Margaret Island Symposium 20223 on Particles and Plasmas

Theoretical advances in the NAPLIFE project

Laszlo P. Csernai, for the NAPLIFE Collaboration
Univ. of Bergen, Norway
Budapest, June 9, 2023

Ensana Margaret Island Thermal Hotel,
Margaret Island,
1007 Budapest,
Hungary

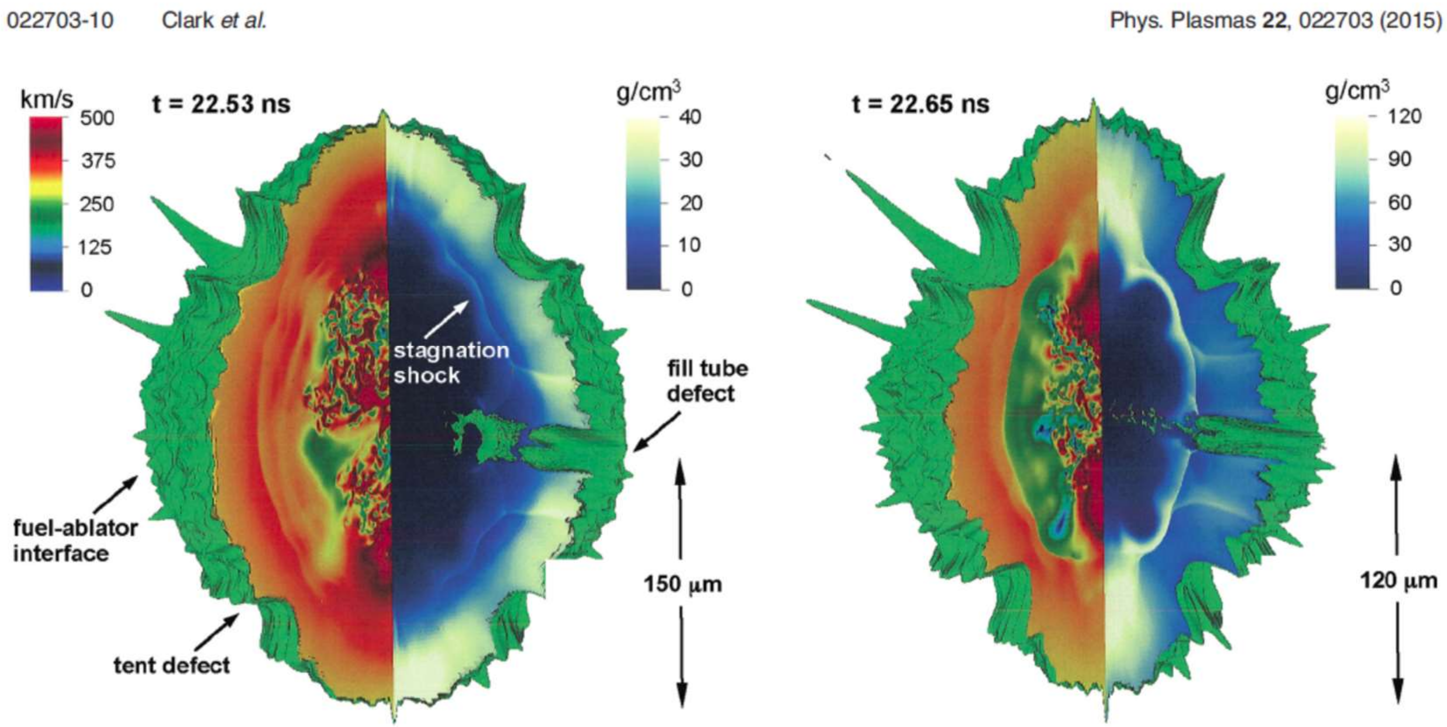
NAPLIFE Collaboration – Participants - ELKH, National Res. Lab.

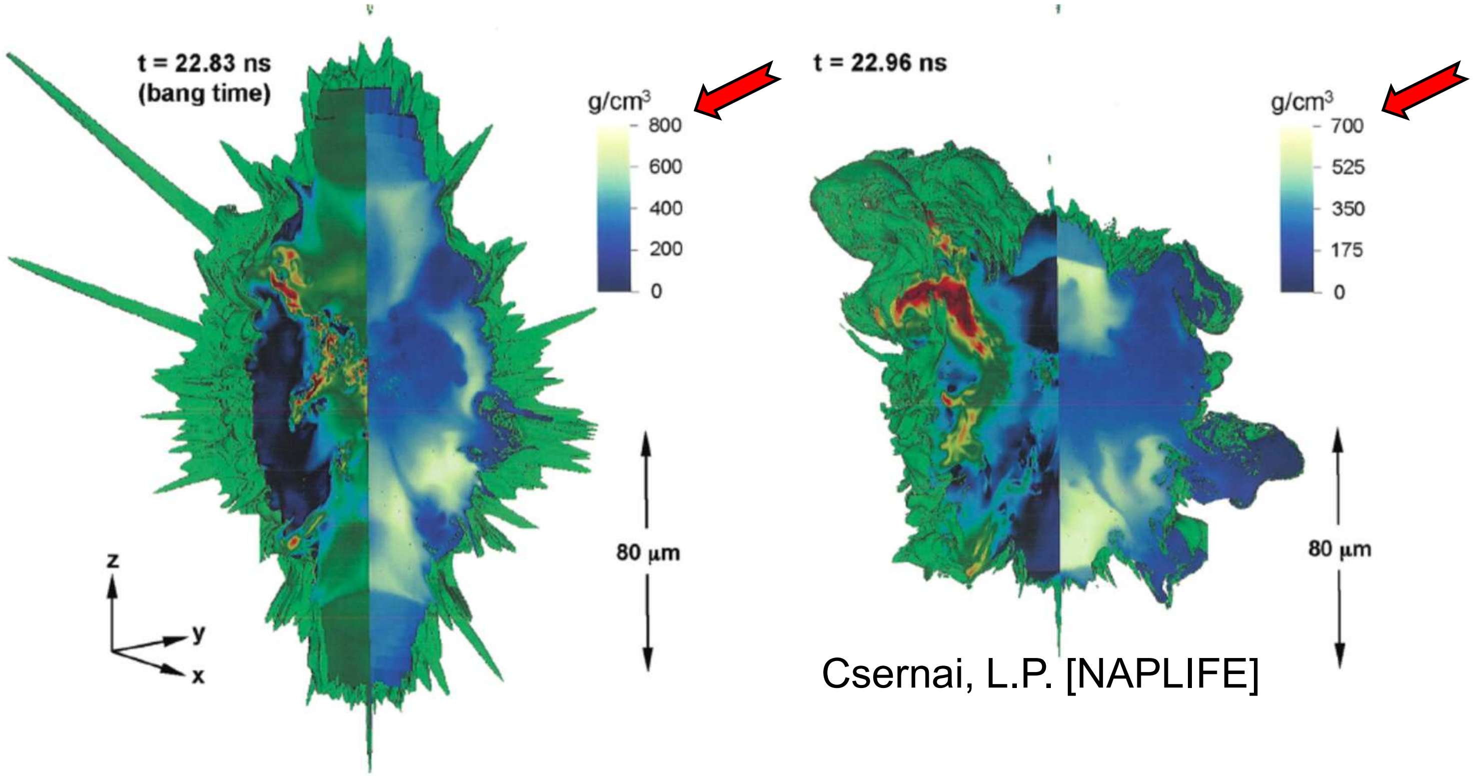
Laszlo P. Csernai, Tamás S. Biró, Norbert Kroó, Peter J. Lévai, Márk Aladi, Roman Holomb, Miklós Kedves, Archana Kumari, István Papp, Péter Petrik, Béla Ráczkevi, István Rigó, Miklós Veres, Anett Szeledi, Ágnes Nagyné Szokol; Gábor Galbács, Balázs Bánhelyi, Mária Csete, Attila Czirják, Olivér Antal Fekete, Péter Földi, Emese Tóth, András Szenes, Dávid Vass; Attila Bonyár, Nour Jalal Abdulameer, Judit Kámán, Alexandra Borók; Zsolt Fogarassy, Kolos Molnár, Roman Holomb, Péter Dombi, Melinda Szalóki, Laura Juhász; Horst Stoecker, Leonid Satarov, Johann Rafelski, Anton Motornenko; Larissa Bravina, Evgeny E. Zabrodin; Igor N. Mishustin, Daniel D. Strottman, Csaba Tóth, Shereen Zangana, Konstantin Zhukovsky (~> 40)

Rayleigh-Taylor Instability

[Clark et al., Phys. Plasmas, **22**, 022703 (2015).]

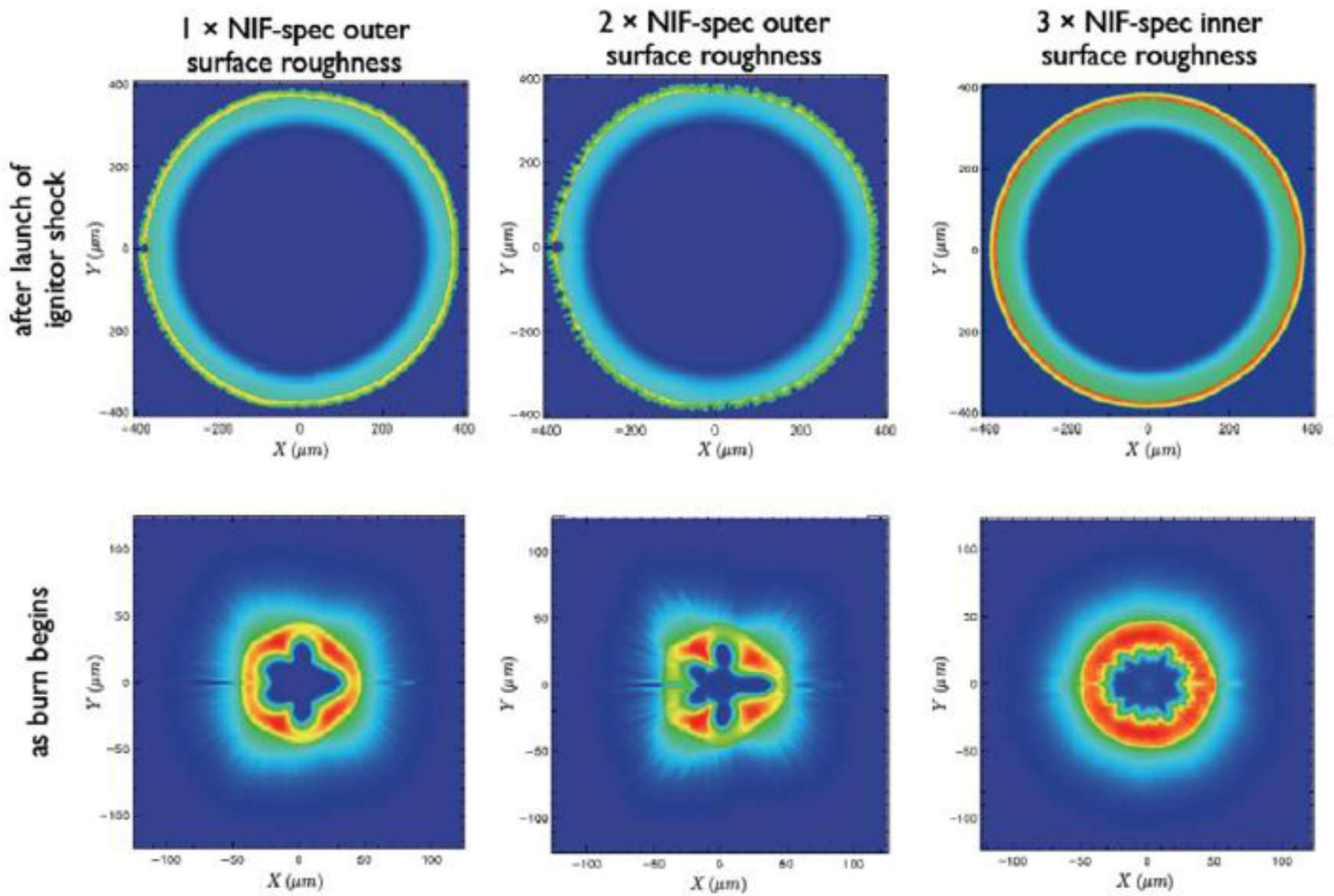
Snapshots of 3D simulation
22.53ns: peak impl. Velocity
23.83ns: bang, max compr.
22.96ns: jet out, up left
Green surface: Ablator/DT-f.
Peaks: Ablator defects
Colours:
Left: fluid speed
Right: matter density





~adiabatic compression ➔ 80 μm & heating

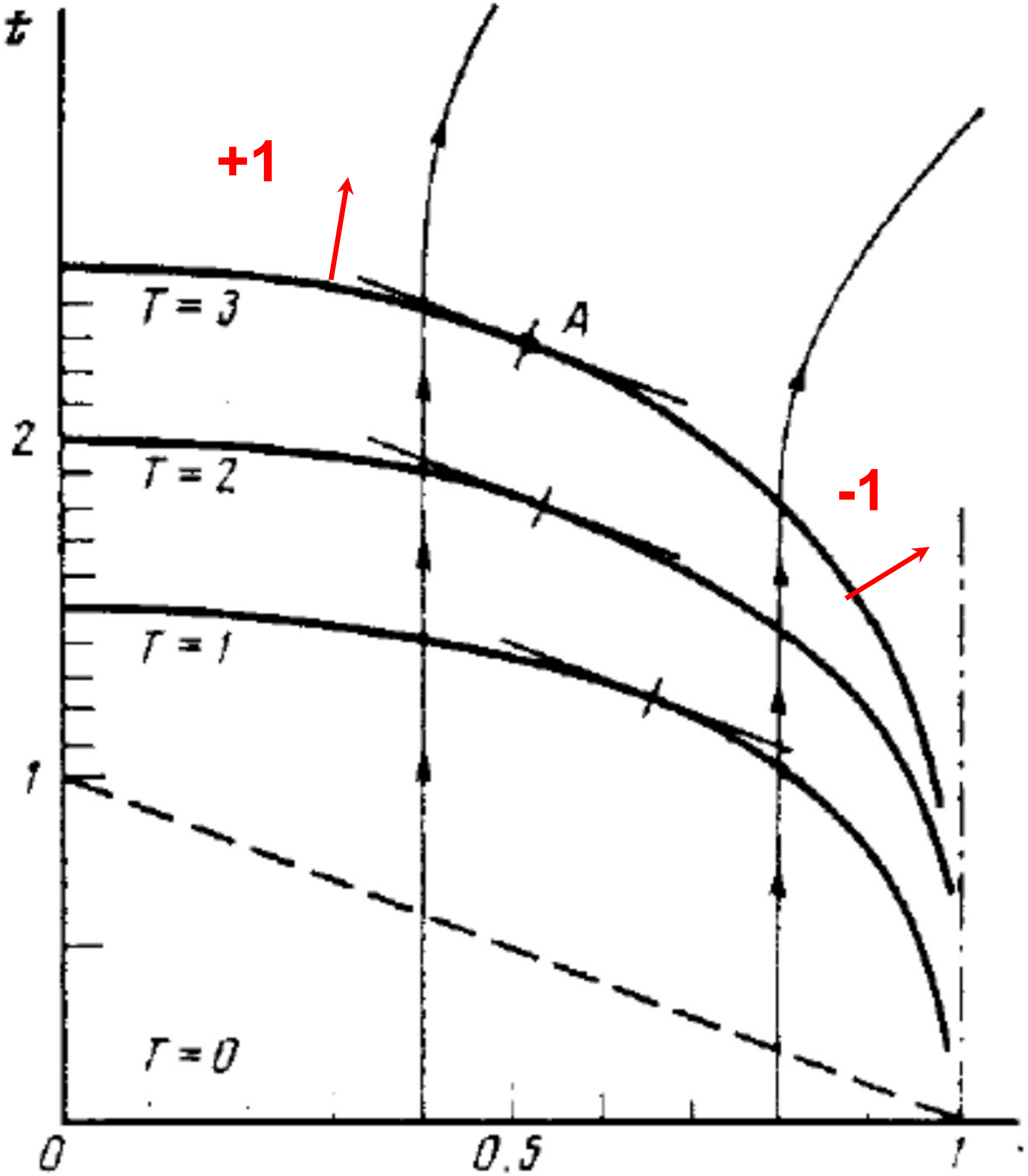
NIF – RT instability



The target is compressed to density ~ 700 g/cm^3.

