Quasi monochromatic carbon ion beams with the peeler acceleration scheme

Theory @ LDED

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ELI-NP, LDED, Magurele (Ro)
*** HHU, Dusseldorf (D)**
**** CELIA, Bordeaux (F)**

eli nuclear physics

hhu Heinrich Heine Universität Düsseldorf

CELIA Centre Lasers Intenses et Applications

LPAW 2025, Ischia

The Theory@LDED group

This is part of B. Corobean Ph.D thesis work tutored by V. Horny

The group is part of the **LDED** (Department Head: **Domenico Doria**)

Theory@LDED

Group Coordinator
P. Tomassini

Performs theory and simulation researches (mostly) for LDED

- Nuclear Physics
- Laser Solid
- LWFA/DLA
- Radiation and secondary sources

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Young Researcher

Vojtěch Horný
Young Researcher

Olimpia Budriga
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Bogdan Corobean
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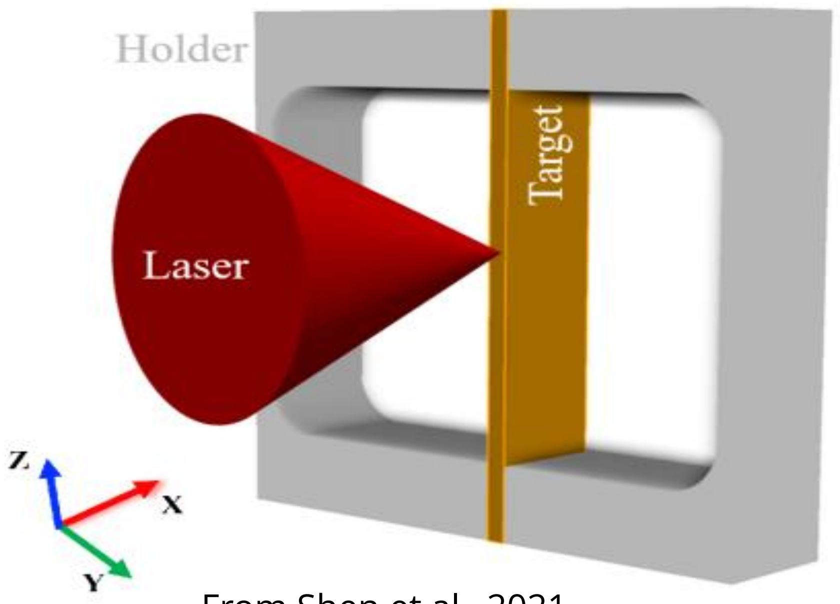
Federico Avella
Ph. D. student **

Maxim Andronic
Master Student

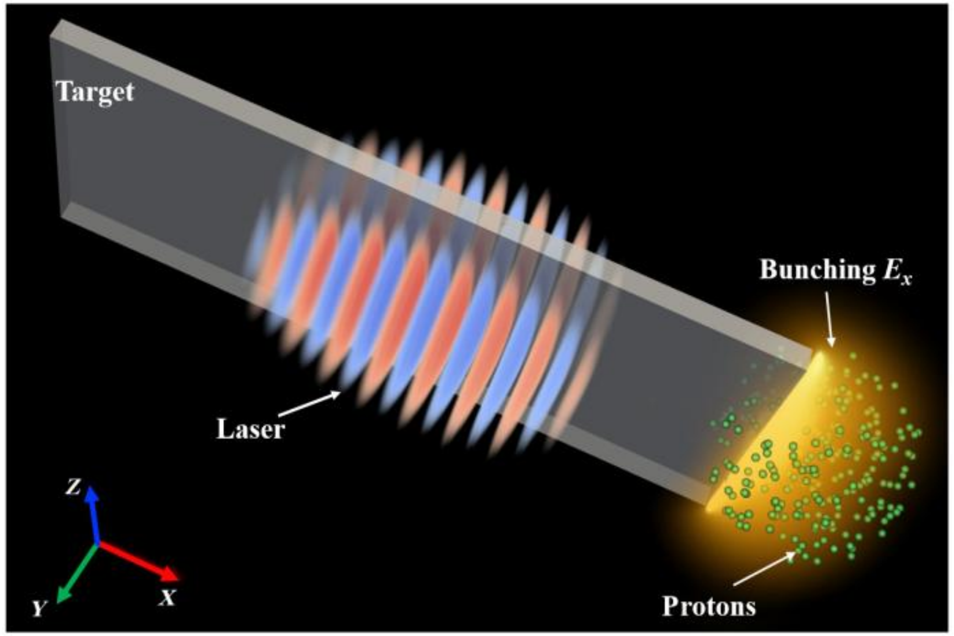
* Part Time, **In Co-Tutoring with CNR-INO

The "peeler" scheme

Monoenergetic High-Energy Ion Source via Femtosecond Laser Interacting with a Microtape,
X.F. Shen, A. Pukhov and B. Quiao**,** 10.1103/PhysRevX.11.041002 (2021)



From Shen et al., 2021,
Supplemental Material



Shen et al., 2021

The laser pulse strips a large amount of electrons out the surface . A surface plasmon wave (SPW) is excited at the target tip and accelerates the extracted electrons. **The very large electric field at the target rear enables the acceleration of quasi monochromatic proton beams**

