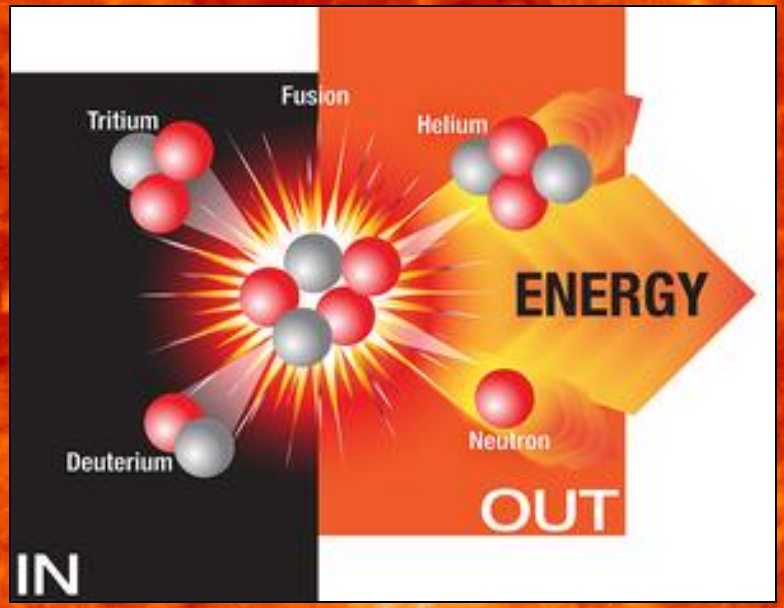
When light is stronger than matter

Marta Fajardo
Instituto de Plasmas e Fusão Nuclear

Today’s lasers can drive
matter into extreme conditions



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XPLAINER | 13 December 2022

clear-fusion lab achieves
nition': what does it mean?

Vox

We have a genuine fusion energy breakthrough

PHYSICS TODAY

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DOI:10.1063/PT.6.2.20221213a

13 Dec 2022 in Politics & Policy

National Ignition Facility surpasses long-awaited fusion milestone

politics The Biden Presidency Facts First 2022 Midterms

cientists reach long-awaited nuclear fusion
kthrough, source says

IGNITION

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Lawrence Livermore National Laboratory

S - NEWSMAKERS >

ide the nuclear fusion breakthrough
t could be a step to unlimited clean
rgy in the distant future