But, although an ablator layer is used, only ~ **10%-of the target** is ignited. Elsewhere the surface protruded as “potato from the potato press”: **RT- instability.**

How can we prevent it
Idea - #1



[**L. P. Csernai**, Zh. Eksp. Teor. Fiz. 92, 379-386 (**1987**) & Sov. Phys. JETP 65, 216-220 (1987)]

corrected the work of [**A. Taub**, Phys. Rev. 74, 328 (**1948**)]

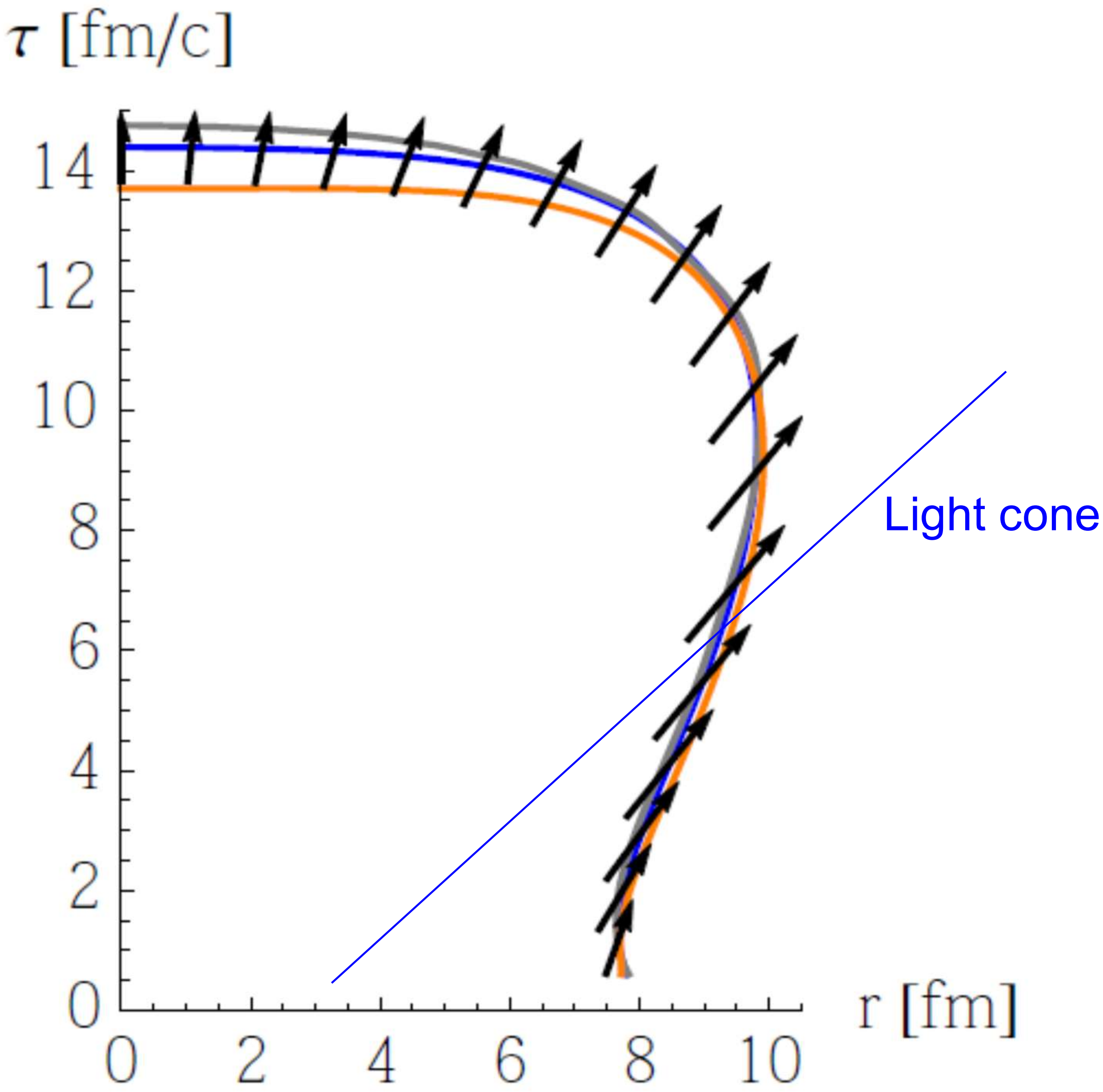
$$\lambda_\alpha \lambda^\alpha = \pm 1$$

Л. П. Чернаи

ДЕТОНАЦИЯ НА ВРЕМЕНИПОДОБНОМ ФРОНТЕ ДЛЯ РЕЛЯТИВИСТСКИХ СИСТЕМ

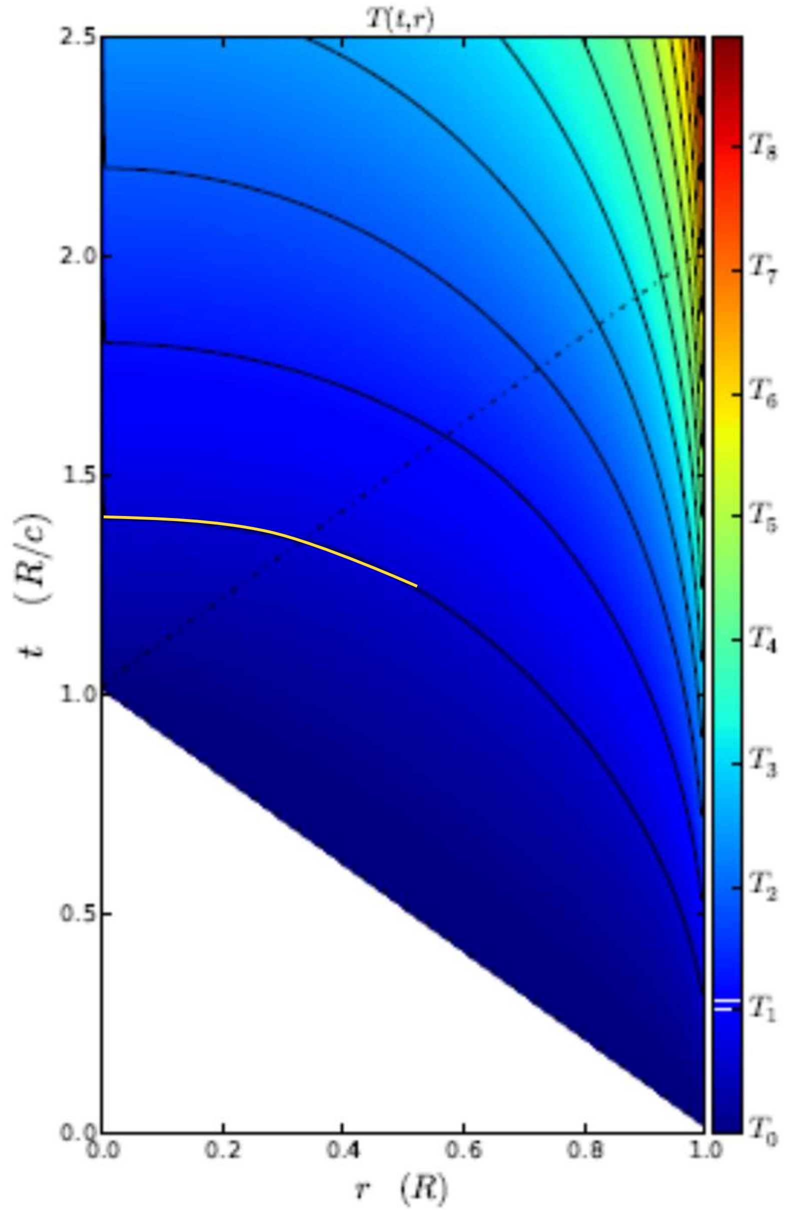
Журнал экспериментальной и теоретической физики

1987



@ CERN in High energy heavy ion collisions

[Stefan Floerchinger, and Urs Achim Wiedemann, Phys. Rev. C 89, 034914 (2014)]



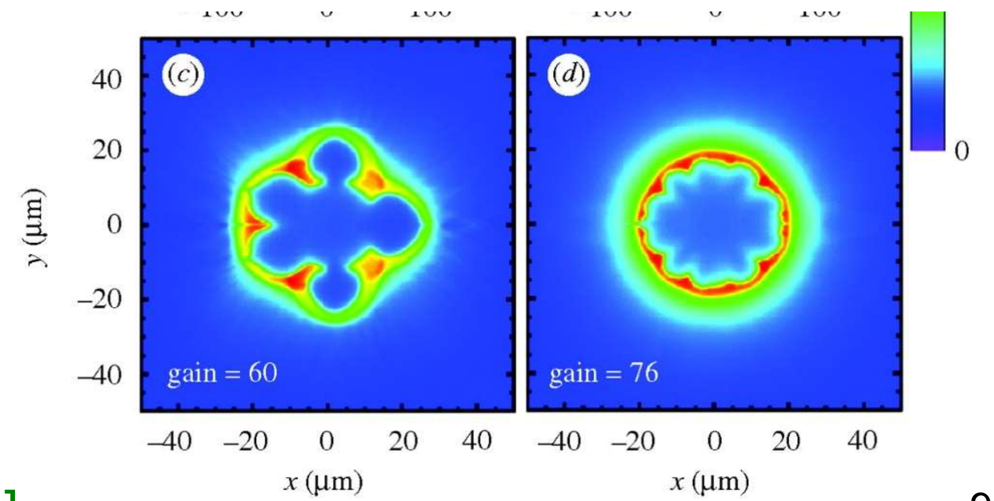
Fusion reaction:

D + T ➔ n(14.1 MeV) + 4He (3.5 MeV)

Constant absorptivity,
Spherical irradiation
Ignition temperature = T1 ➔

Simultaneous, volume ignition up to 0.5 R (i.e. **12%** of the volume).

Not too good, but better than:



[L.P. Csernai & D.D. Strottman,
Laser and Particle Beams 33, 279 (2015).]

How can we realize it
Idea - #2

LPB, 36(2), (2018) 171-178.

Laser and Particle Beams

cambridge.org/lpb

Radiation dominated implosion with nano-plasmonics

L.P. Csernai[1], N. Kroo[2,3] and I. Papp[4]

[1]Department of Physics and Technology, University of Bergen, Bergen, Norway; [2]Hungarian Academy of Sciences, Budapest, Hungary; [3]Wigner Research Centre for Physics, Budapest, Hungary and [4]Department of Physics, Babes-Bolyai University, Cluj, Romania

Research Article

Cite this article: Csernai LP, Kroo N, Papp I (2018). Radiation dominated implosion with nano-plasmonics. *Laser and Particle Beams* 1–8. https://doi.org/10.1017/S0263034618000149

Received: 28 November 2017
Revised: 14 March 2018
Accepted: 3 April 2018

Key words:
Inertial confinement fusion; nano-shells; relativistic fluid dynamics; time-like detonation

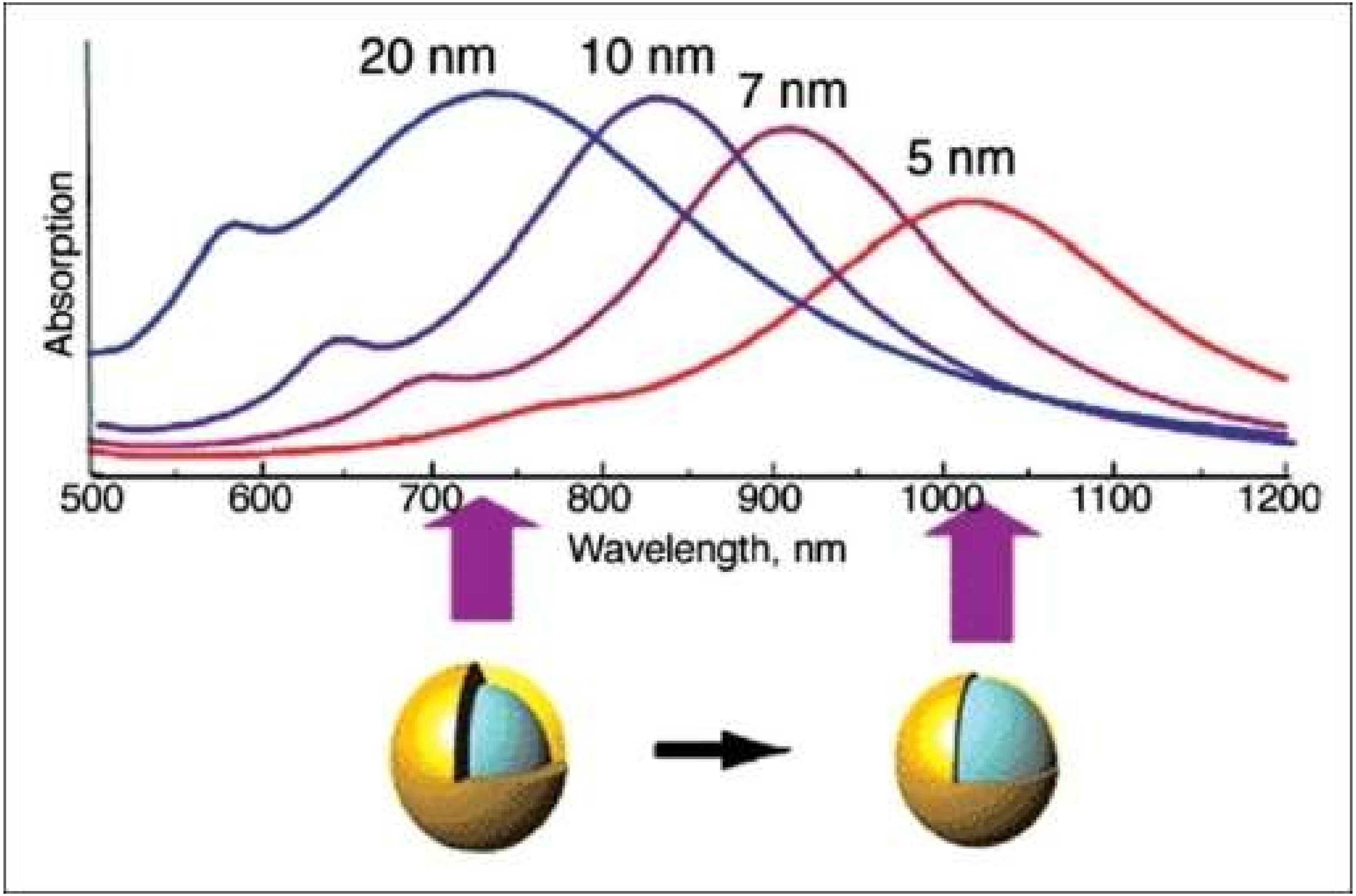
Author for correspondence:
L.P. Csernai, Department of Physics and Technology, University of Bergen, Bergen, Norway. E-mail: Laszlo.Csernai@uib.no

Abstract

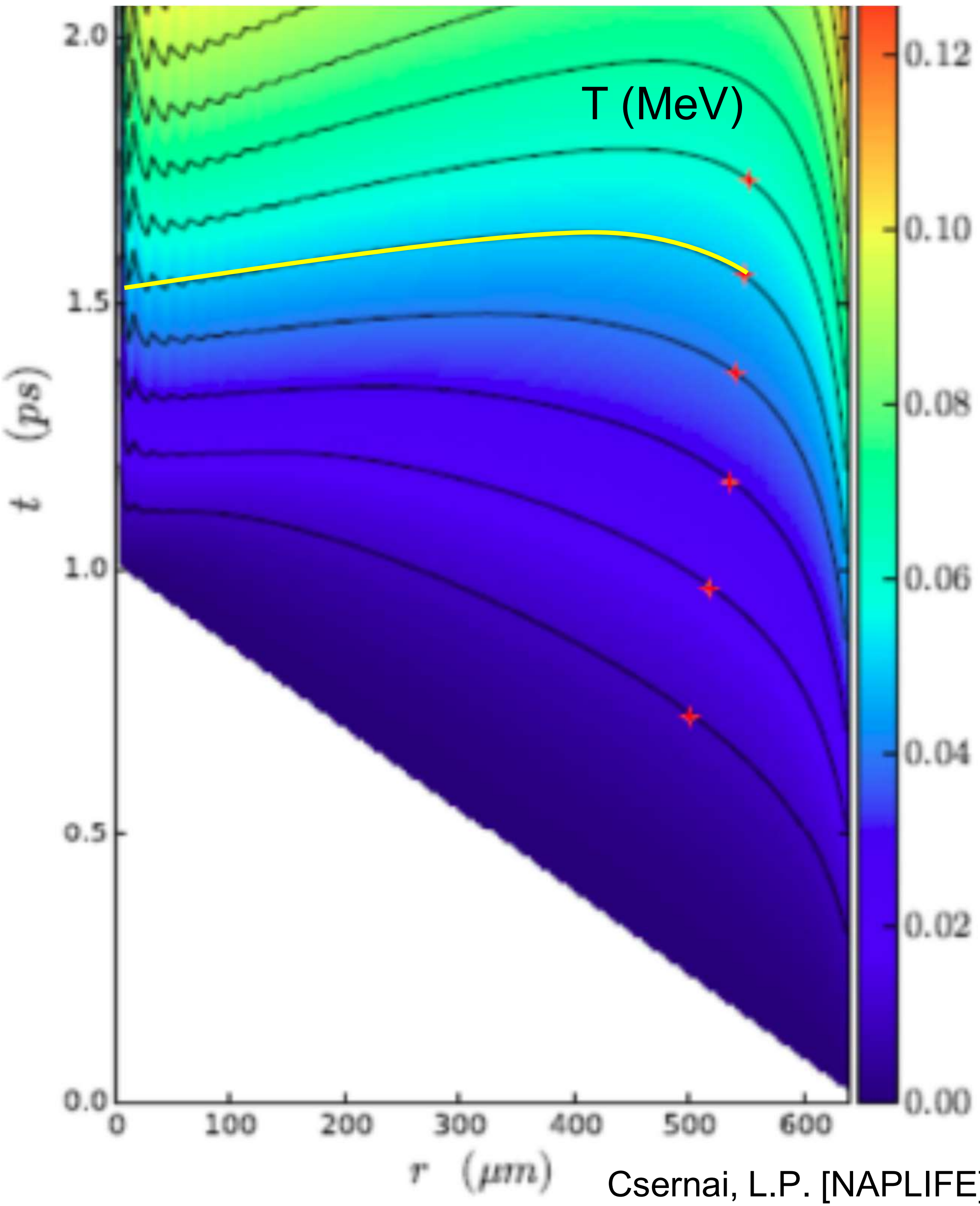
Inertial Confinement Fusion is a promising option to provide massive, clean, and affordable energy for mankind in the future. The present status of research and development is hindered by hydrodynamical instabilities occurring at the intense compression of the target fuel by energetic laser beams. A recent patent combines advances in two fields: Detonations in relativistic fluid dynamics (RFD) and radiative energy deposition by plasmonic nano-shells. The initial compression of the target pellet can be decreased, not to reach the Rayleigh–Taylor or other instabilities, and rapid volume ignition can be achieved by a final and more energetic laser pulse, which can be as short as the penetration time of the light across the pellet. The reflectivity of the target can be made negligible as in the present direct drive and indirect drive experiments, and the absorptivity can be increased by one or two orders of magnitude by plasmonic nano-shells embedded in the target fuel. Thus, higher ignition temperature and radiation dominated dynamics can be achieved with the limited initial compression. Here, we propose that a short final light pulse can heat the target so that most of the interior will reach the ignition temperature simultaneously based on the results of RFD. This makes the development of any kind of instability impossible, which would prevent complete ignition of the target.

… and 35th Hirschegg Int. Workshop on High Energy Density Physics, Jan. 25-30, **2015**

Golden Nano-Shells – Resonant Light Absorption



Csernai, L.P. [NAPLIFE]



Csernai, L.P. [NAPLIFE]

The absorption coefficient is **linearly** changing with the radius: In the center,

$r = 0, \ \alpha_K = 30 \text{ cm}^{-1}$ while at the outside

edge $\alpha_K = 8 \text{ cm}^{-1}$.

The temperature is measured in units of $T_1 = 272$ keV, and $T_n = n\, T_1$.