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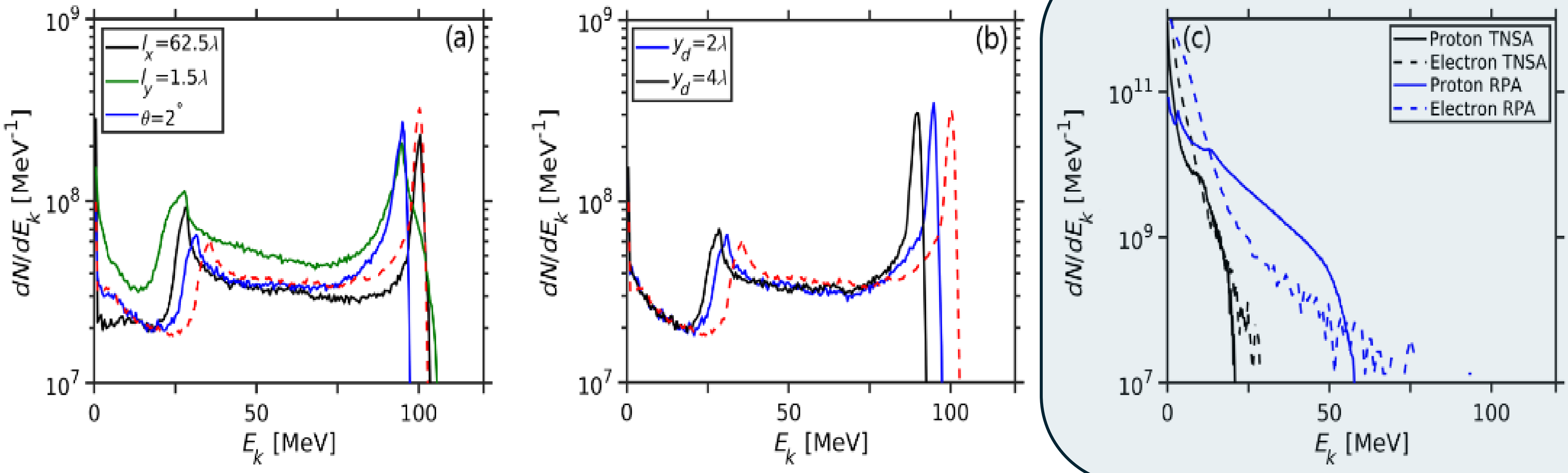


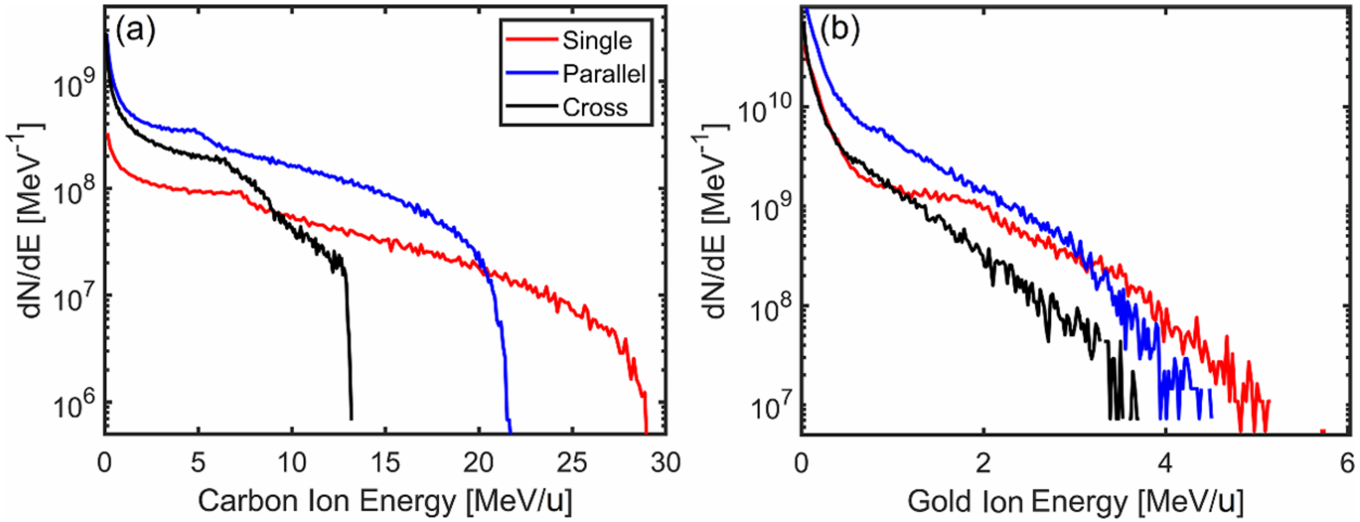
PROTON ENERGY

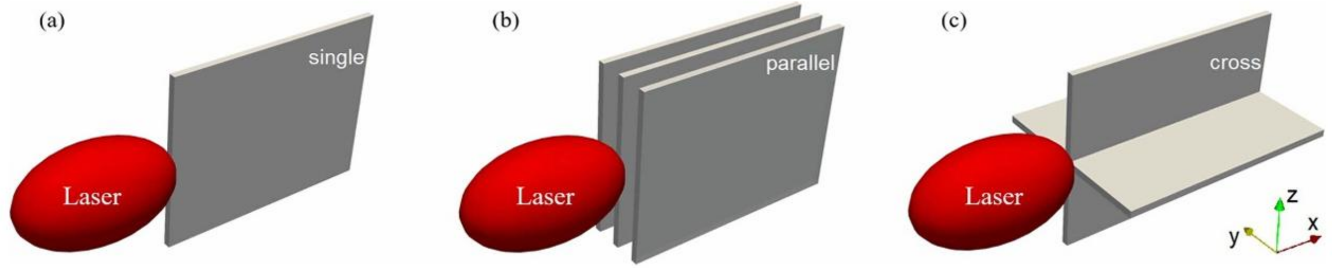
The “peeler” scheme

Electron and ion acceleration from femtosecond laser-plasma peeler scheme,
X.F. Shen, A. Pukhov and B. Quiao, (2023)