BY SCOTT PELLEY

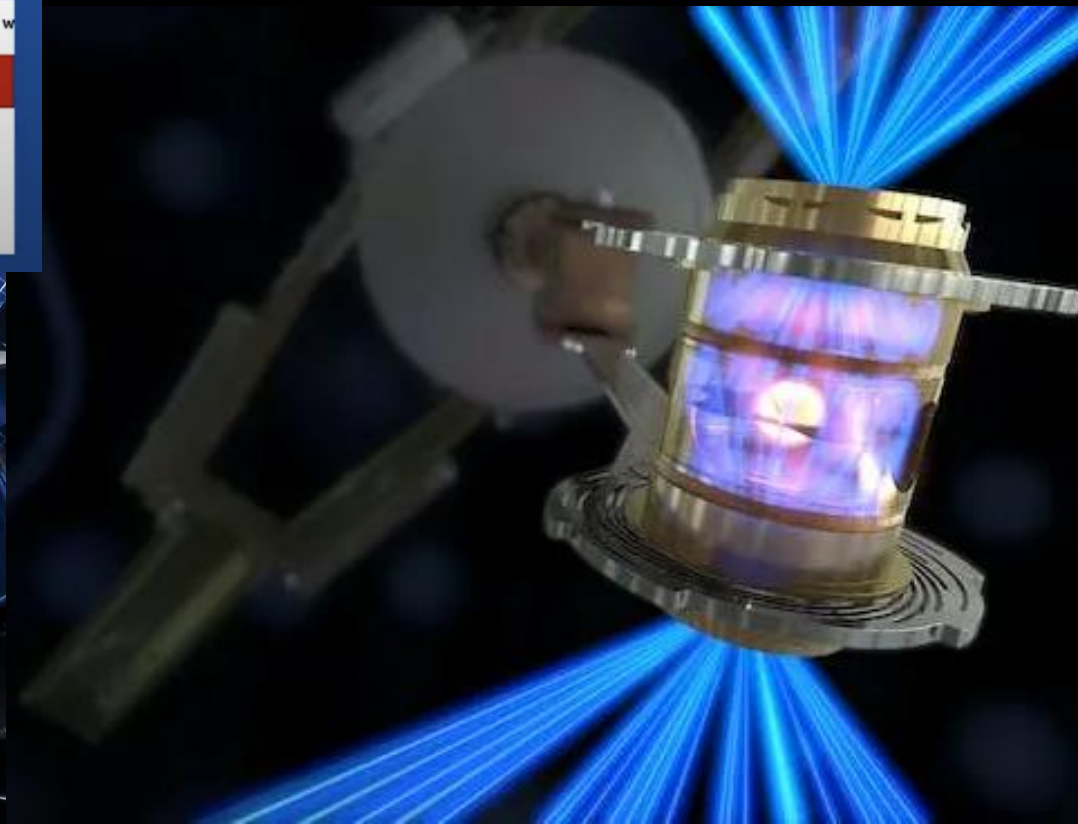
JANUARY 15, 2023 / 6:58 PM / CBS NEWS

BBC Sign in Home News Sport Reel W

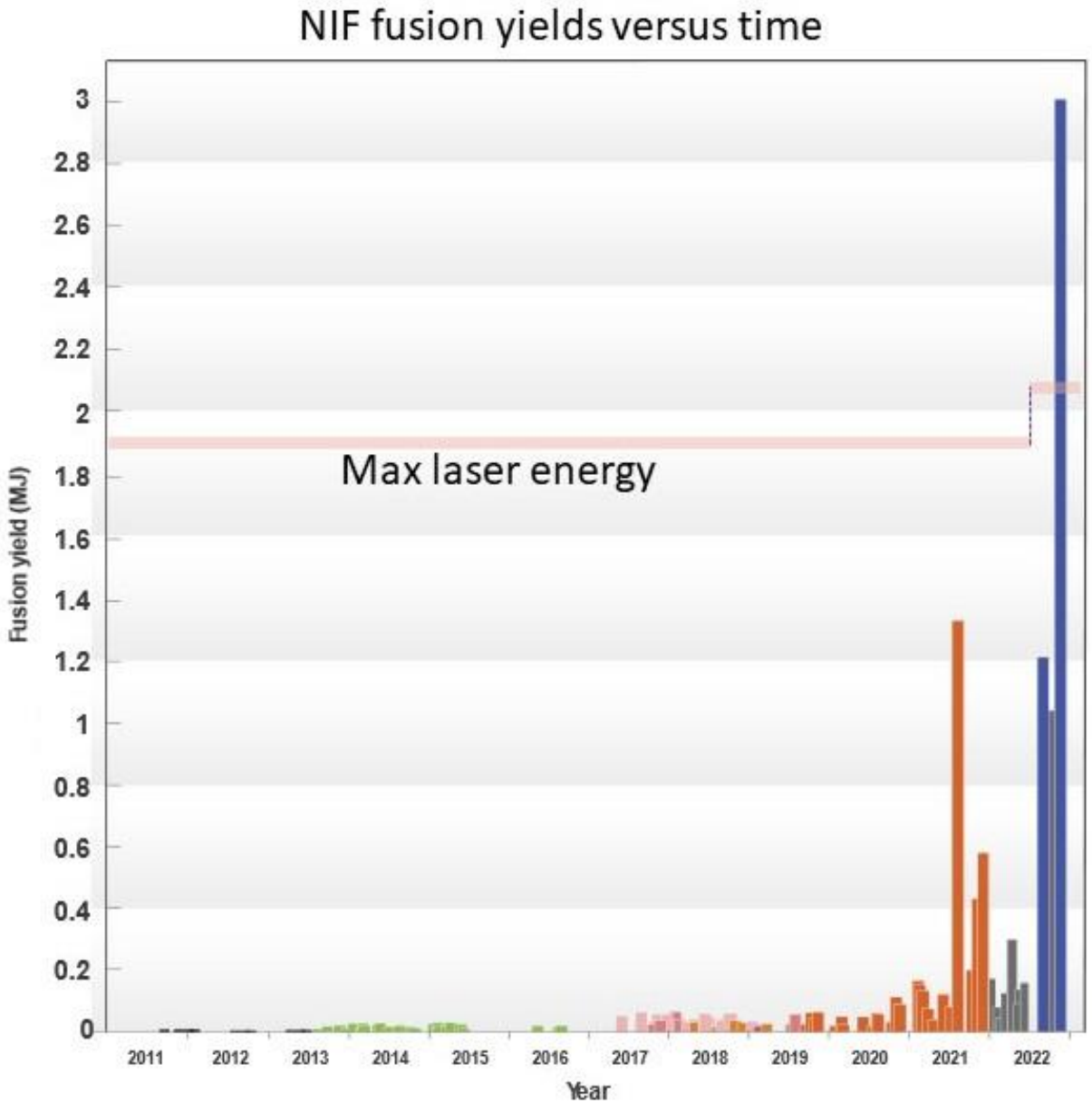
NEWS

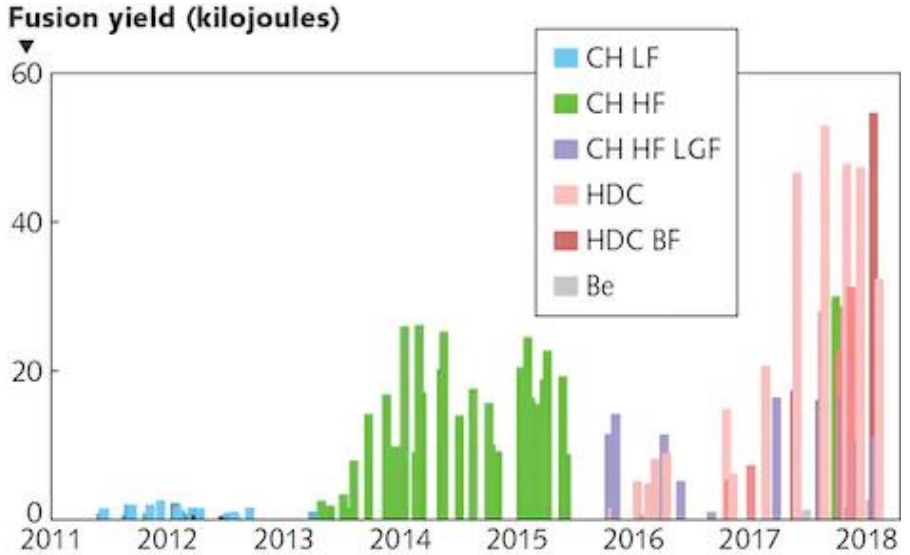
Breakthrough in nuclear fusion energy announced