Simultaneous, volume ignition is up to 0.9 R, so **73% of the fuel target!**

How can we realize it simpler and with less expense

Thick coin like flat target & Two beams only

Thickness of the target is: h

h depends on pulse energy, ignition energy, target mass, …

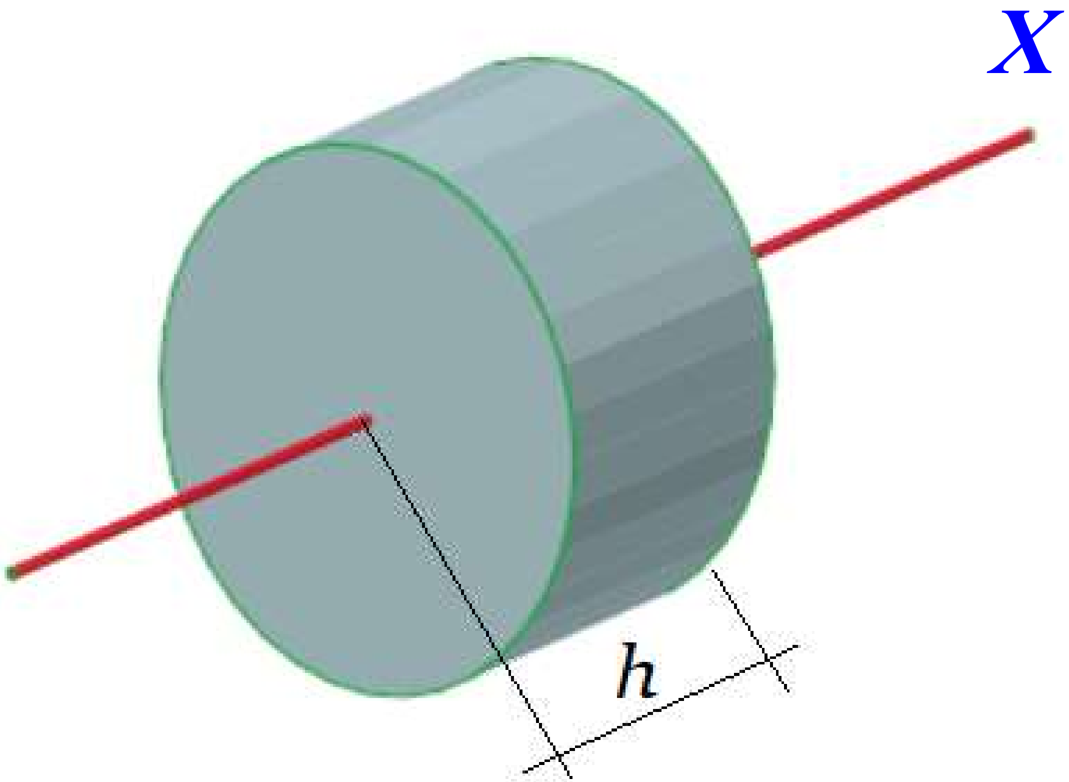
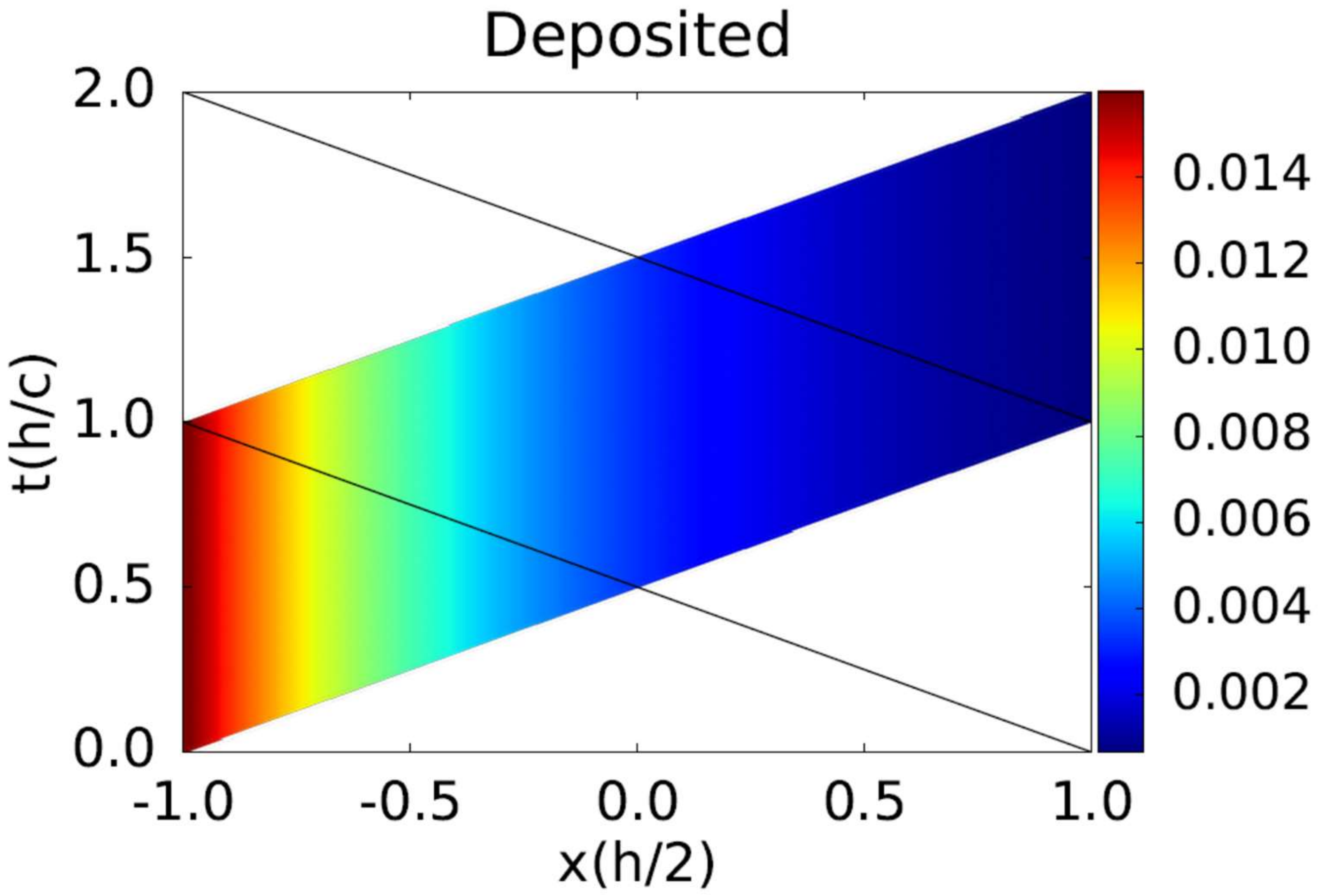


Figure 1: (color online) The target still should be compact to minimize the surface effects. The irradiation is performed along the x−axis from both sides towards the target. The laser beam should be uniform hitting the whole face of the coin shaped target.

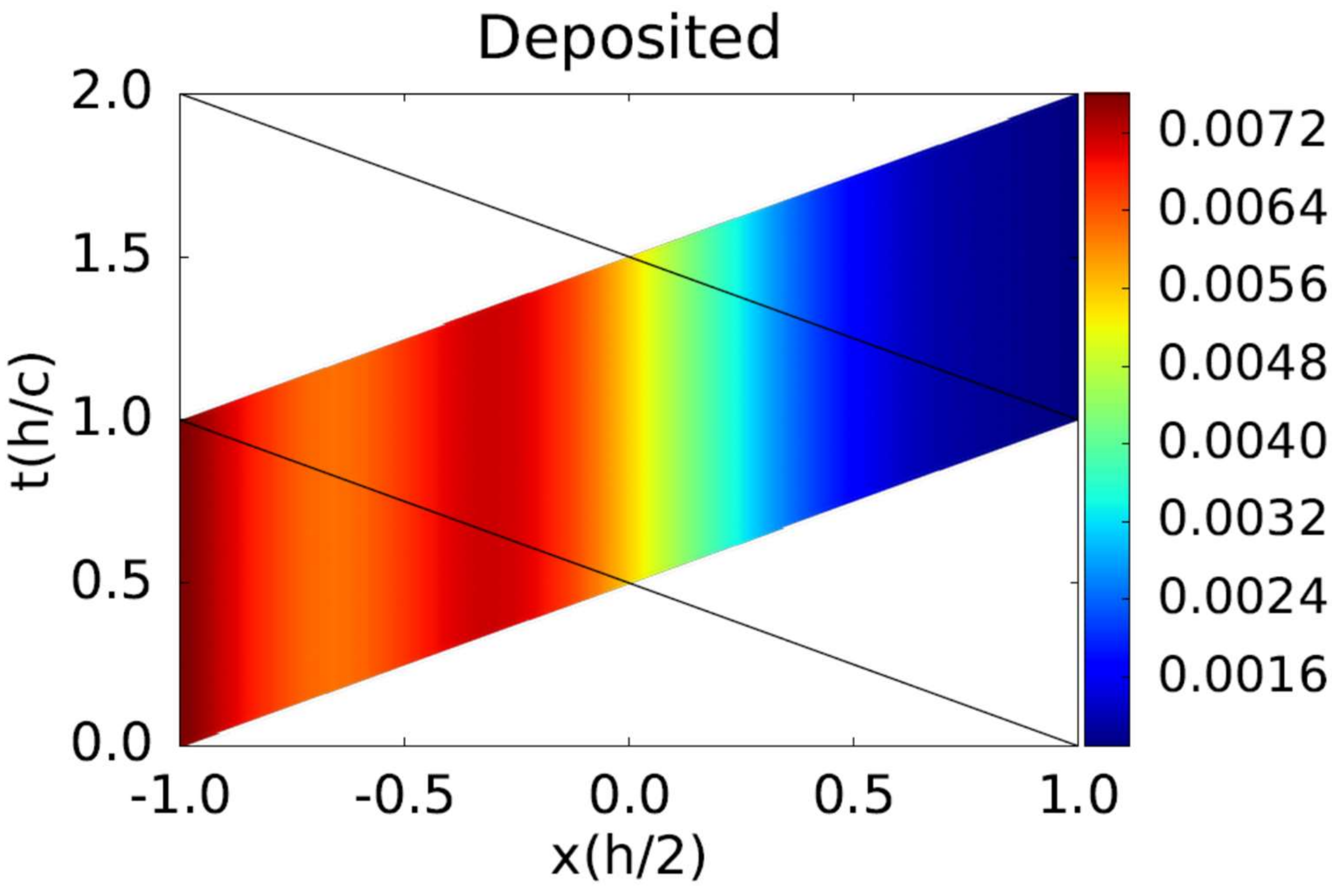
[Csernai et al., (**NAPLIFE** Collaboration) *Phys. of Wave Phenomena,* **28** (3), 187-199 **(2020).**]

However,
- no simultaneous ignition, and
- no nano-antennas up to now !



Without nano antennas

The deposited energy from laser irradiation from one side only. The absorption is constant, this leads to an exponentially decreasing energy deposition, and only a negligibly small energy reaches the opposite end of the target.



With nano antennas

The absorptivity is increased towards the center, due to the implanted nano antennas.

The deposited energy from laser irradiation from one side only. The absorption is modified by nano antennas so that the absorptivity is increasing towards the middle, so that the deposited energy is constant up to the middle. Then the absorptivity is decreasing, but hardly any energy is left in the irradiation front. Thus again only a negligibly small energy reaches the opposite end of the target.

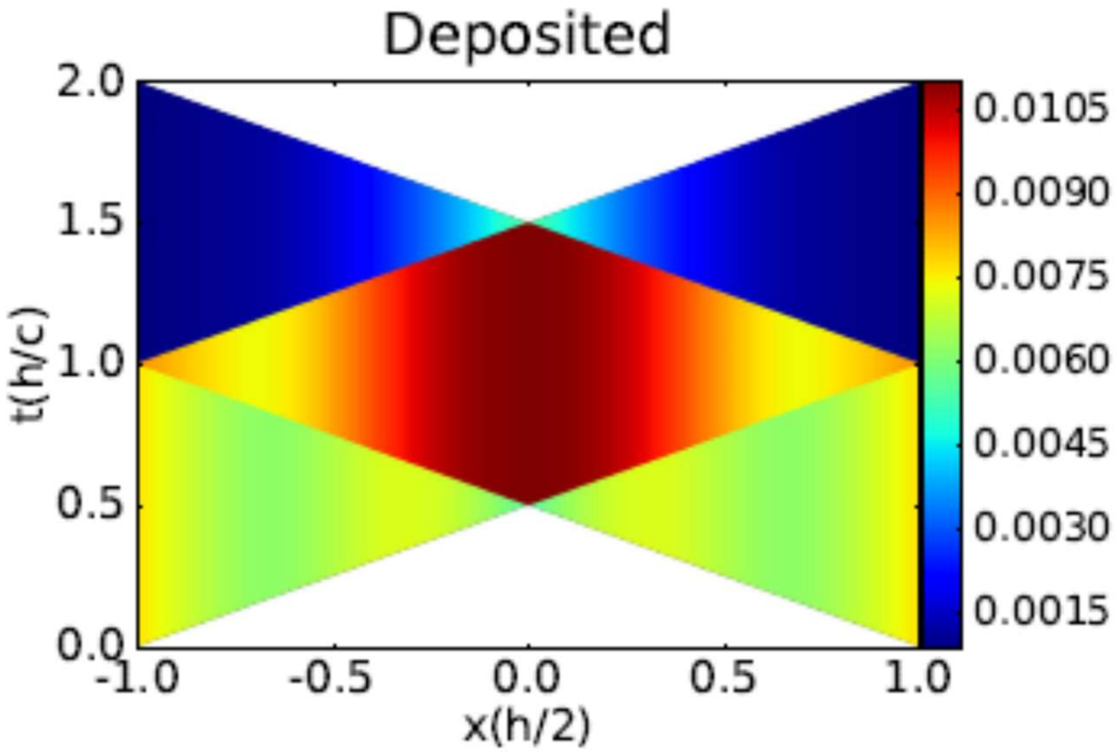


Figure 2: (color online) Deposited energy per unit time in the space-time across the depth, h, of the flat target. The time is measured in units of (h/c), where c is the speed of light in the material of the target. The irradiation lasts for a period of $\Delta t = h/c$ the time needed to cross the target. The irradiated energy during this time period is Q from one side, so it is $2Q$ from both sides together.
The color code indicates the deposited energy per unit time and unit cross section (a.u.). The deposited length is $\Delta x = c\Delta t$. Note! The absorptivity in this case $\alpha_K \neq$ const. For more details please see Appendix B.

With nano antennas

Irradiation from both sides.

Ignition energy is: Q_i/m
e.g. for DT target: $Q_i/m = 27$ kJ/g
➔ if we have $Q = 100$ J , then we can have a target mass:
$m_{DT} = Q / Q_i$ g = 3.703 mg.

Then with m_{DT} and ρ_{DT} given we get the DT-target's volume, V_{DT} and h_{DT} = 2.67 mm .

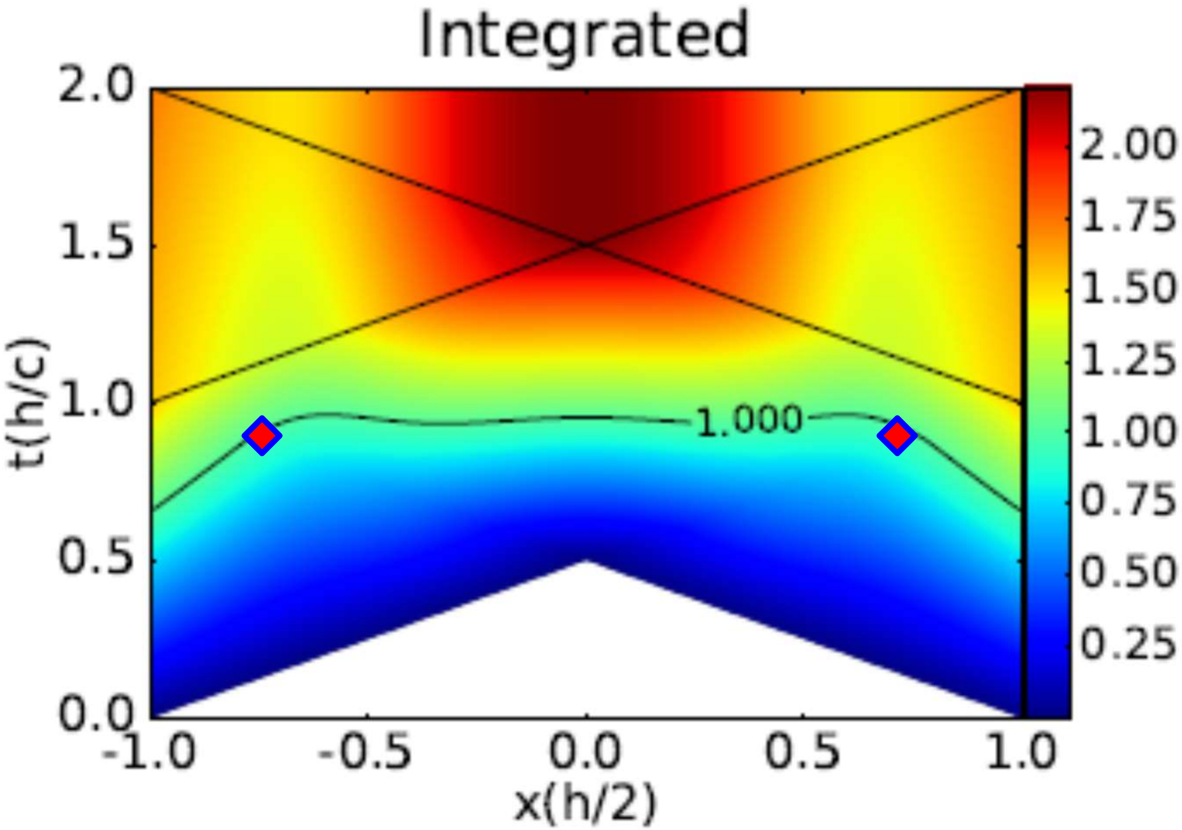


Figure 3: (color online) Integrated energy up to a given time in the space-time across the depth, h, of the flat target. The color code indicates the temperature, T, reached in a given space-time point, in units of the critical temperature, (T_c). The contour line $T = 1$, indicates the critical temperature, T_c where the phase transition or the ignition in the target is reached. This contour line is almost at a constant time, indicating simultaneous whole volume transition or ignition. The irradiated energy, Q is chosen so that, $1Q$ irradiation will achieve the critical temperature.

Csernai, L.P. [NAPLIFE]

With nano antennas

Ignition is reached at contour line $Q = 1$.