Plasma Phys. Control. Fusion **65** (2023) 034005 X F Shen *et al*

a_0=19, Au target, **CH** layer
35 μm × 0.6 μm × 36 μm

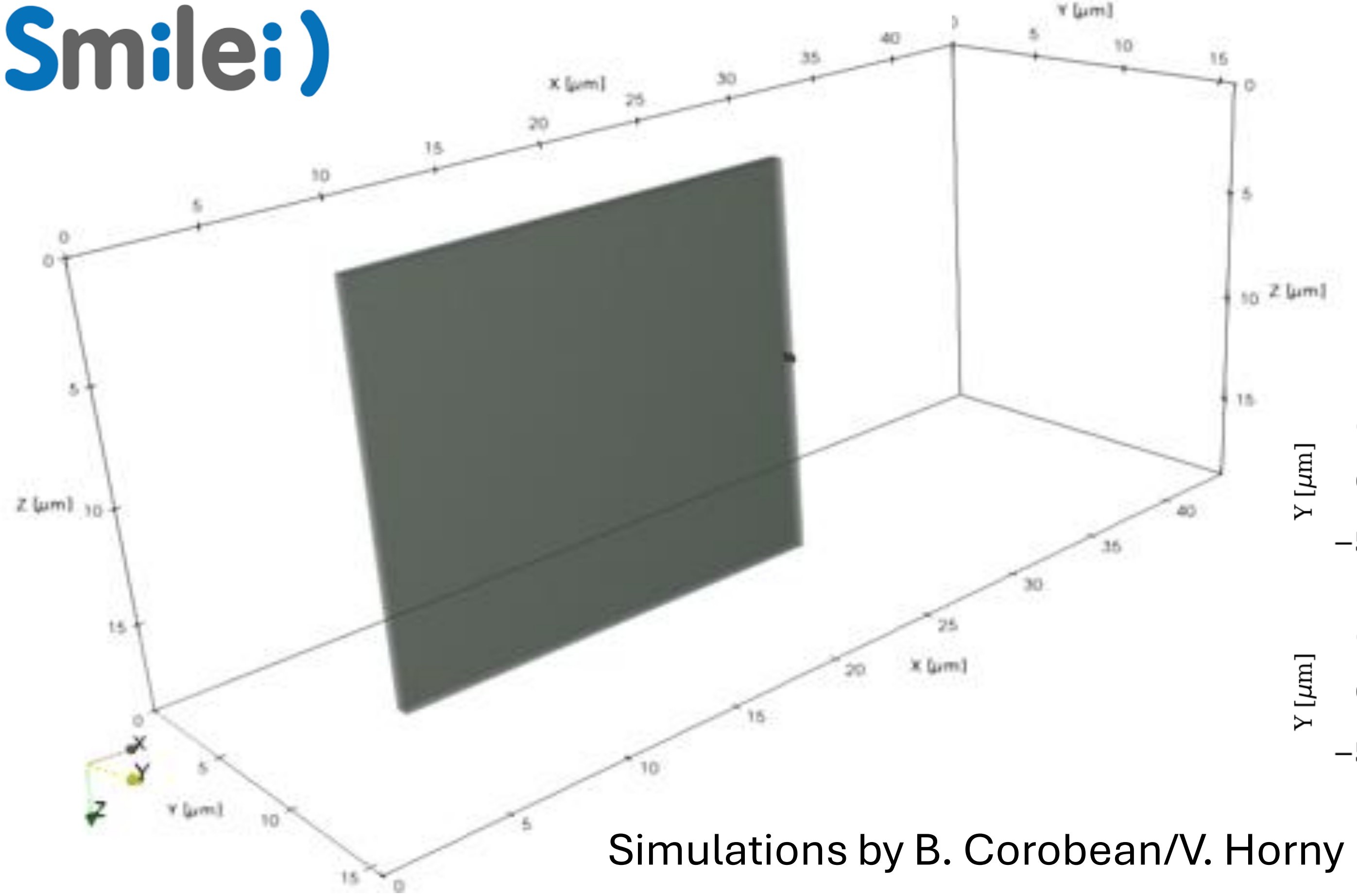




The quasi monochromatic C acceleration scheme

Laser-plasma acceleration of quasi-monoenergetic carbon ion beams with the "peeler" scheme,
B. Corobean, V. Horný, A. Pukhov, E. d'Humières, D. Doria, C. A. Ur, and P. Tomassini, *submitted*

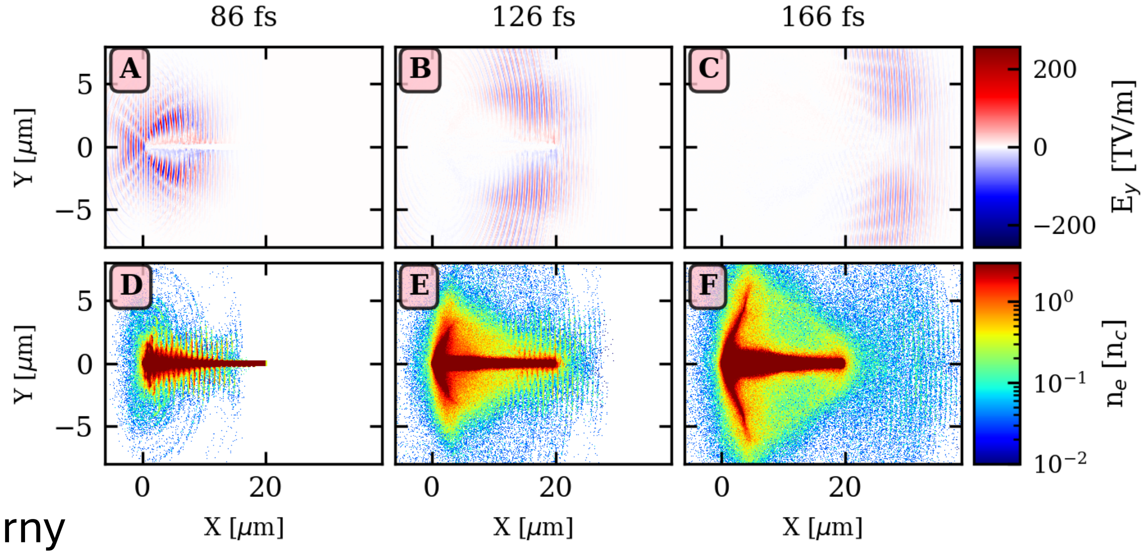
Smilei



Simulations by B. Corobean/V. Horny

ELI-NP 10PW (E1) +PM

I_0 = 3.5 x 10^{22} W/cm^2 ($a_0 \simeq 130$)
w_0= 3.06 μm; λ = 810 nm
Al target: [20 × 0.5 × 18] μm
Engineered C structure: [160×500×320] nm
n_C =1/20 solid carbon density



