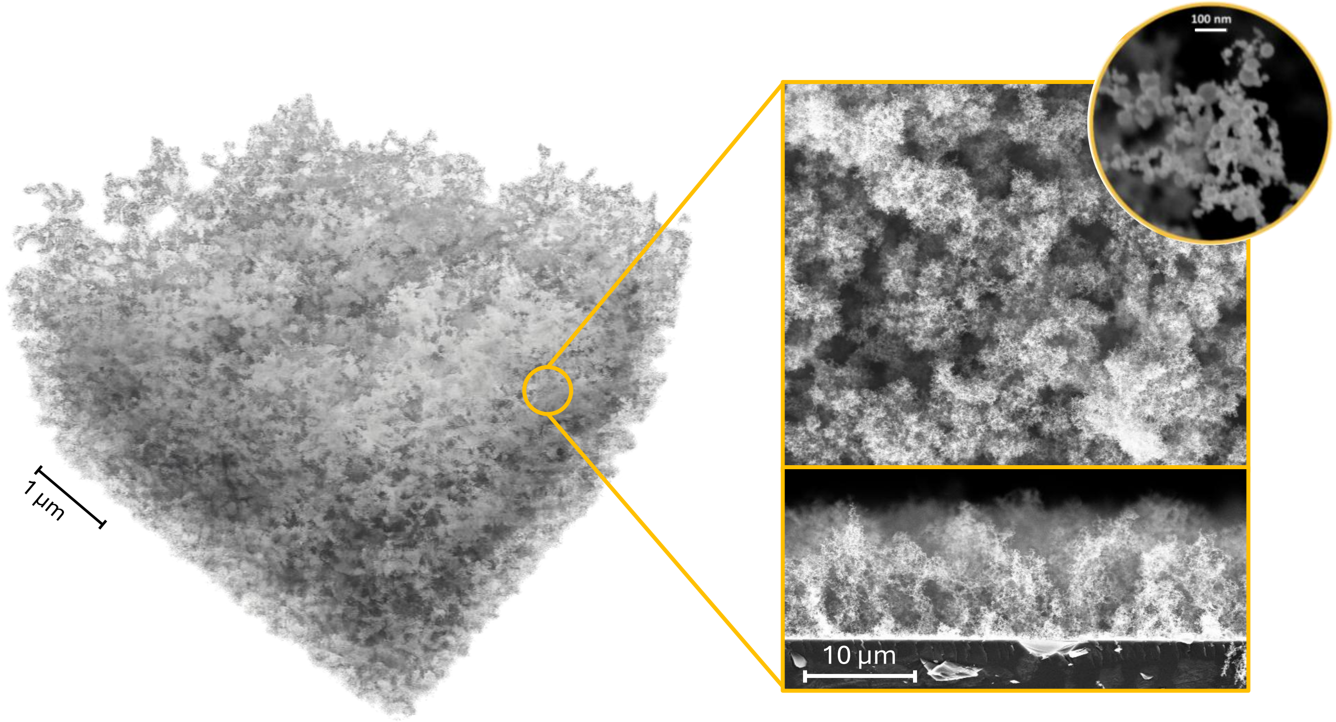
Regimes of interaction depending on plasma density (n_p) with respect to the **critical density (n_c)** ⇨ $n_c = \frac{m_e \cdot \omega_L^2}{4\pi \cdot e^2}$

Optimized near-critical material!

$n_p \sim n_c$ ⇨ **↑ Laser-plasma coupling**

Nanofoam @PoliMi

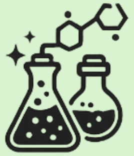
What is a nanofoam?



- **Fractal-like aggregates of nanoparticles** forming a highly porous disordered network
- **Ultra low-density (few mg/cm^3)**
- Large effective surface area → **volumetric laser absorption**
- Improved hot electron generation

Nanofoam Production Methods

Chemical Synthesis



- ✓ Cheap & easy manufacturing
- ✓ Easily scalable
- × Limited control over properties

Additive Manufacturing

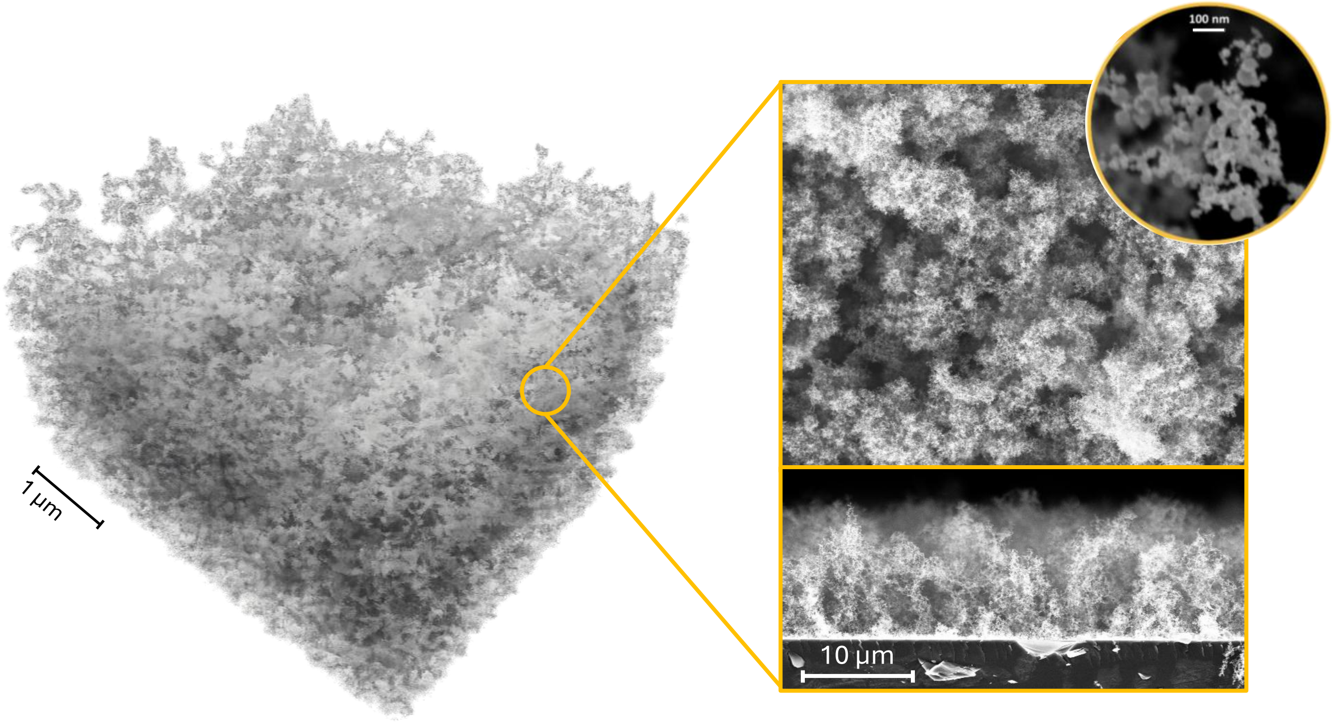
- ✓ Precise & reproducible
- ✓ High control over properties
- × Micrometric scale (10-100 µm)