[Csernai et al., (**NAPLIFE** Collaboration) *Phys. of Wave Phenomena,* **28** (3), 187-199 **(2020).**]

Simultaneous ignition in the whole target volume → Short Pulse: ELI - ALPS

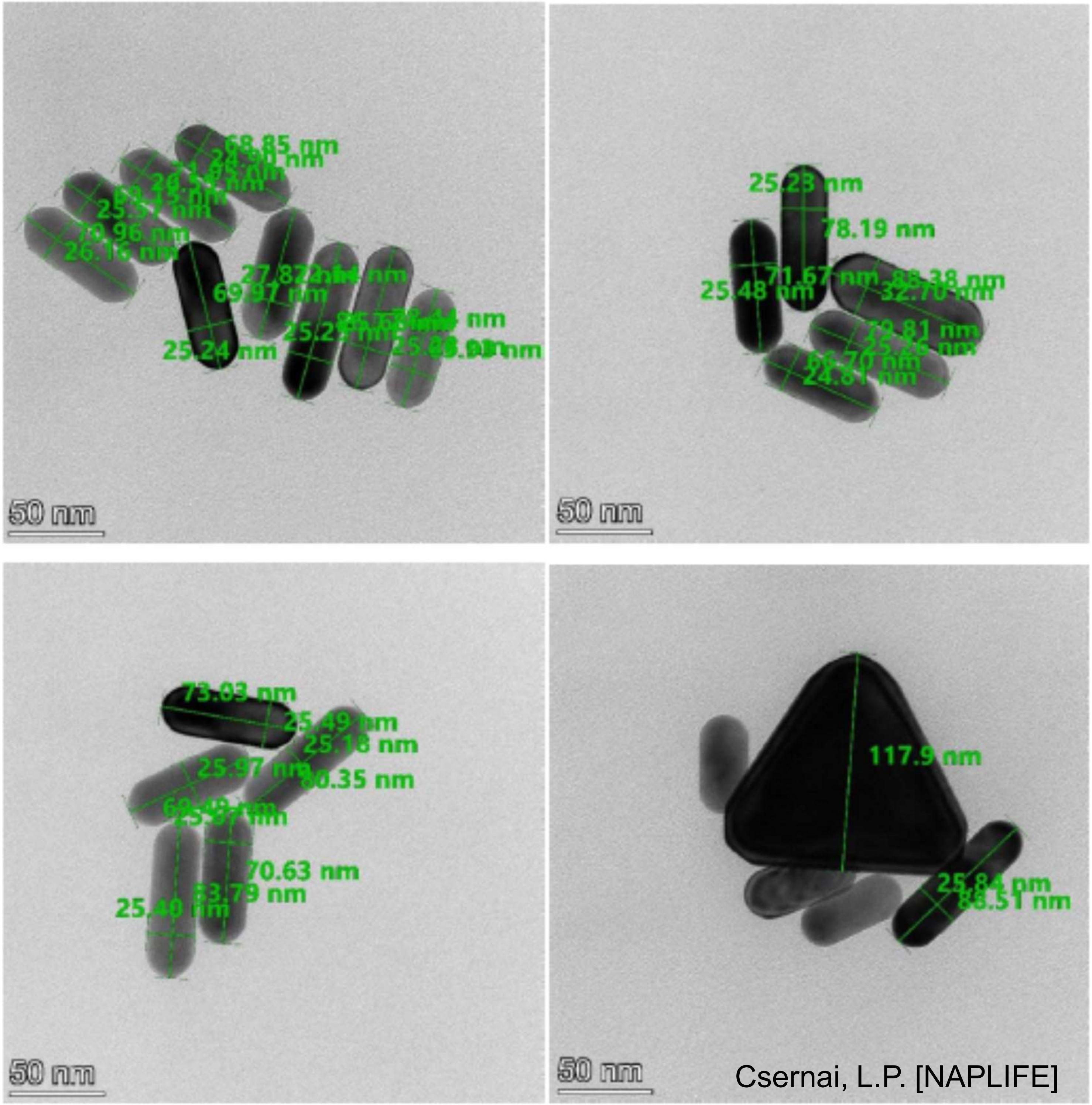
Validation tests at lower energies idea #2 increased absorption via nano-antennas

Wigner RCP, Budapest

Ti:Sa Hidra Laser: 30mJ, 10Hz, 40fs **[P. Racz et al., Wigner RCP]**

Target Modeling and Manufacturing

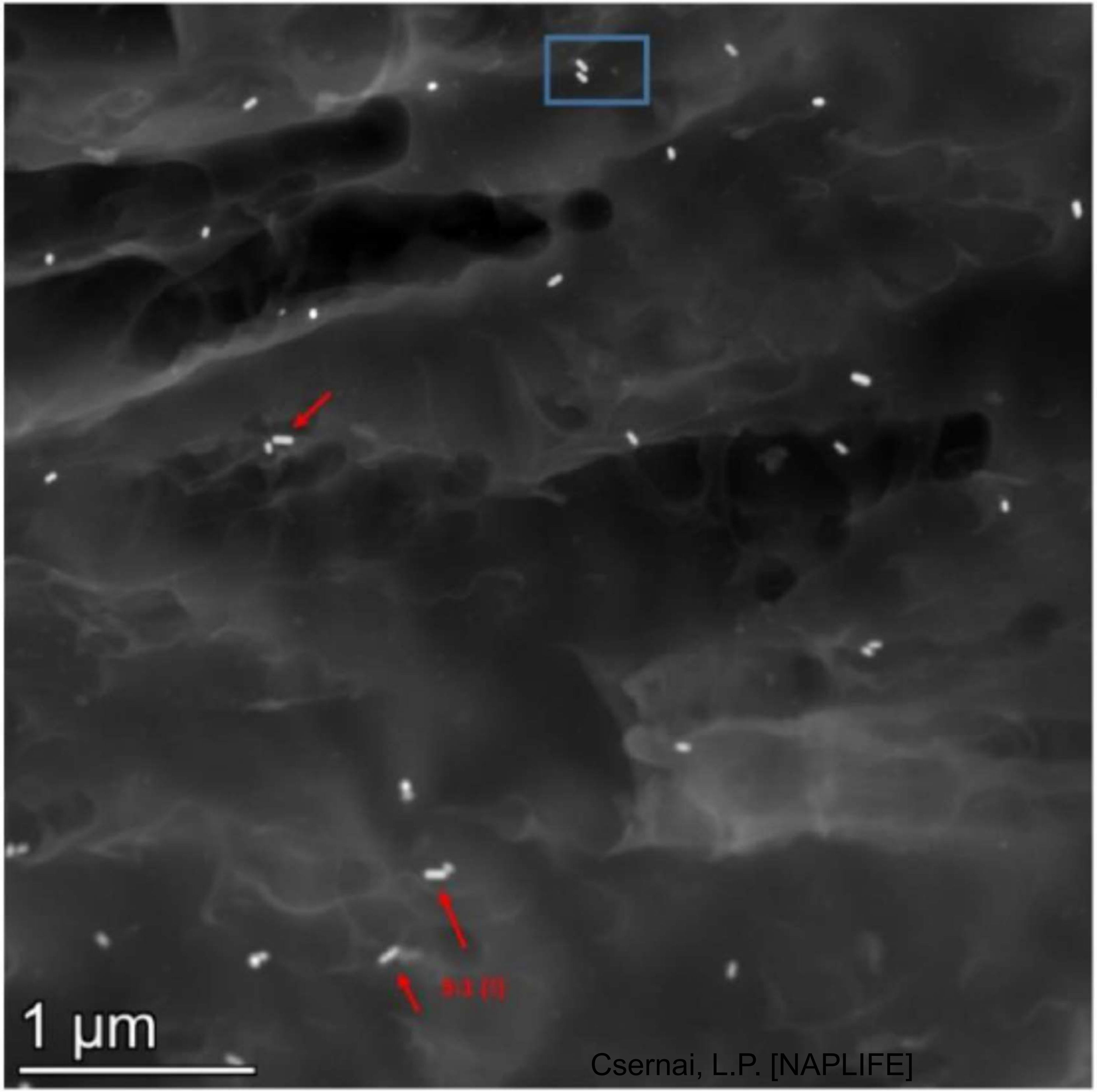
➔ Attila Bonyár's talk



Csernai, L.P. [NAPLIFE]

Transmission Electron-microscopy photos of 75x25 nm gold nano-rod antennas

[Judit Kámán, A. Bonyár et al. (NAPLIFE Collab.)., Gold nanorods …, 10th ICNFP 2021, **Kolymbari]**

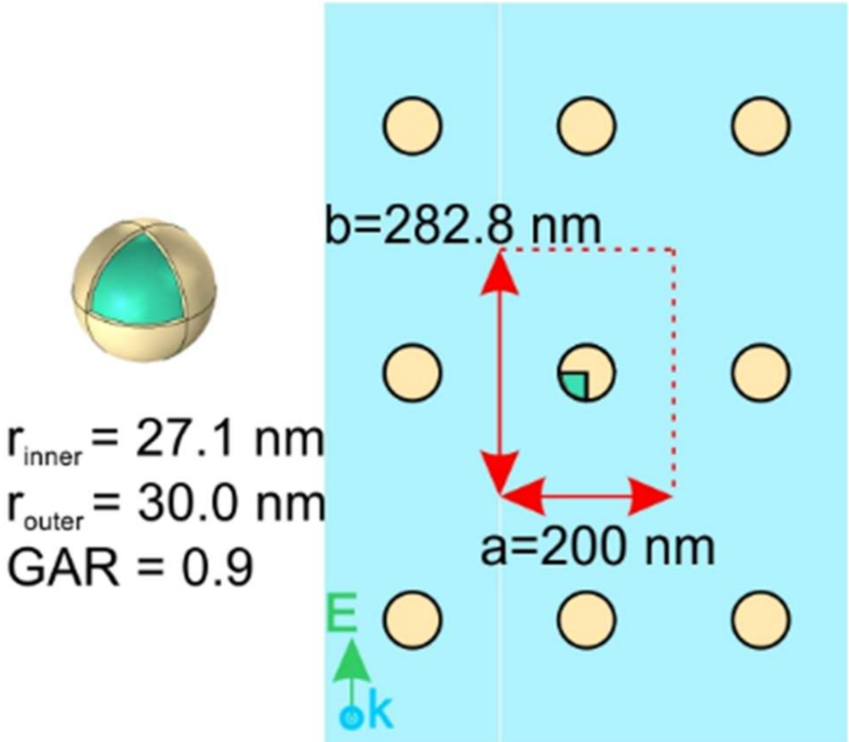


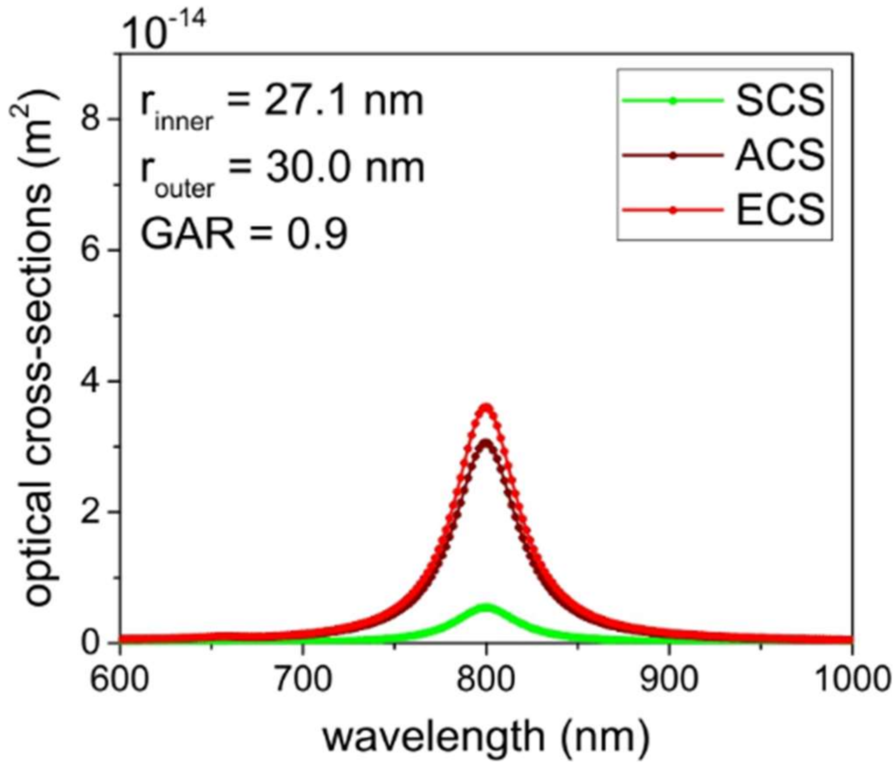
TEM Photo of ~uniformly implanted nanorod antennas in UDMA target polymer. The density is 9-20 / µm^3

[**Judit Kámán, A. Bonyár** et al. (NAPLIFE Collab.)., Gold nanorods …, 10th ICNFP 2021, K**olymbari**, Crete, Greece, 30 August 2021.**]**

Nano-particle absorption

The target absorptivity is increased via core-shell type plasmonic nano-shells. Calculations via solving the Maxwell equations, and evaluating the ohmic heating were performed using the COMSOL simulation package.





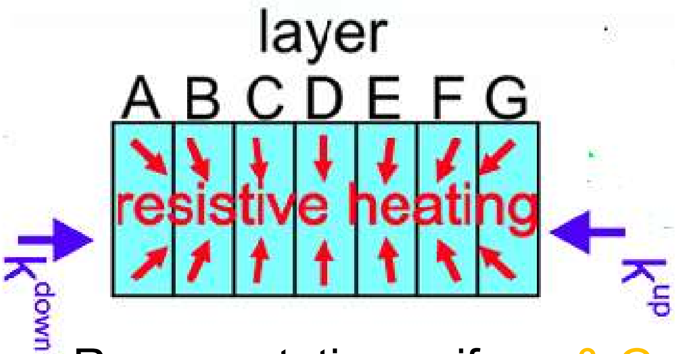
1 ps laser pulse length, λ = 800 nm, one-sided & two-sided irradiation tested, 85-100 % absorption in the target length h.

Nano-antenna shapes, layer configurations, layer distribution varied & analyzed.

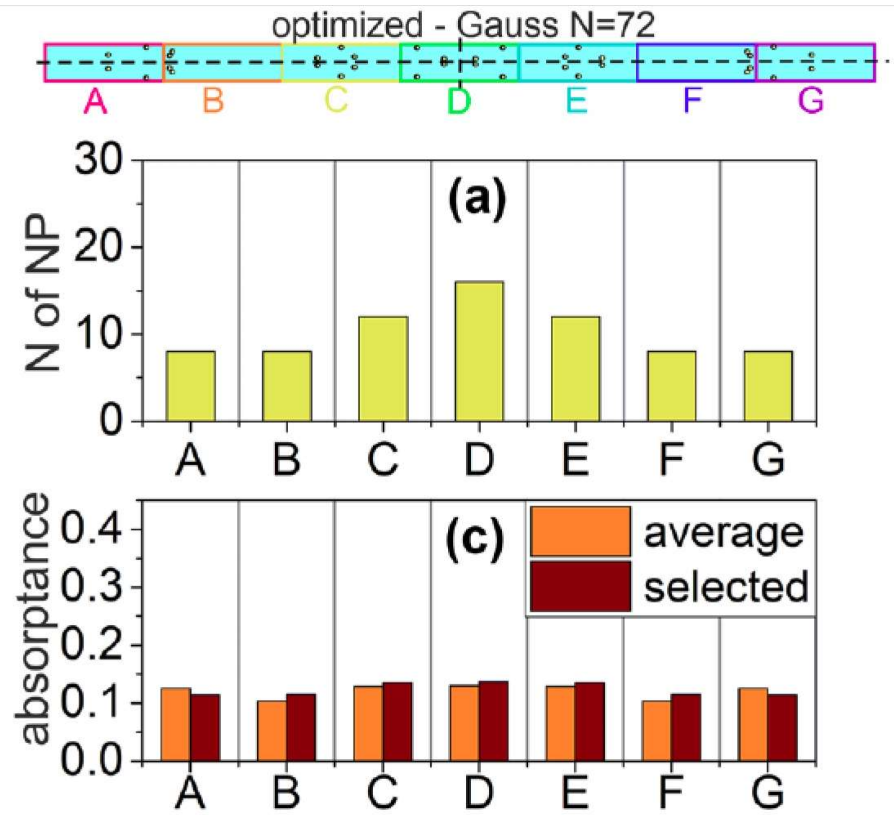
[**M. Csete**, et al., U. Szeged, HU https://doi.org/10.1007/s11468-021-01571-x

10.3103/S1541308X20030048]

Layered target with variable light absorption



Representative uniform & Gaussian number density distributions of (d) 70 oriented nanorods, in a 1 × 1 × 21 µm3 supercell of UDMA polymer target, with random location distribution.



Plasmonics (2022) 17:775–787
https://doi.org/10.1007/s11468-021-01571-x

Comparative Study on the Uniform Energy Deposition Achievable via Optimized Plasmonic Nanoresonator Distributions

Mária Csete[1] · András Szenes[1] · Emese Tóth[1] · Dávid Vass[1] · Olivér Fekete[1] · Balázs Bánhelyi[2] · István Papp[3,4] · Tamás Bíró[3] · László P. Csernai[3,4,5] · Norbert Kroó[3,6]

[**M. Csete**, A. Szenes, E. Tóth, D. Vass, O. Fekete, B. Bánhelyi, T. S. Bíró, L. P. Csernai, N. Kroó: *„Comparative study on the uniform energy deposition achievable via optimized plasmonic nanoresonator distributions*“, Plasmonics (2022), 17: 775-787; https://doi.org/10.1007/s11468-021-01571-x.]

Validation tests at lower energies idea #1 Simultaneous (time-like) transition (ignition)

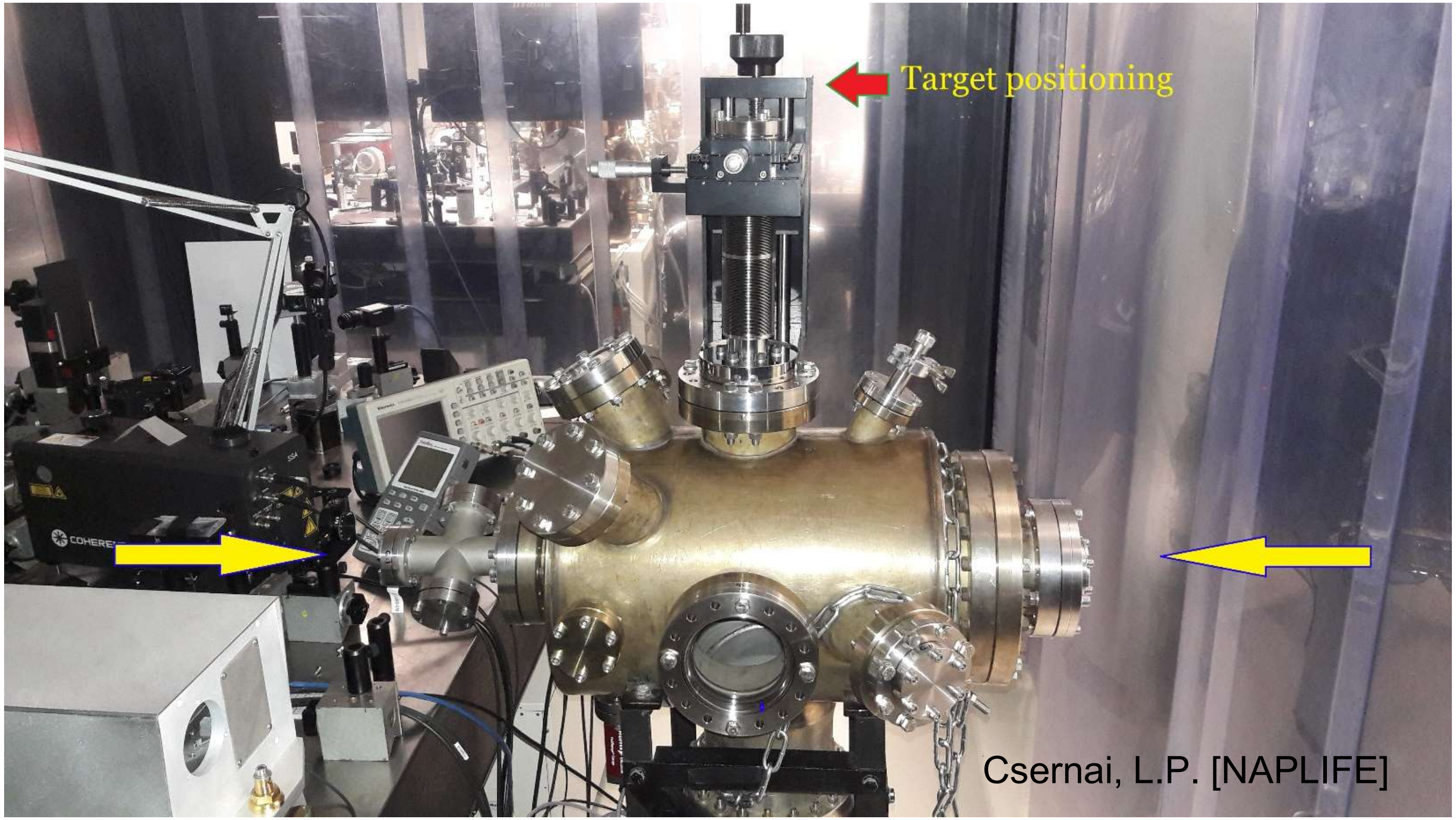
➔

Two opposing beams

Validation tests – Target manufacturing

Two basic principles are tested on non-fusion material targets at low energies

- **Implanted with nano-antennas ➔ Amplified absorption** √
- **Multilayer targets ➔ Simultaneous Ignition (in progress)**