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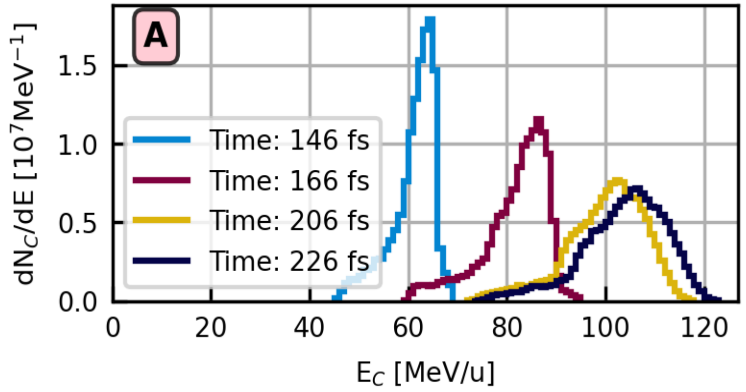
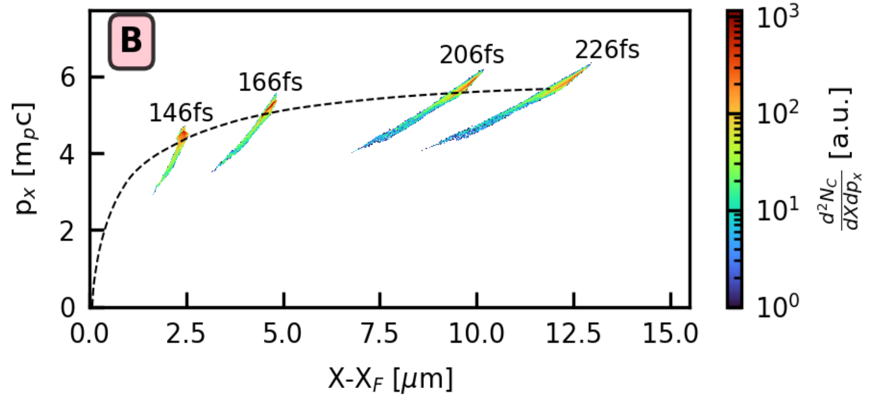
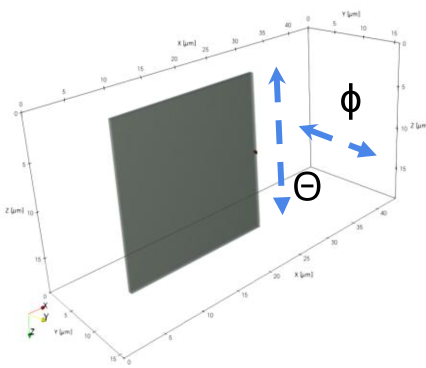
B. Corobean, V. Horný, A. Pukhov, E. d'Humières, D. Doria, C. A. Ur, and P. Tomassini, *submitted*

