

Nanofoam based double layer targets for laser-plasma interaction experiments

Matteo Iaccarino

17/03/2026

ELIMED 2026

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ELI Beamlines Facility
Dolní Břežany, Czech Republic




- Activities performed within the framework of a collaboration between:

- Our group from



POLITECNICO
MILANO 1863

- The  **eli beamlines** team



D. Margarone



L. Giuffrida



V. Kantarelou

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



M. Passoni

Principal Investigator



A. Maffini



F. Mirani



M. Galbiati



D. Vavassori



M. Iaccarino



M.S. De Magistris

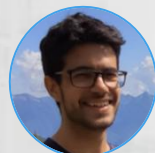
- And ...



QUEEN'S UNIVERSITY BELFAST



K. Ambrogioni



D. Orecchia

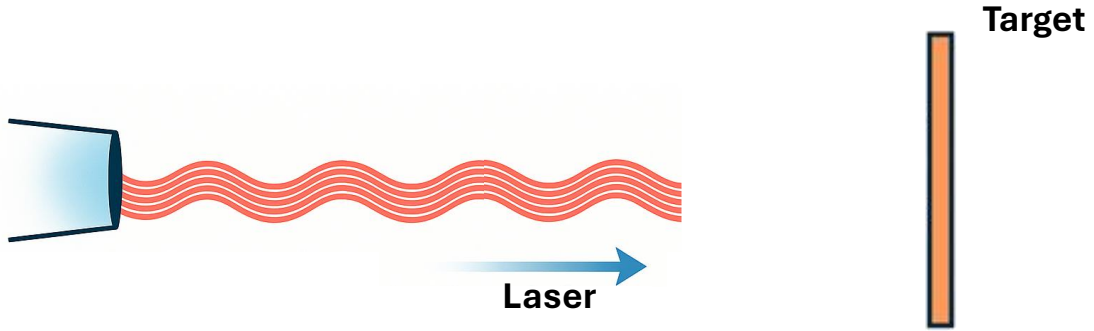


D. Dellasega



V. Russo

Laser-plasma interaction



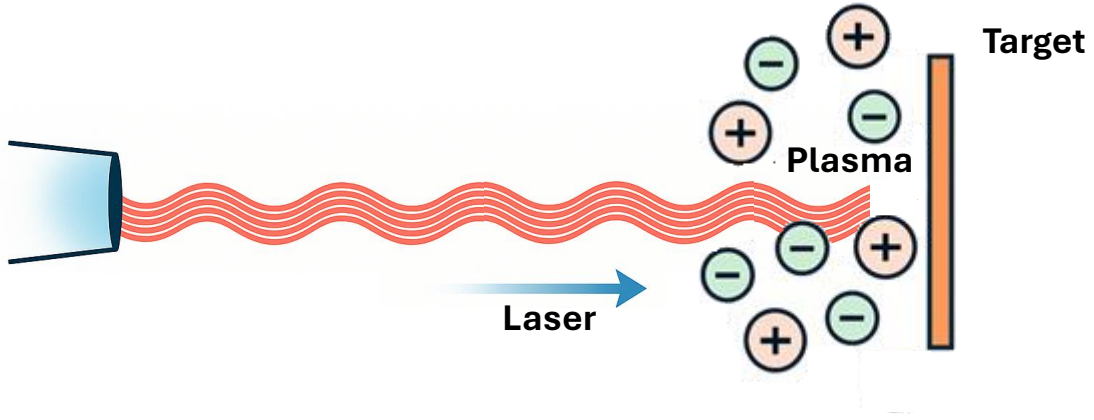
Laser

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

Target

- Density
- Thickness
- Composition

Laser-plasma interaction



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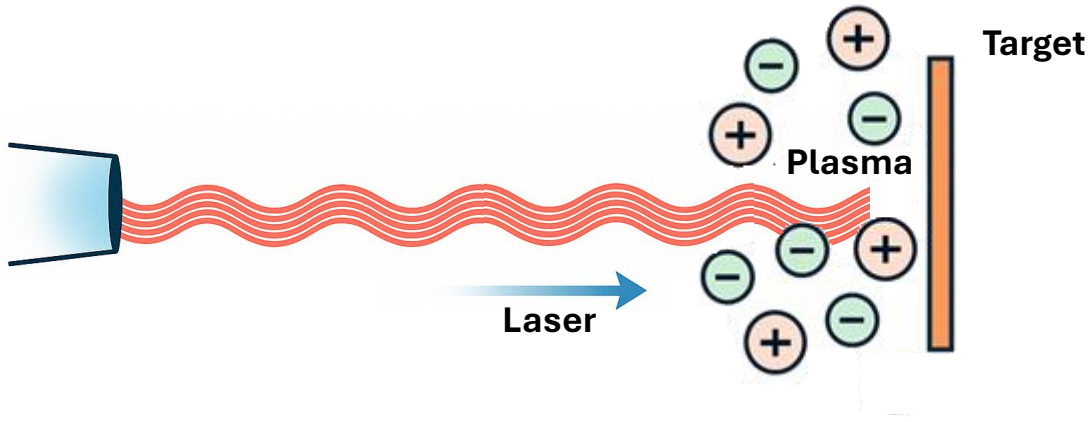
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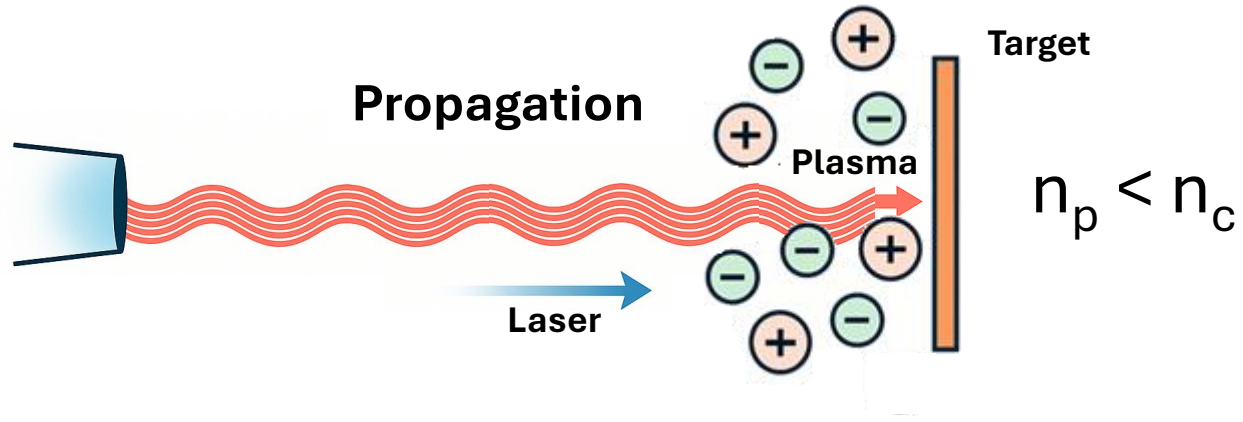
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Plasma formation

Regimes of interaction depending on plasma density (n_p) with respect to the **critical density** (n_c)

$$\Rightarrow n_c = \frac{m_e \cdot \omega_L^2}{4\pi \cdot e^2}$$

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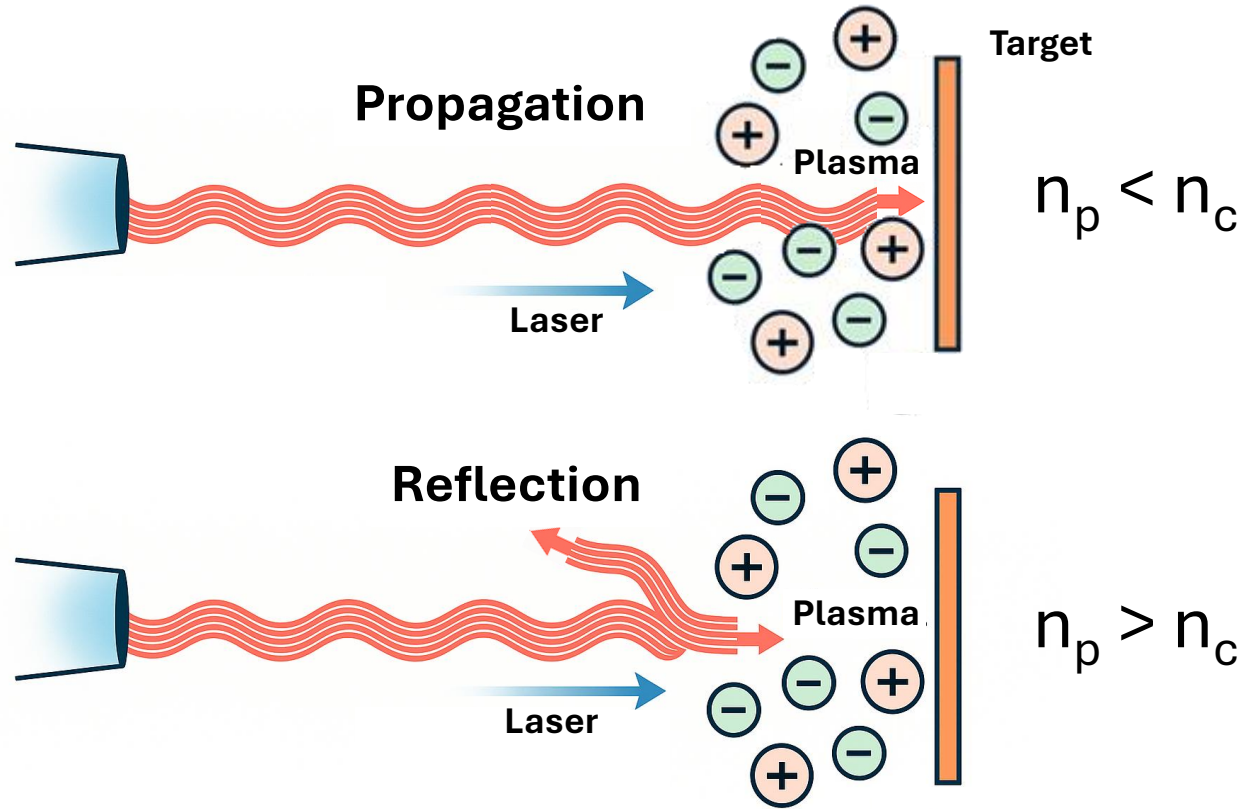
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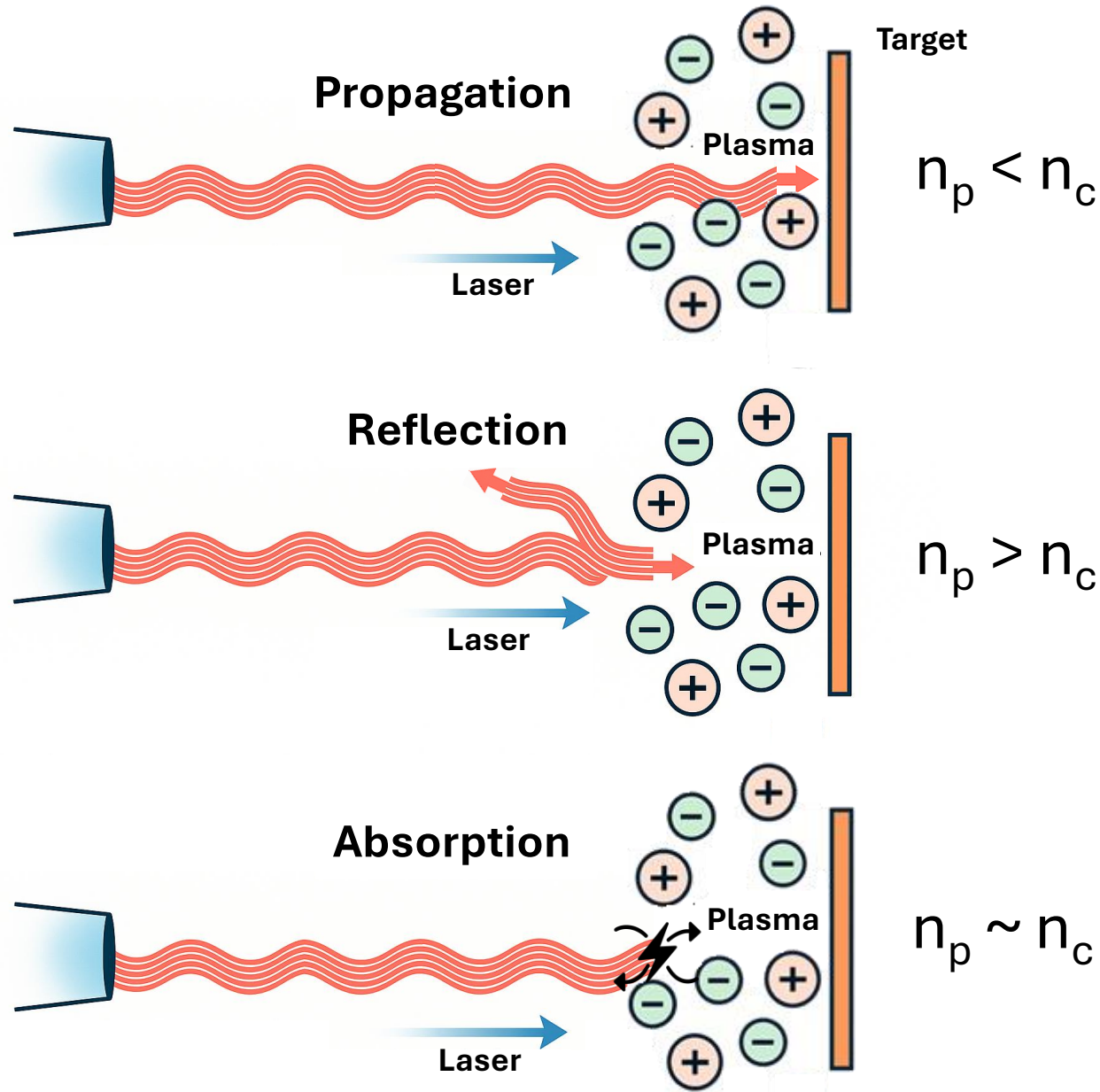
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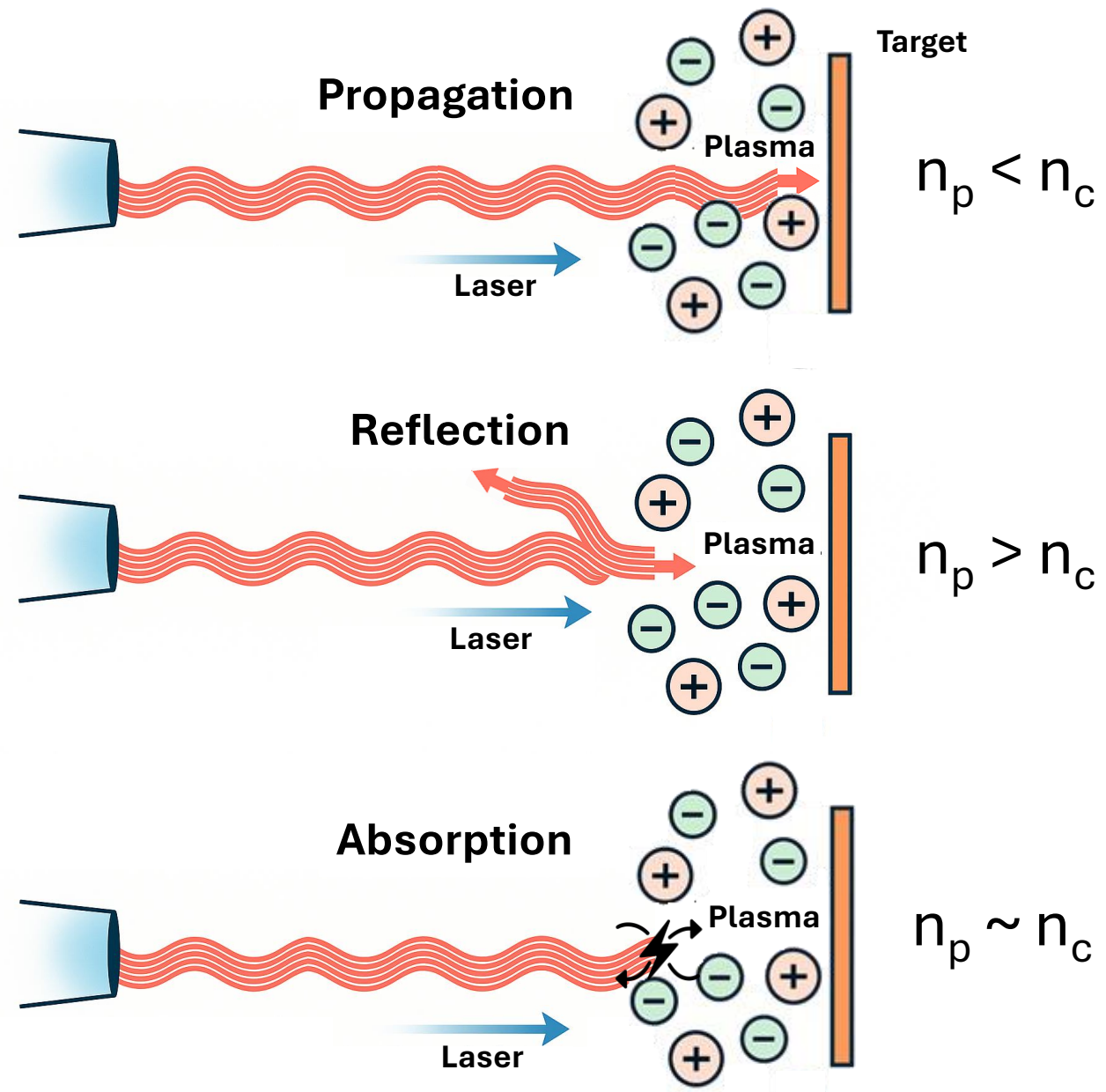
Optimized near-critical material!