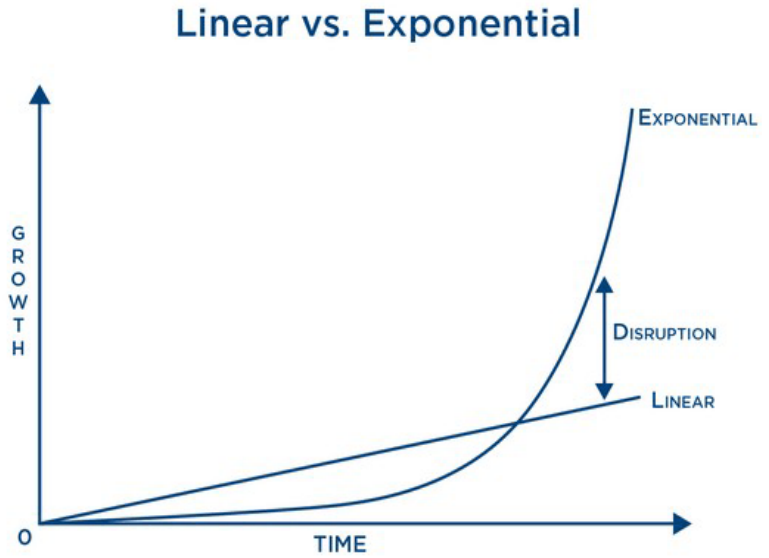
13 December 2022 Comments



A disruptive result





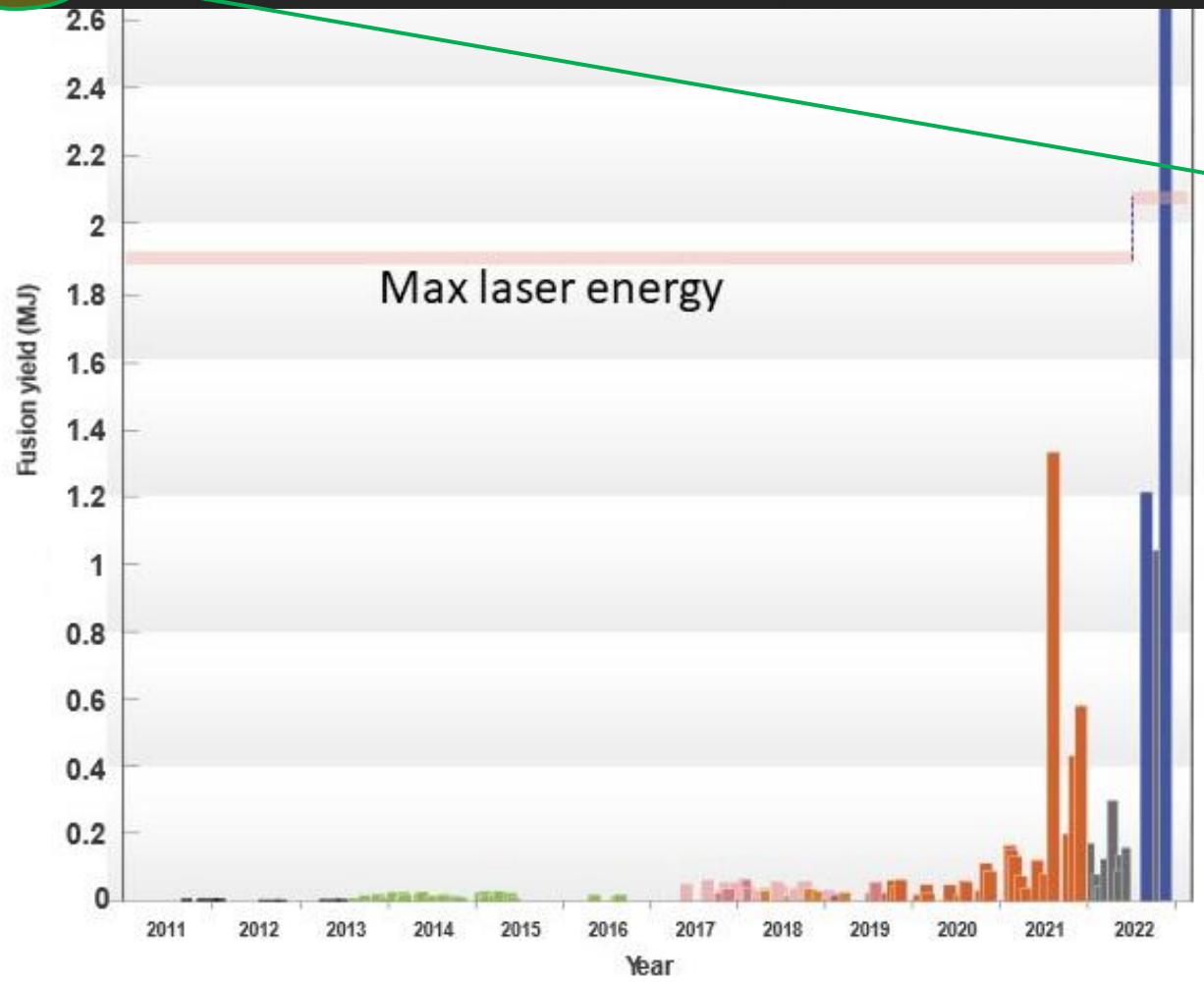


Phys today DOI:10.1063/PT.6.2.20221213a

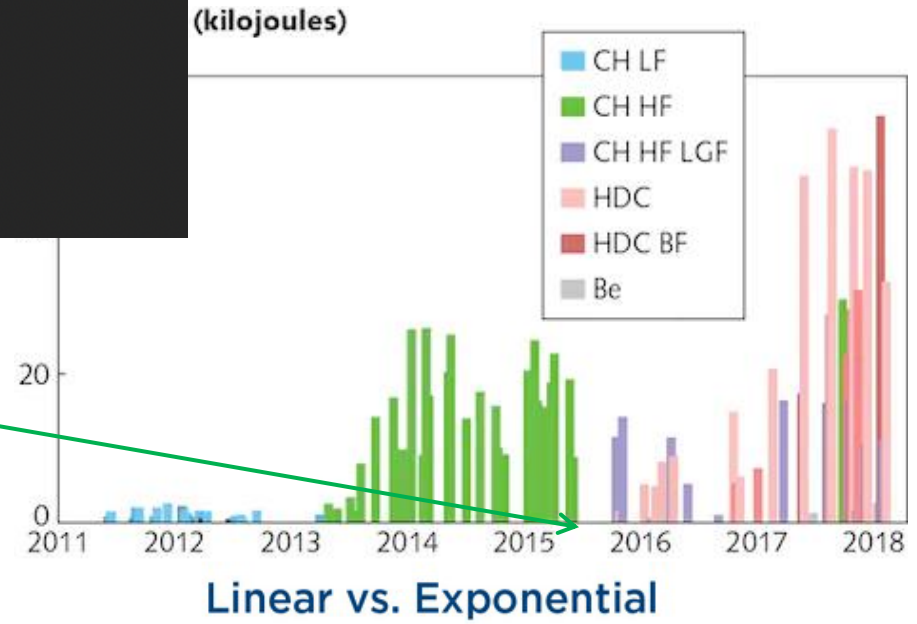
Giant U.S. fusion laser might never achieve goal, report concludes

National Ignition Facility should rethink efforts, DOE panel recommends

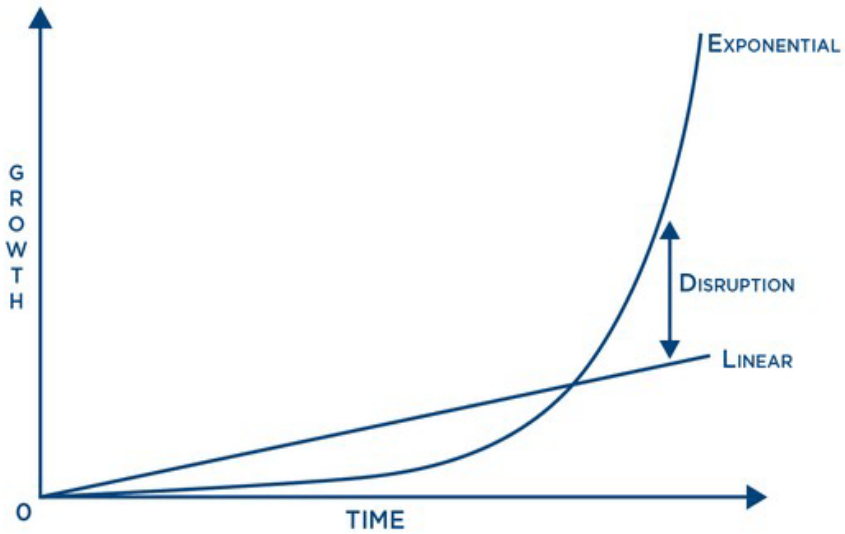
21 JUN 2016 · BY DANIEL CLERY



A disruptive result



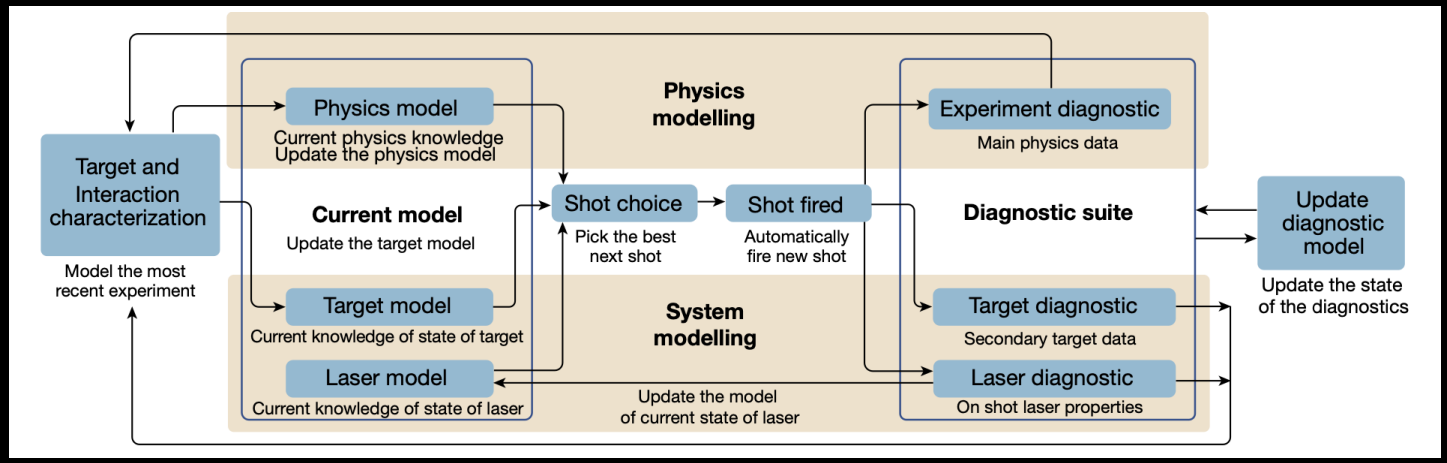
Linear vs. Exponential



*Megajoule, a unit of energy equal to one million joules.