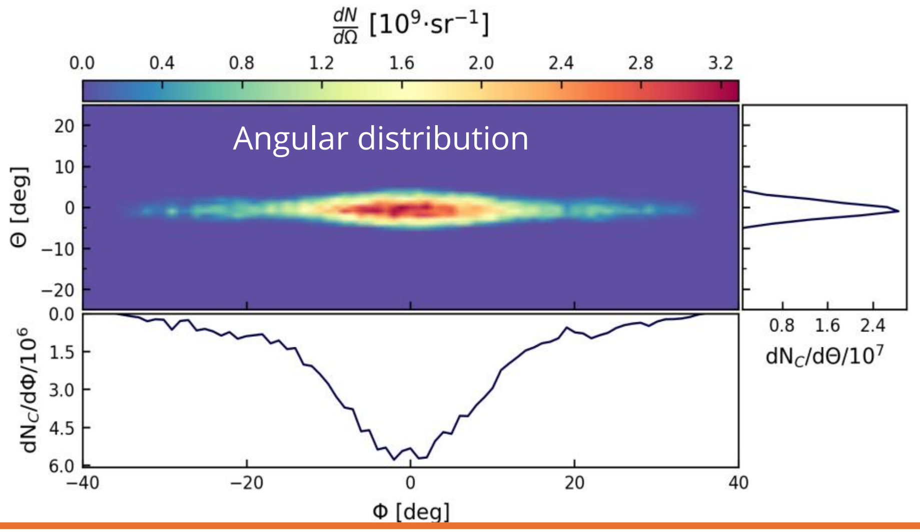
Energy and phase space evolution



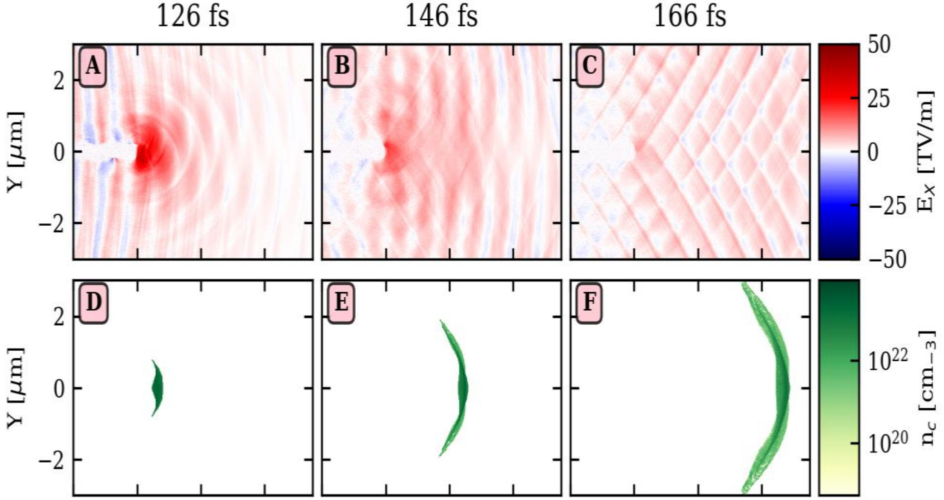


$>10^8$ C ions,
18% FWHM energy spread,
~110 MeV/u peak energy





Evolution of ion beam



The quasi monochromatic C acceleration scheme

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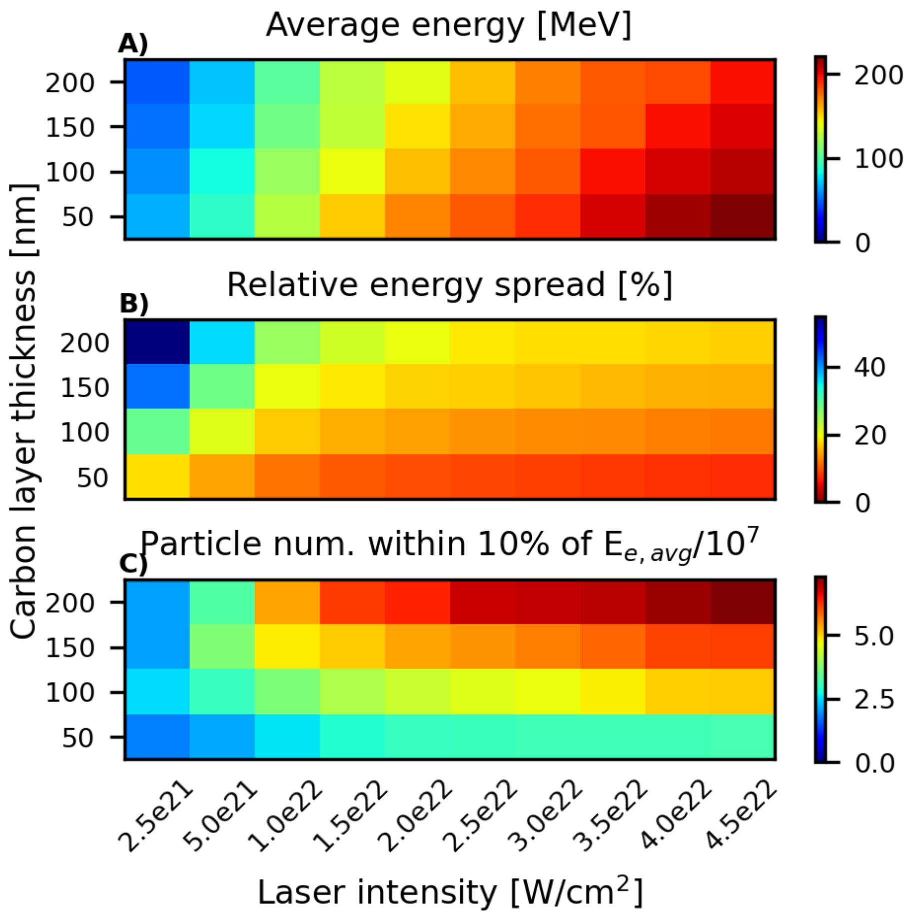
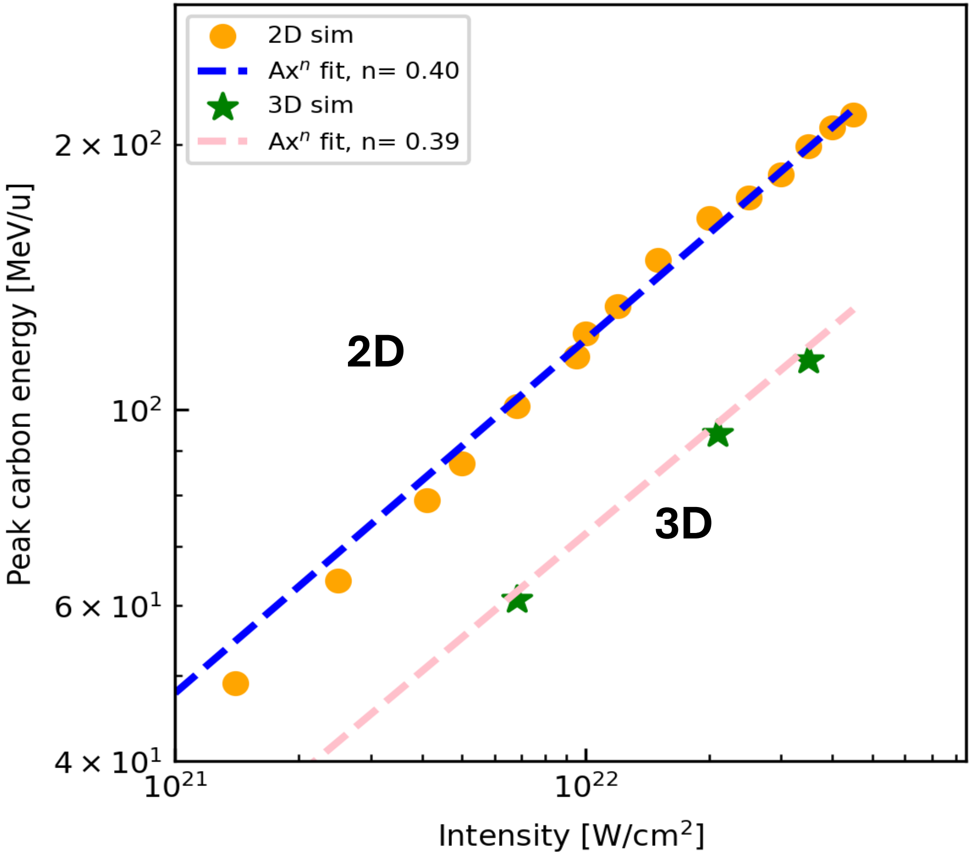
B. Corobean, V. Horný, A. Pukhov, E. d'Humières, D. Doria, C. A. Ur, and P. Tomassini, *submitted*