$n_p \sim n_c$

➔

\uparrow Laser-plasma coupling

Laser-plasma interaction



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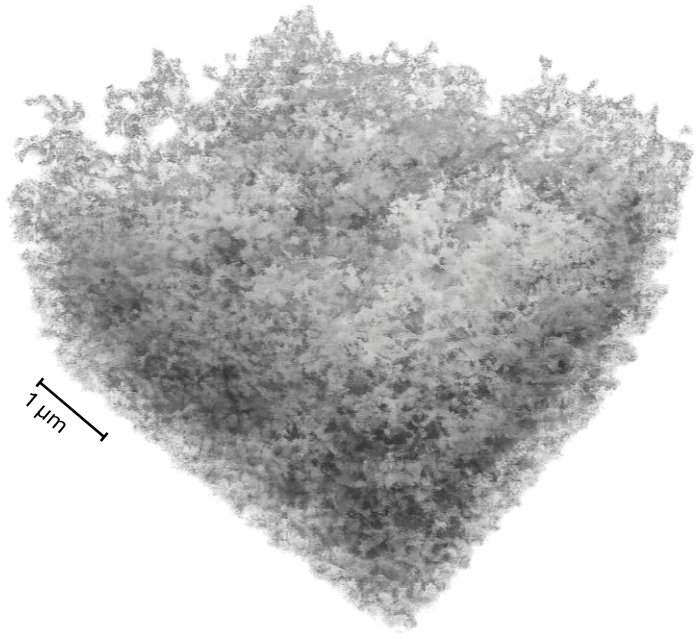
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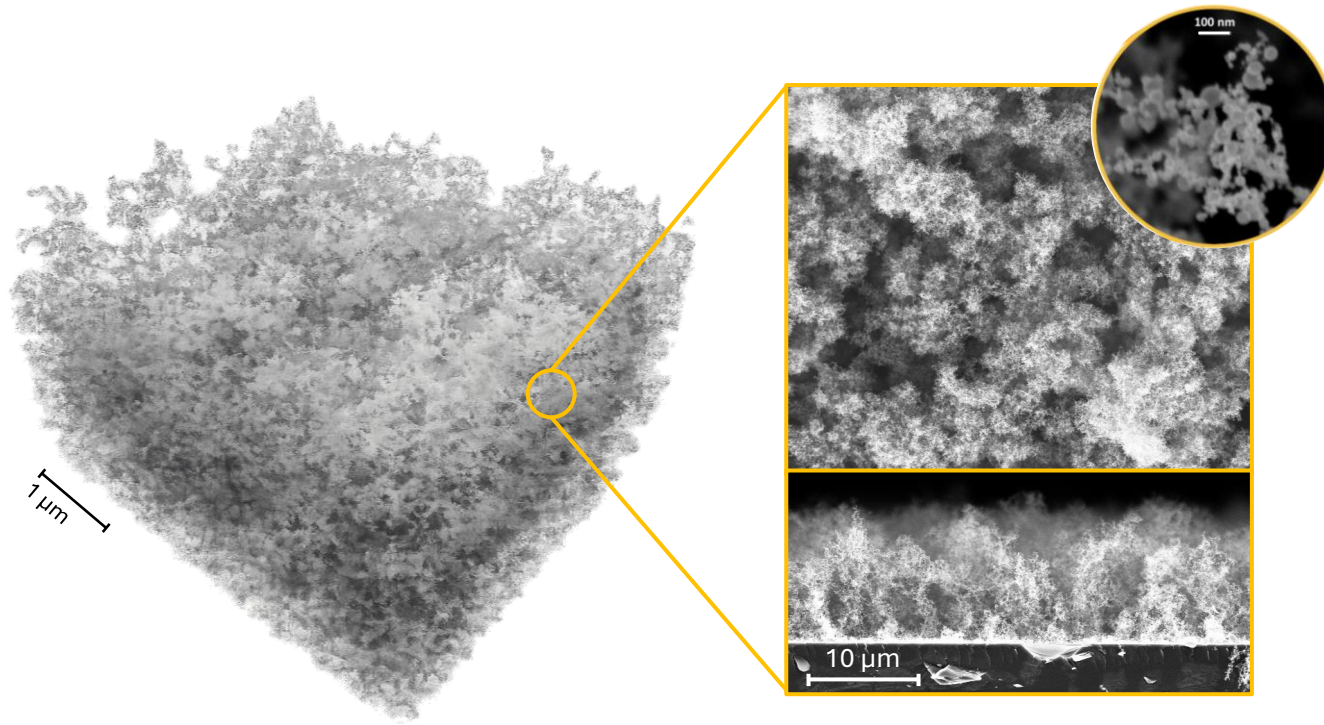
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Nanofoam @PoliMi

What is a nanofoam?

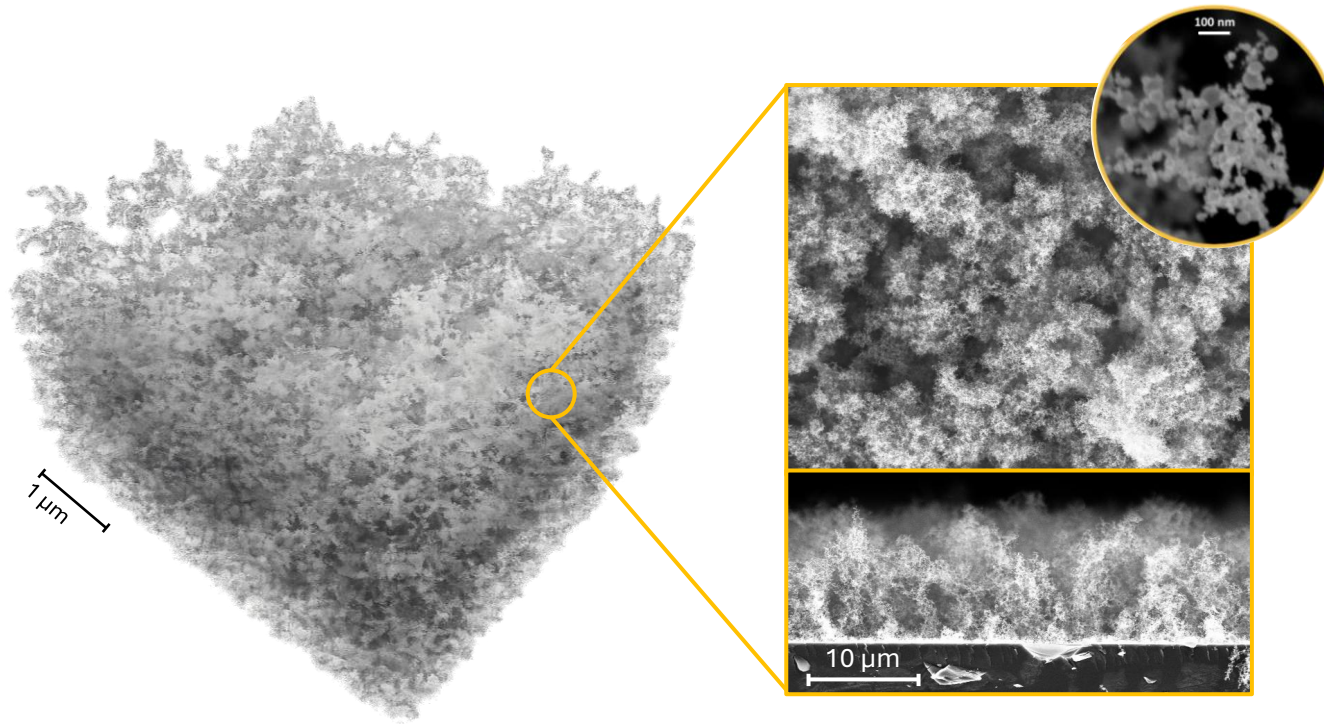


What is a nanofoam?