Physical Vapour Deposition

- ✓ Extreme versatility
- ✓ High control over properties
- ✓ Nanostructured layers

A. Maffini, et al. Plasma Physics and Controlled Fusion 68 (2026): 035007

What is a nanofoam?



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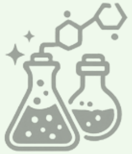

Additive Manufacturing

- ✓ Precise & reproducible
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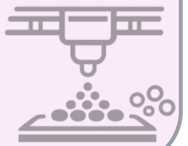


Physical Vapour Deposition

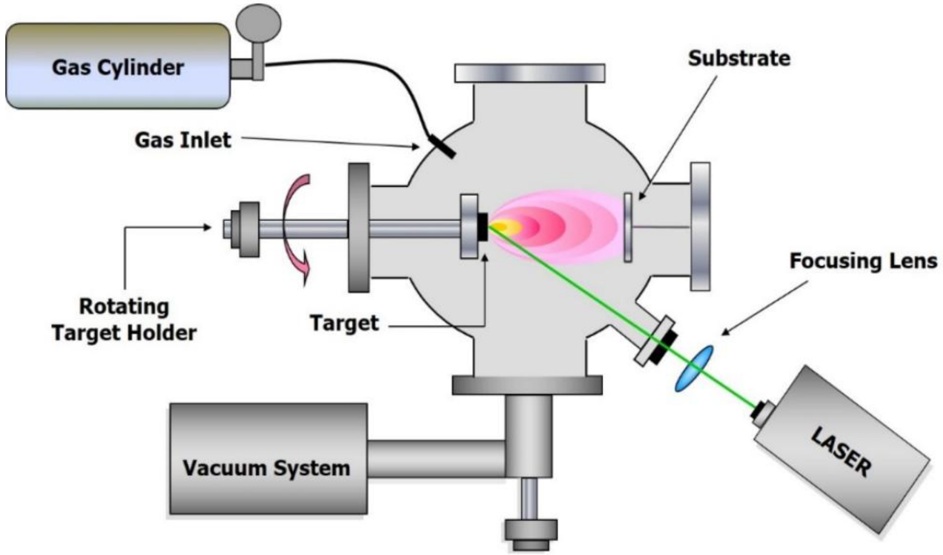
- ✓ Extreme versatility
- ✓ High control over properties
- ✓ Nanostructured layers

↳ **Pulsed Laser Deposition (PLD)**

Nanofoam production with Pulsed Laser Deposition (PLD)

How does it work?

Laser induced **target ablation** → **Plasma plume** → **Film deposition**

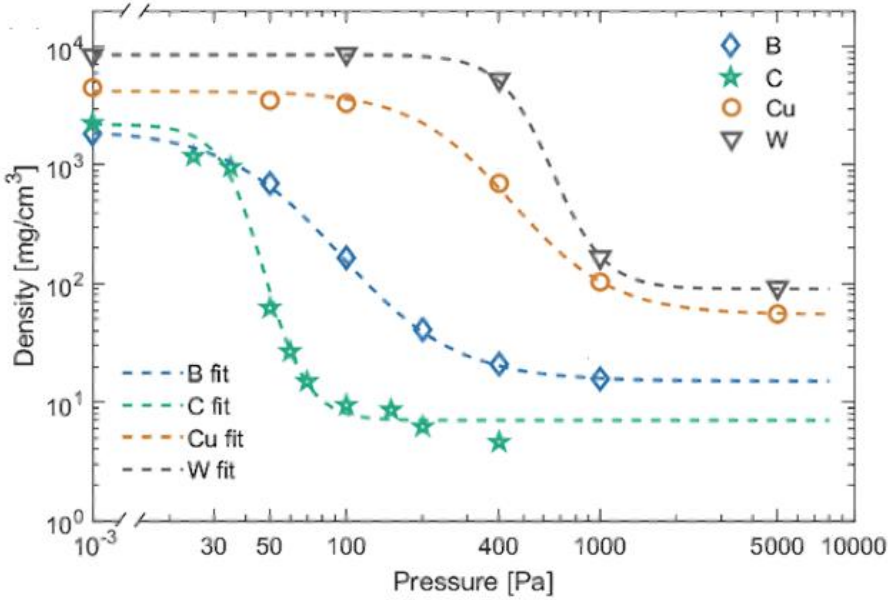


Film properties

- Composition
- Nanostructure
- Thickness
- Density

Operating parameters

- Target Composition
- Pulse Duration
- Laser Fluence
- Deposition Time
- Background Pressure