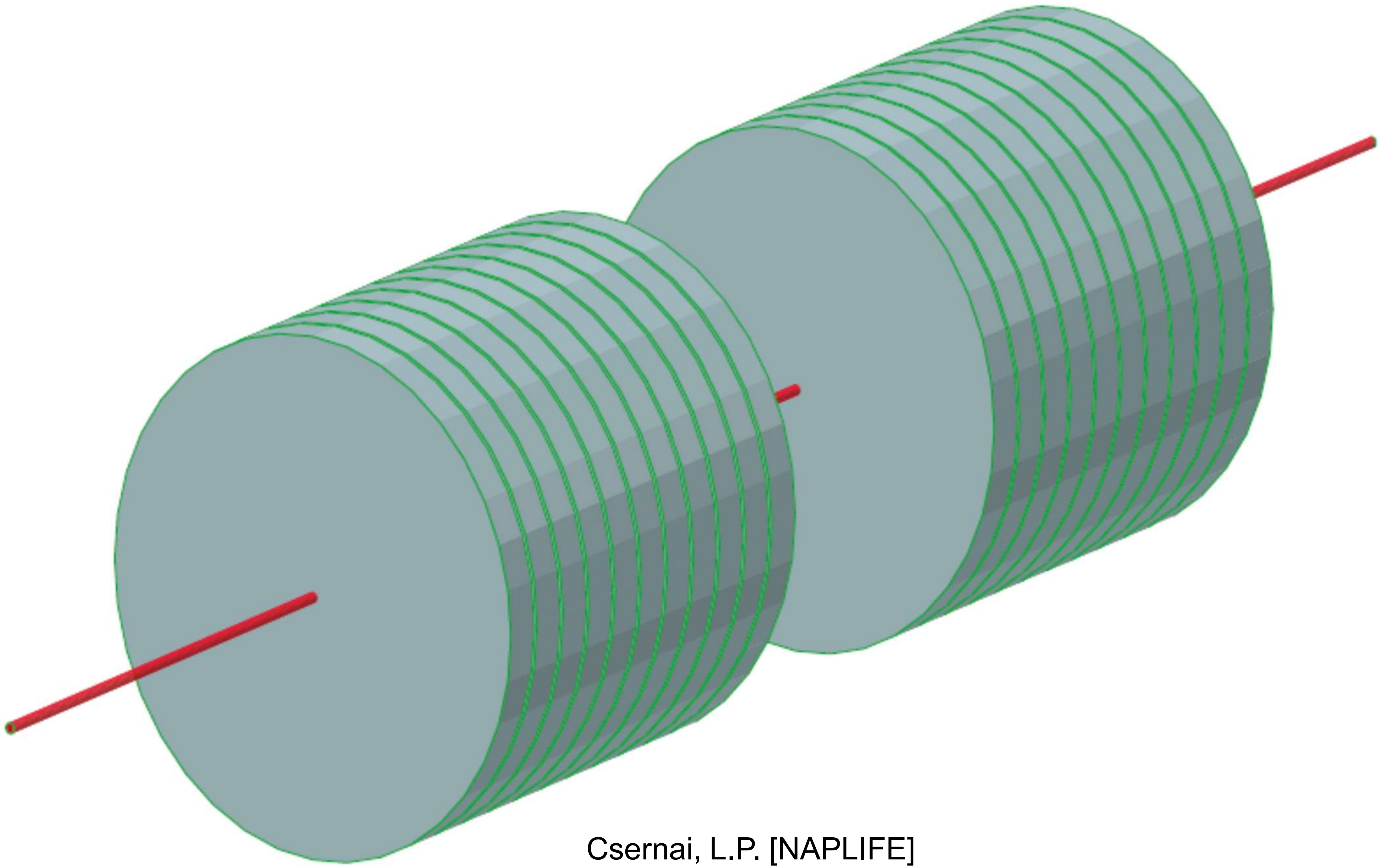


[M. Csete, A. Bonyár, I. Papp, P. Rácz, et al.]

In preparation

Csernai, L.P. [NAPLIFE]

Multilayered fuel target



Laser Wake Field Collider

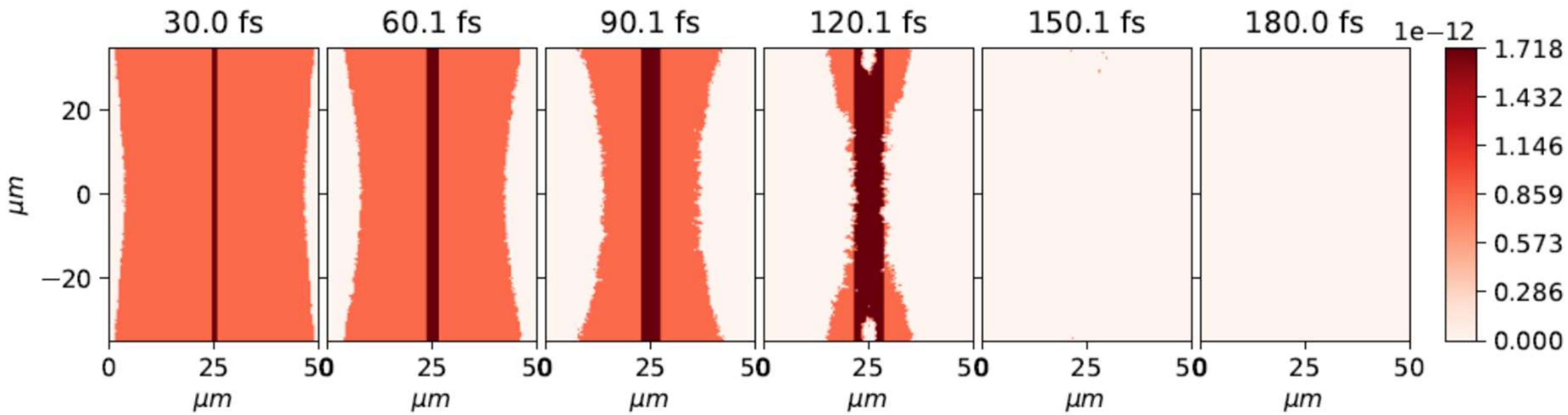
∃ Pre-compression/acceleration, before ignition

Ion (e.g. p) Energy $E_p \approx 50$ MeV (or more)

Initial beam densities assumed: $n_H \approx \gamma\, n_0 = 2 \cdot 10^{-19}/cm^3$ and $2 \cdot 10^{-21}/cm^3$

$\approx n_{liquid\text{-}H}$, $\approx n_{NIF}$ /1000 (/wo precompression!)

Target density after interpenetration: $n_t \geq 2\, n_H$



The ionization of the H atoms at ignition in a Laser Wake Field (LWF) wave due to the irradiation from both the +/- *x* directions

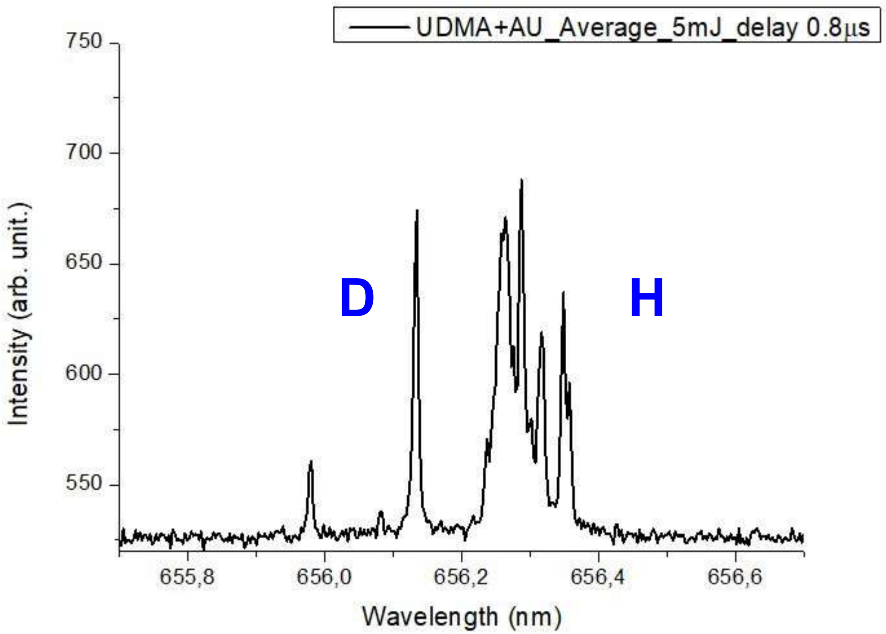
[Papp, I., et al., NAPLIFE, Phys. Lett. A 396, 12724 (2021).]

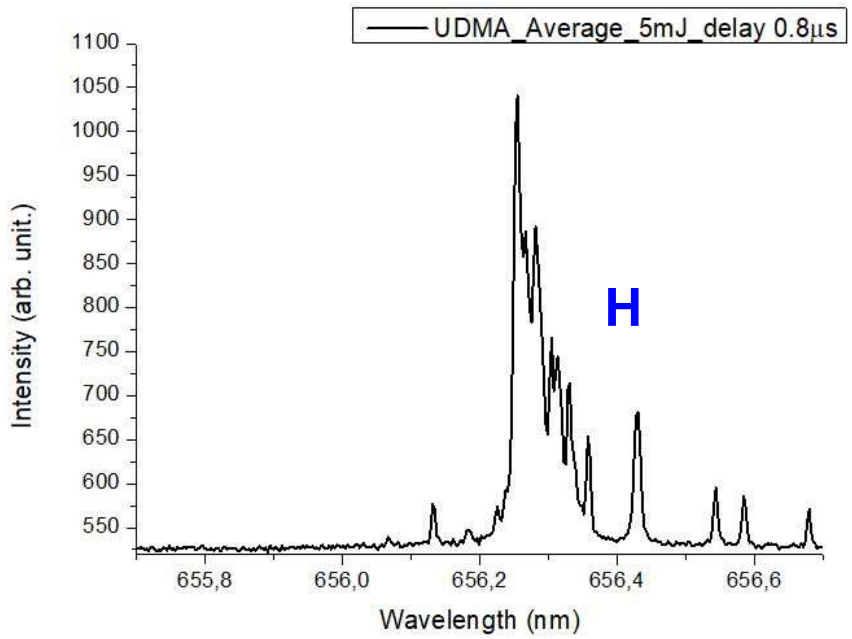
Csernai, L.P. [NAPLIFE]

Validation tests →

Laser Induced Fusion with Nanoantennas

Deuterium production (PRELIMINARY !) (N.K.*)





5-12% **D + 88-95% H**

~ **10^{17} D** / pulse (10Hz)

100% **H**

Balmer-α line

Two step process (average of 20 shots):

p + e* → n + **ν** \ electron capture (-1.24 MeV)

n + p → d + **γ** \ neutron capture (+2.22 MeV)

Electron capture may happen spontaneously in heavy nuclei,
here laser light and resonant nanorods act similarly, high e density

UDMA (470: H38, C23, O8, N2)

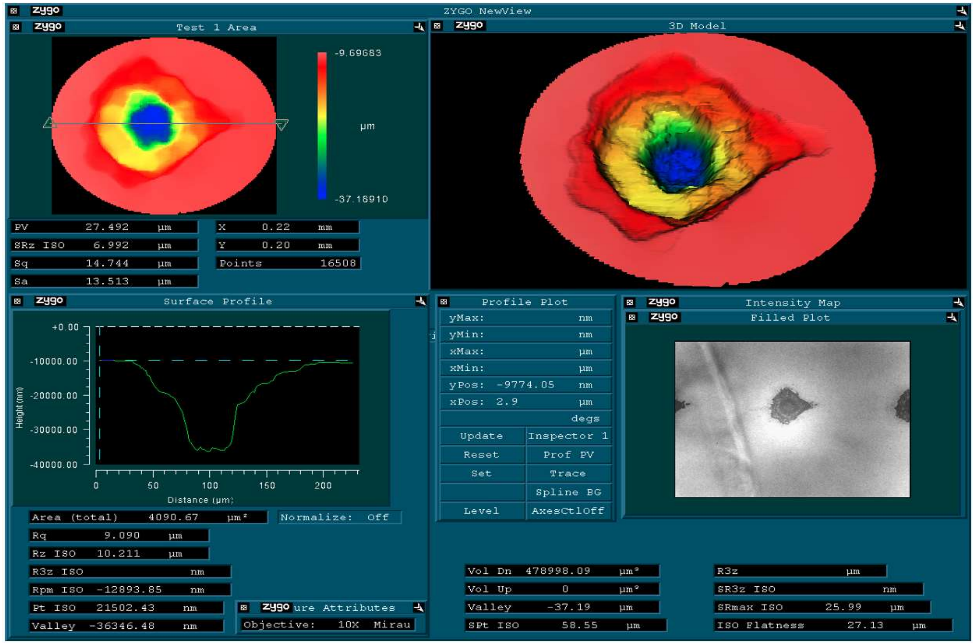
Csernai, L.P. [NAPLIFE]

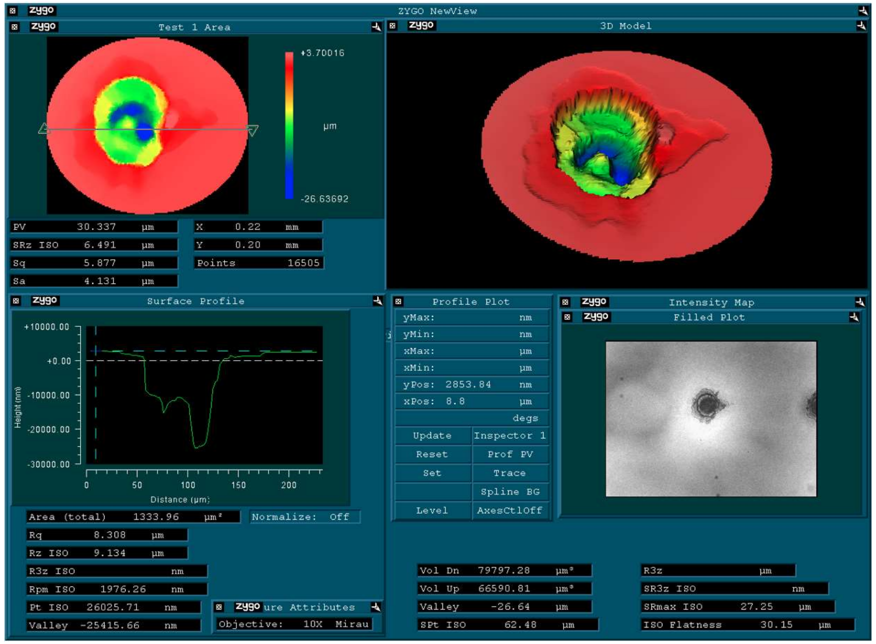
Deuterium production w

(N.K.*)

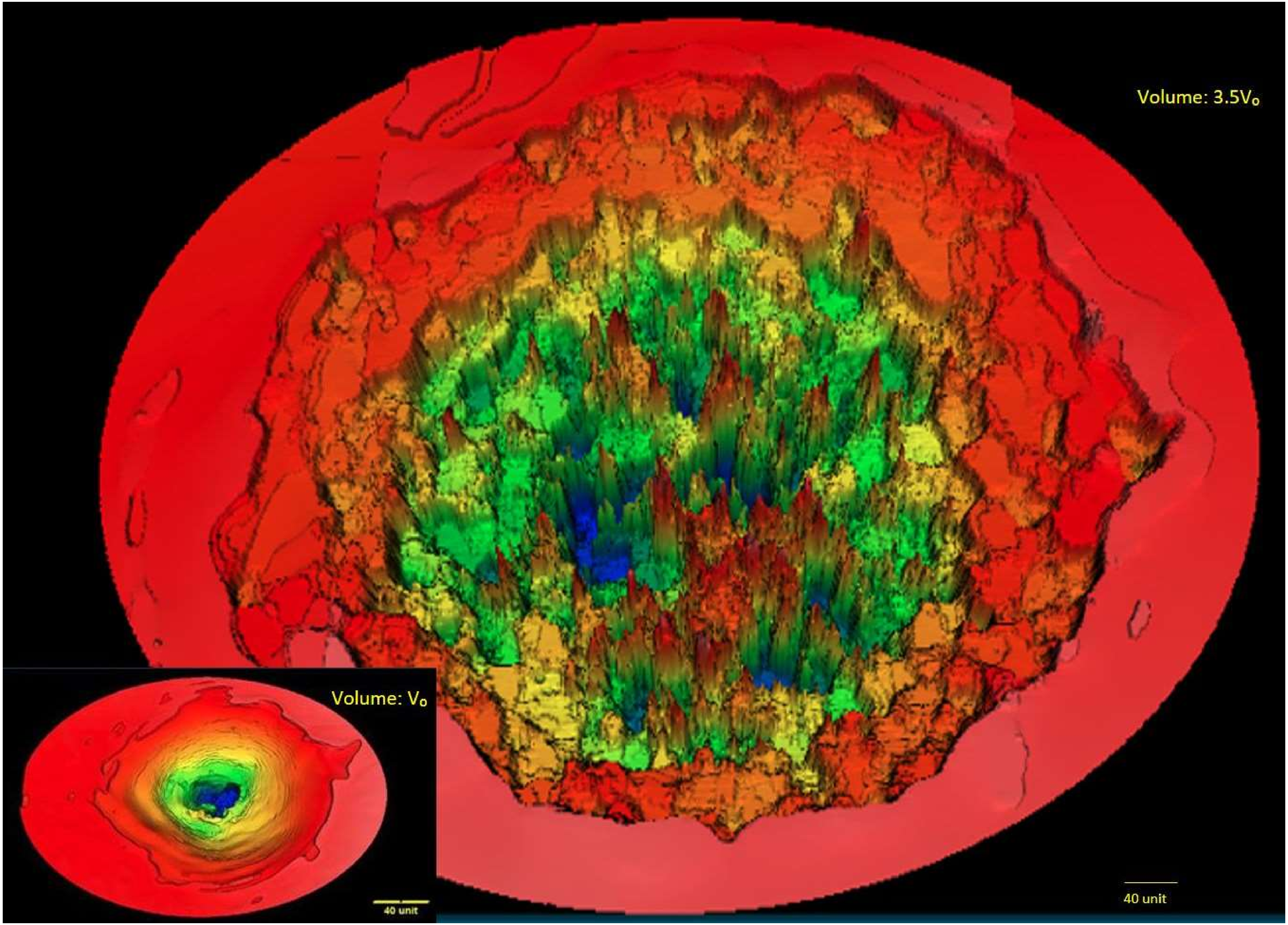
ith 795nm 40fs Ti:Sa laser 10^{16}-10^{17} W/cm^2 intensity

UDMA-TEGDMA target 20-100 μm thick, \w & \wo Au nanorods 25x85nm.
➔ 5 mJ pulse -> crater of 4.55-1.07·10^{14} μm^3 \w &\wo Au ~ 15/ μm^3





➔ From the crater the emitted matter was analysed by Raman spectroscopy & Laser Induced Breakdown Spectroscopy (LIBS).