- **Fractal-like aggregates of nanoparticles** forming a highly porous disordered network
- **Ultra low-density (few mg/cm³)**
- Large effective surface area → **volumetric laser absorption**
- Improved hot electron generation

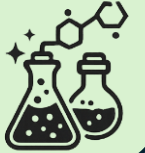
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Nanofoam Production Methods

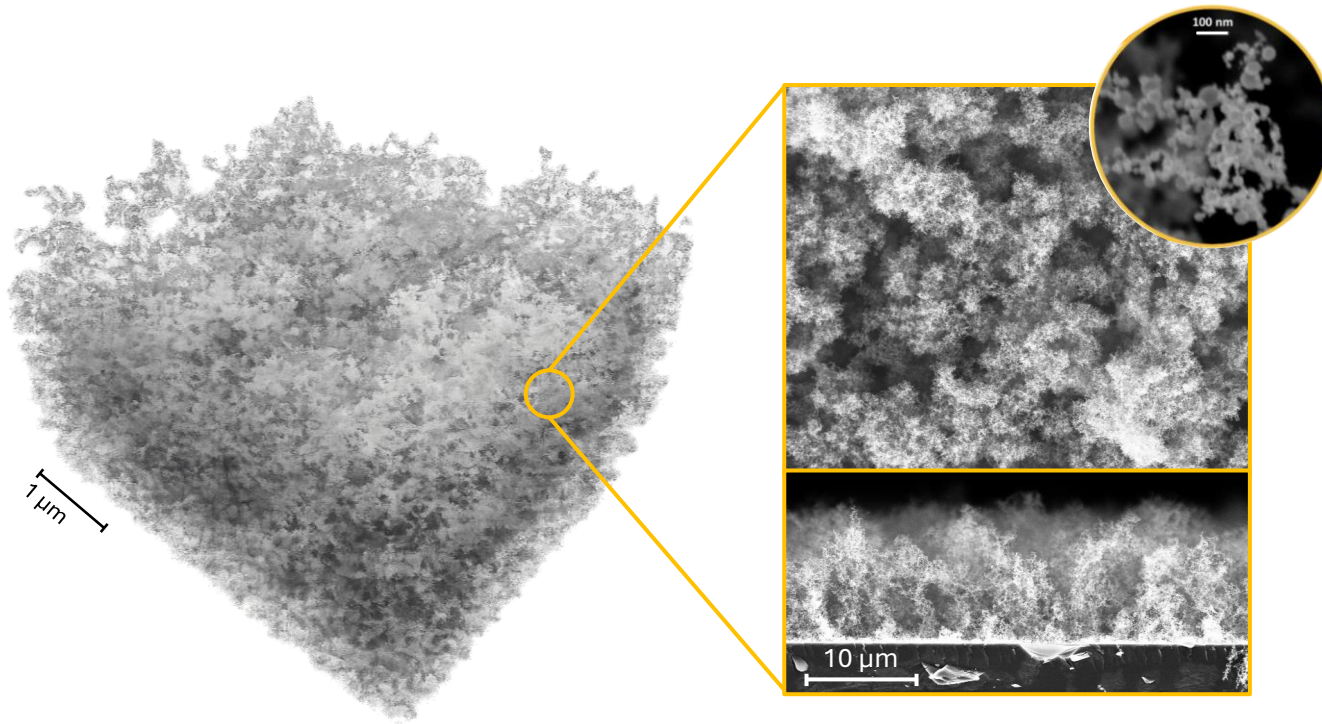
Chemical Synthesis

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



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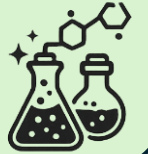


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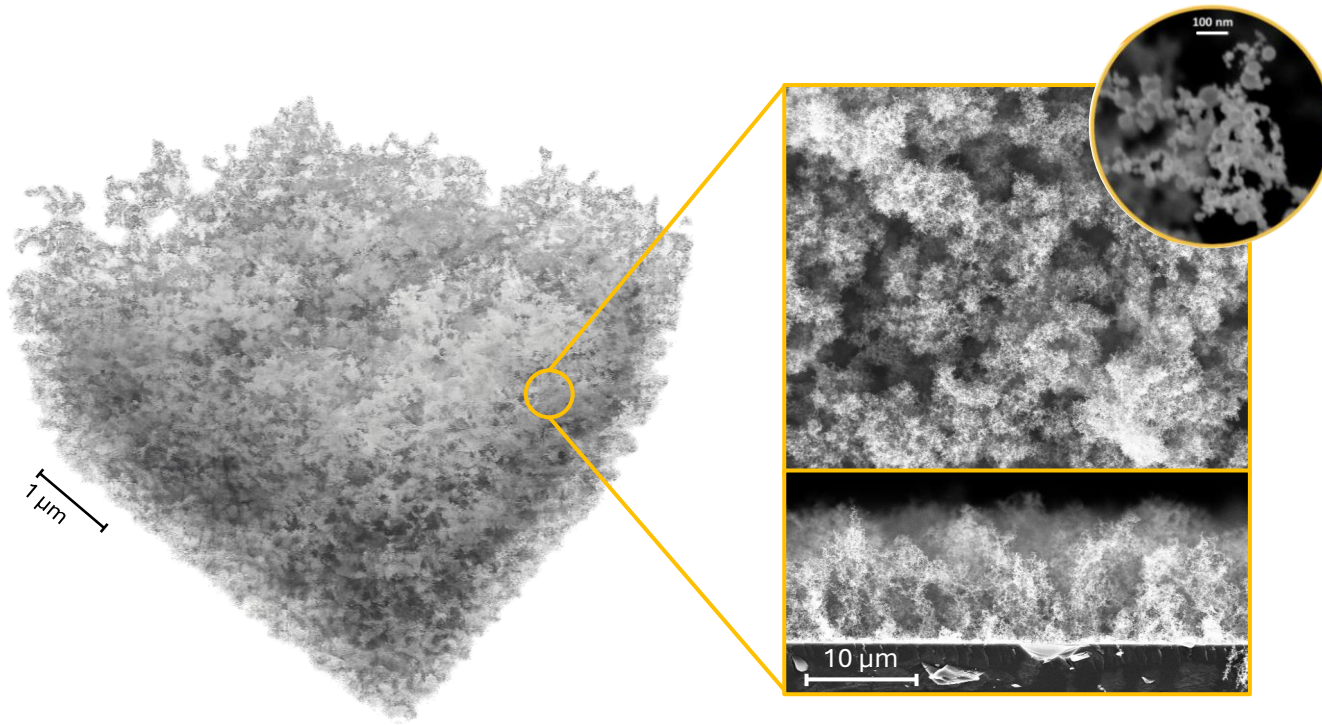


Additive Manufacturing

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



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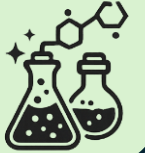


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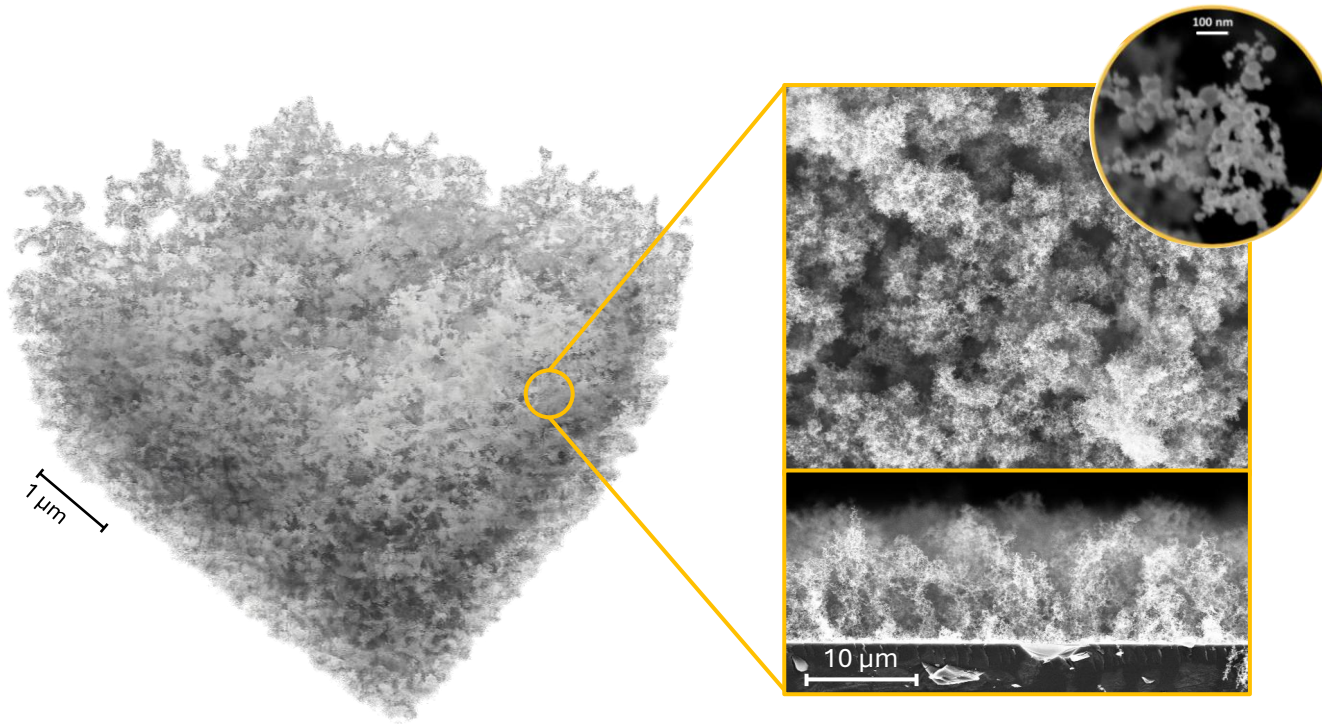


Physical Vapour Deposition

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



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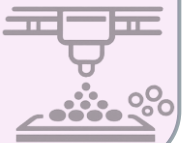
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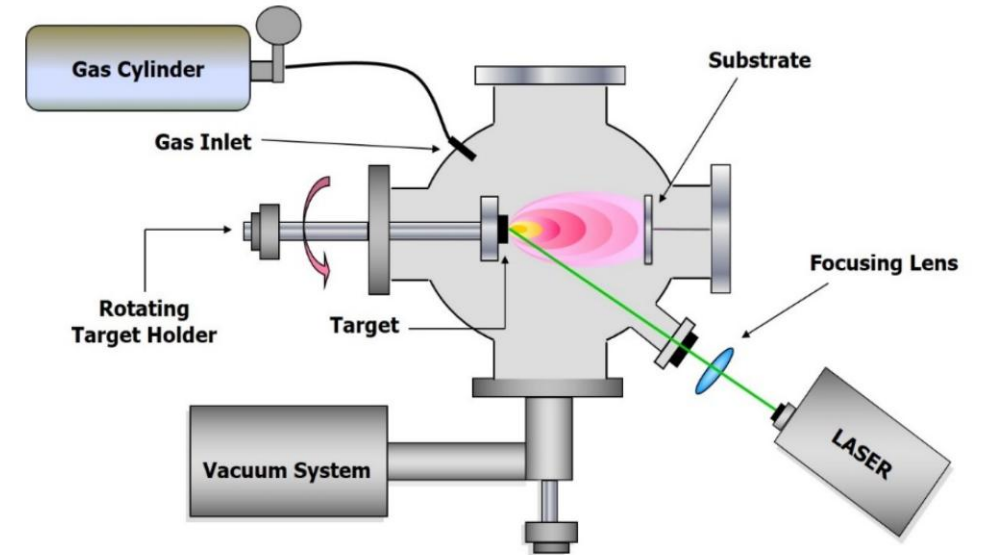


↳ **Pulsed Laser Deposition (PLD)**

Nanofoam production with Pulsed Laser Deposition (PLD)

How does it work?

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



Nanofoam production with Pulsed Laser Deposition (PLD)

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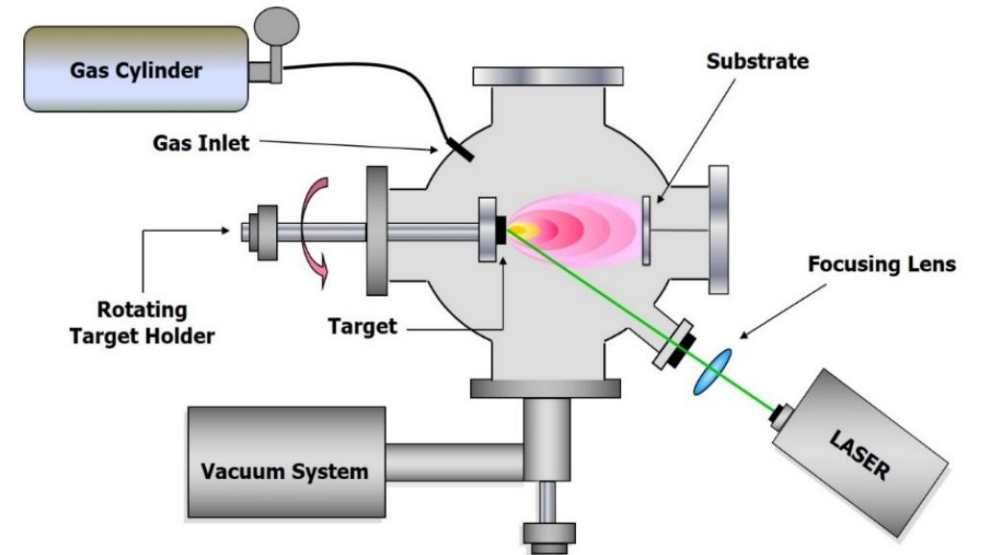
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Film properties