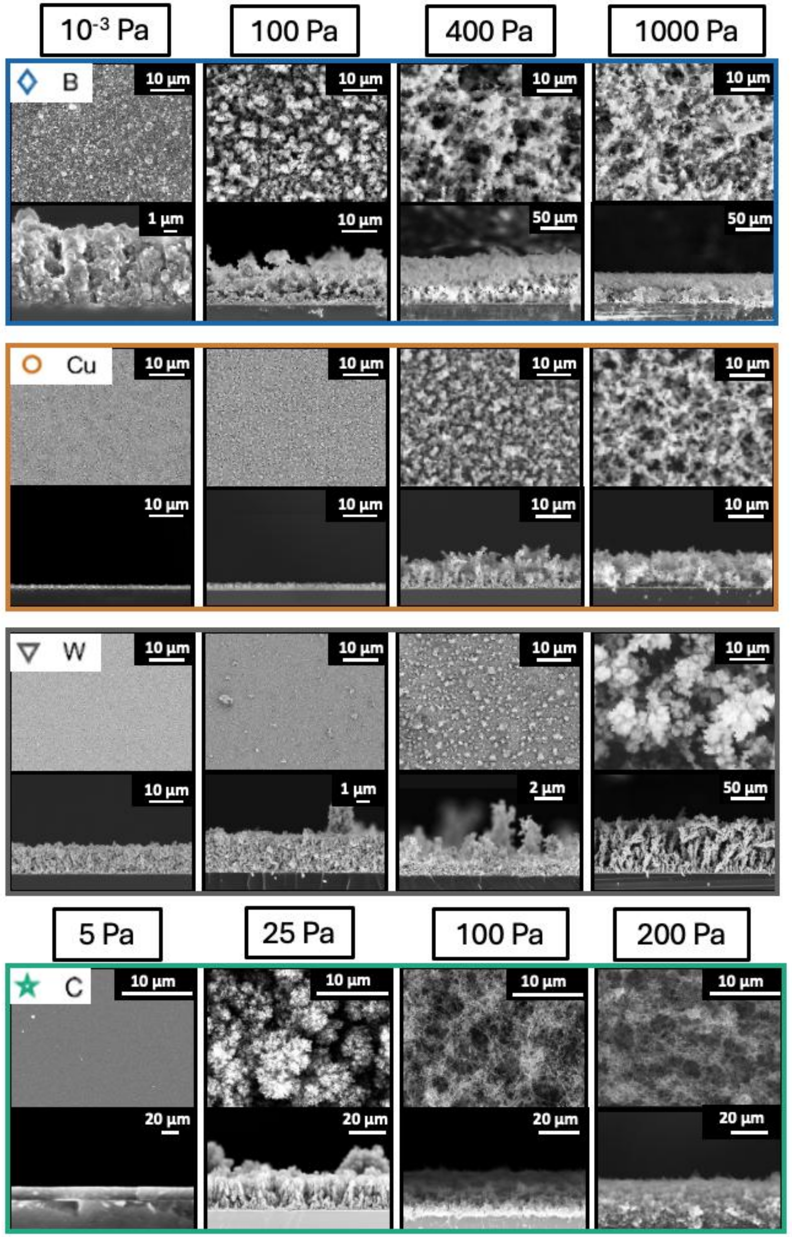


↑ Deposition time → ↑ Thickness

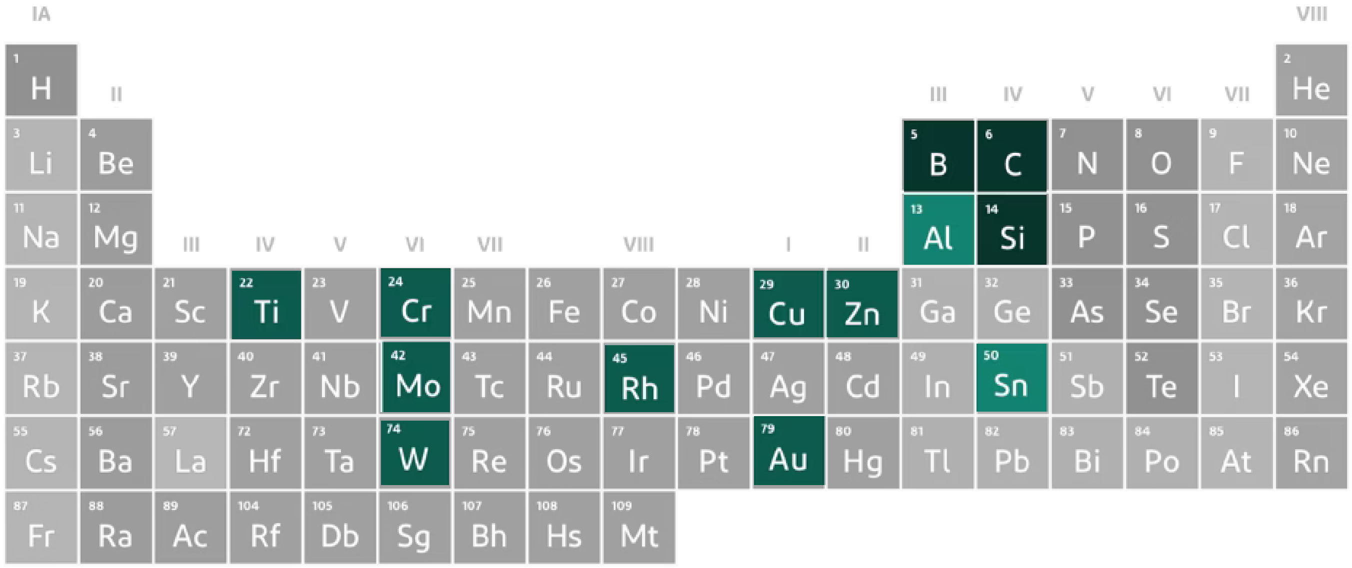
↑ Pressure → Nanoparticle clustering → ↓ Density