Volume: 3.5V$_o$
Volume: V$_o$
40 unit
40 unit

(2022)

Cornell University

the Sim

arXiv > physics > arXiv:2210.00619

Search...

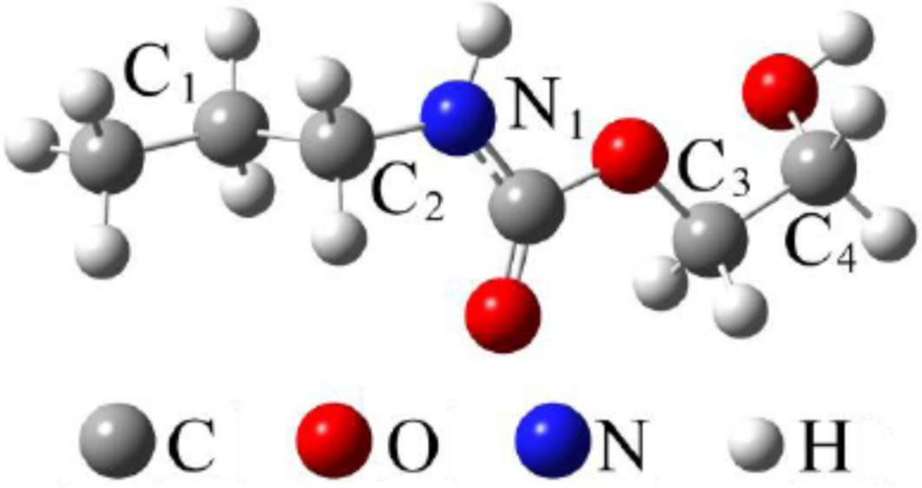
Help | Advanced

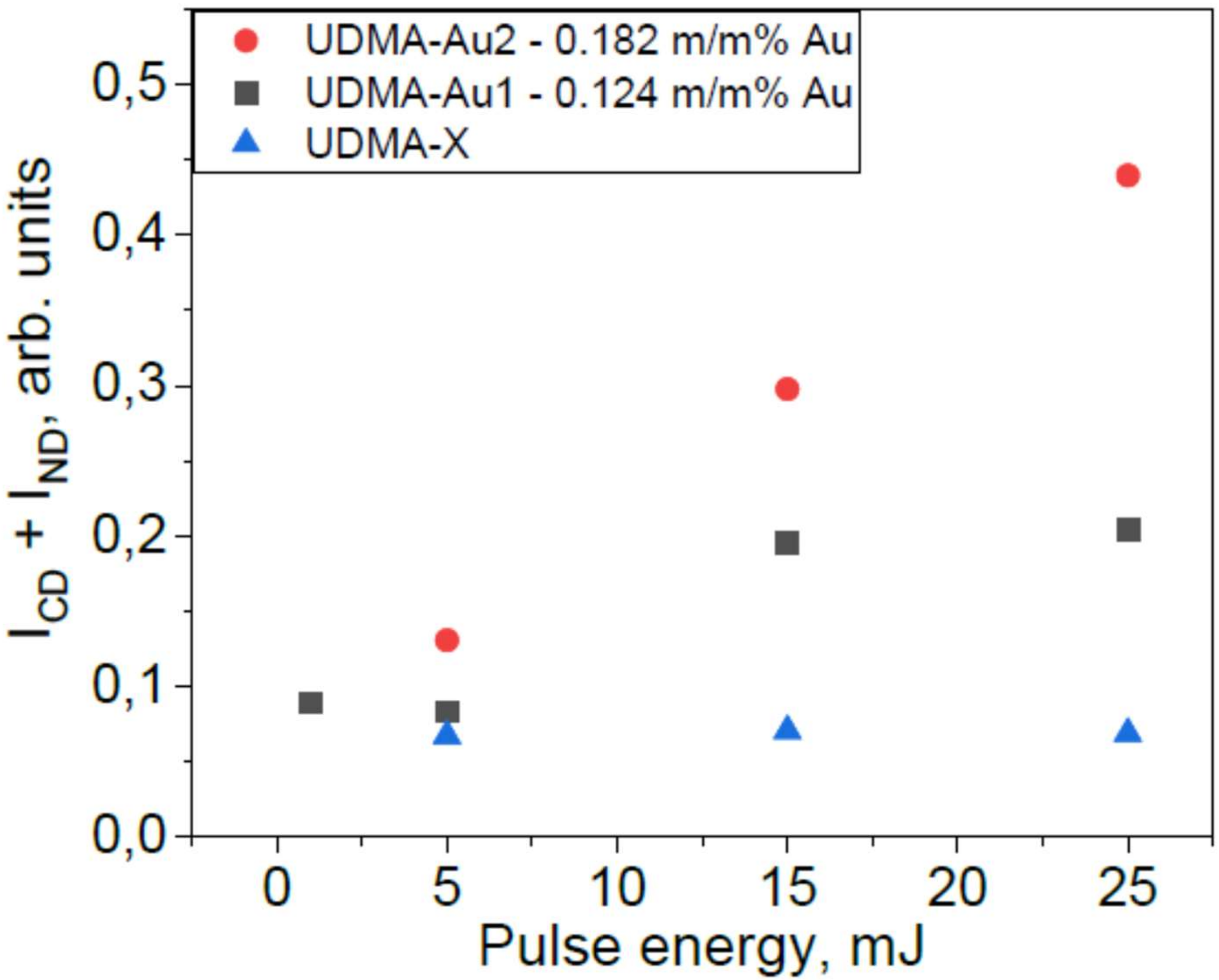
Physics > Plasma Physics

[Submitted on 2 Oct 2022]

Raman spectroscopic characterization of crater walls formed upon single-shot high energy femtosecond laser irradiation of dimethacrylate polymer doped with plasmonic gold nanorods

István Rigó[1], Judit Kámán[1], Ágnes Nagyné Szokol[1], Attila Bonyár[2], Melinda Szalóki[3], Alexandra Borók[1,2], Shereen Zangana[2], Péter Rácz[1], Márk Aladi[1], Miklós Ákos Kedves[1], Gábor Galbács[5], László P. Csernai[1,6,7], Tamás S. Biró[1], Norbert Kroó[1,8], Miklós Veres[1], NAPLIFE Collaboration





With Nanorods (Au2) at 25 mJ laser pulse ~4 times increased D production, compared to 1 mJ pulse

PRX ENERGY

Highlights Recent Accepted Authors Referees Search About Scope Editorial Team

Open Access

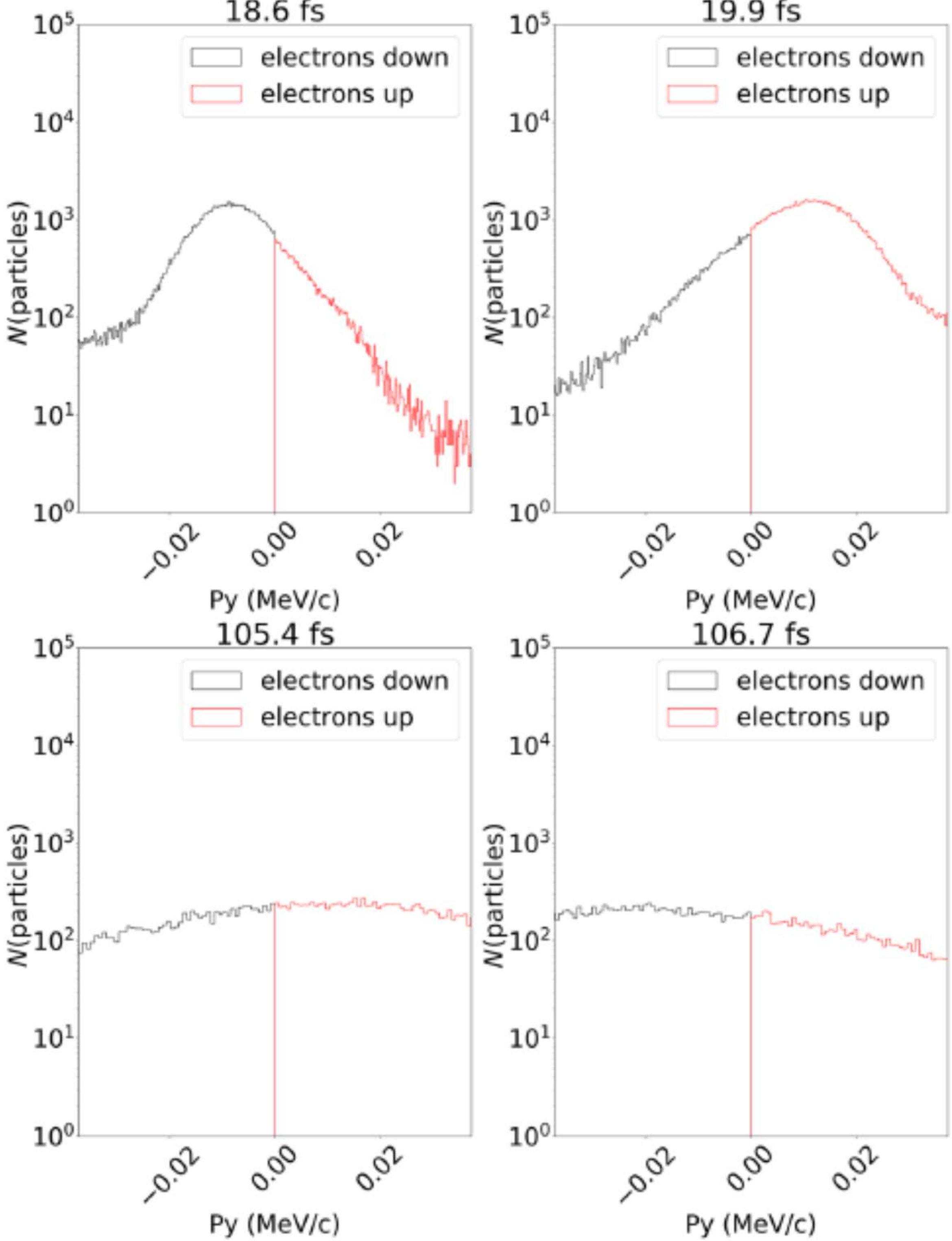
Kinetic Model Evaluation of the Resilience of Plasmonic Nanoantennas for Laser-Induced Fusion

Kinetic Model Evaluation of the Resilience of Plasmonic Nanoantennas for Laser-Induced Fusion

István Papp,[1,2] Larissa Bravina,[4] Mária Csete,[1,5] Archana Kumari,[1,2,*] Igor N. Mishustin,[6] Dénes Molnár,[7] Anton Motornenko,[6] Péter Rácz,[1,2] Leonid M. Satarov,[6] Horst Stöcker,[6,8,9] Daniel D. Strottman,[10] András Szenes,[1,5] Dávid Vass,[1,5] Tamás S. Biró,[1,2] László P. Csernai,[1,2,3,6] and Norbert Kroó[1,2,11]
(NAPLIFE Collaboration)

[1] *Wigner Research Centre for Physics, Budapest, Hungary*
[2] *National Research, Development and Innovation Office of Hungary, Hungary*
[3] *Department of Physics and Technology, University of Bergen, Bergen, Norway*
[4] *Department of Physics, University of Oslo, Norway*
[5] *Department of Optics and Quantum Electronics, University of Szeged, Hungary*
[6] *Frankfurt Institute for Advanced Studies, Frankfurt/Main 60438, Germany*
[7] *Department of Physics, Purdue University, West Lafayette, Indiana 47907, USA*
[8] *Institut für Theoretische Physik, Goethe Universität Frankfurt, Frankfurt/Main 60438, Germany*
[9] *GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt 64291, Germany*
[10] *Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA*
[11] *Hungarian Academy of Sciences, Budapest 1051, Hungary*

(2022)



25x130 nm antennas,
resonant for λ=795 nm

Initial   2 ord. magn.

[L. Novotny (2007)]

$$\frac{\lambda_{\text{eff}}}{2R\pi} = 13.74 - 0.12[\varepsilon_\infty + 141.04] - \frac{2}{\pi} + \frac{\lambda}{\lambda_p} 0.12\sqrt{\varepsilon_\infty + 141.04}.$$

“Final.

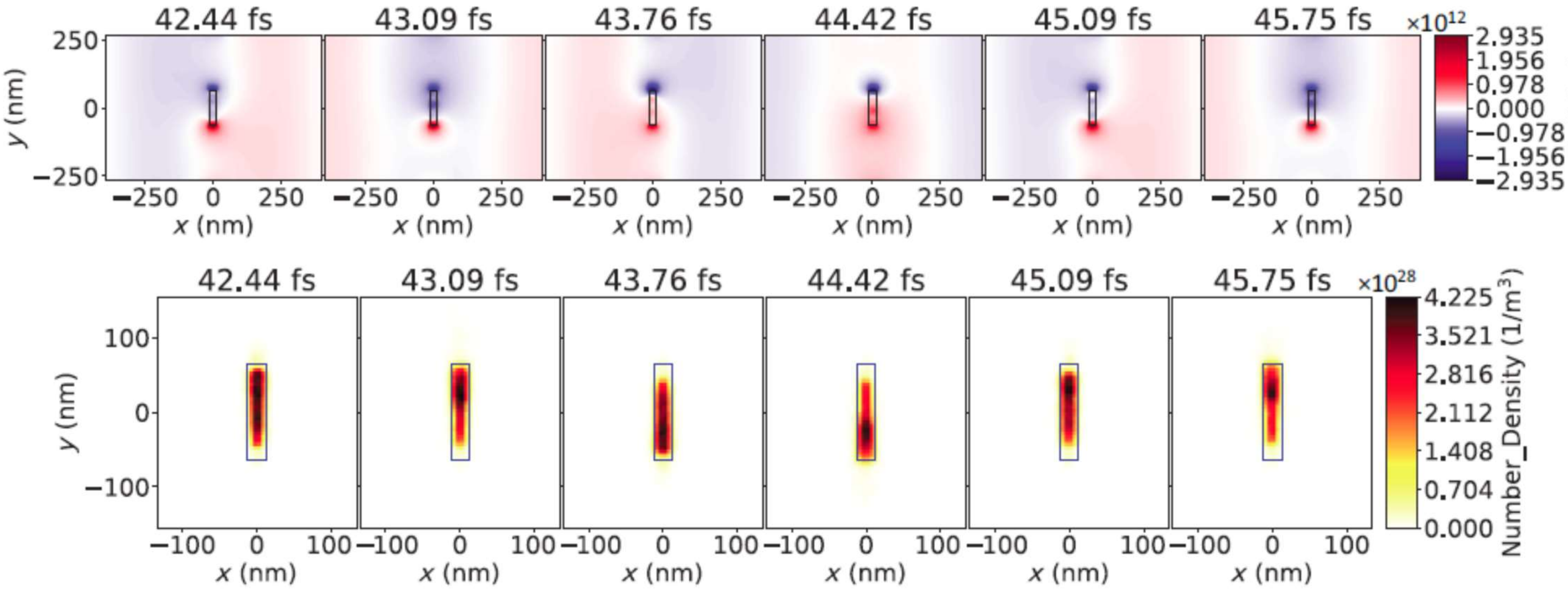
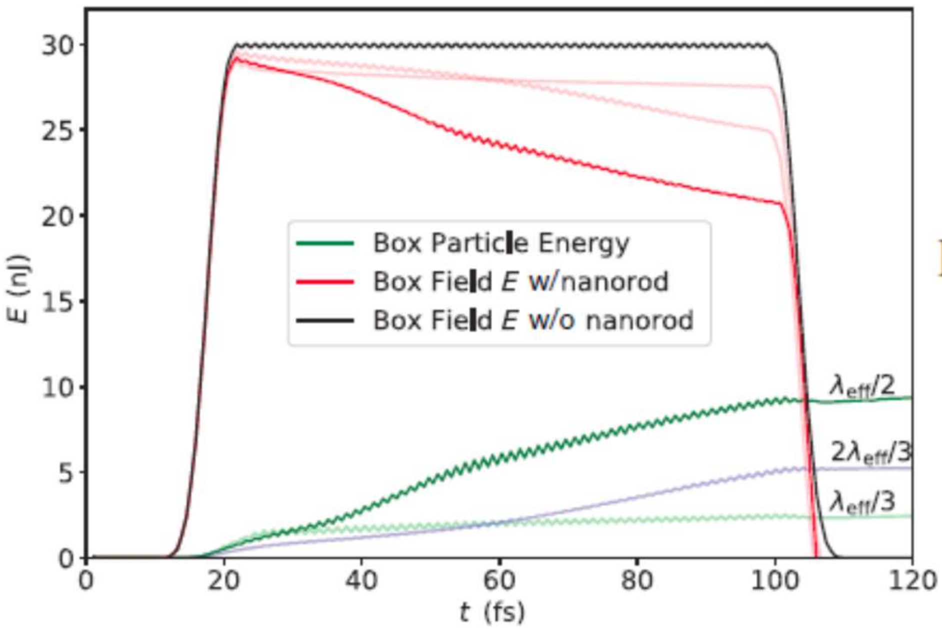


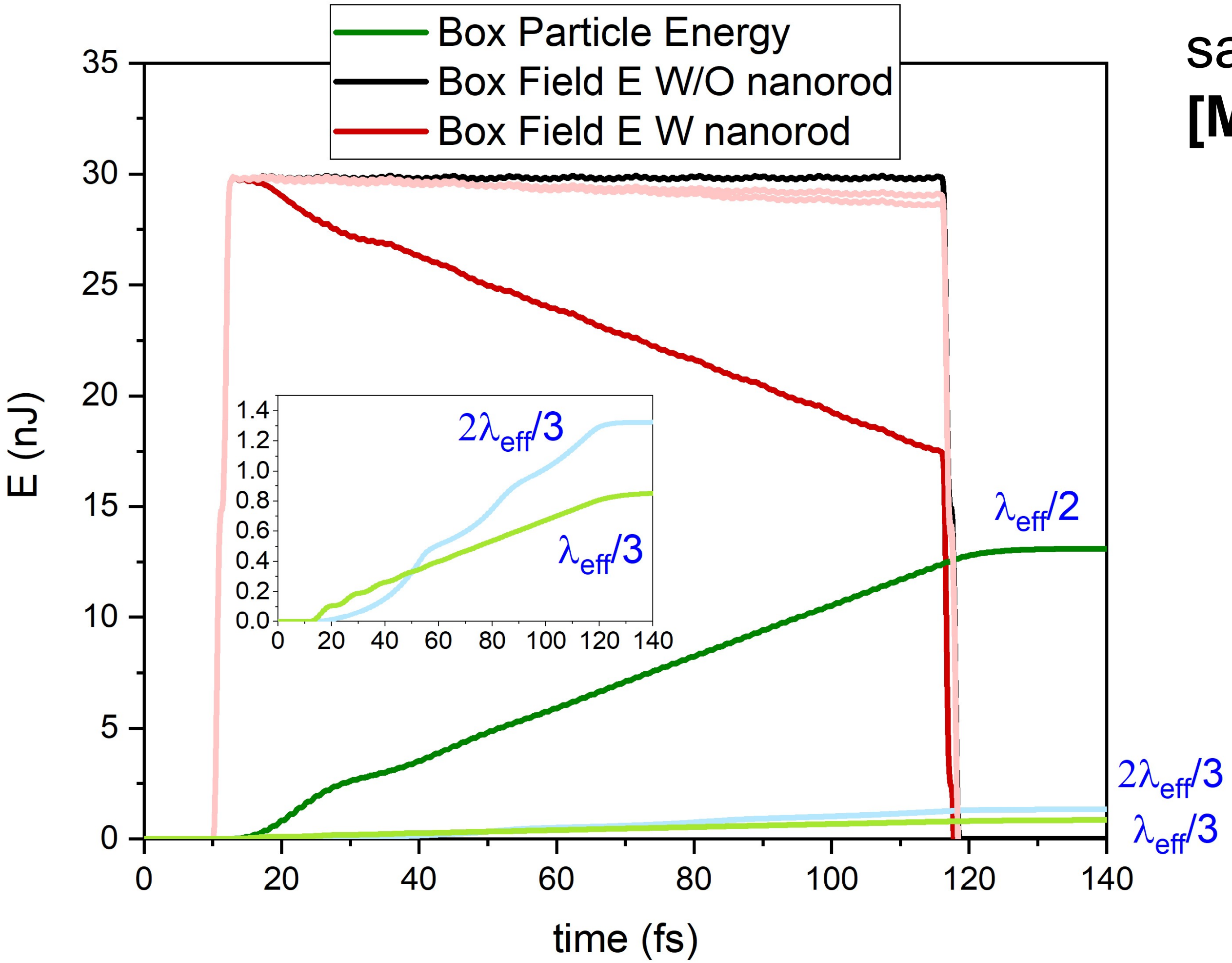
FIG. 2. Top: evolution of the E field's y component from 42.44 till 45.75 fs in a quarter of a period ($T/4 = 0.6625$ fs) steps, aroun