- Composition

Operating parameters

- Target Composition



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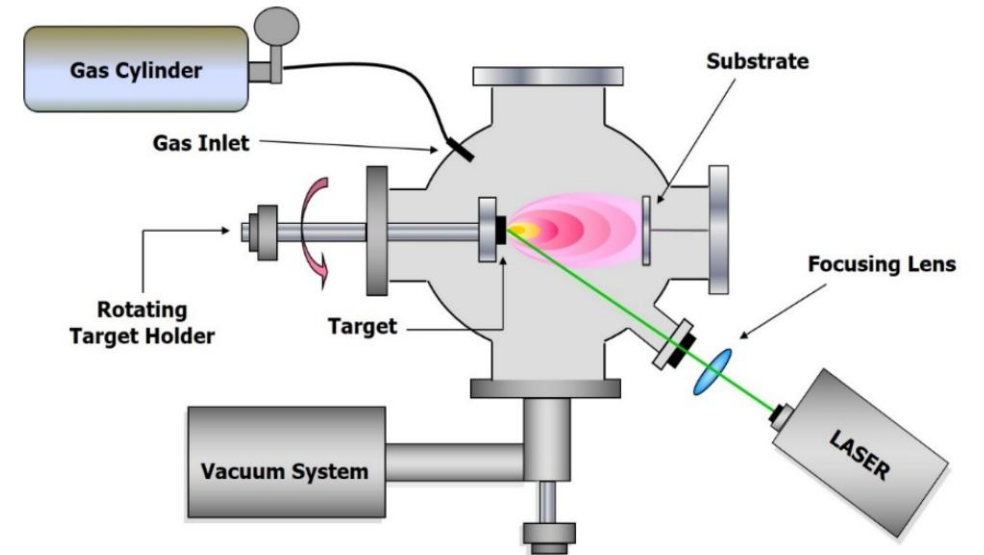
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- Composition
- Nanostructure

Operating parameters

- Target Composition
- Pulse Duration
- Laser Fluence



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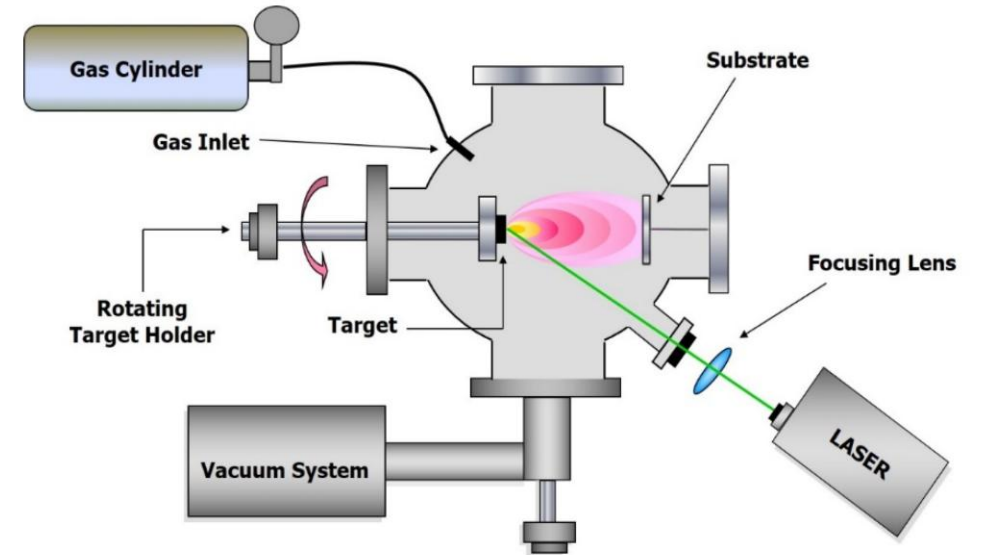
Laser induced **target ablation** → **Plasma plume** → **Film deposition**

Film properties

- Composition
- Nanostructure
- Thickness

Operating parameters

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



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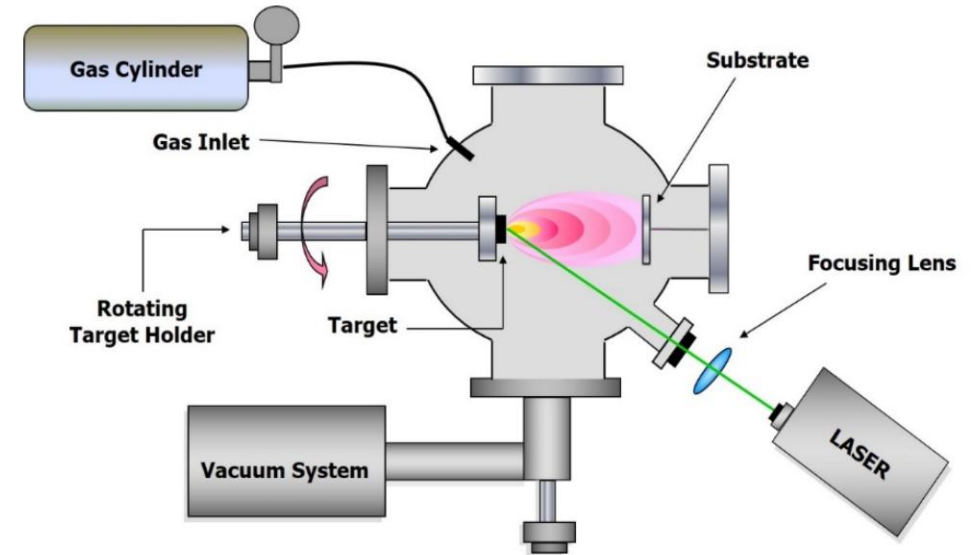
Laser induced **target ablation** → **Plasma plume** → **Film deposition**

Film properties

- Composition
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- Thickness
- Density

Operating parameters

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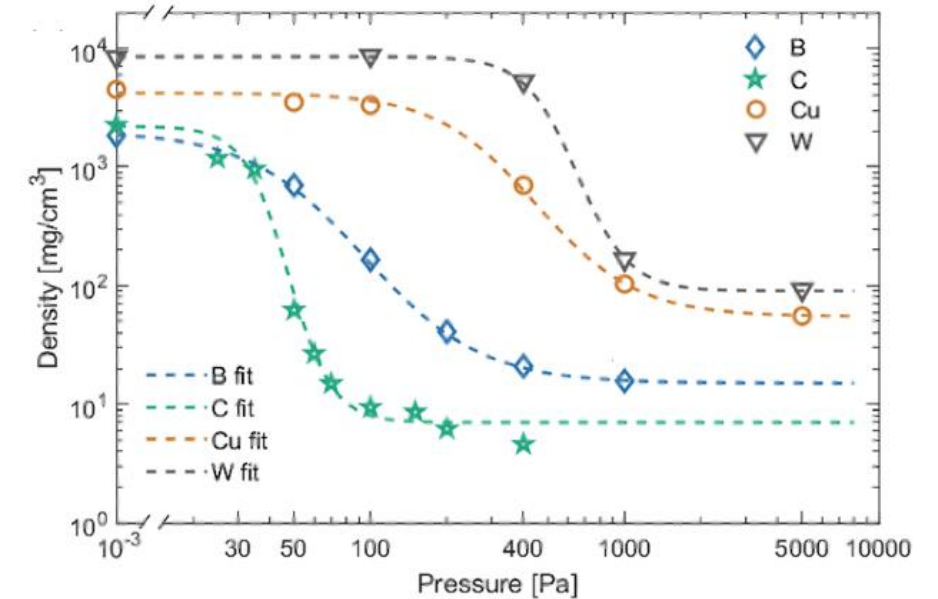
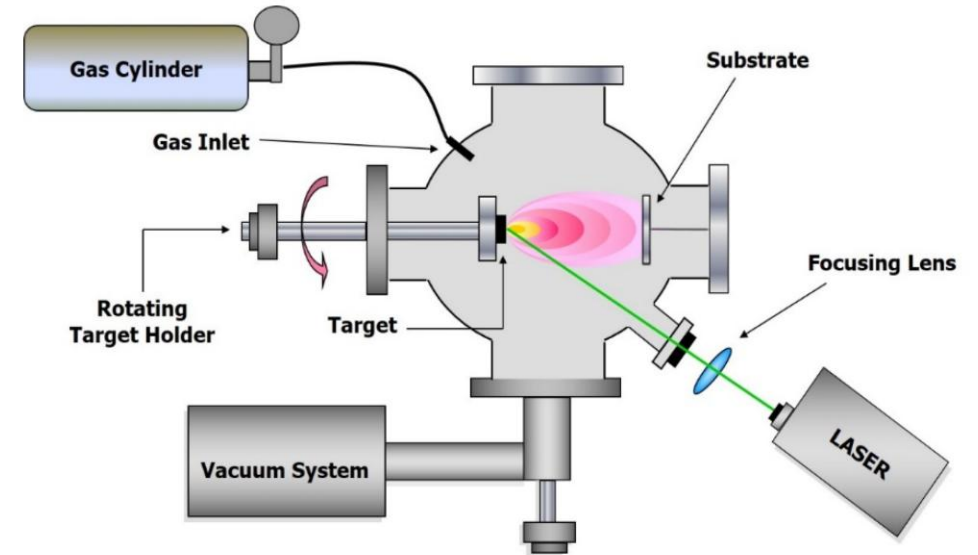
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- **Thickness**
- **Density**

Operating parameters

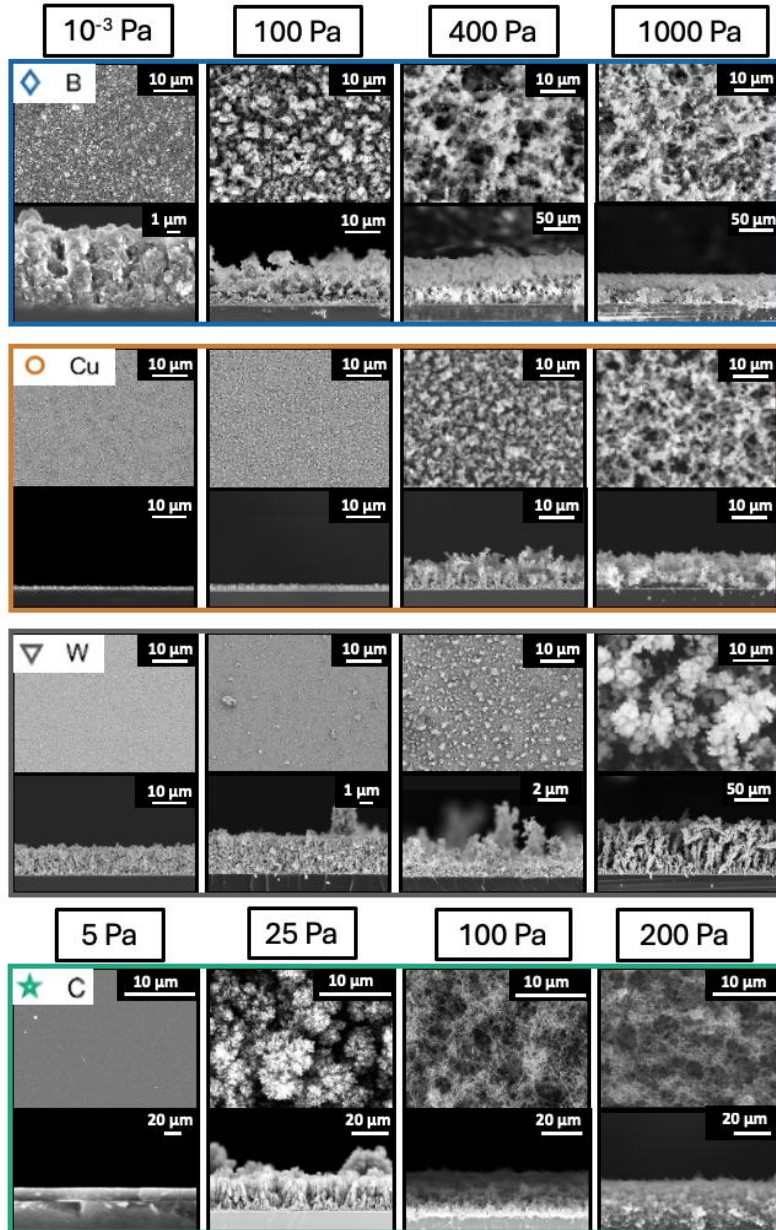
- Target Composition
- Pulse Duration
- Laser Fluence
- **Deposition Time**
- **Background Pressure**

↑ Deposition time → ↑ Thickness

↑ Pressure → Nanoparticle clustering → ↓ Density

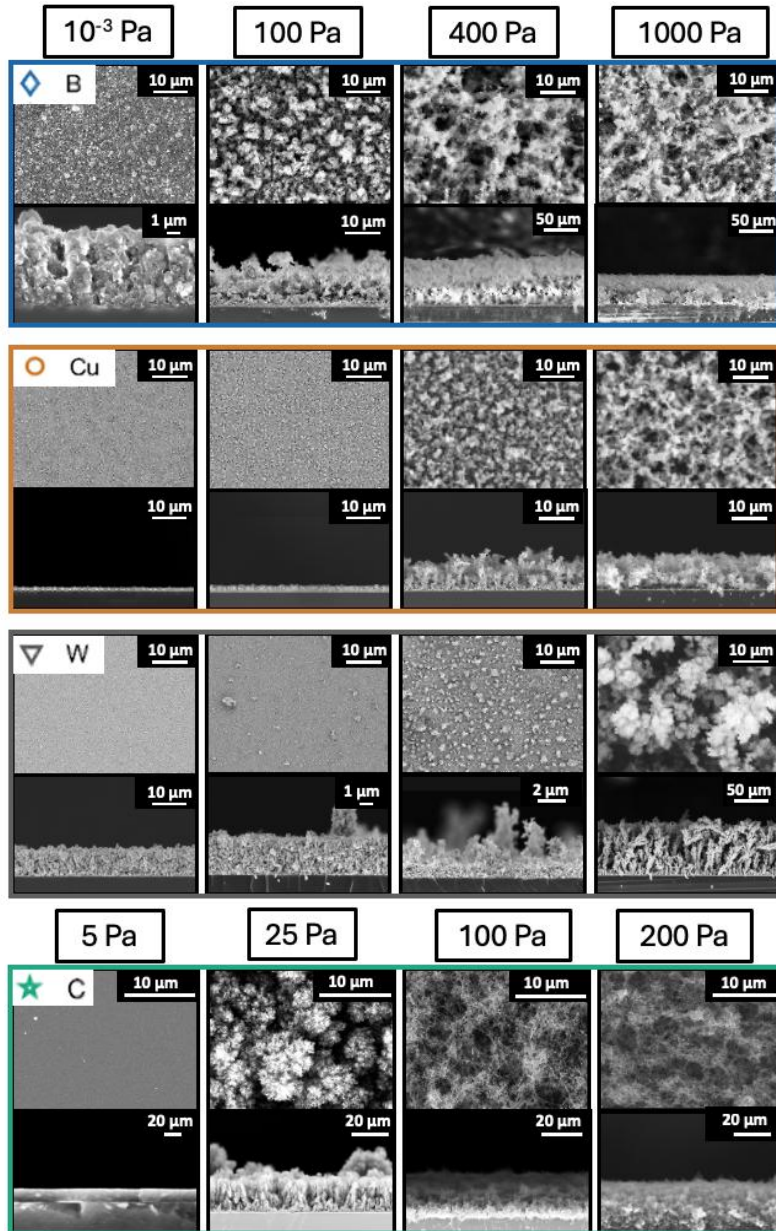


Nanofoam production with Pulsed Laser Deposition (PLD)