D. Orecchia et al., Small Structures, 5, 2300560 (2024)

Nanofoam production with Pulsed Laser Deposition (PLD)

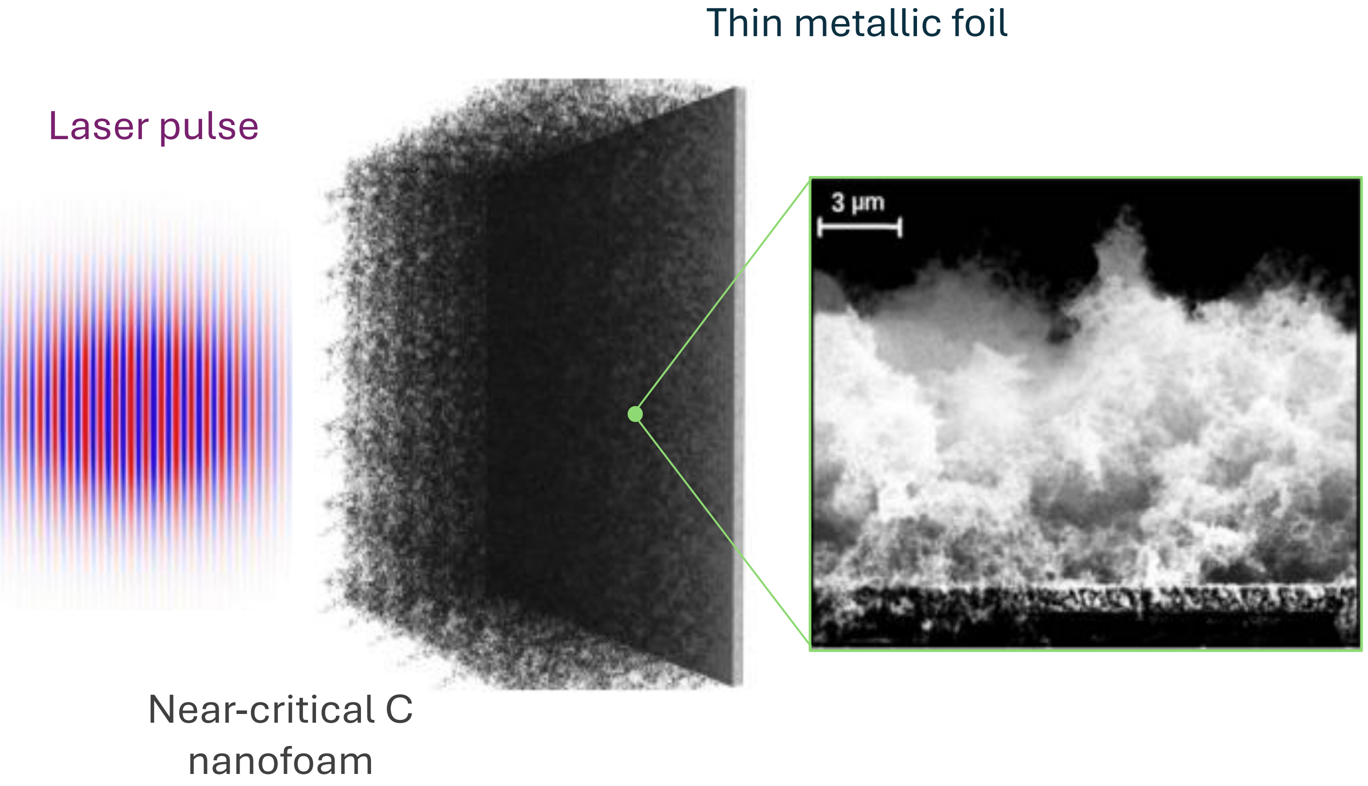


- ns and fs ablation regimes **guarantee high versatility**
- Wide choice of **metallic and non-metallic materials**
- Possibility of **Co-deposition of different materials**
- **Stoichiometric transfer** from target to film



D. Orecchia et al., Small Structures, 5, 2300560 (2024)

Nanofoam-based Double Layer Targets (DLTs)



DLTs

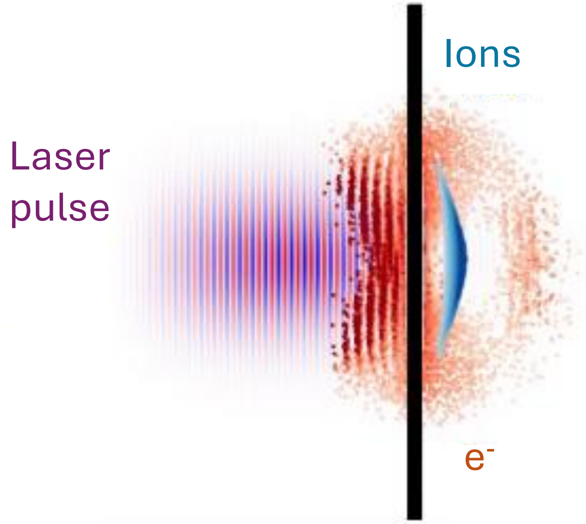
- Thin film + Nanofoam
- Enhanced laser-plasma coupling
- Increased hot-electron generation

Application

- **Laser-driven proton acceleration**
- **Gamma photon generation**
- **Proton-Boron fusion studies**
- Neutron sources
- High-energy electron generation
- Radioisotope production