Lawrence Livermore National Laboratory

Hatfield et al, Nature 2021
The data-driven future of high-energy-density physics

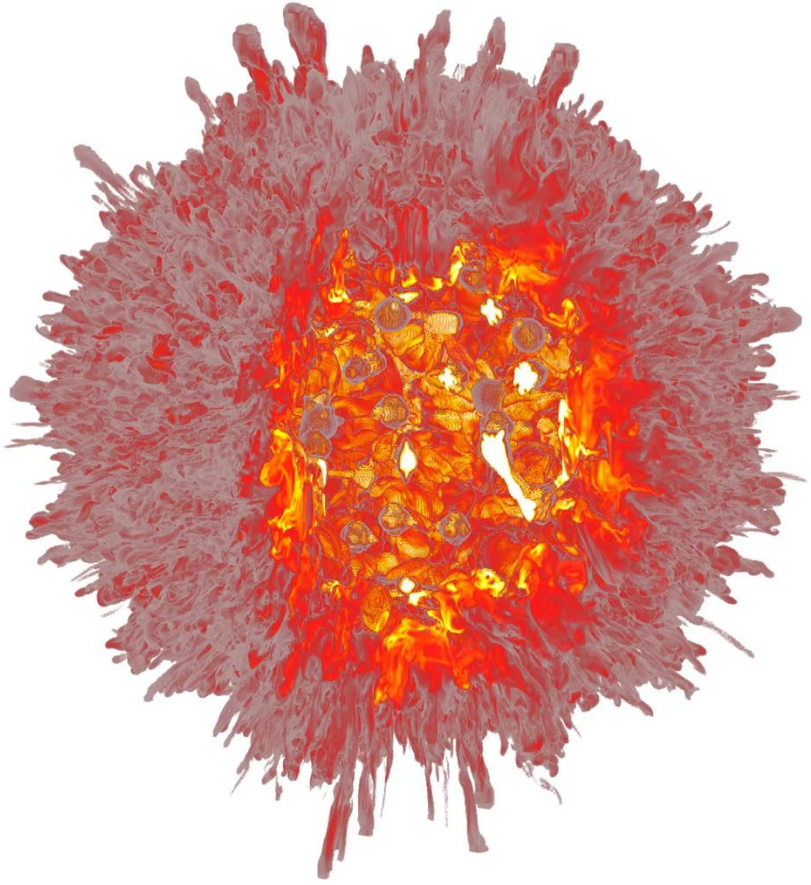


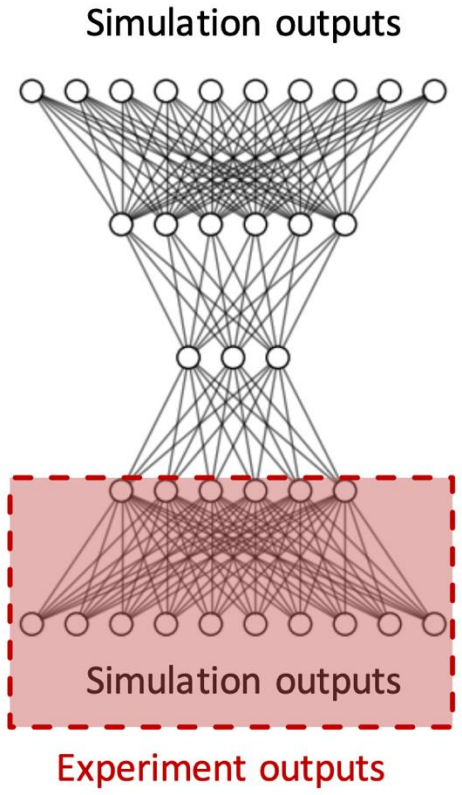
Recommendations

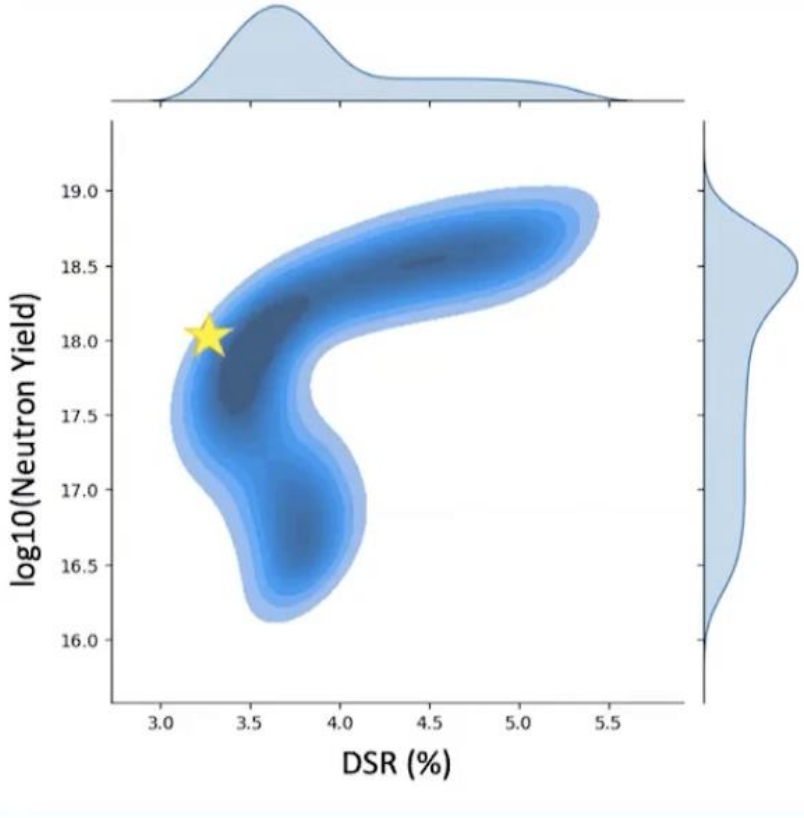
(1) Researchers should think carefully about how best to use their data: what methods and diagnostics they can use to take the best data, get sensible uncertainties, and coherently combine with other datasets.