➤ ns and fs ablation regimes **guarantee high versatility**

Nanofoam production with Pulsed Laser Deposition (PLD)

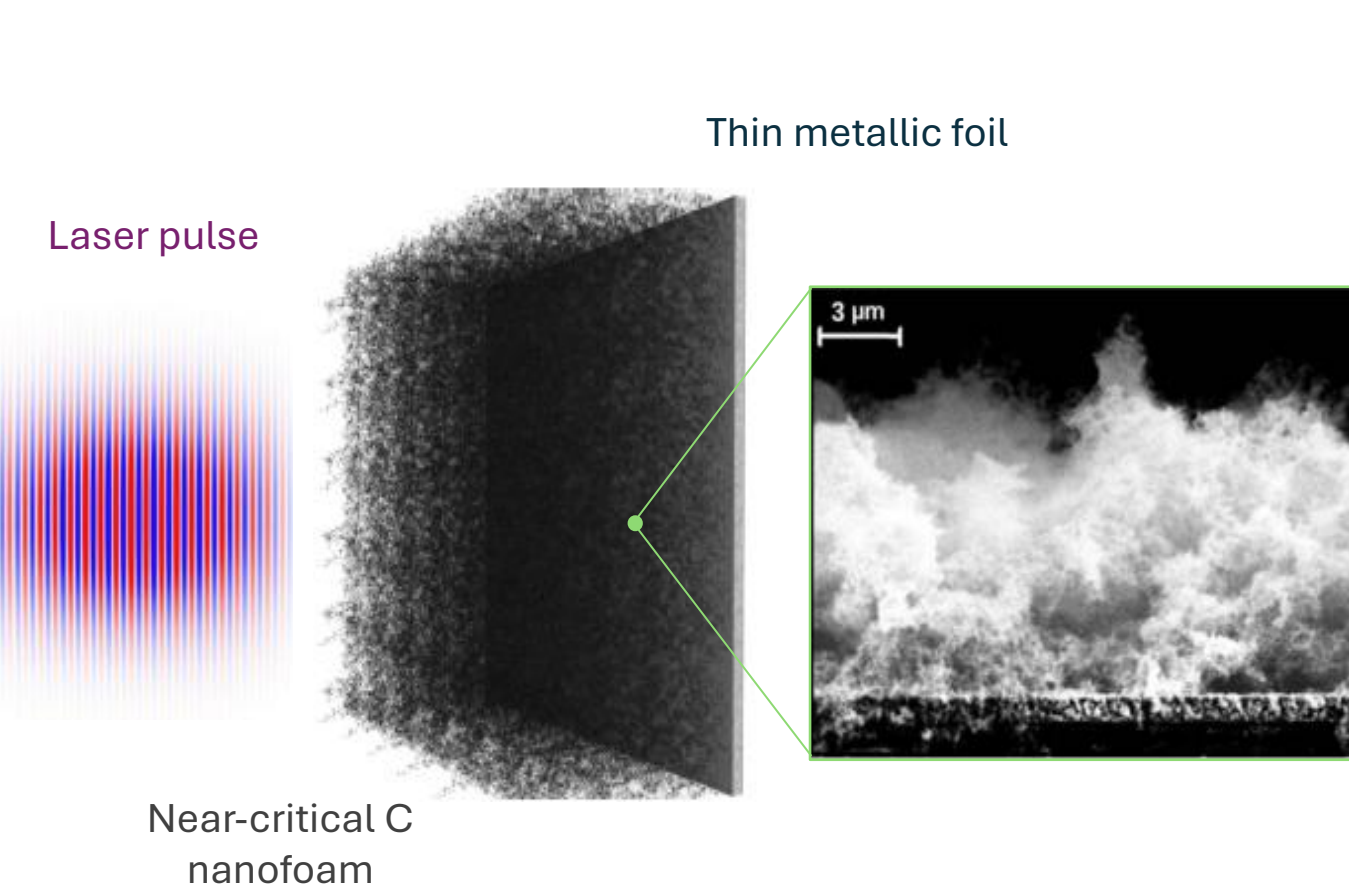


- ns and fs ablation regimes **guarantee high versatility**
- Wide choice of **metallic and non-metallic materials**
- Possibility of **Co-deposition of different materials**
- **Stoichiometric transfer** from target to film

IA																				VIII										II									
1																															2								
H																															He								
3	4																					5	6	7	8	9	10												
Li	Be																					B	C	N	O	F	Ne												
11	12																					13	14	15	16	17	18												
Na	Mg																					Al	Si	P	S	Cl	Ar												
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36																						
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr																						
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54																						
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe																						
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86																						
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn																						
87	88	89	104	105	106	107	108	109																															
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt																															

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

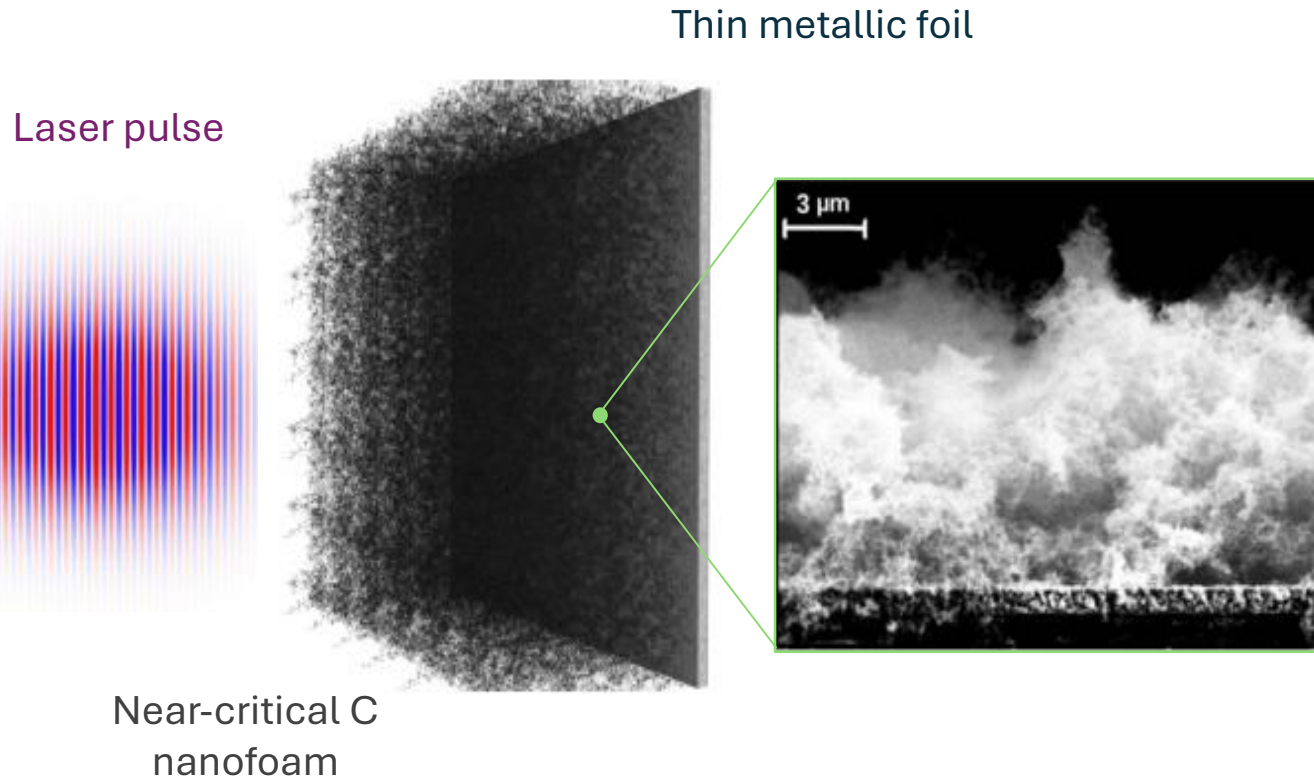
Nanofoam-based Double Layer Targets (DLTs)



DLTs

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

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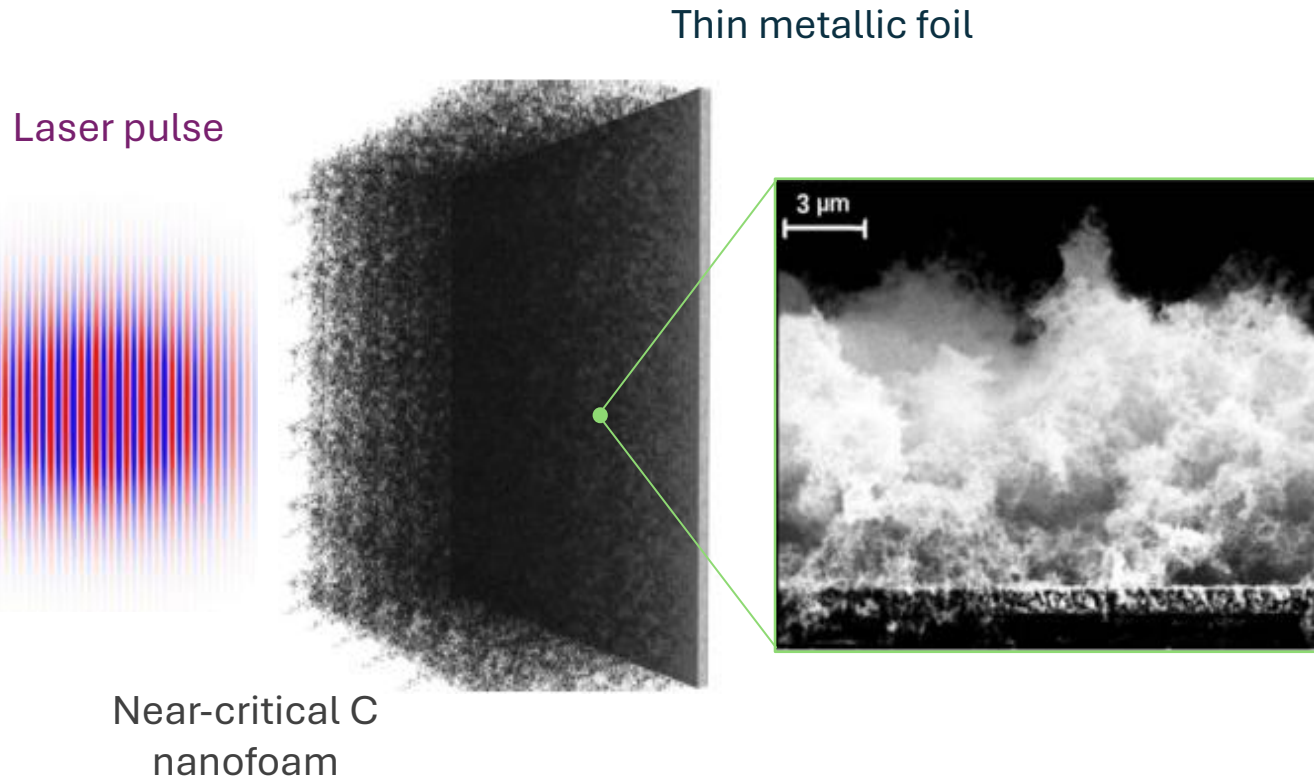
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Application

