Nanofusion:

Laser, plasmons, proton energy, p+11B

Biró Tamás Sándor [1 2 3]

[1]NKFIH NAPLIFE program

Research Centre for Physics, Budapest

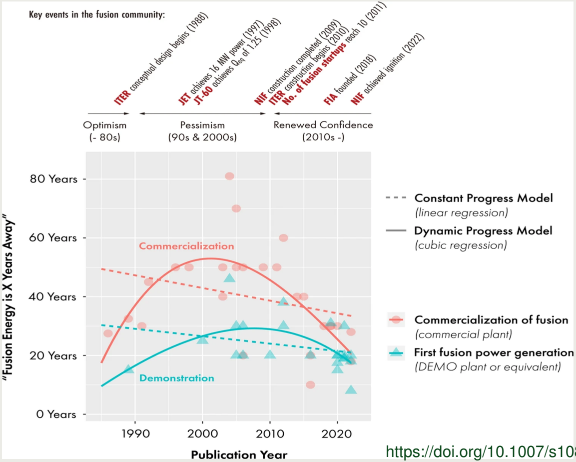
[2]Complexity Science Hub, Vienna

May 7, 2025

Austrian Croatian Hungarian Triangle, ACHT, Budapest 2025.05.05-07

Fusion, when?

expert replies do change



https://doi.org/10.1007/s10894-023-00361-z

FIA = Fusion Industry Assciation

https://www.fusionindustryassociation.org/

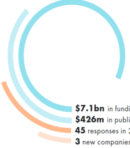
FIA 2024 survey

HIGHLIGHTS TO DATE

1. Total funding*

Total this year	>$900,000,000 (900m)
Total to date	~$7,122,435,000 (7.1bn)
Total Public	~$426,000,000 (426m)

2. Change since 2023 survey



$7.1bn in funding, compared to **$6.2bn** at time of 2023 survey
$426m in public funding, compared to **$271m** in 2023
45 responses in 2024 vs **43** in 2023
3 new companies emerged and added to our survey, while one withdrew from the commercial industry.

* Some figures have been converted to dollars/rounded

3. Notable investments since 2023 survey*

- $100m Xcimer
- $90m SHINE
- $65m Helion
- $41m Startorus Fusion
- $25m Type One
- $21.7m Proxima Fusion

* Several other large investments have not yet been publicly announced so are not included here

4. Companies with $200m investment or more

- Commonwealth Fusion Systems ($2bn+)
- TAE Technologies ($1bn+)
- ENN
- General Fusion
- Helion Energy
- Tokamak Energy
- SHINE Technologies
- Zap Energy

5. Location

By primary HQ

Specific data, availability

1 J/mg = 1 kJ/g = 1 MJ/kg = 1 GJ/t

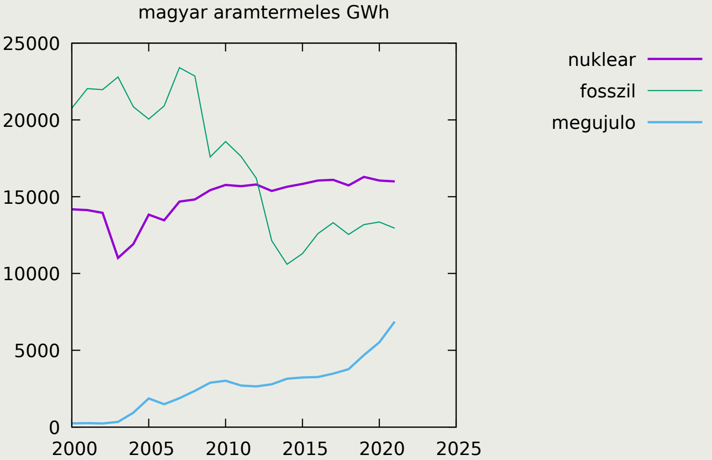
https://afdc.energy.gov/fuels/properties; https://en.wikipedia.org/wiki/energy_density