2D scan





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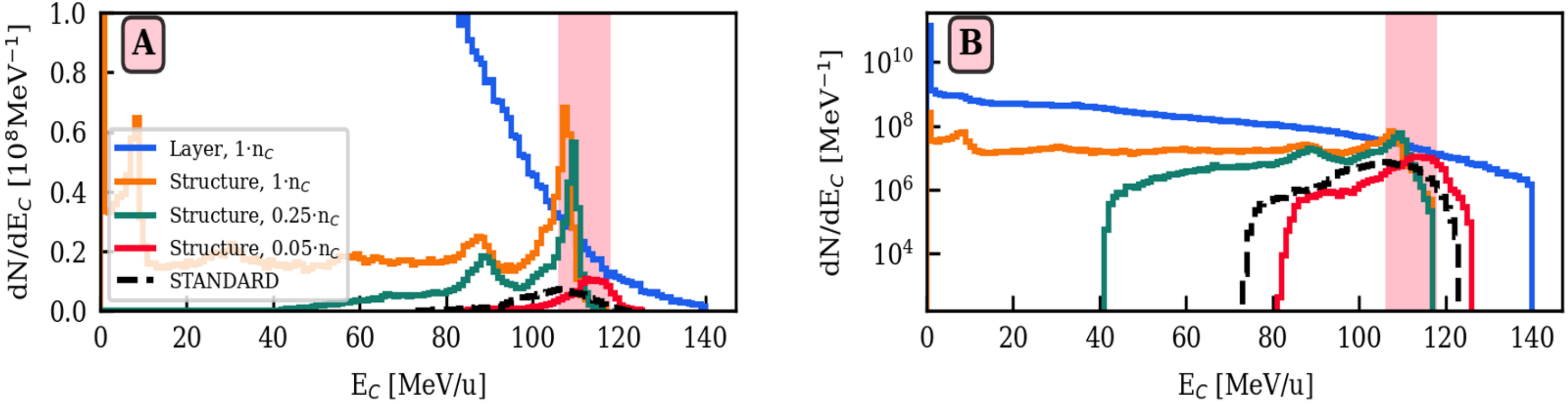
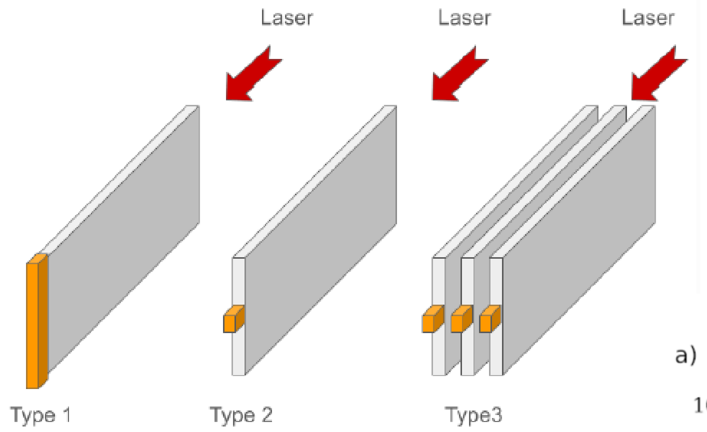
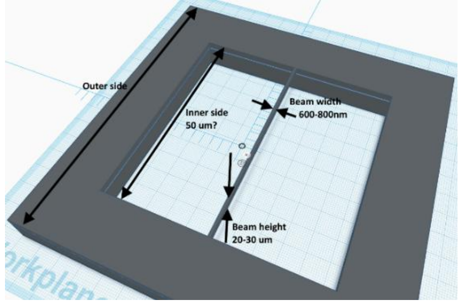
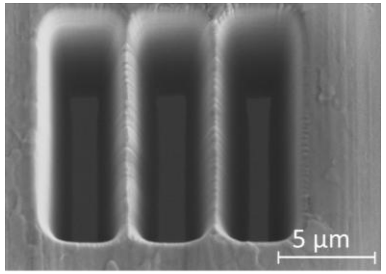


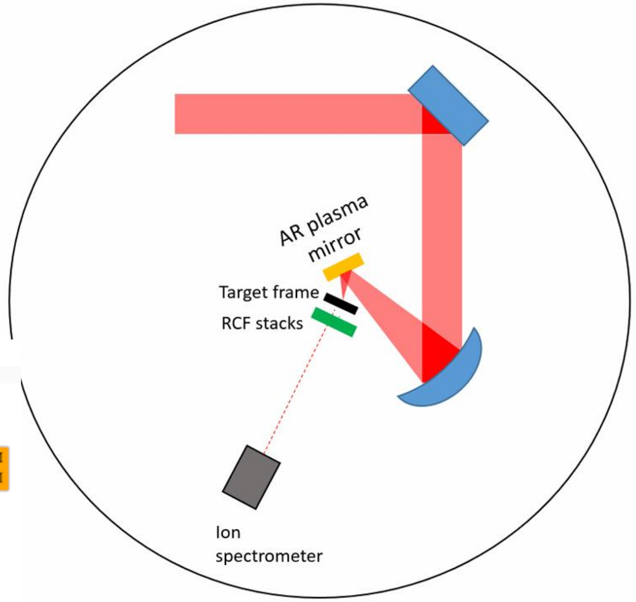
Towards an experimental investigation of the scheme

Beam time granted in ELI-NP/E5 area (1PW) in early **September** (D. Doria, M. Cernaianu, H. Ahmed, L. Romagnani et al., *in the experimental team*, **proposal** by P. Tomassini, D. Doria, A. Pukhov, M. Cernaianu , H. Ahmed, E. D'Humieres, V. Horny, B. Corobean , L. Romagnani, et al.).