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

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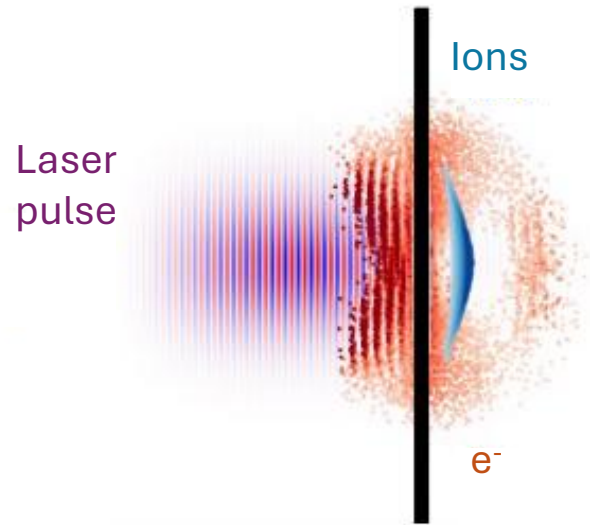
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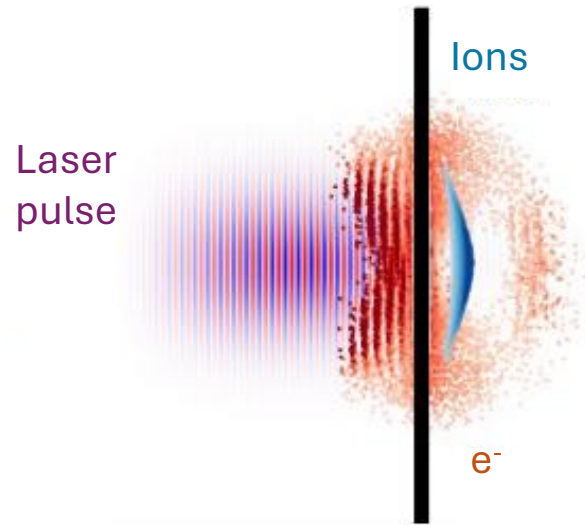
Double Layer Targets for proton acceleration



Single Layer Target (SLT)

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

Double Layer Targets for proton acceleration



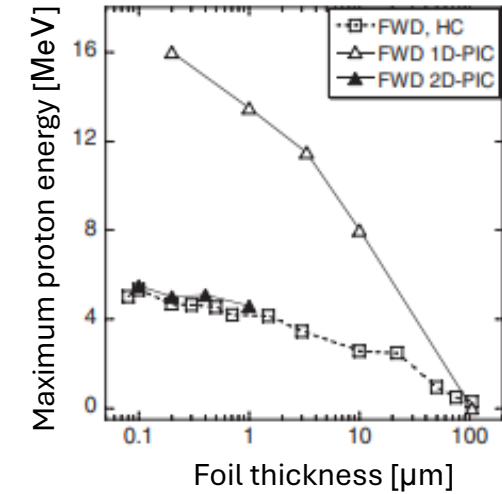
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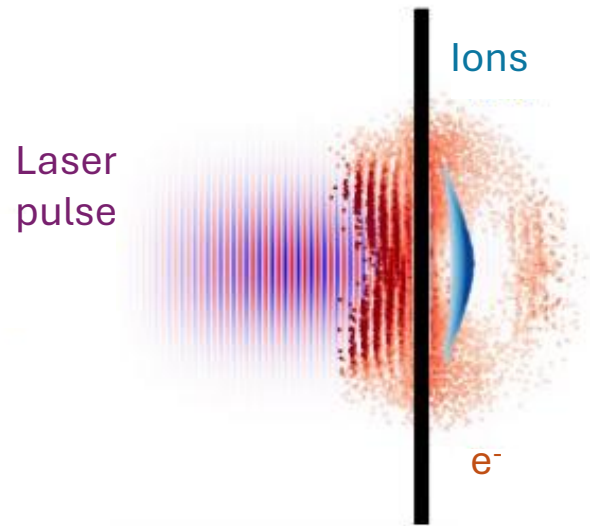


↑ Cut-off
energy



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

Double Layer Targets for proton acceleration



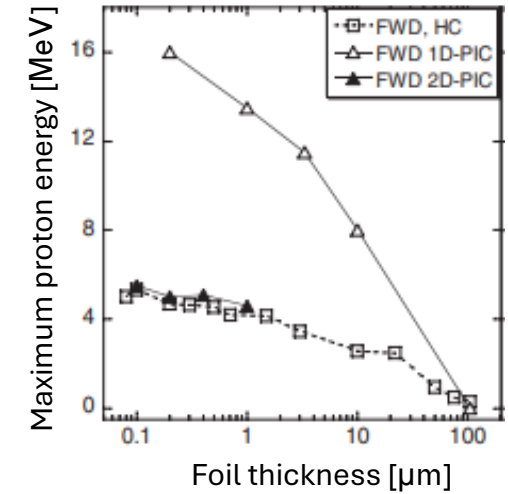
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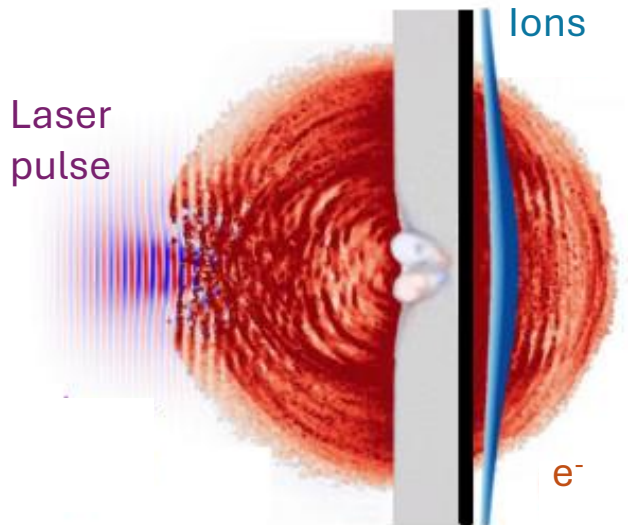
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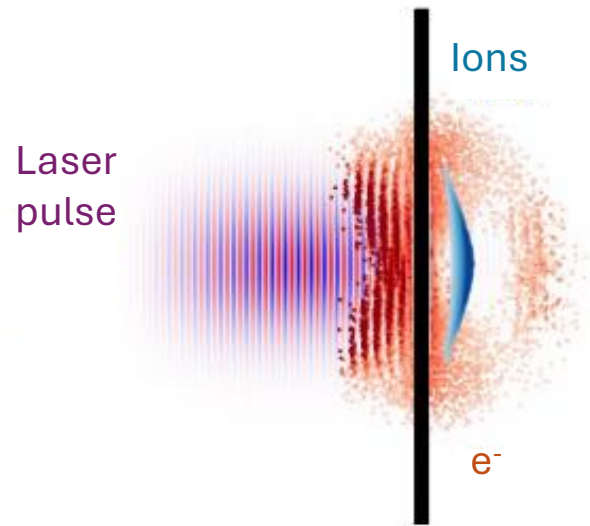


Double Layer Target (DLT)

- Solid foil + **Nanostructured layer**

- Nanospheres
- Nanowires
- **Carbon Nanofoams**

Double Layer Targets for proton acceleration



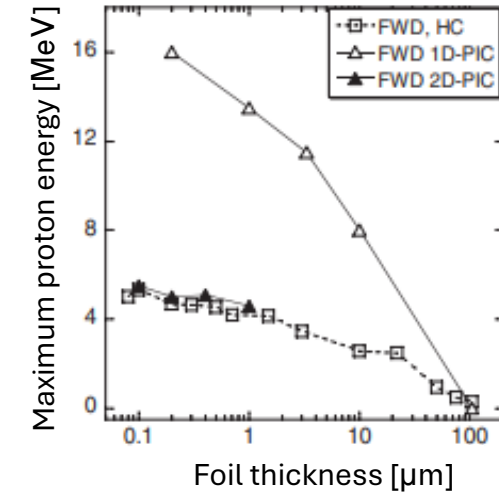
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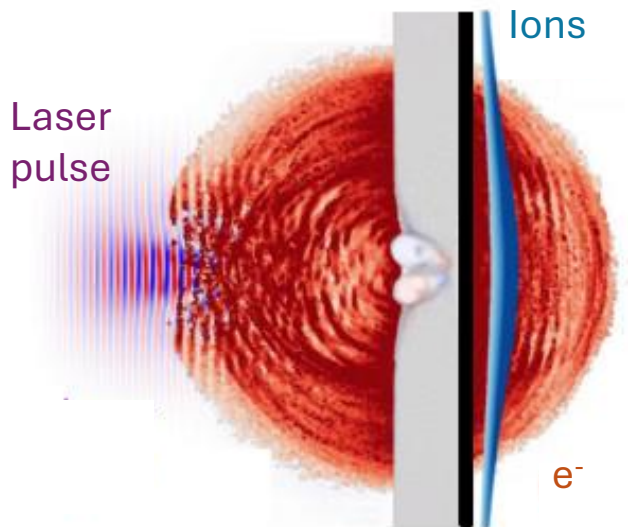
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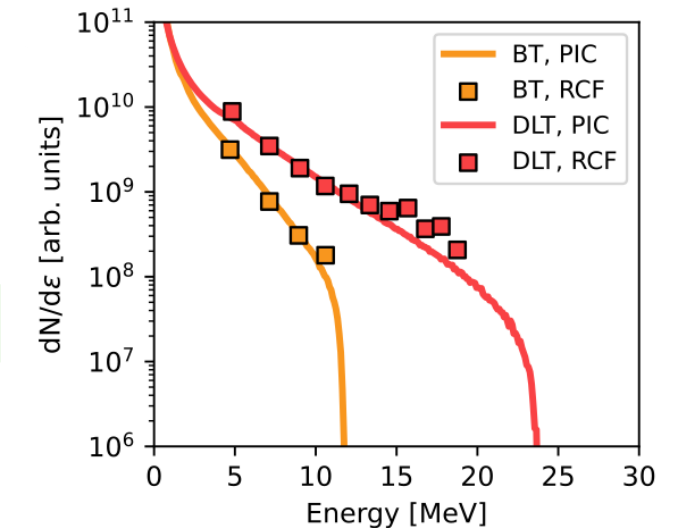
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↑ Laser-plasma coupling



↑ 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

CLPU
CENTRO DE
LÁSERES
PULSADOS



800 nm



4 J in spot



$1.25 \cdot 10^{20}$ W/cm²



30-50 fs



12 μm FWHM




10^{-5} - 10^{-10} contrast

Double Layer Targets for proton acceleration


Centro de Láseres Pulsados – VEGA-3




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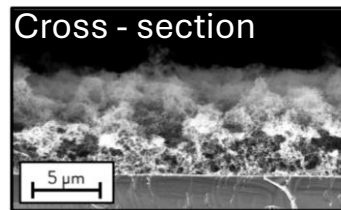
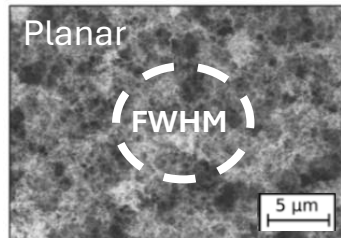
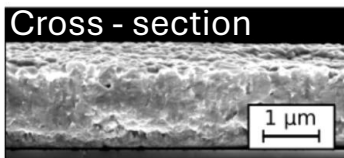
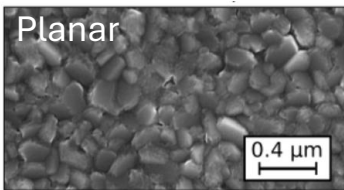
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 12 μ m FWHM

 10^{-5} - 10^{-10} contrast

DLTs

MS Al foils + C nanofoam



- 1.6 μ m Al foil
- 7.8 mg/cm³ C nanofoam
- 9, 18, 36, 54 μ m thick nanofoam

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4 J in spot

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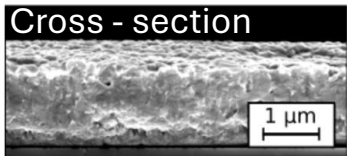
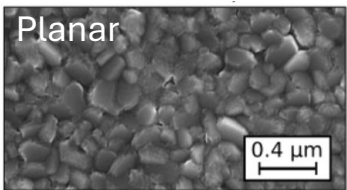
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12 μ m FWHM

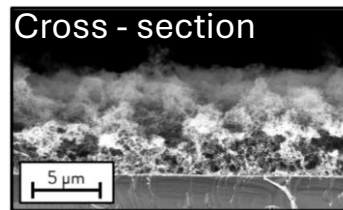
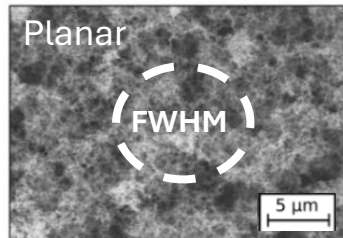
10^{-5} - 10^{-10} contrast