- coal 23; lignit 18; thorf 7; wood 11; biomass 10; waste 9; oil pala 20
- petroleum, propan-butan gas 40; bio-fuel 30; waste 25
- earth gas 47; Hydrogen 40; biogas 20; rest gas 15
- uranium 460.000; fusion 640.000.000

20 t of coal ≈ 1 kg of uranium ≈ 0,7 g fusion fuel

Current Hungarian electricity mix

fossil 36 %, nuklear 42 %, ”renewable” 22 %



ITER update 2024

HUN REN Wigner

Science article

SCIENCEINSIDER | TECHNOLOGY

Giant international fusion project is in big trouble

ITER operations delayed to 2034, with energy-producing reactions expected 5 years later

3 JUL 2024 • 4:30 AM ET • BY DANIEL CLERY

NIF

out/in factor Q = 1.5 ?

Share Tweet in CONGRATULATIONS! | ITER APPLAUDS NIF FUSION BREAKTHROUGH

NEWS & MEDIA

- ALL NEWS
- PHOTOS
- NEWS IN FRENCH
- 3D VIRTUAL TOUR
- ITER NEWSLINE
- VIDEOS
- EVENTS
- PRESS RELEASES
- PUBLICATION CENTRE
- ITER MAG ARCHIVES

ITER NEWSLINE -

12 DEC, 2022 Print Read the latest published articles

Congratulations!

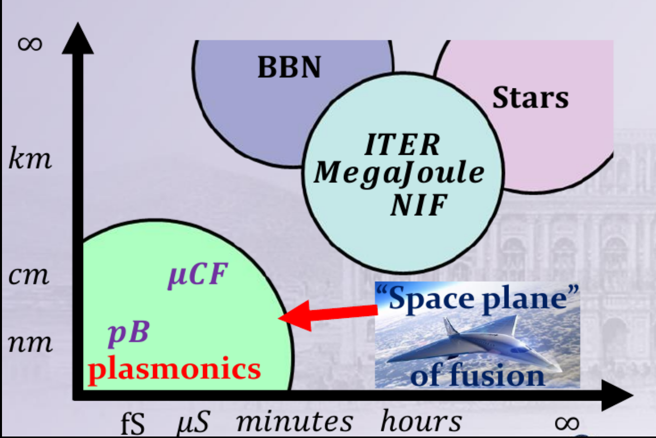
ITER APPLAUDS NIF FUSION BREAKTHROUGH

ITER scientists hailed the latest experimental results at the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory in California: the achievement of "breakeven" fusion energy. "When future generations look back on the evolution of fusion energy research, I believe this will be recognized as a historic milestone," said ITER Director-General Pietro Barabaschi. NIF's experiment used 2.05 megajoules of laser energy to produce 3.15 megajoules of fusion energy, reaching a Q value of 1.5.

Nuclear fusion

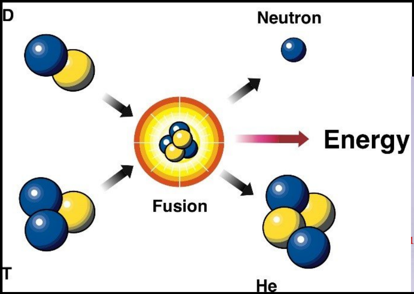
in nature and in experiments

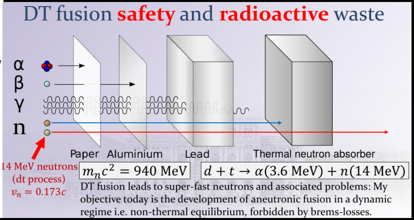
(Rafelski MTA talk 2022.)