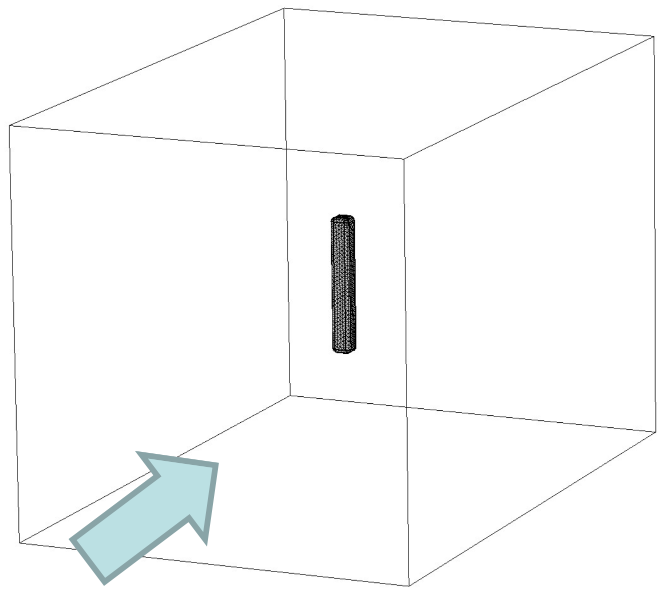
Regarding the intensity, we estimate an enhancement of

$$I_x = 0.3\, I_p\, \frac{S_{\mathrm{CB}}}{S_{\mathrm{NR}}} = 25.9\, I_p. \tag{3}$$

Resilience of Nanorod Antenna with COMSOL



FEM computations with the same model parameters **[M.Csete et al.]**



Good qualitative agreement between FEM and EPOCH/PIC methods
Quantitative difference:
the hydrodynamic model of the electron plasma (FEM) predicts a sharper resonance than the kinetic model (EPOCH/PIC)

frontiers | Frontiers in Physics

TYPE Brief Research Report
PUBLISHED 07 February 2023
DOI 10.3389/fphy.2023.1116023

Kinetic model of resonant nanoantennas in polymer for laser induced fusion

(2023)

István Papp[1,2]*, Larissa Bravina[3], Mária Csete[1,4], Archana Kumari[1,2], Igor N. Mishustin[5], Anton Motornenko[5], Péter Rácz[1,2], Leonid M. Satarov[5], Horst Stöcker[5,6,7], Daniel D. Strottman[8], András Szenes[1,4], Dávid Vass[1,4], Ágnes Nagyné Szokol[1,2], Judit Kámán[1,2], Attila Bonyár[9], Tamás S. Biró[1,2], László P. Csernai[1,2,5,10,11] and Norbert Kroó[1,2,12] on behalf of (part of NAPLIFE Collaboration)

[1]Wigner Research Centre for Physics, Budapest, Hungary, [2]Hungarian Bureau for Research Development and Innovation, Budapest, Norway, [3]Department of Physics, University of Oslo, Oslo, Norway, [4]Department of Optics and Quantum Electronics, University of Szeged, Szeged, Hungary, [5]Frankfurt Institute for Advanced Studies, Frankfurt/Main, Germany, [6]Institute für Theoretische Physik, Goethe Universität, Frankfurt/Main, Germany, [7]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany, [8]Los Alamos National Laboratory, Los Alamos, NM, United States, [9]Department of Electronics Technology, Faculty of Electrical Engineering and Informatics, Budapest University of Technology and Economics, Budapest, Hungary, [10]Department of Physics and Technology, University of Bergen, Bergen, Norway, [11]Csernai Consult Bergen, Bergen, Norway, [12]Hungarian Academy of Sciences, Budapest, Hungary

EDITED BY
Aldo Bonasera,
Texas A&M University, United States

REVIEWED BY
Guoqiang Zhang,
Shanghai Advanced Research Institute (CAS), China
Johann Rafelski,
University of Arizona, United States

*CORRESPONDENCE
István Papp,
papp.istvan@wigner.hu

SPECIALTY SECTION
This article was submitted to Nuclear Physics, a section of the journal Frontiers in Physics

RECEIVED 05 December 2022
ACCEPTED 26 January 2023
PUBLISHED 07 February 2023

CITATION
Papp I, Bravina L, Csete M, Kumari A, Mishustin IN, Motornenko A, Rácz P, Satarov LM, Stöcker H, Strottman DD, Szenes A, Vass D, Szokol ÁN, Kámán J, Bonyár A, Biró TS, Csernai LP and Kroó N (2023), Kinetic model of resonant nanoantennas in polymer for laser induced fusion.
Front. Phys. 11:1116023.
doi: 10.3389/fphy.2023.1116023

Studies of resilience of light-resonant nanoantennas in vacuum are extended to consider the case of polymer embedding. This modifies the nanoantenna's lifetime and resonant laser pulse energy absorption. The effective resonance wavelength is shortened, the peak momentum of resonantly oscillating electrons

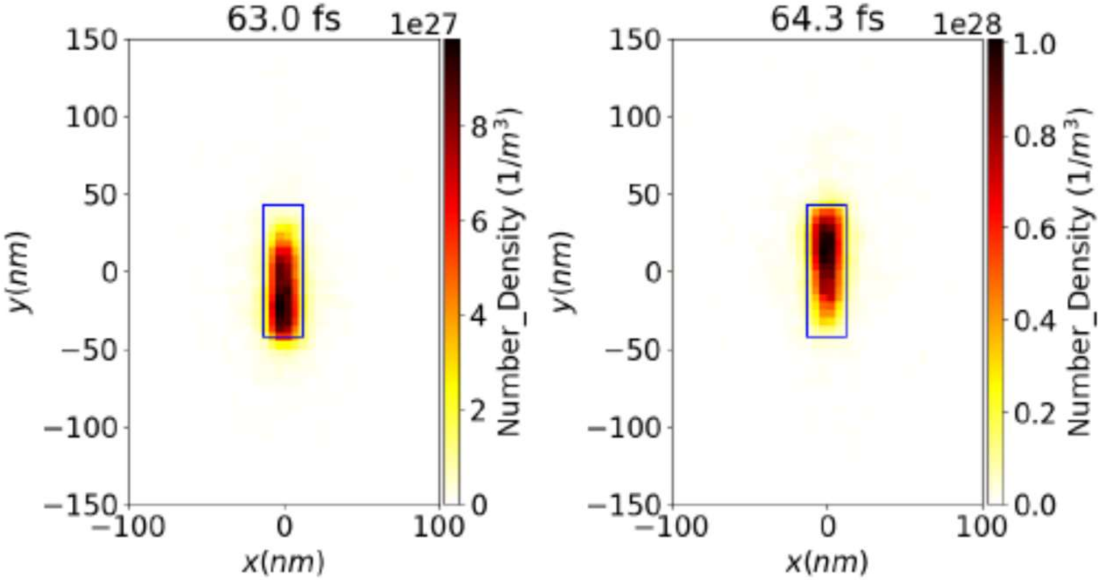
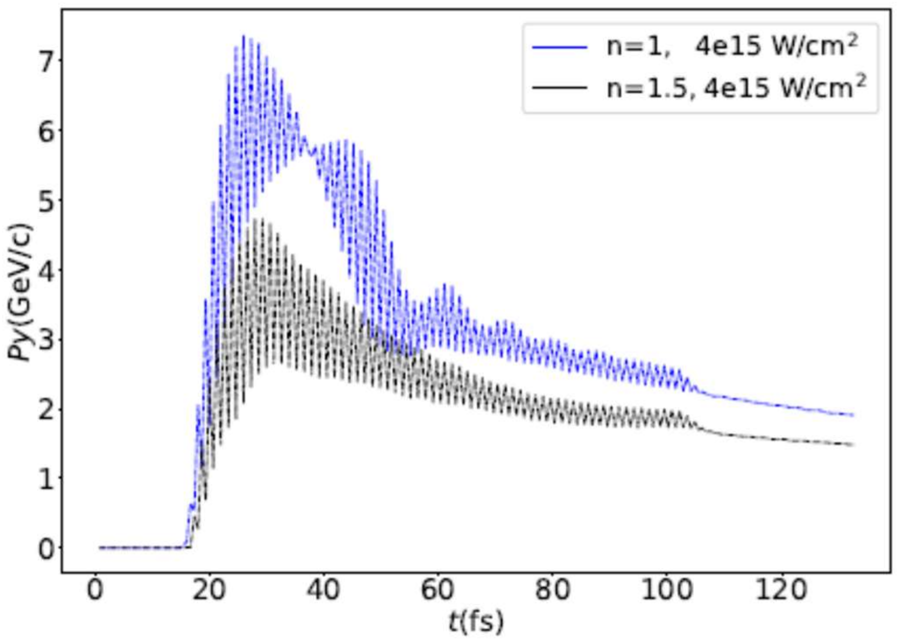


Figure 1: (color online) Cross section of the 25 nm (diameter) x 85 nm nanorod

25x85 nm antennas, resonant for λ=795 nm in UDMA polymer

[L. Novotny (2007)]

$$\frac{\lambda_{eff}}{2R\pi} = 13.74 - 0.12[\varepsilon_\infty + \varepsilon_s 141.04]/\varepsilon_s - \frac{2}{\pi} + \frac{\lambda}{\lambda_p} 0.12\sqrt{\varepsilon_\infty + \varepsilon_s 141.04}/\varepsilon_s$$



Accumulated momentum of conduction electrons in vacuum (blue) and in UDMA (black)

Physics > Plasma Physics

[Submitted on 25 Nov 2022]

Crater Formation and Deuterium Production in Laser Irradiation of Polymers with Implanted Nano-antennas

L. P. Csernai, I. N. Mishustin, L. M. Satarov, H. Stoecker, L. Bravina, M. Csete, J. Kaman, A. Kumari, A. Motornenko, I. Papp, P. Racz, D. D. Strottman, A. Scenes, A. Szokol, D. Vass, M. Veres, T. S. Biro, N. Kroo (NAPLIFE Collaboration)

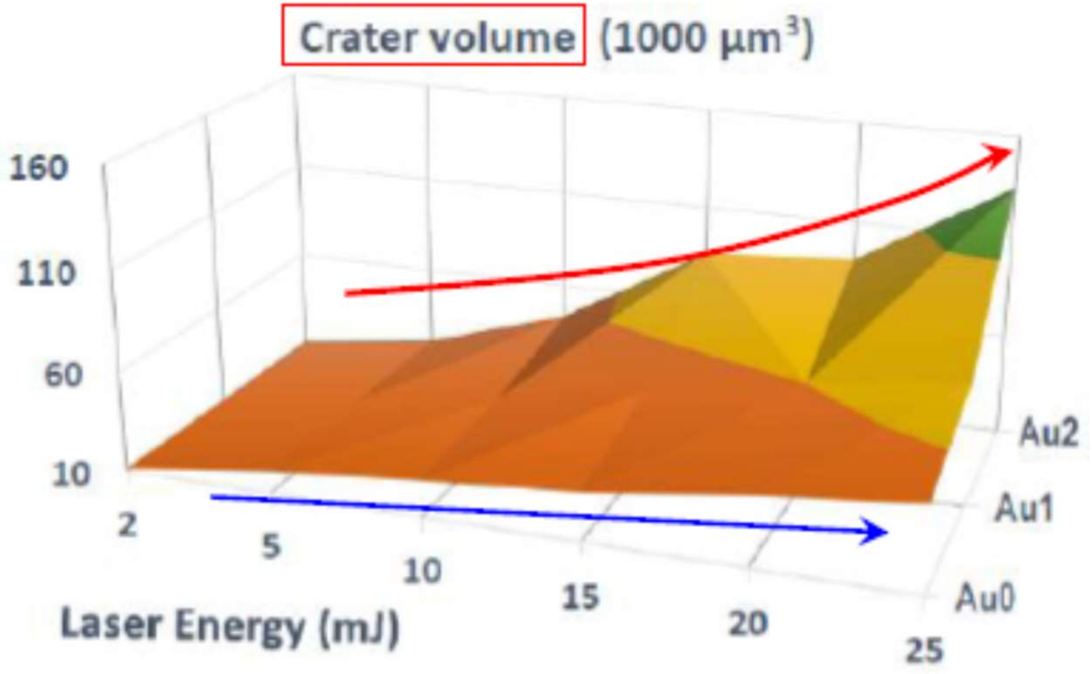
(2022)

Crater Formation and Deuterium Production in Laser Irradiation of Polymers with Implanted Nano-antennas

László P. Csernai[1,2,3], Igor N. Mishustin[3], Leonid M. Satarov[3], Horst Stöcker[3,7,8], Larissa Bravina[4], Mária Csete[5,6], Judit Kámán[1,5], Archana Kumari[1,5], Anton Motornenko[3], István Papp[1,5], Péter Rácz[1,5], Daniel D. Strottman[9], András Szenes[5,6], Ágnes Szokol[1,5], Dávid Vass[5,6], Miklós Veres[1,5], Tamás S. Biró[1,5], Norbert Kroó[1,5,10]
(NAPLIFE Collaboration)

[1] *Wigner Research Centre for Physics, Budapest, Hungary*
[2] *Deptartment of Physics and Technology, University of Bergen, Norway*
[3] *Frankfurt Institute for Advanced Studies, Frankfurt am Main, Germany*
[4] *Department of Physics, University of Oslo, Norway*
[5] *National Research, Development and Innovation Office of Hungary,*
[6] *Deptartment of Optics and Quantum Electronics, Univ. of Szeged, Hungary*
[7] *Institute für Theoretische Physik, Goethe Universität, Frankfurt am Main, Germany*
[8] *GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany*
[9] *Los Alamos National Laboratory, Los Alamos, 87545 NM, USA*
[10] *Hungarian Academy of Sciences, 1051 Budapest, Hungary*

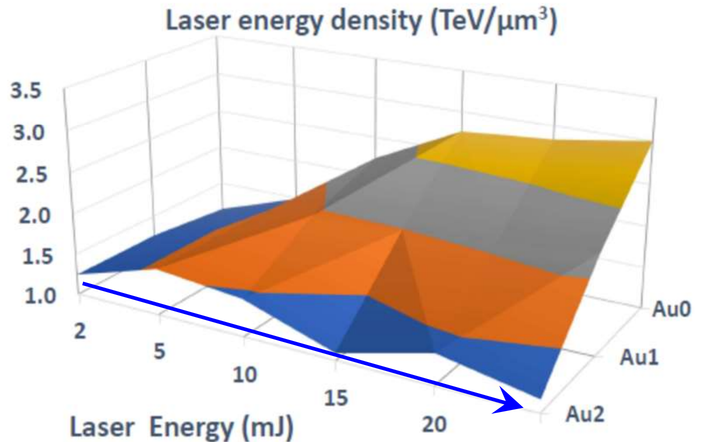
Theoretical analyzis of Crater & Deuterium production



Crater Formation and Deuterium Production in Laser Irradiation of Polymers with Implanted Nano-antennas

László P. Csernai[1,2,3], Igor N. Mishustin[3], Leonid M. Satarov[3], Horst Stöcker[3,7,8], Larissa Bravina[4], Mária Csete[5,6], Judit Kámán[1,5], Archana Kumari[1,5], Anton Motornenko[3], István Papp[1,5], Péter Rácz[1,5], Daniel D. Strottman[9], András Szenes[5,6], Ágnes Szokol[1,5], Dávid Vass[5,6], Miklós Veres[1,5], Tamás S. Biró[1,5], Norbert Kroó[1,5,10]

arXiv: 2211.14031 [physics-

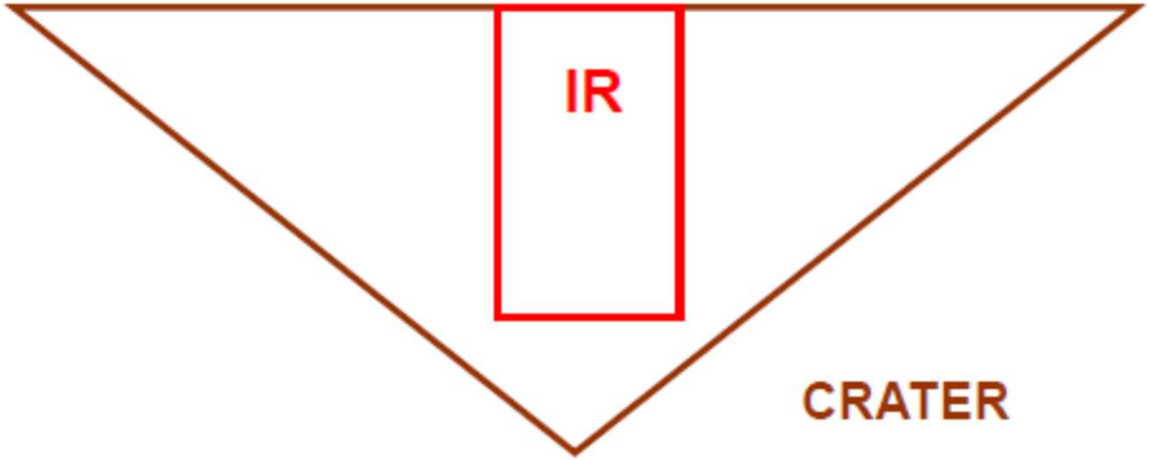


Puzzle ?