DLTs

MS Al foils

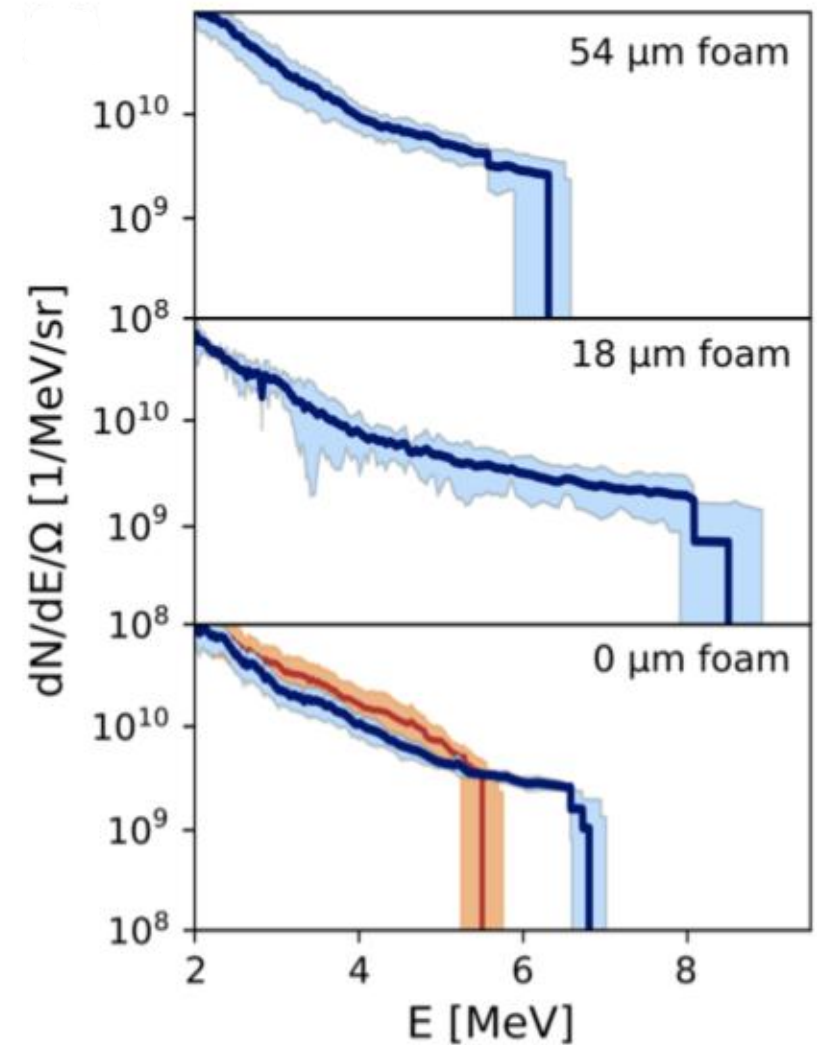


+ C nanofoam

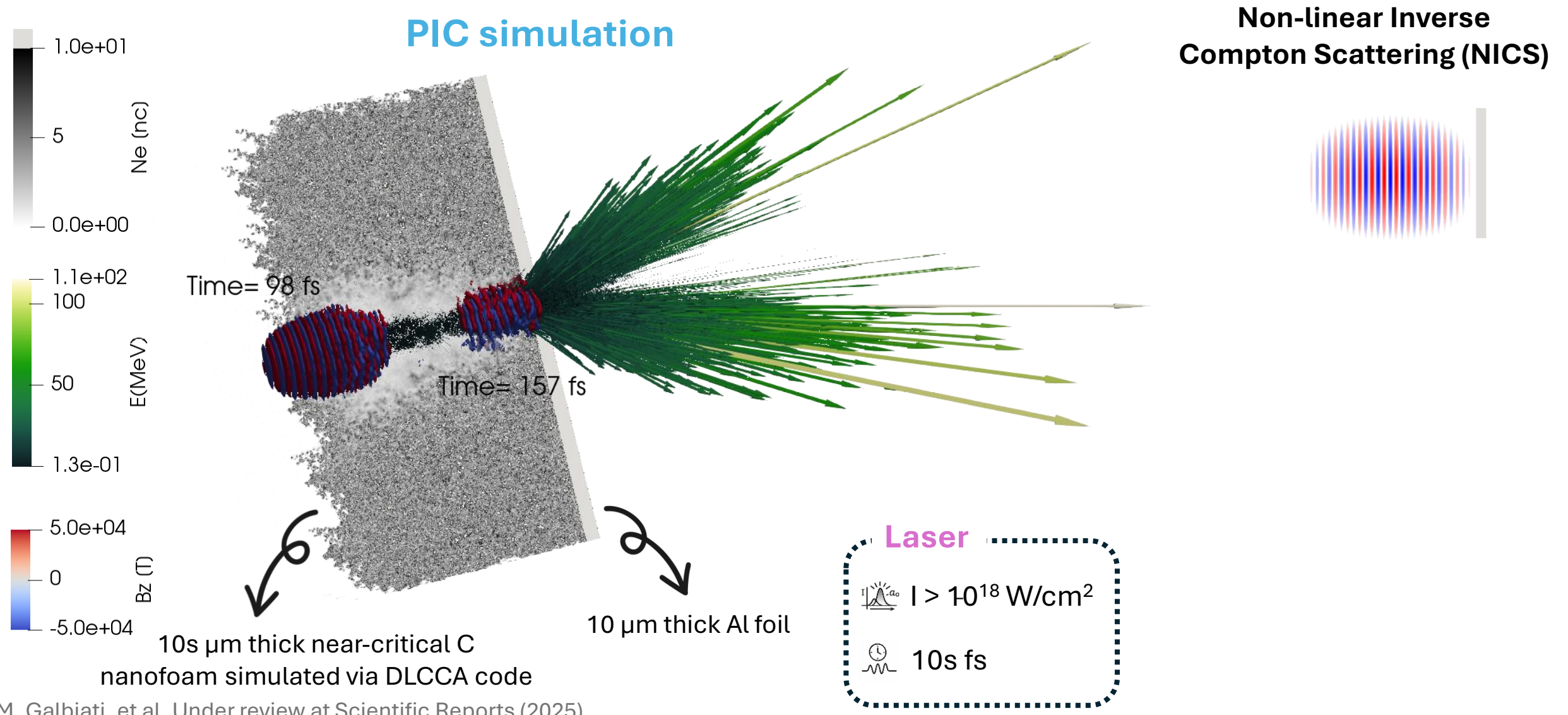


- 1.6 μ m Al foil
- 7.8 mg/cm³ C nanofoam
- 9, 18, 36, 54 μ m thick nanofoam

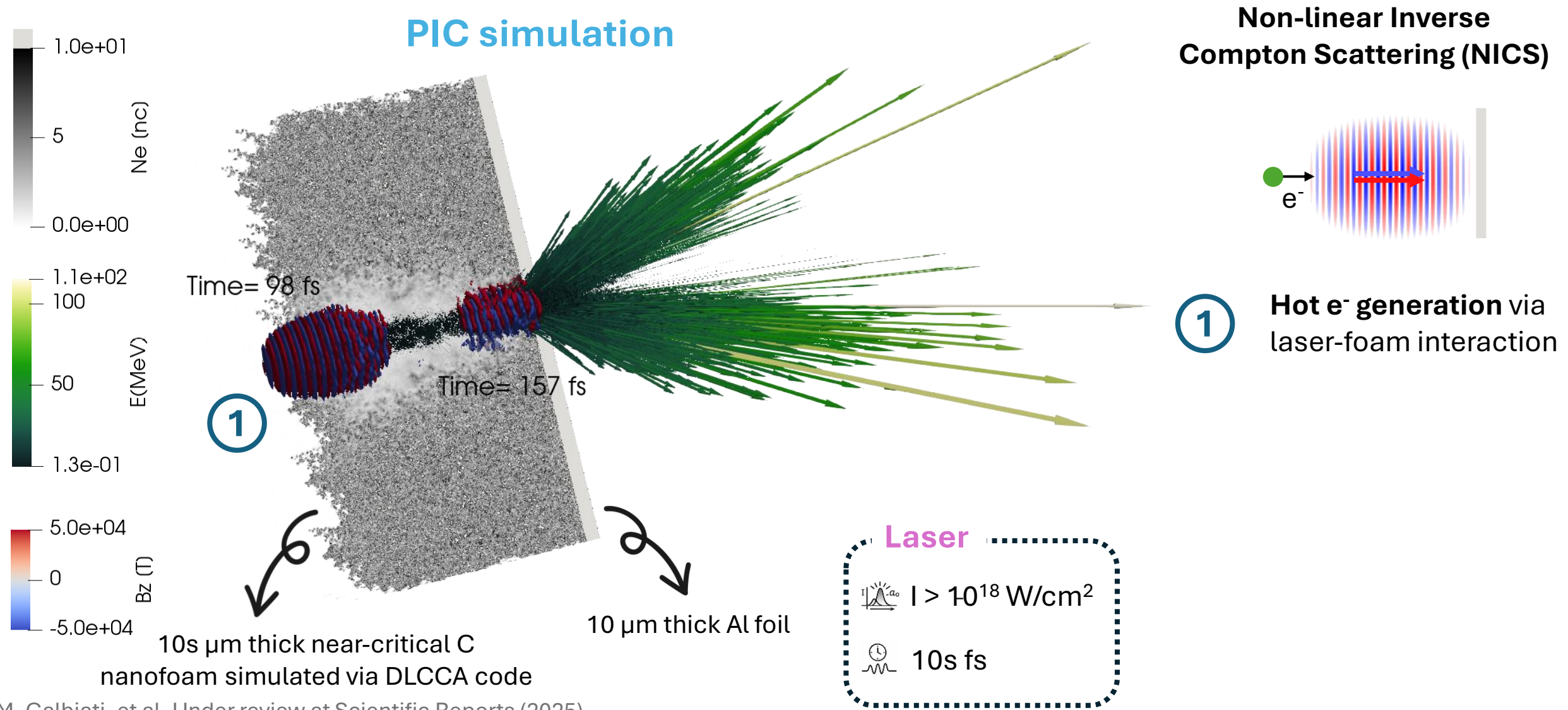
- ✓ Increased proton number with respect to both **Commercial Al foils** and **MS deposited Al foils**
- ✓ Increase of proton cutoff energy from 6.7 to 8.7 MeV in DLTs with respect to both **Commercial Al foils** and **MS deposited Al foils**
- ✓ Proton cutoff energy depends on **nanofoam thickness**, with a maximum reached for an **optimal value**.