D + T fusion

problems (Rafelski)





Neutronfree fusion

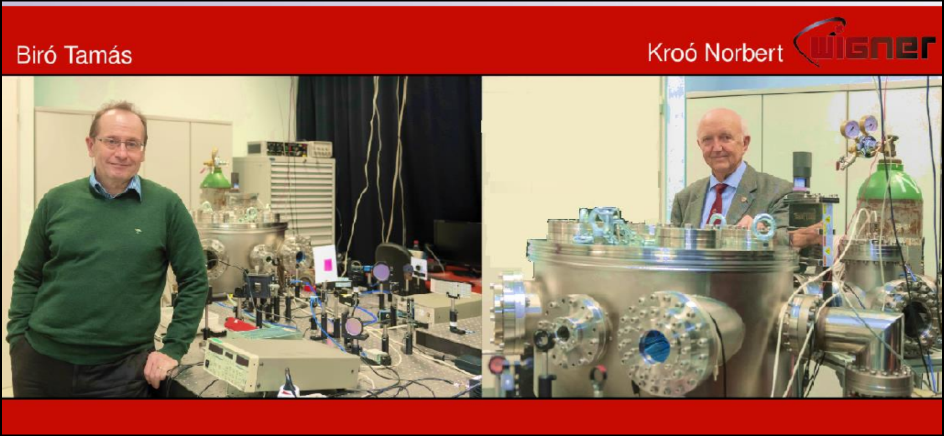
examples (wiki)

High nuclear cross section aneutronic reactions[1]

Isotopes	Reaction
Deuterium - ^{3}He	^{2}D + ^{3}He → ^{4}He + ^{1}p + 18.3 MeV
Deuterium - ^{6}lithium	^{2}D + ^{6}Li → 2 ^{4}He + 22.4 MeV
Proton - ^{6}lithium	^{1}p + ^{6}Li → ^{4}He + ^{3}He + 4.0 MeV
^{3}He – ^{6}lithium	^{3}He + ^{6}Li → 2 ^{4}He + ^{1}p + 16.9 MeV
^{3}He - ^{3}He	^{3}He + ^{3}He → ^{4}He + 2 ^{1}p + 12.86 MeV
Proton – Lithium-7	^{1}p + ^{7}Li → 2 ^{4}He + 17.2 MeV
Proton – Boron-11	^{1}p + ^{11}B → 3 ^{4}He + 8.7 MeV
Proton – Nitrogen	^{1}p + ^{15}N → ^{12}C + ^{4}He + 5.0 MeV

NAPLIFE lab Wigner FK

vacuum + laser + targets + detectors

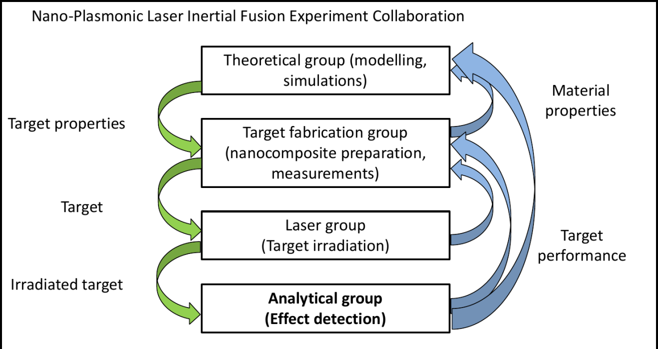


NAPLIFE user ELI-ALPS

vacuum + laser + targets + detectors

NAPLIFE work sharing

connected activities (cf. Kámán Judit)



NAPLIFE 1

HUN REN Wigner

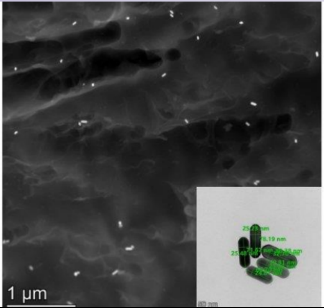
Au nanoparticles, microscope picture, absorption