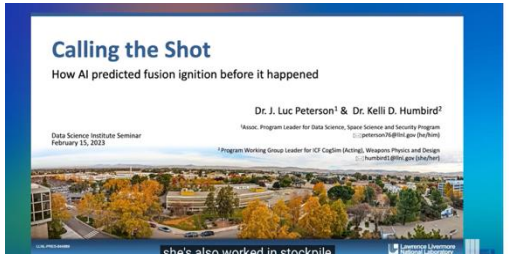
A challenge for AI

- Multiple unknown and correlated sources;
- Highly nonlinear response to perturbations;
- Sparse incompletely diagnosed data





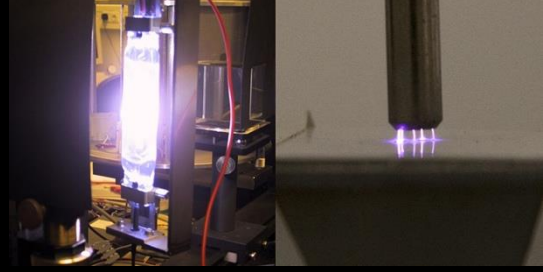




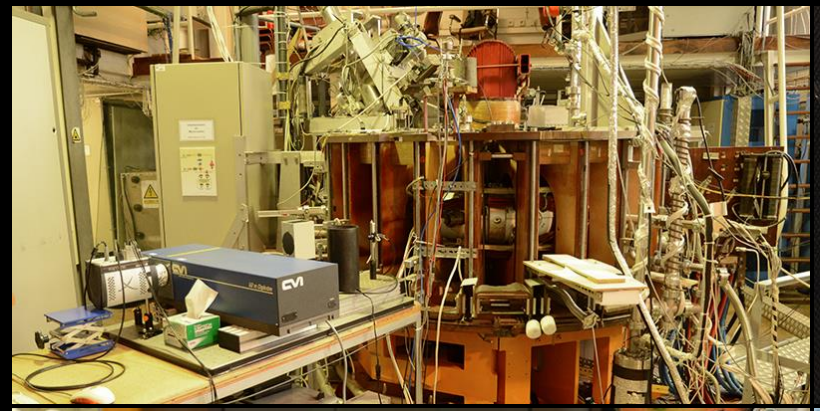
1. Build surrogate model of complex “high fidelity” hydrodynamic simulations with smaller set of inputs
2. Do uncertainty quantification to find best fit to calibration shots via Bayesian Inference $P(x_i|y_{exp,i})$ > what inputs are consistent with the data?
3. Use input parameters as priors for new design
4. Update inputs with new results

ipfn
INSTITUTO DE PLASMAS
E FUSÃO NUCLEAR

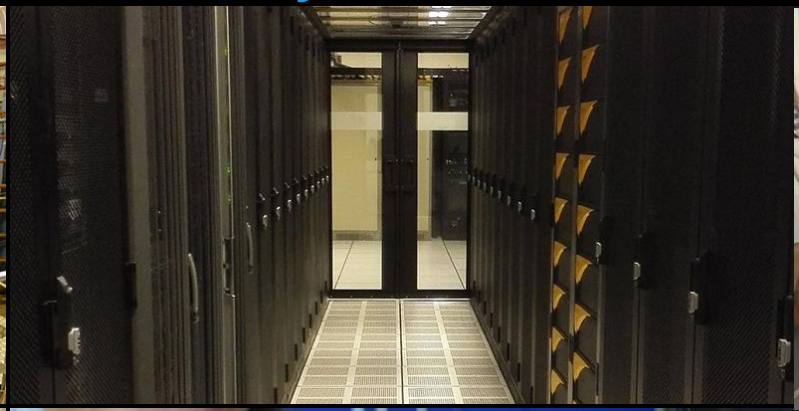
PL - Plasma Laboratory
Madeira University