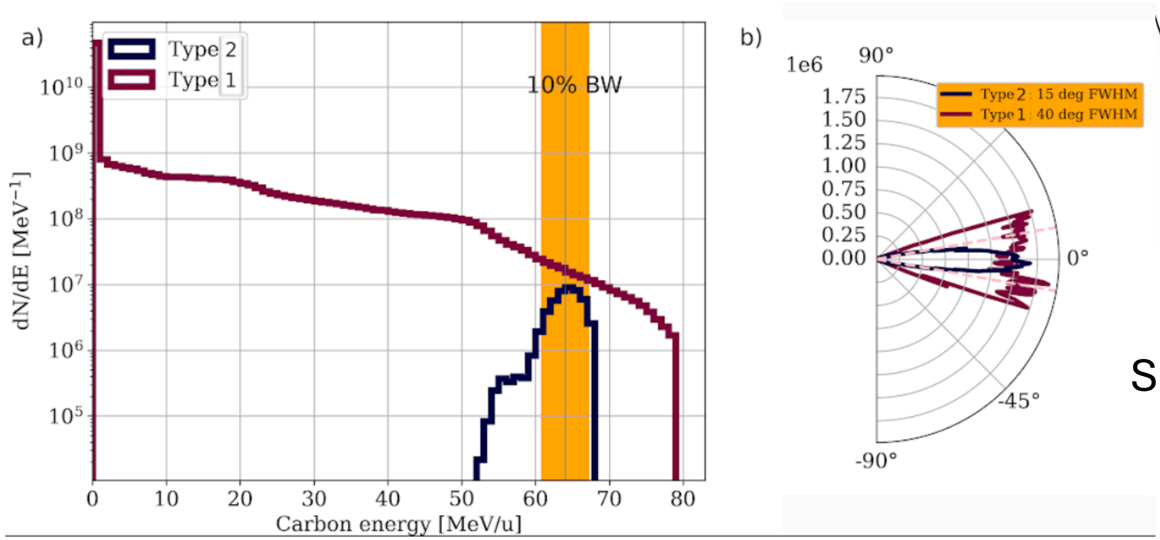








3D PIC simulation with 1PW +PM +50% encircled energy

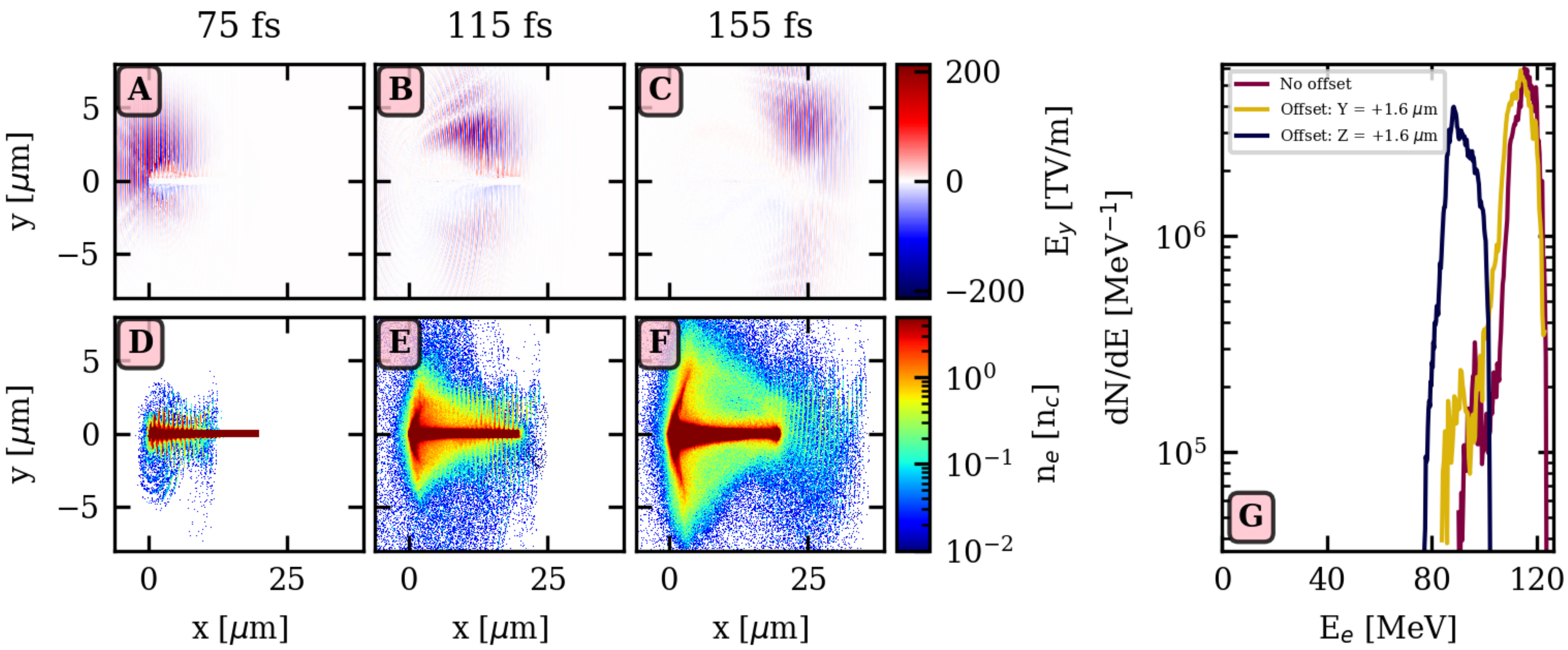


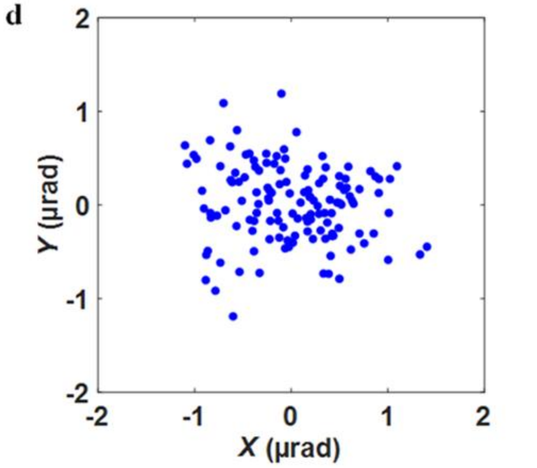
Simplified setup with single PM (M. Cernaianu)