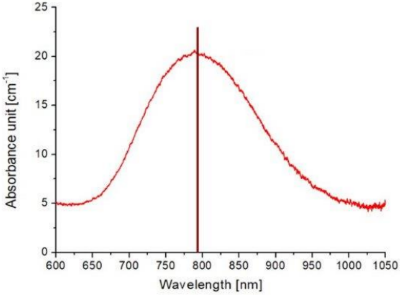
The NAPlife plasmonic fusion project

UDMA polymer with resonant gold nano-rods

Gold nano-rods embedded in polymer matrix: Transmission electron microscope image; insert shows actual nano-rods

Actual absorption curve for nano composites measured by optical spectroscopy. The absorption peak is tuned to resonate with laser wavelength at 795 nm



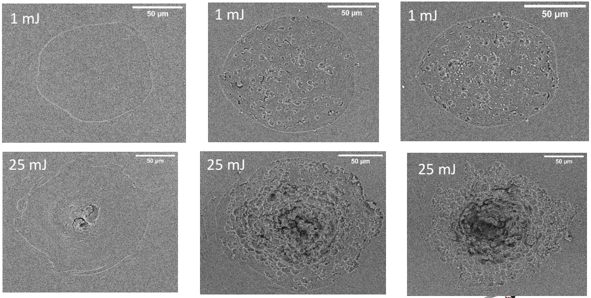


NAPLIFE 2

craters by Scanning Electron Microscope

7. Surface structure of the laser ablated area, investigated by SEM

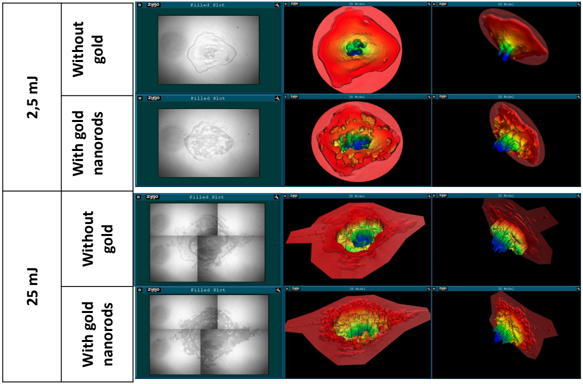
UDMA_X | **UDMA_AU1** | **UDMA_AU2**



NAPLIFE 2

shot craters

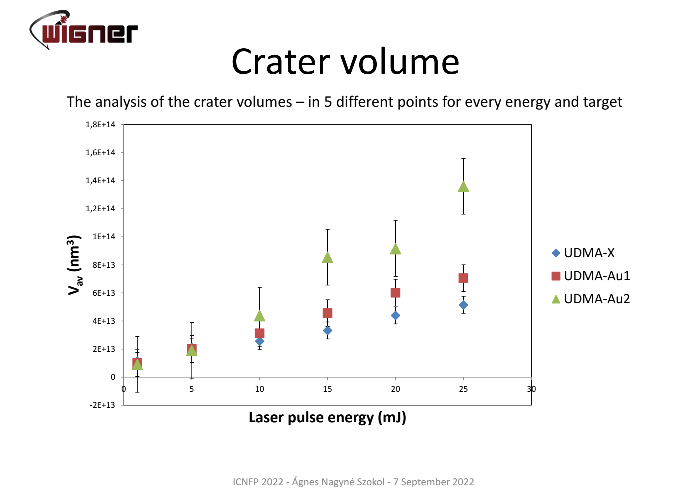