M. Passoni et al., Plasma Physics and Controlled Fusion 61, 014022 (2019)

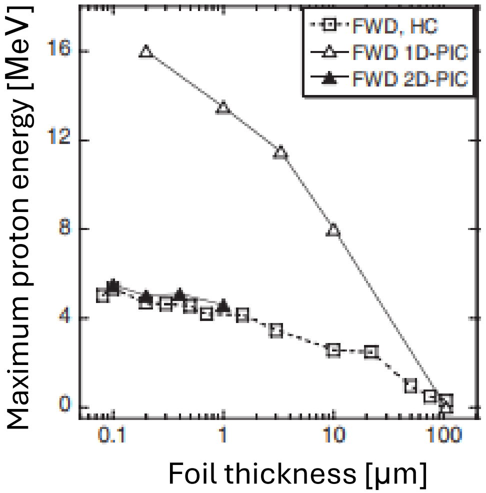
Double Layer Targets for proton acceleration



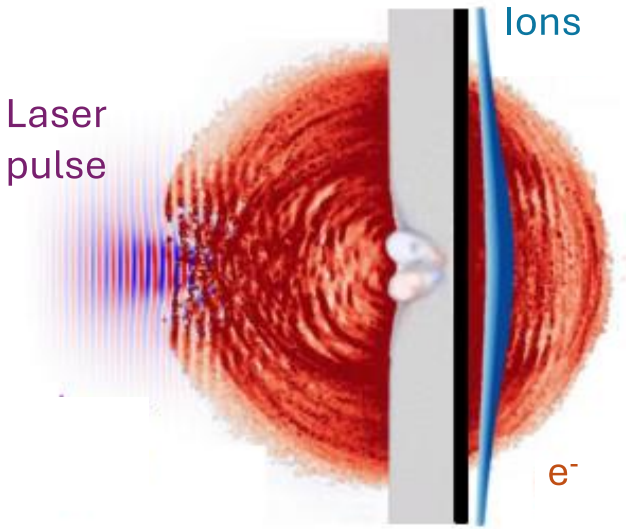
Single Layer Target (SLT)

- Thin **solid foil**
- **Metallic** or polymeric
- **Micrometric** thickness

↓ Target thickness ⇨ ↑ Cut-off energy



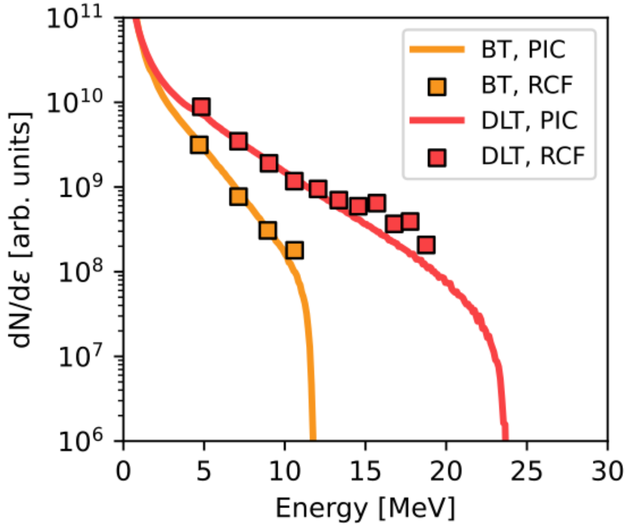
S. Ceccotti et al., Phys. Rev. Lett. 99, (2007)



Double Layer Target (DLT)

- Solid foil + **Nanostructured layer**
  - Nanospheres
  - Nanowires
  - **Carbon Nanofoams**

↑ Laser-plasma coupling ⇨ ↑ Cut-off energy, ↑ Ion number



A. Maffini et al., Frontiers in Physics 11 (2023)

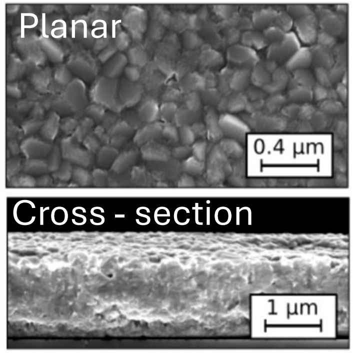
Double Layer Targets for proton acceleration

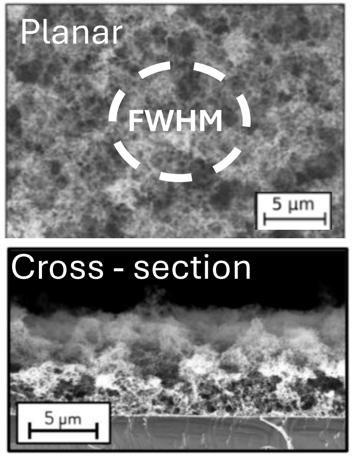
Centro de Láseres Pulsados – VEGA-3

- 800 nm
- 4 J in spot
- $1.25 \cdot 10^{20}$ W/cm^2
- 30-50 fs
- 12 µm FWHM
- 10^{-5} - 10^{-10} contrast