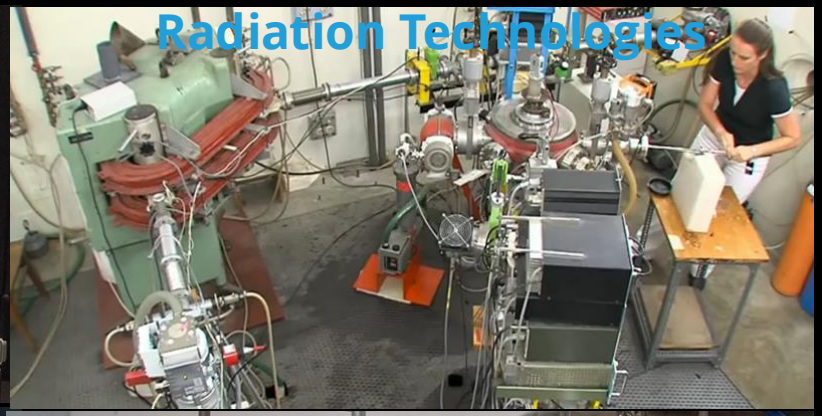
ISTTOK - IST Tokamak



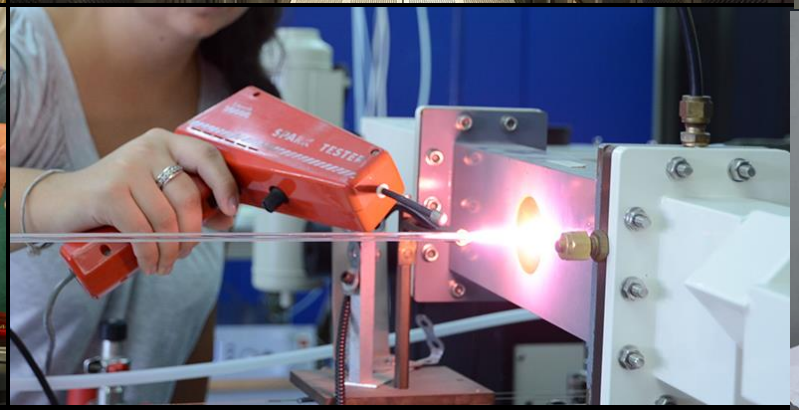
EPP - Computational facility ISTCluster



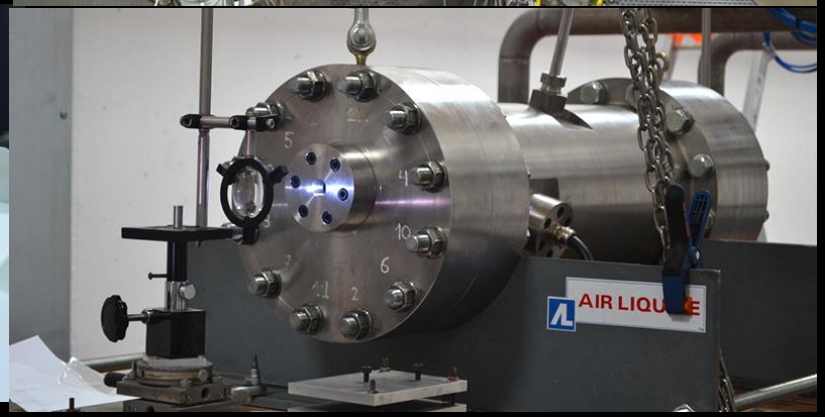
LATR - Laboratory of Accelerators and Radiation Technologies



MotLab - Laboratory for Ultracold