Preliminary measurements



ICNFP 2022 - Ágnes Nagyné Szokol - 7 September 2022

NAPLIFE 2

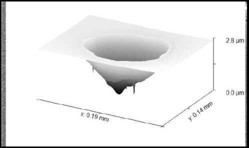
crater volumes vs energy

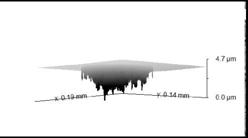


NAPLIFE 2

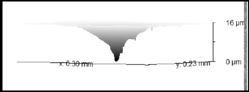
micro craters in craters

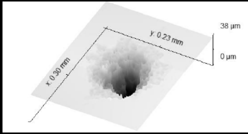
1 mJ AuX Au2





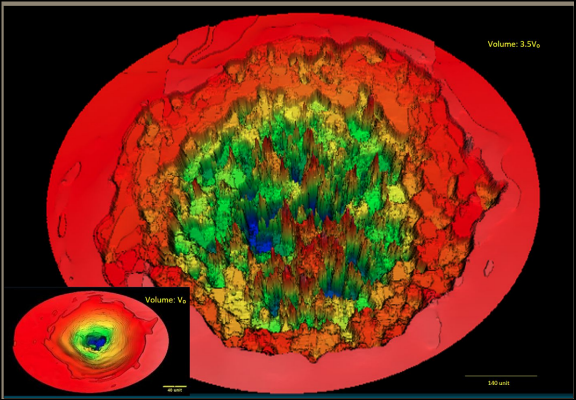
25 mJ AuX Au2





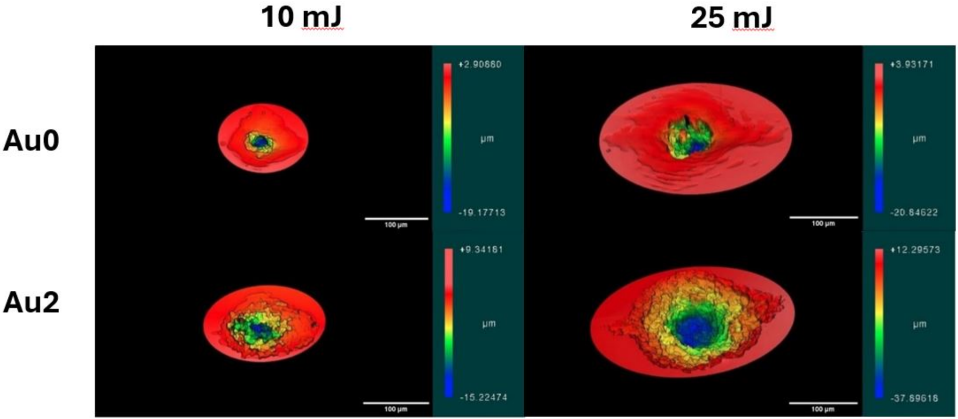
The real size of craters

an example $(140/40 = 3.5)$



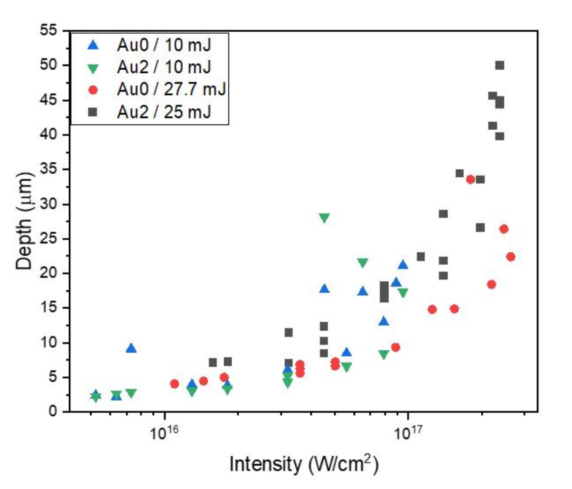
Real Size Comparison

newest microscope data (Szokol 2025 April)



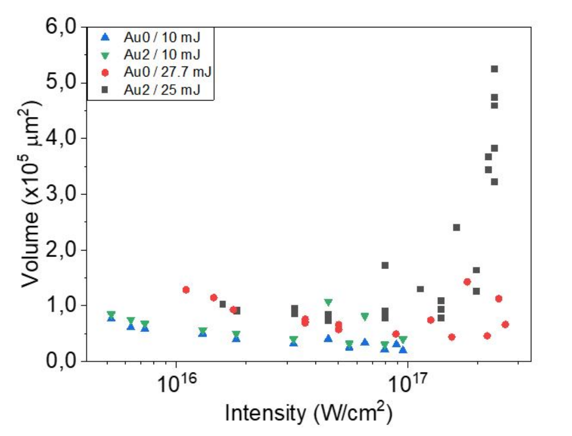
Crater depth

vs intensity (Szokol 2025 April)