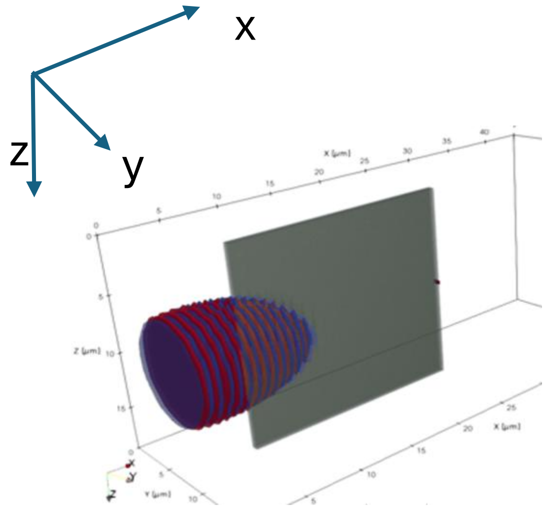
Laser pointing jitter effect

Maps show *Offset along Y* case

Laser pointing jitter is a fraction of the beam waist.
Here we have both the horizontal (z) and vertical (y) effects







Conclusions

1. By structuring the carbon source at the rear of the target, **quasi monochromatic and low-divergence carbon beams can be obtained**

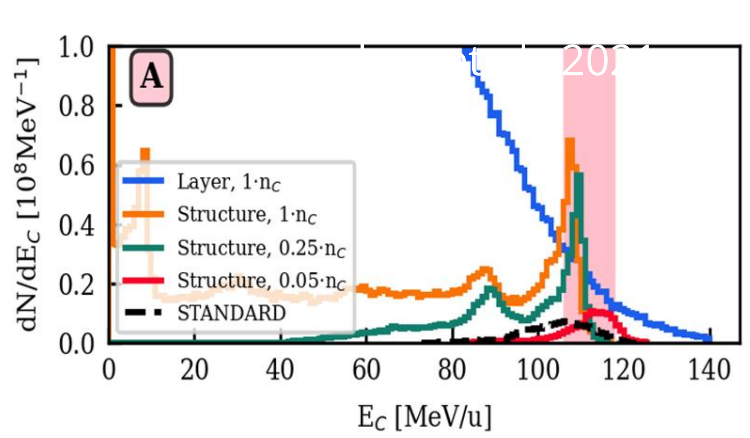
2. This is at **the cost of the total number of the accelerated ions** (~10^8). If a broadband spectrum showing a peak is enough, >10^9 ions can be accelerated.

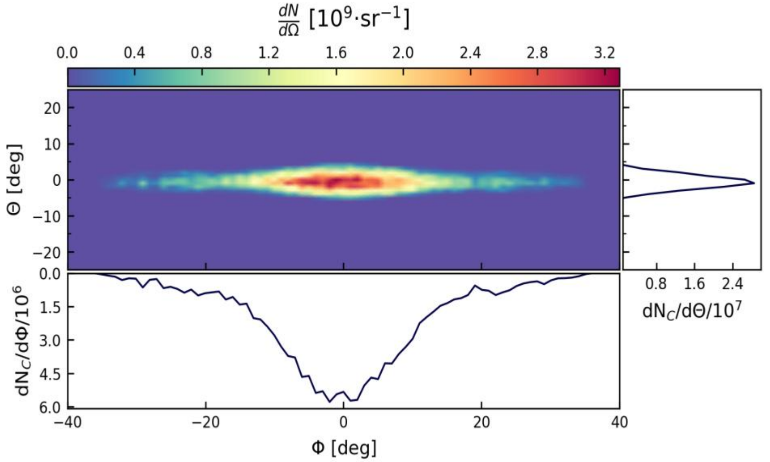
3. **The direct application of the scheme might be the Carbon therapy of tumors, although the dose/shot should be optimized**

4. Pointing jitter fluctuations **don't change the picture, just the peak energy**

5. **Prepulse effects must be thoroughly controlled**. At 1PW level (E5 area in ELI-NP), a PM is necessary to prevent the disruption of the target tip.

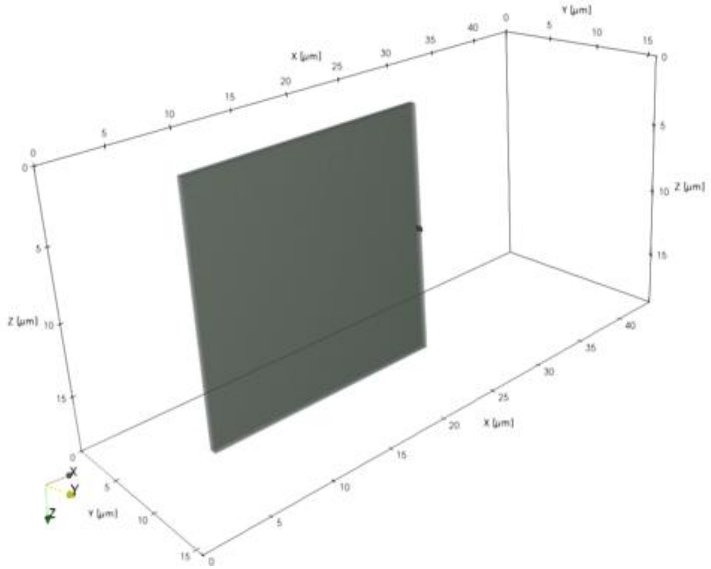
6. In September a 2.5 weeks experimental campaign in E5/1PW will be devoted to experimental demonstration of the scheme





Conclusions

Thank you!



ELI-NP has Ph.D./post doc positions, contact us if interested.

Funding acknowledgments:

ELIRO/IFA/SPARC (Romania), Medical Project SMIS 326475 (Romania), s BMBF grant 05P24PF2 (Germany), EuroHPC Joint Undertaking for awarding us access to Karolina at IT4Innovations (VŠB-TU), Czechia under project number EHPC-REG-2023R02-006 (DD-23-157); Ministry of Education, Youth and Sports of the Czech Republic through the e-INFRA CZ (ID:90140)