DLTs

MS Al foils + **C nanofoam**



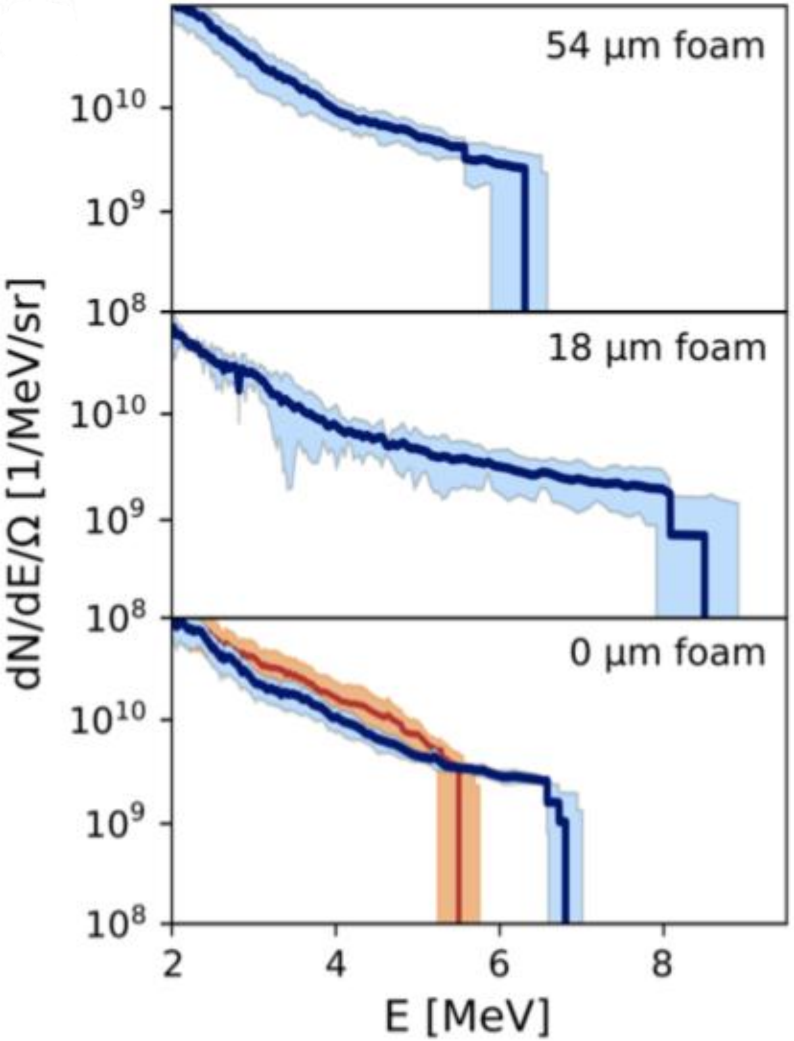


- 1.6 µm Al foil
- 7.8 mg/cm^3 C nanofoam
- 9, 18, 36, 54 µm thick nanofoam

✓ **Increased proton number** with respect to both Commercial Al foils and MS deposited Al foils

✓ **Increase of proton cutoff** energy from 6.7 to 8.7 MeV in DLTs with respect to both Commercial Al foils and MS deposited Al foils

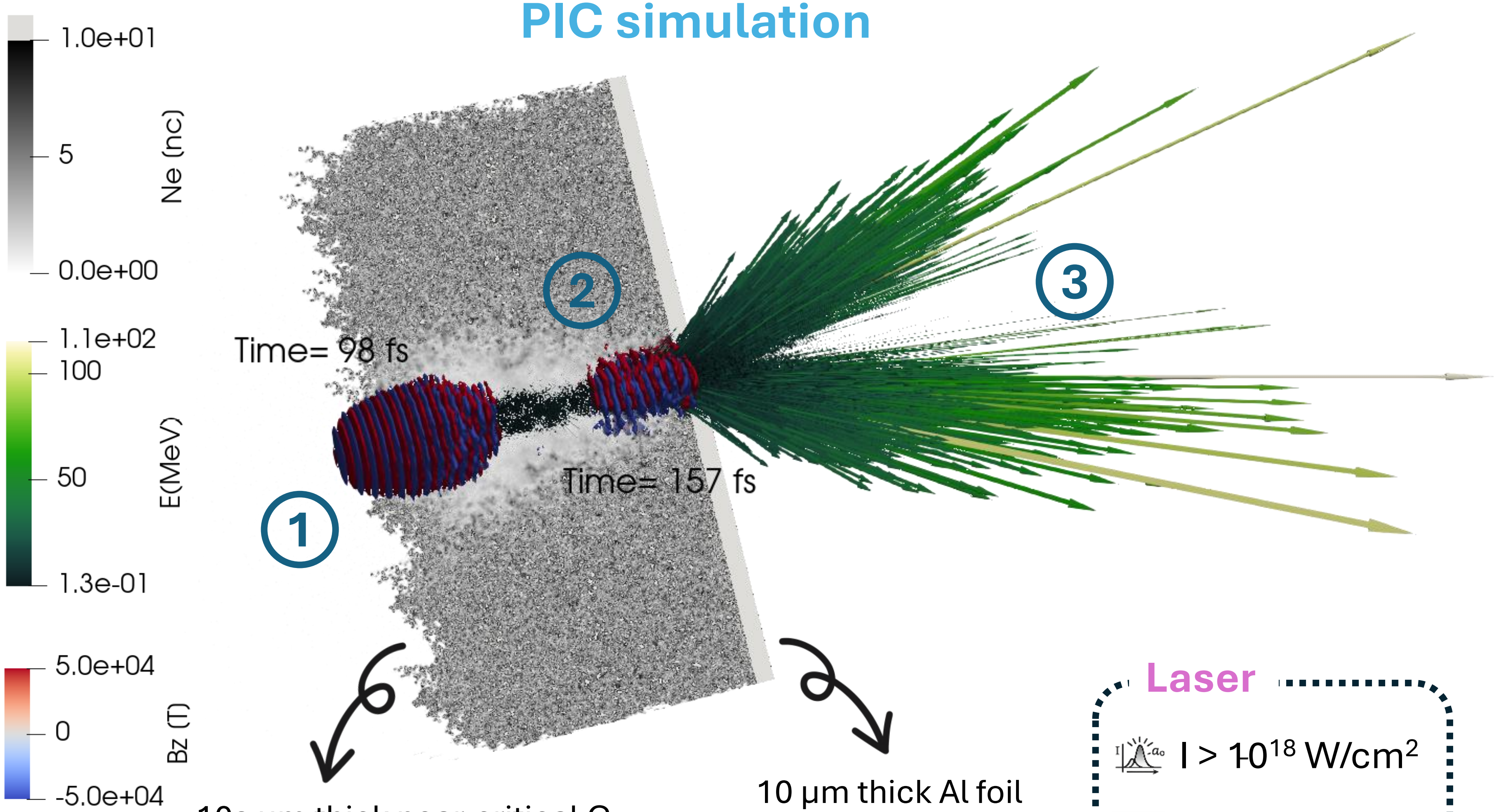
✓ Proton cutoff energy depends on **nanofoam thickness**, with a maximum reached for an **optimal value**.