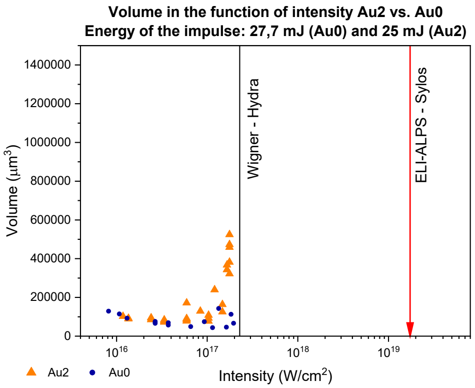
Crater volume

vs intensity (Szokol 2025 April)



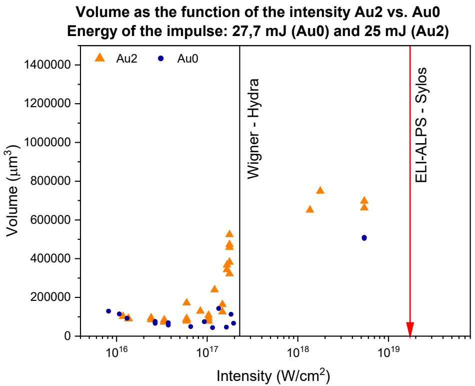
Crater volumes

as a function of laser intensity 2024 May



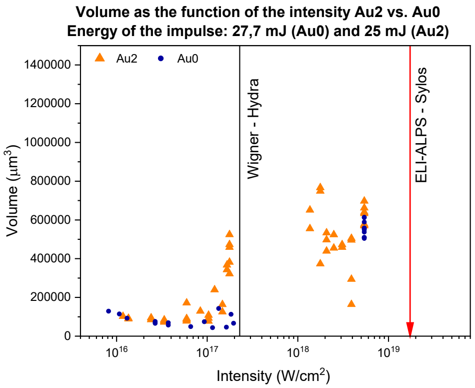
Crater volumes

as a function of laser intensity 2024 May



Crater volumes

as a function of laser intensity 2024 May



NAPLIFE 3

LIBS: plasma plume

Automatic Zoom

DIAGNOSIS No3: LIBS analysis of the laser plume plasma

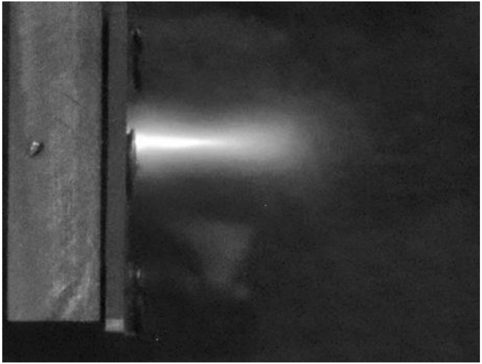
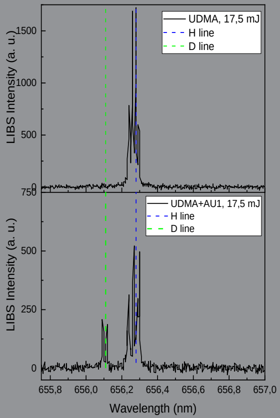


PHOTO OF A LASER SHOT INDUCED PLASMA PLUME

NAPLIFE 3

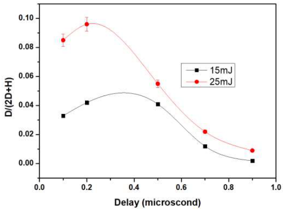
LIBS: atomic ionisation → D/H

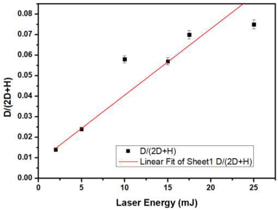


NAPLIFE 3

LIBS: spectral areas → D/(2D+H)