PEL - Plasma Engineering Laboratory



ESTHER - European Shock-Tube for High-Enthalpy Research

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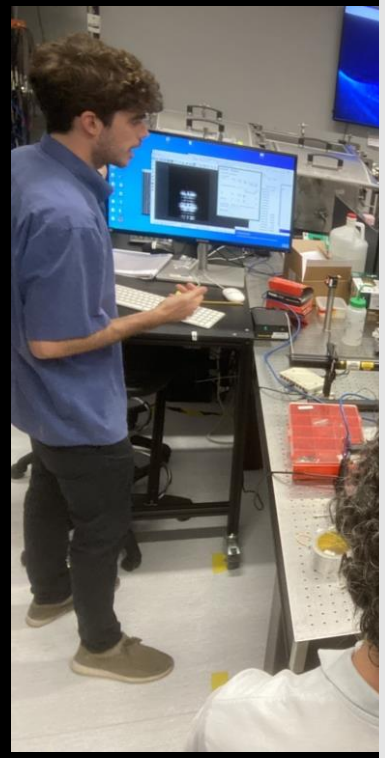
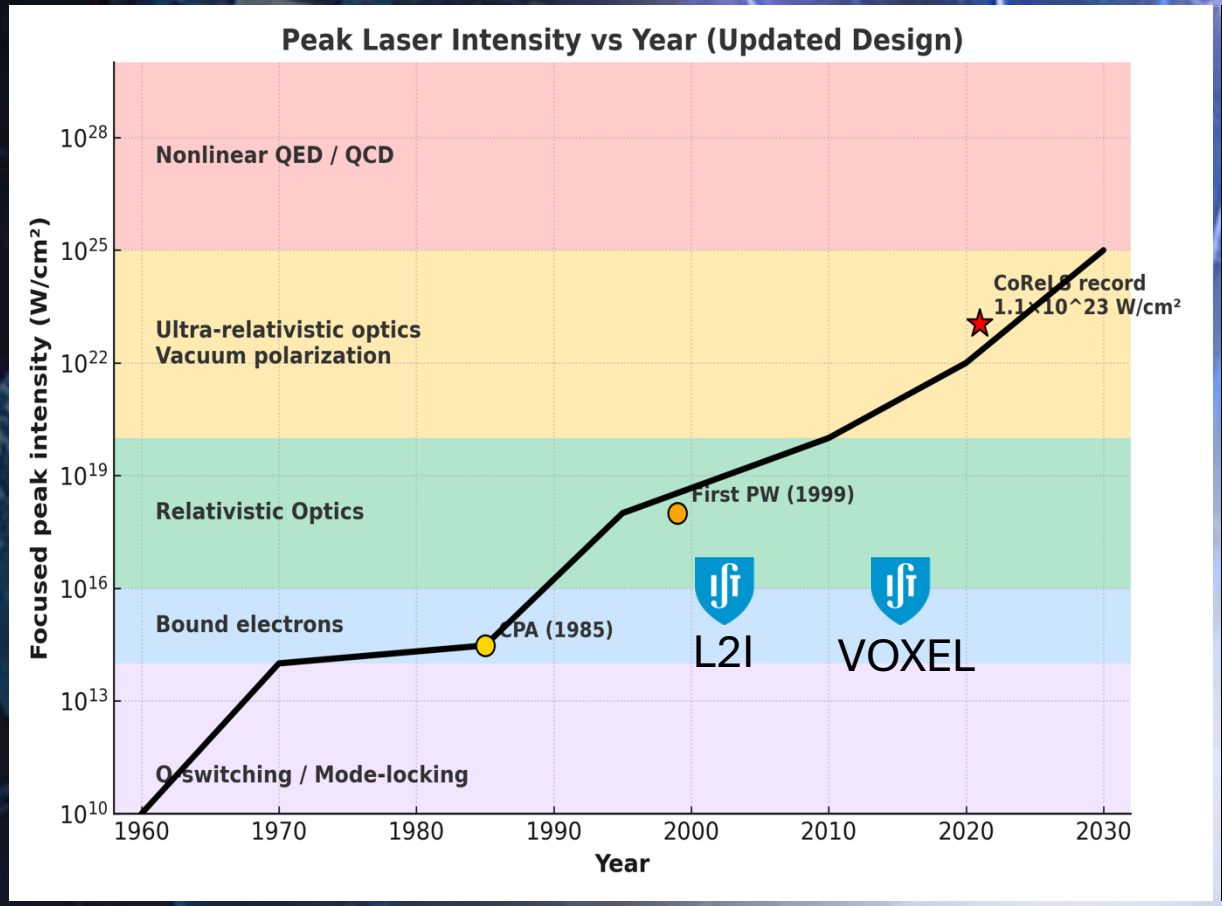
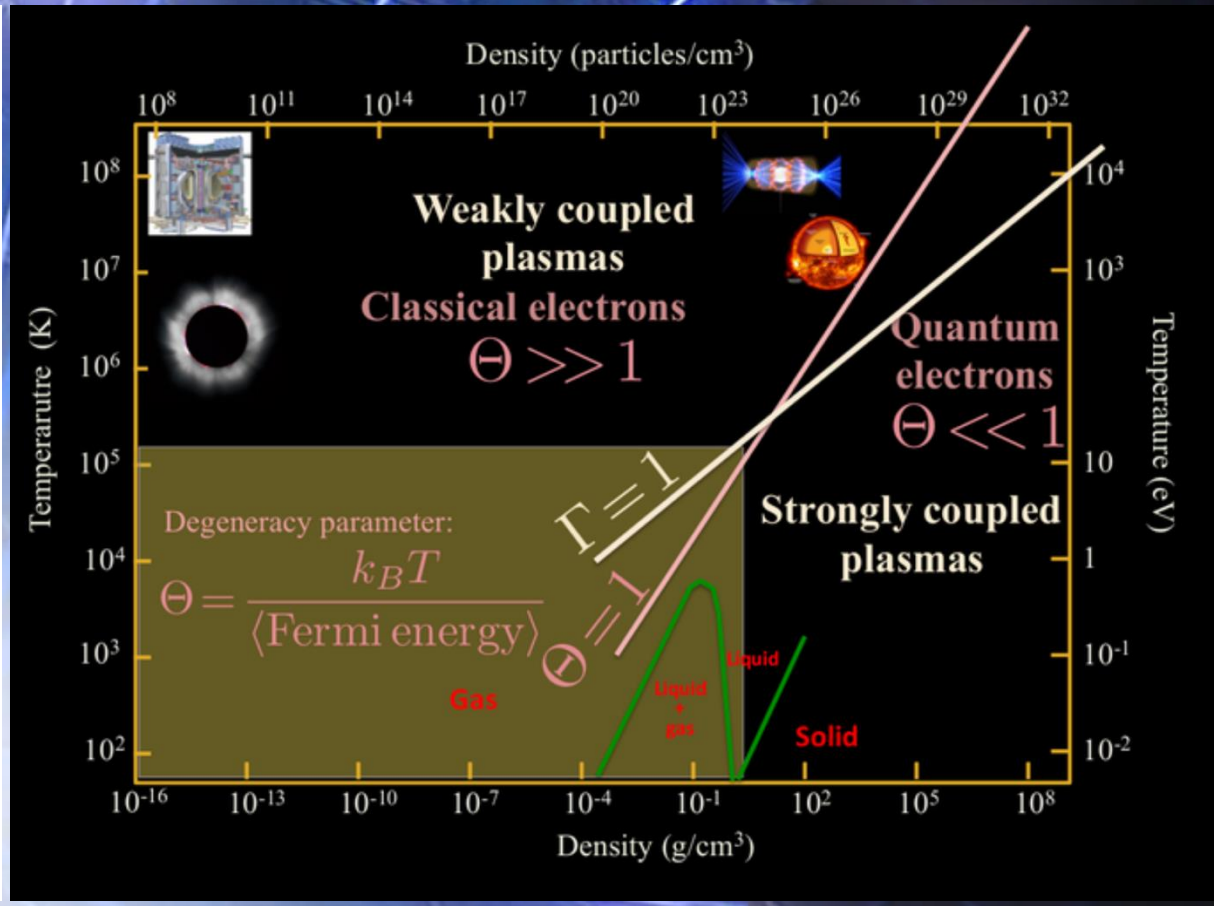
EUROfusion