F. Mirani, et al. Physical Review Applied 24.1 (2025)

Double Layer Targets for ɣ photon generation

PIC simulation



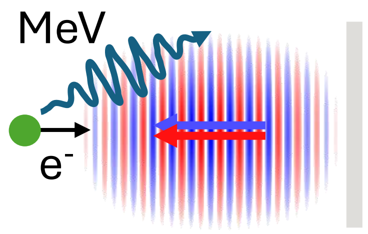
10s µm thick near-critical C nanofoam simulated via DLCCA code

10 µm thick Al foil

Laser

- $I > 10^{18}$ W/cm^2
- 10s fs

Non-linear Inverse Compton Scattering (NICS)

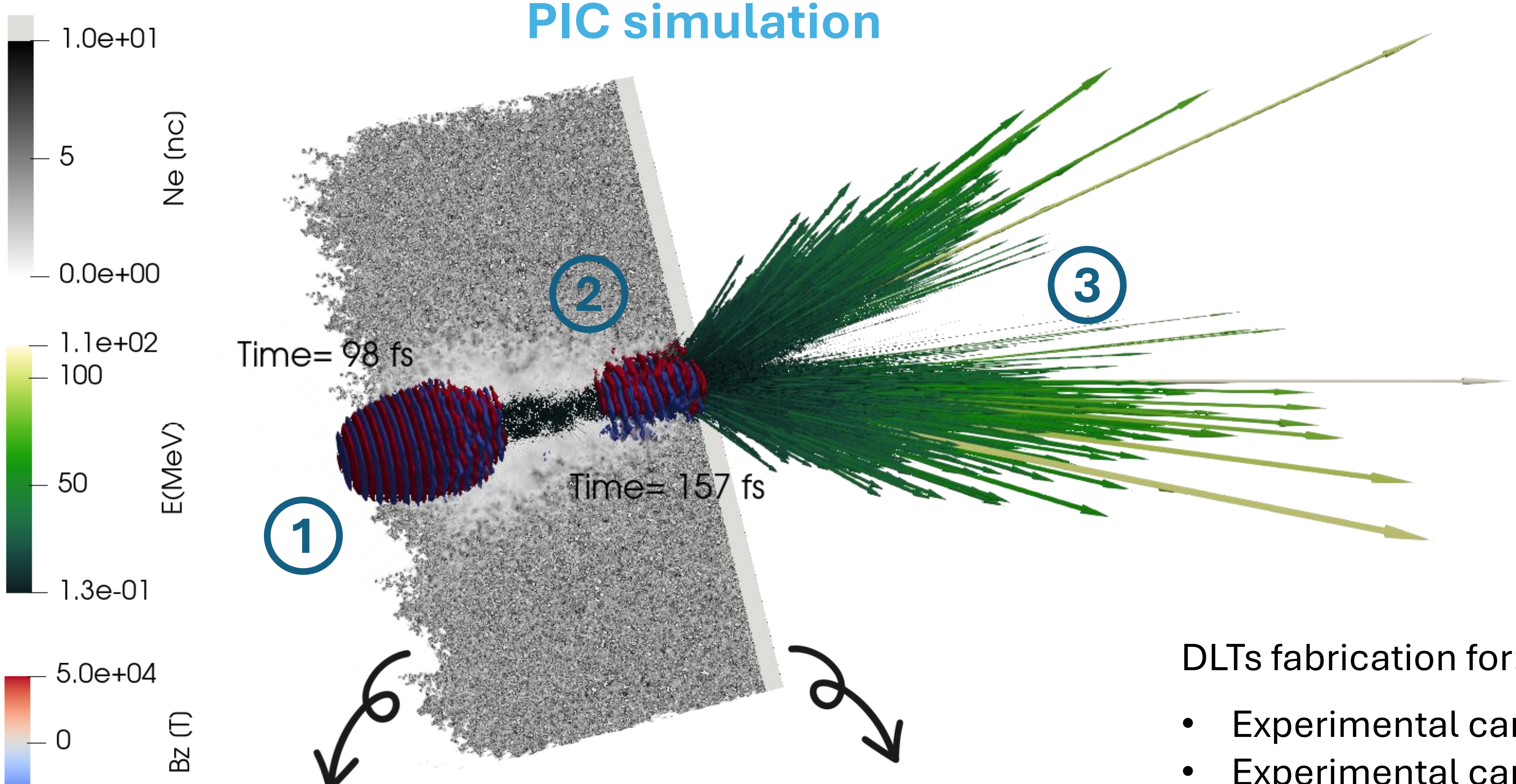


1. **Hot e⁻ generation** via laser-foam interaction
2. **Laser back-reflection** from the metallic foil
3. **ɣ generation via NICS** for head on collision between relativistic e⁻ and reflected laser

M. Galbiati, et al. Under review at Scientific Reports (2025)

Double Layer Targets for ɣ photon generation

PIC simulation



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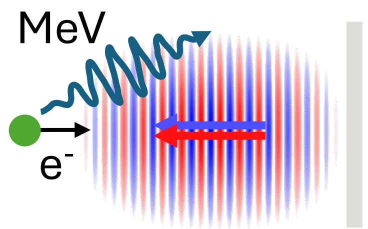