Calculation of ratio; D/(2D+H)





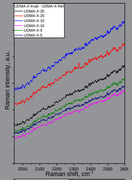
At 17.5 mJ, D(A)=1.828, H(A)=8.32
D(A)/H(A)=0.21
D(A)/[2*D(A)+H(A)]=0.15
No. of H atoms=2.51*10^16
No. of atoms that were converted from H to D=3.765*10^15

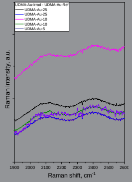
Please refer to Agnes Nagyne Sokol's talk on Crater Data Analysis!

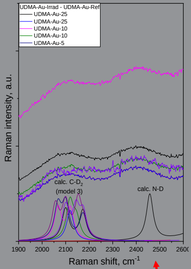
15

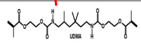
NAPLIFE 4

Raman: CD vs CH bond vibrations, crater walls







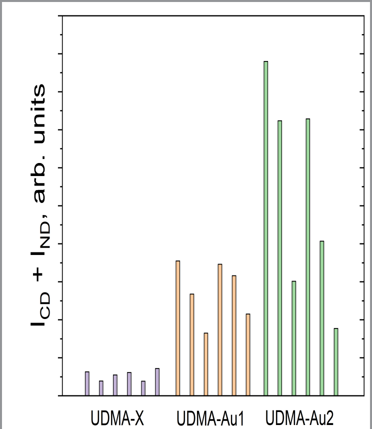


$I_{laser} > 10^{16}$

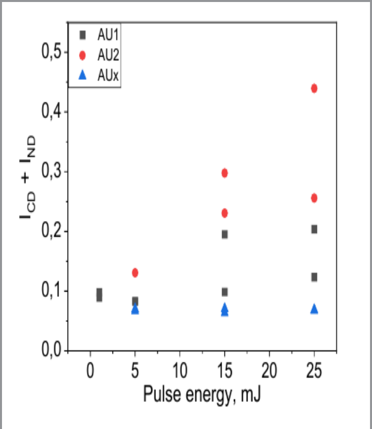
NAPLIFE 4

Raman: molecular voibrations from varying crater spots

30 mJ, 6 points, X Au1 Au2.

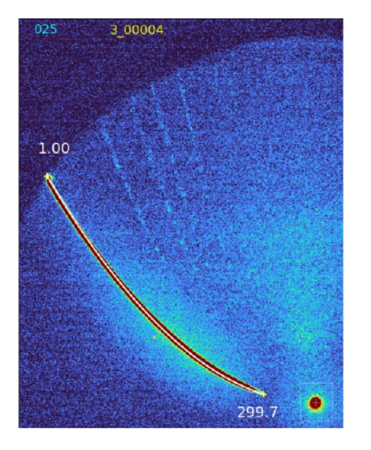


More energy, 2-2 points.



Proton energy measurement

..the highest energy in Thomson parabola so far 300 keV



NAPLIFE plans

contracted until February 2026

- Nuclear detection (CR39, Thomson parabola, alpha detector)
- More ELI-ALPS usering (shorter pulse, better contrast)
- Variation of nanoparticles, medium and shooting geometry
- Nanofusion Game (strategic card game under development)
- Infroton Fusion, U. Arizona, SRNL (new connections)

NAPLIFE summary

. . . and message

1. **Nanofusion = nanotechnology + fs laser + nuclear fusion**
2. **Research: nanotech+spectro, development of energy and fusion product detection**
3. **Aims: more plasmonic enhancement, better fusion fuel, stronger lasers, n-free processes (p+11B).**
4. **Business model: bounteous and cheep electricity.**
5. **Wigner partners: ELI, EK, BME, SZTE, DE, MCG Digital, Infroton Fusion, ATOMKI, OCL, Optilab, Spirocco**