With nanorods V grows non-linearly. Increasing energy deposition. Several types of targets are considered: Au1 and Au2 with implanted nano-rod antennas, and Au0 without implantation. The mass concentrations of implanted particles in UDMA are 0.126% and 0.182% for targets Au1 and Au2, respectively.

With nanorods, Au2, deposited energy into the crater increases non-linearly (!?)

Origin of this extra energy (?)



In the case of the reaction (5), substituting $E_p = 20$ MeV, $E_d = 5.92$ MeV (this value follows from Eq. (9)), and using Eqs. (34), (35), one gets the estimate

$$\frac{\mathrm{D}}{\mathrm{H}} \sim 118 \times \frac{d}{p} \simeq 1.2 \cdot 10^{-3}. \qquad (37)$$

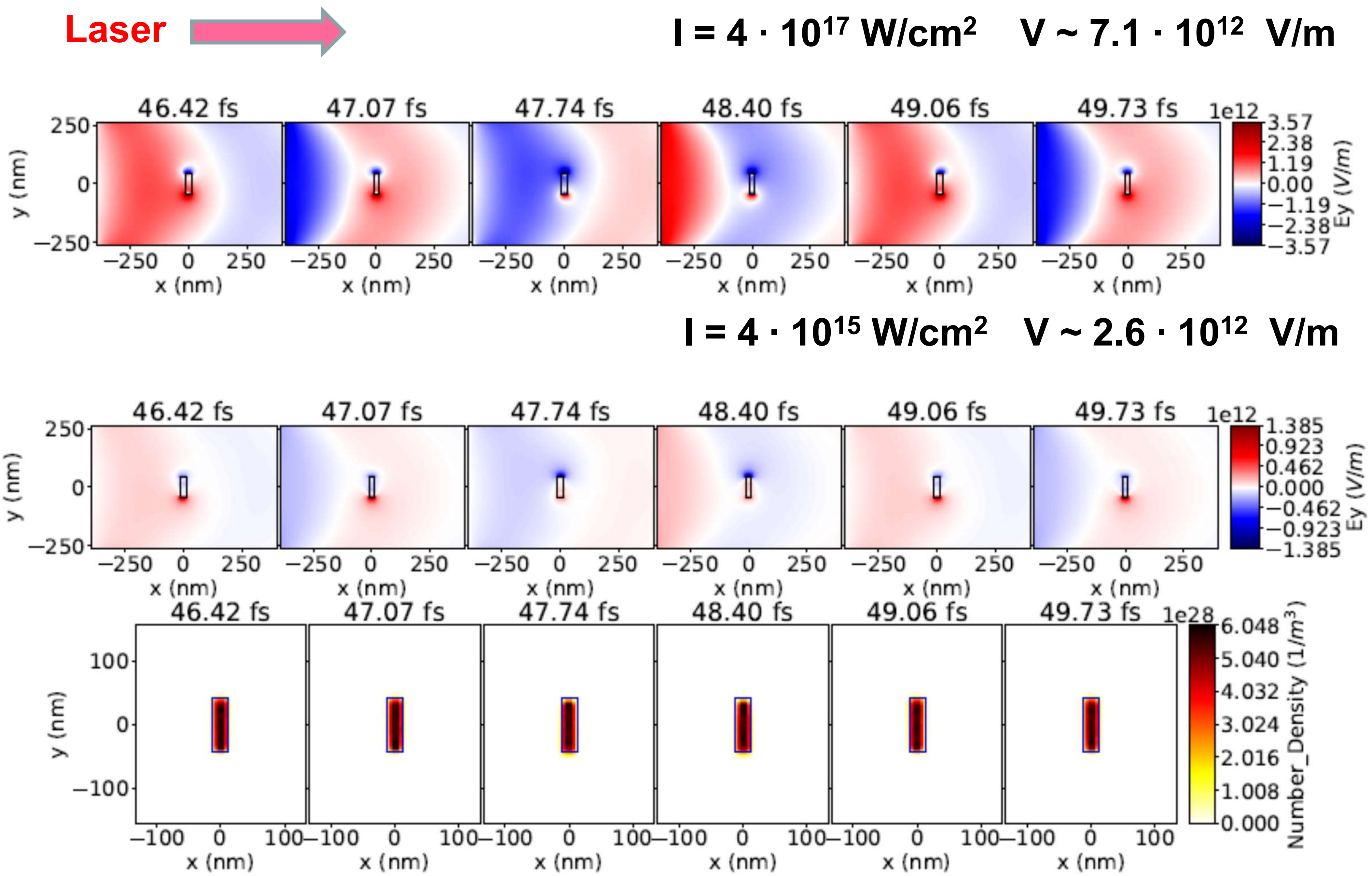
This value is still below experimental ratios for the Au2

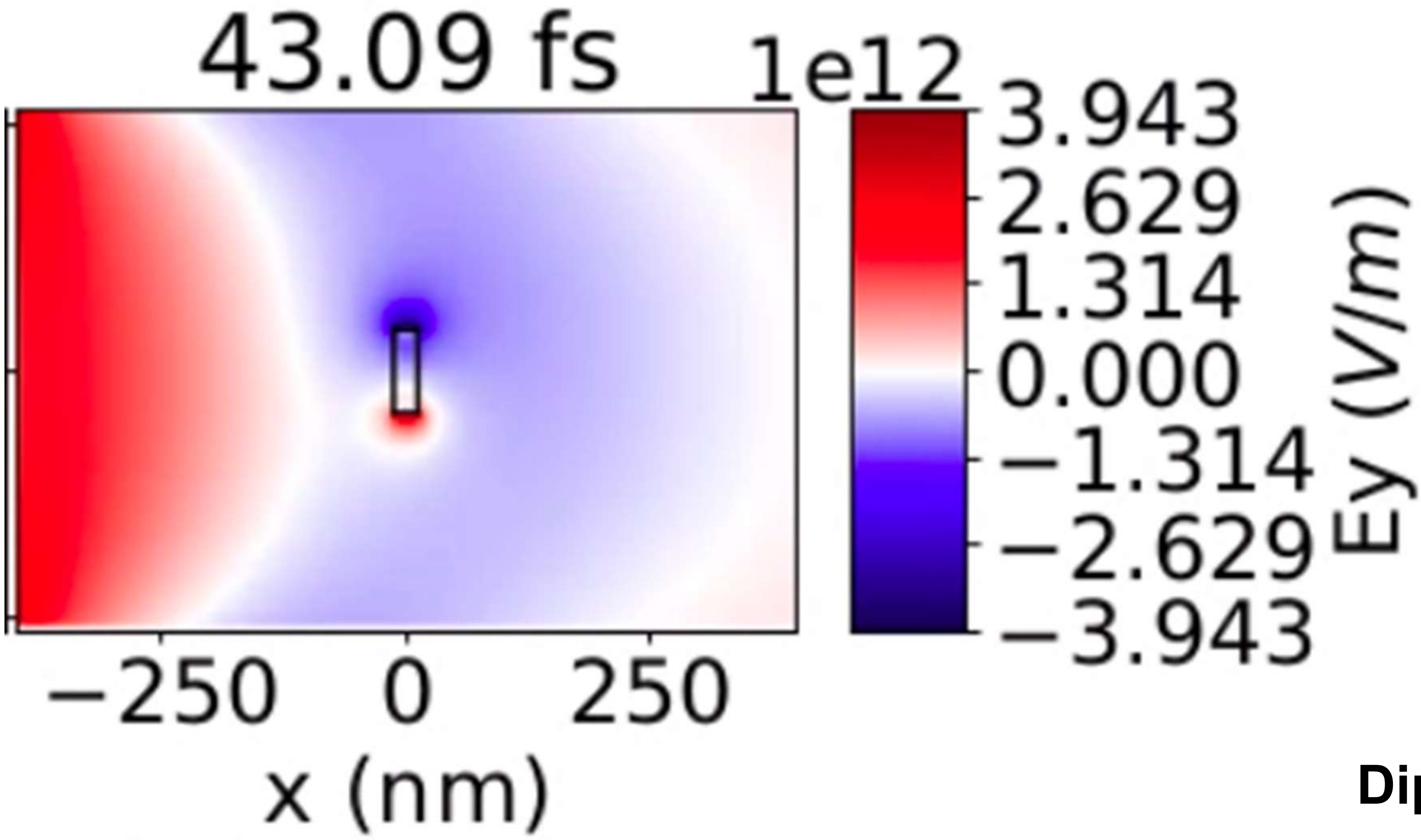
Theoretical studies in progress =>

Idea #3

We pursue kinetic model (EPOCH) studies in the same Calculational Box, where the nano-rod antenna is surrounded be hydrogen target.

W assume that the hydrogen is relatively dense and ionized, in order to study what effect will have the nano-rod antennas on the surrounding protons.

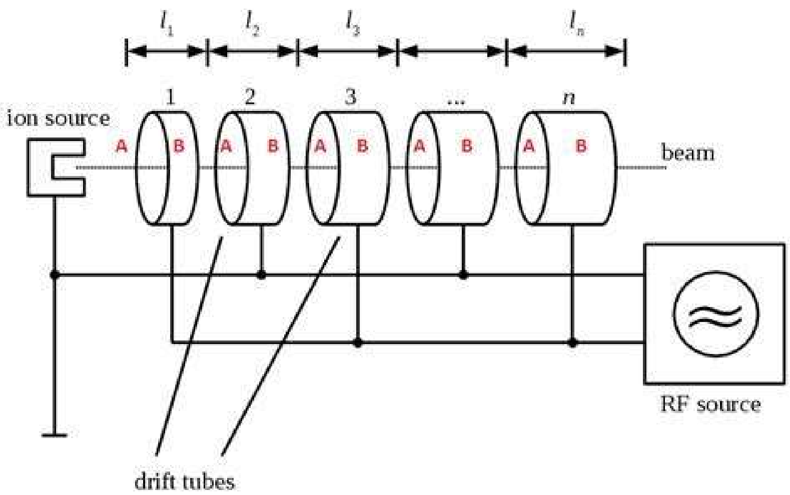

Laser
I = 4 · 10^17 W/cm^2   V ~ 7.1 · 10^12 V/m
46.42 fs
47.07 fs
47.74 fs
48.40 fs
49.06 fs
49.73 fs
y (nm)
x (nm)
1e12
Ey (V/m)
3.57
2.38
1.19
0.00
−1.19
−2.38
−3.57
I = 4 · 10^15 W/cm^2   V ~ 2.6 · 10^12 V/m
1.385
0.923
0.462
0.000
−0.462
−0.923
−1.385
1e28
Number_Density (1/m^3)
6.048
5.040
4.032
3.024
2.016
1.008
0.000



Neighboring protons are accelerated (100-200 nm)

Dipole L = 85 nm

I = 4 · 10^{17} W/cm^2 **dV ~ 8 · 10^{12} V/m**

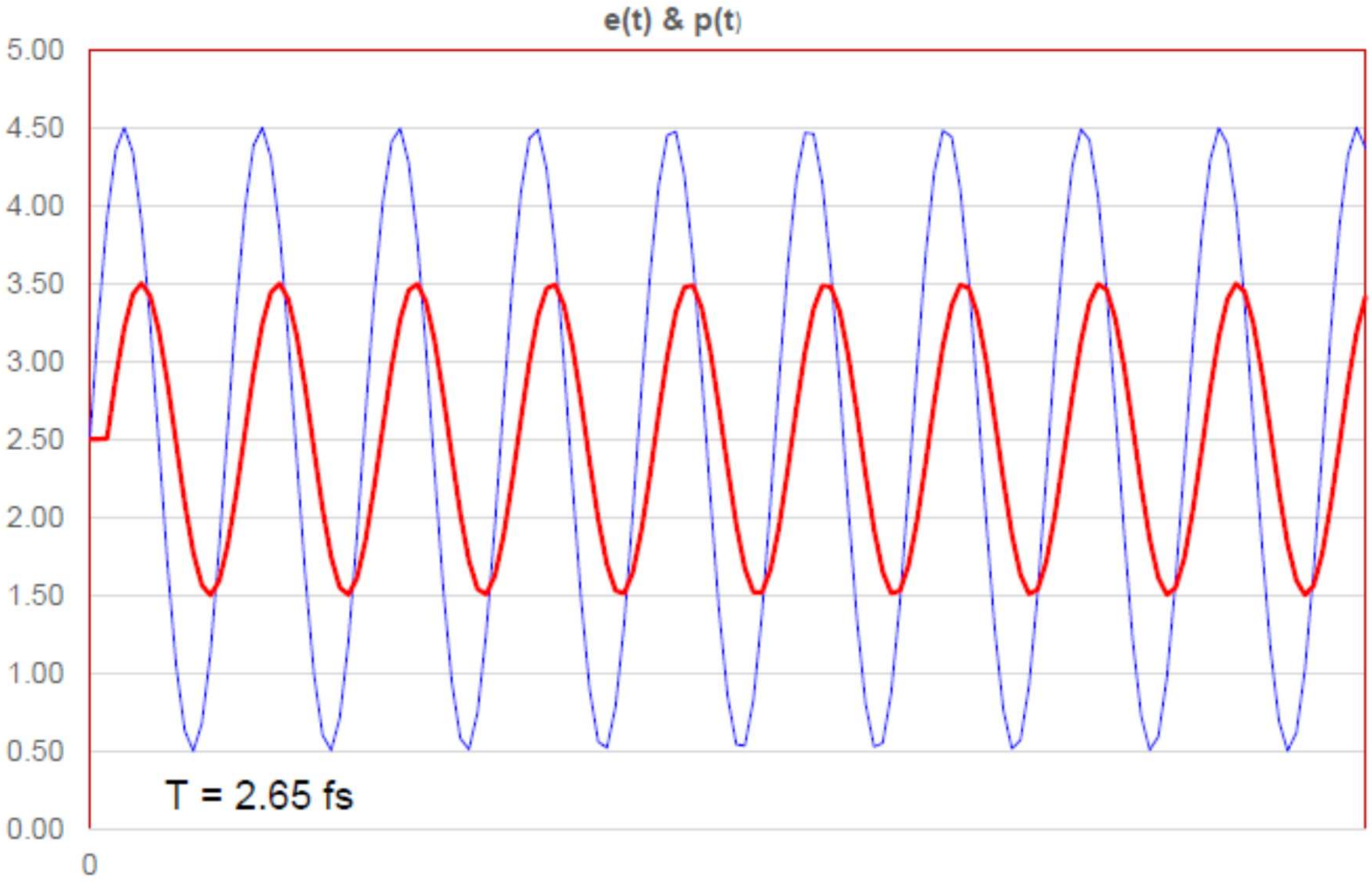


LHC **dV ~ 1 · 10^{6} V/m**

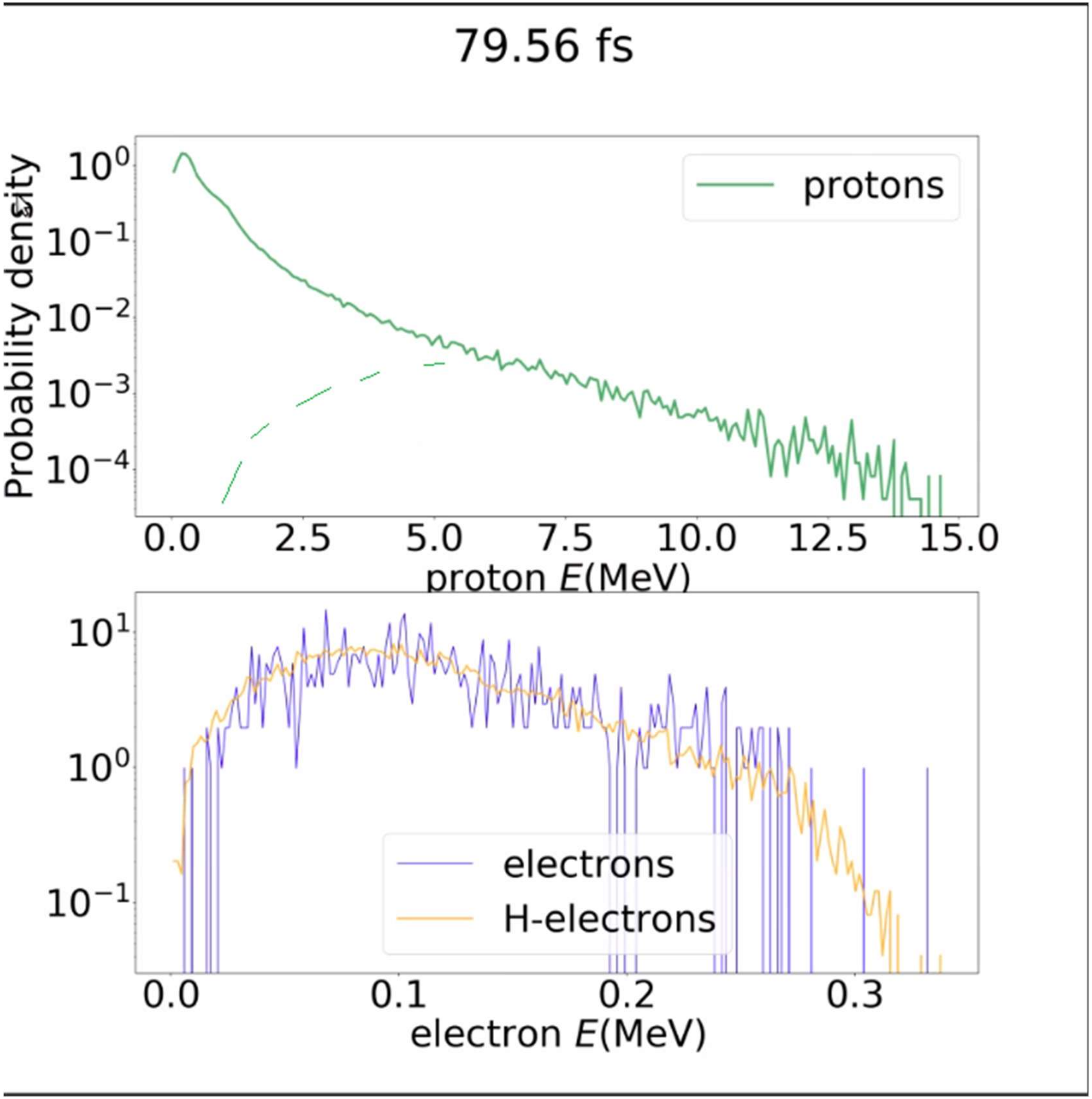
Dipole L ~ 16 cm

Csernai, L.P. [NAPLIFE]

Laser wake field acceleration mechanism =>



BUT
Proton
amplitudes
& speeds
are
smaller



Number of 1-2 MeV protons is about 1-100
=>
About 3 ordrs of magnitude less than electrons
=>
small number of Deuterium

➔ IDEA # 3: New fusion mechanism

Traditionally (NIF) after ignition, DT burning is spreading by *alpha particle self heating*. This turns out to be slower than expansion after extreme compression and extreme pressure.

HINT:

Here after simultaneous (time-like) ignition attraction of large number of electrons ***collectively accelerate protons,*** which can induce nuclear reaction (e.g. transmutation).

We try to verify this mechanism and evaluate if the rate that can be achieved this way is sufficient for massive energy production

Thanks for your attention