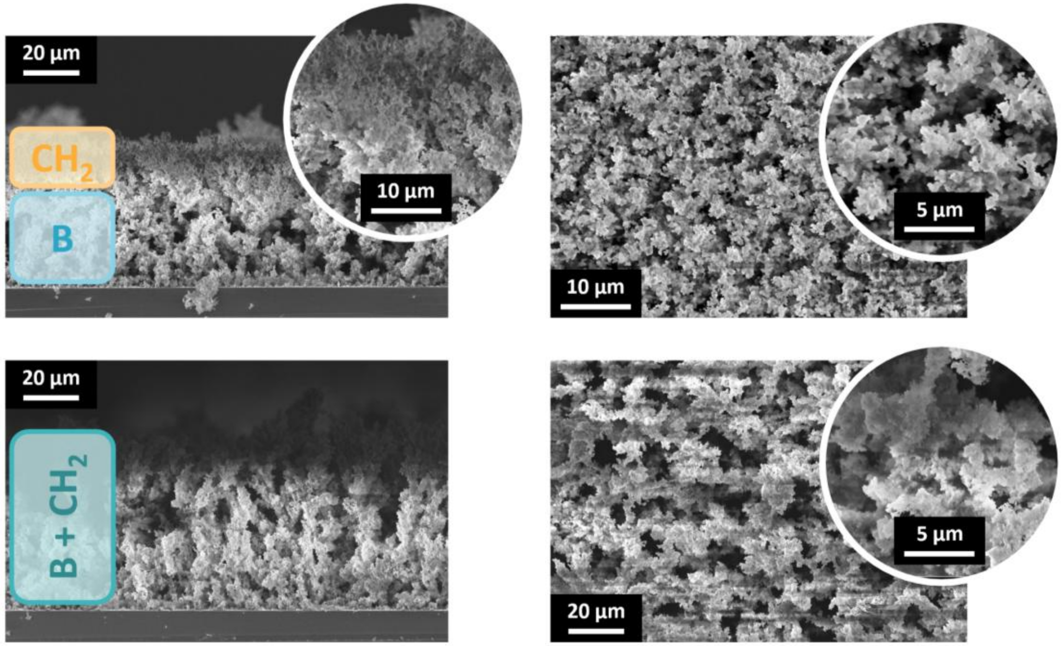
Stay tuned!

DLTs fabrication for:

- Experimental campaign in April 2024 with F2
- Experimental campaign in April/May 2026 with F1

Collaboration with LULI: Livia Lancia, Marta Galbiati, Lorenzo Romagnani

Nanofoams for $p^{11}B$ fusion



Queen's University – TARANIS

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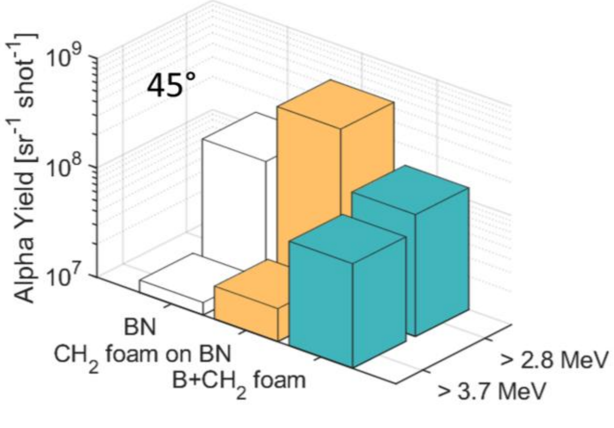
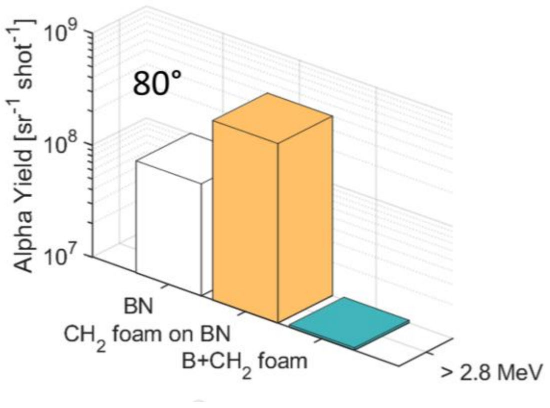
- 1053 nm
- 10 J in spot
- $2 \cdot 10^{19}$ W/cm^2
- 800 fs
- 5.1 µm FWHM
- $5 \cdot 10^{-7}$ contrast

DLTs

- Double layered **B + CH_2 nanofoam**
- **Mixed B-CH_2** nanofoam

Higher proton density from plastic layer





- ✓ **Proton–boron fusion was successfully driven** using a moderate laser system in an **in-target configuration**
- ✓ Low-density B-CH_2 nanofoam targets significantly **enhance α-particle yield** compared to standard BN targets
- ✓ **Angular dependence of the α-particle** signal has been observed due to shielding effect of the nanofoam layer

D. P. Molloy, et al. Physical Review Research 7.1 (2025)

Conclusions

- ✓ Nanofoam based DLTs have demostrated a **versatile tool for Laser-Plasma interaction** experiment
- ✓ Modelling and experiments indicate that low-density nanofoam in front of a micrometric foil increases electron heating and **shift the proton spectrum toward higher energy and charge**
- ✓ Simulations confirmed the importance of the nanofoam layer to **enahnce gamma photon generation** via non-linear inverse compton scattering
- ✓ Experimens using polymer and boron-polymer nanofoams produced by PLD demonstrate **alpha particle fluxes competitive with the state of the art** at moderate laser energy

For more information

M. Passoni, et al. Plasma Physics and Controlled Fusion 61.1 (2019)

A. Maffini et al., Applied Surface Science 599, 153859 (2022)

D. Orecchia et al., Small Structures, 5, 2300560 (2024)

M. Galbiati, et al. Under review at Scientific Reports (2025)

F. Mirani, et al. Physical Review Applied 24.1 (2025)

D. P. Molloy, et al. Physical Review Research 7.1 (2025)

A. Maffini, et al. Plasma Physics and Controlled Fusion 68 (2026)

Thank you
for the attention