Double Layer Targets for γ photon generation

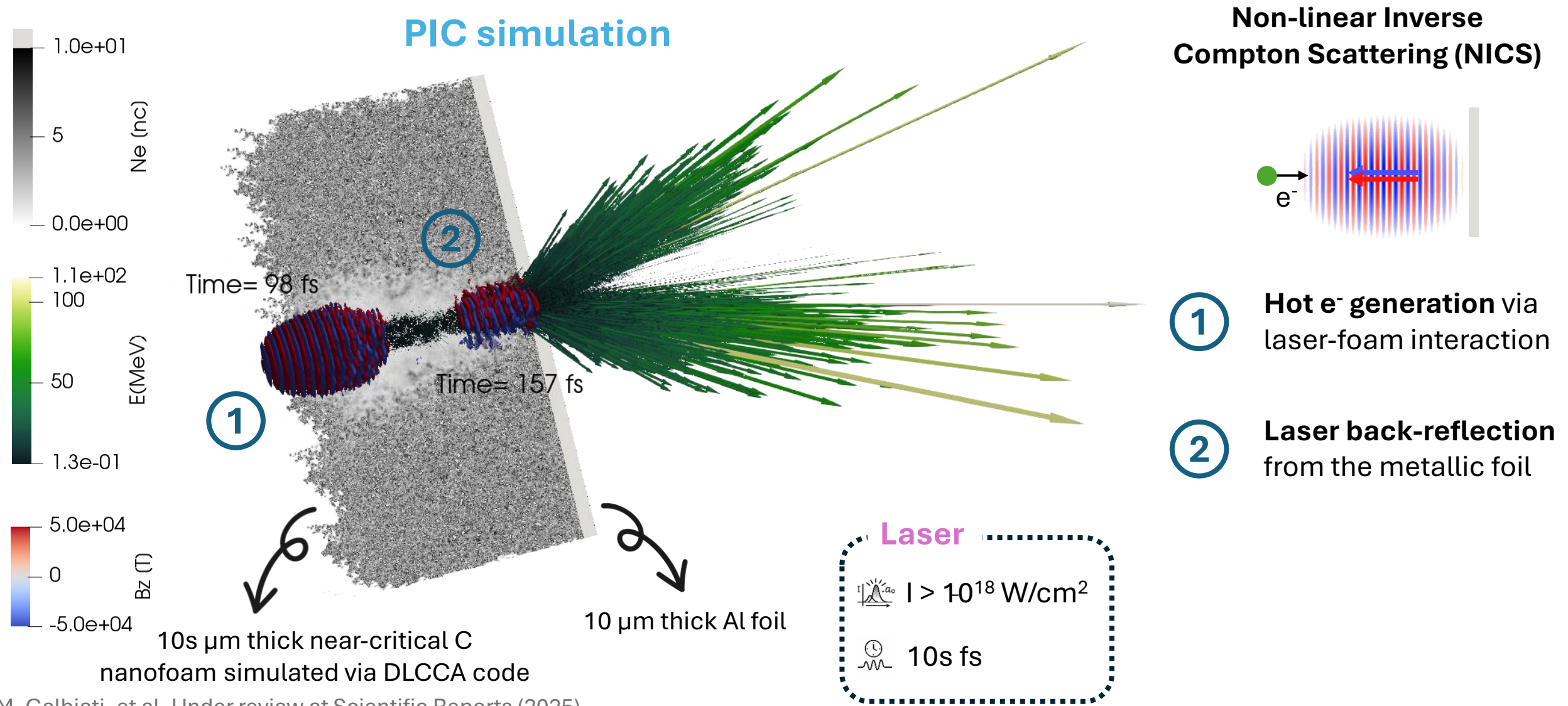


Double Layer Targets for γ photon generation



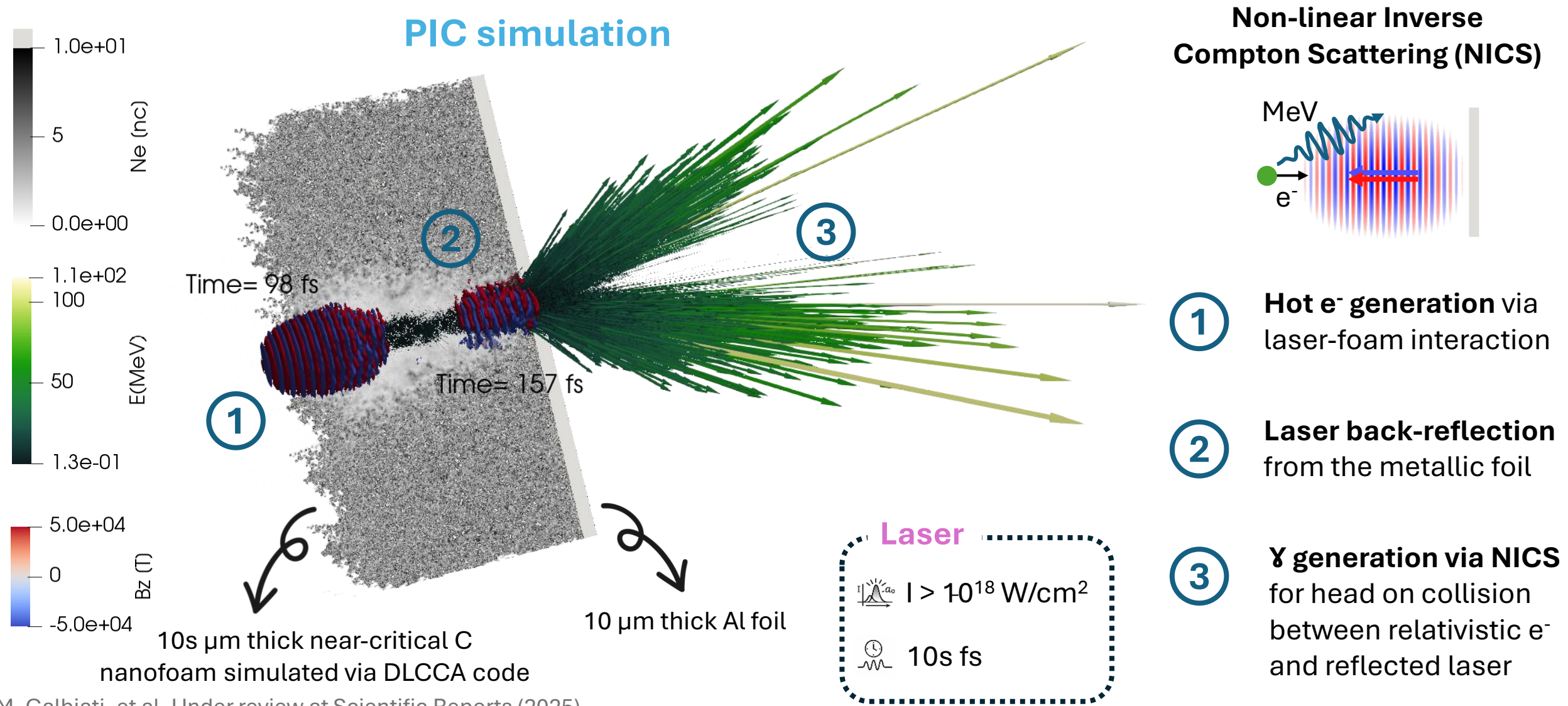
M. Galbiati, et al. Under review at Scientific Reports (2025)

Double Layer Targets for γ photon generation



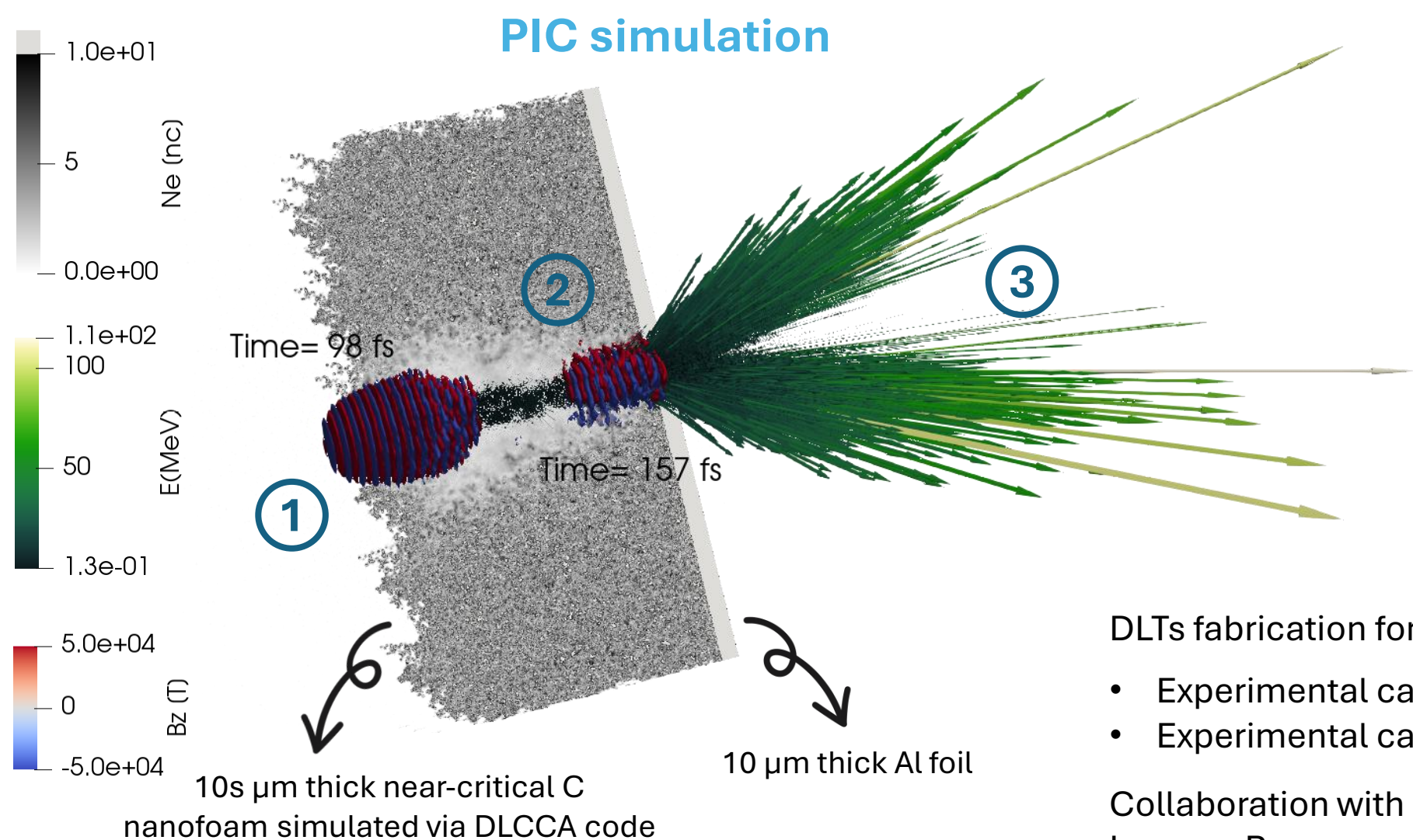
M. Galbiati, et al. Under review at Scientific Reports (2025)

Double Layer Targets for γ photon generation

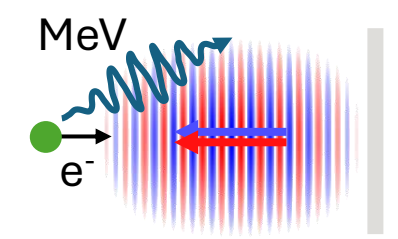


M. Galbiati, et al. Under review at Scientific Reports (2025)

Double Layer Targets for γ photon generation



Non-linear Inverse Compton Scattering (NICS)



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

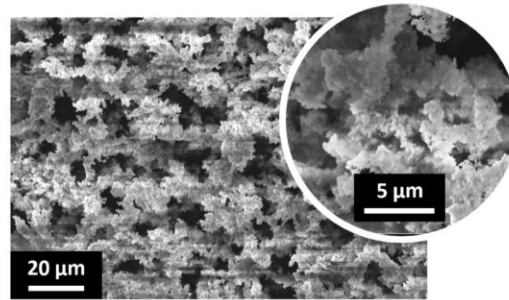
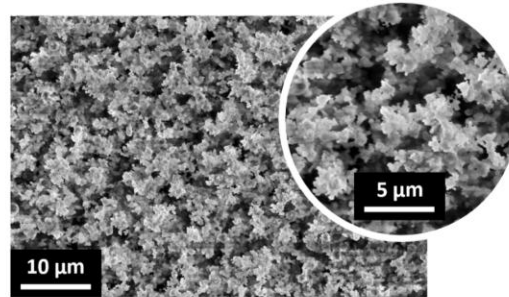
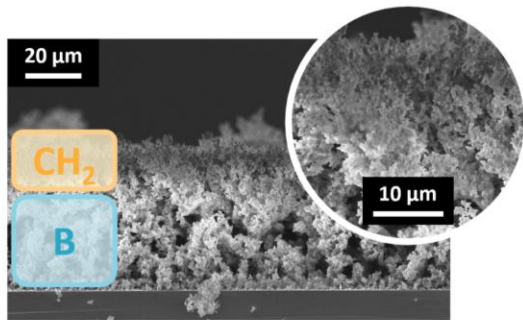
M. Galbiati, et al. Under review at Scientific Reports (2025)

Nanofoams for $p^{11}B$ fusion

 **Queen's University – TARANIS**

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

Nanofoams for $p^{11}\text{B}$ fusion



Queen's University – TARANIS

QUEEN'S UNIVERSITY BELFAST

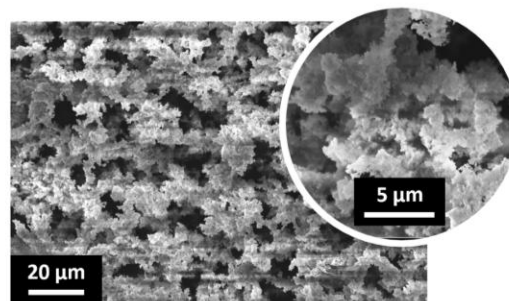
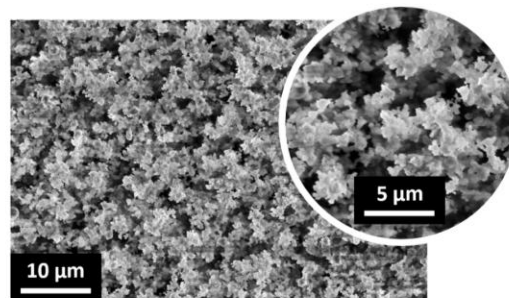
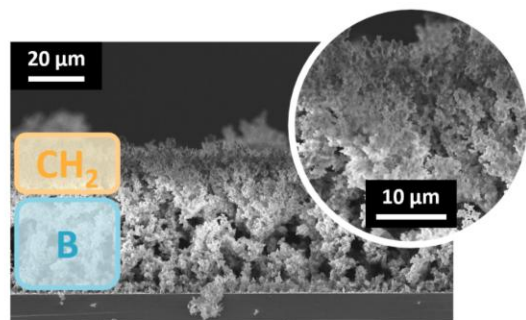
λ 1053 nm E 10 J in spot I_{peak} $2 \cdot 10^{19}$ W/cm²

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

Nanofoams for $p^{11}\text{B}$ fusion

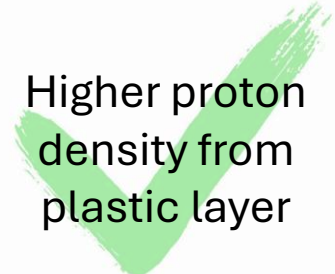
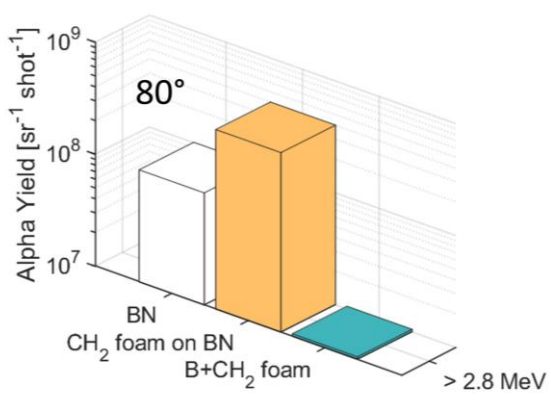
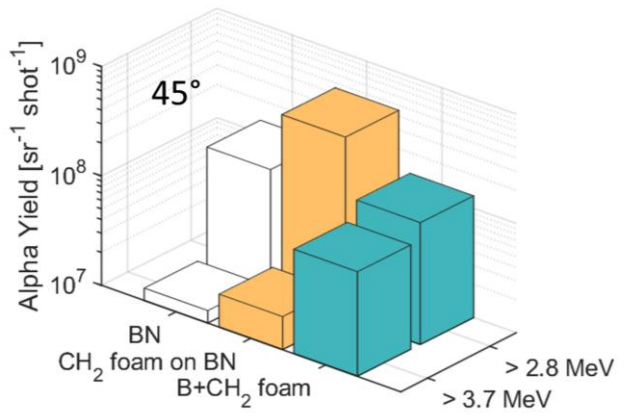


Queen's University – TARANIS


 1053 nm
  10 J in spot
  $2 \cdot 10^{19}$ W/cm²
 800 fs
  5.1 μm FWHM
  $5 \cdot 10^{-7}$ contrast

- DLTs**
- Double layered **B + CH₂ nanofoam**
 - **Mixed B-CH₂ 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-CH₂ 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 demonstrated 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 **enhance gamma photon generation** via non-linear inverse Compton scattering
- ✓ Experiments 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