boratories



VOXEL Dense
X-rays



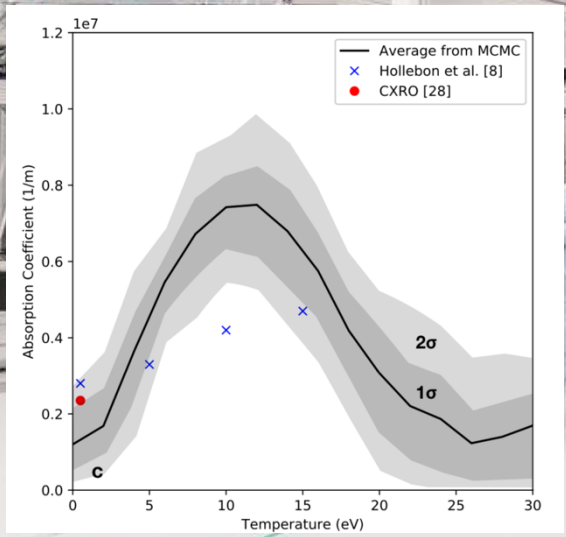


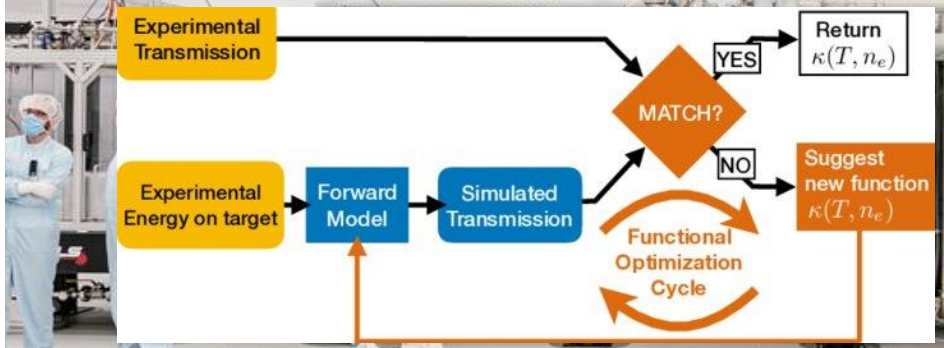
Energy density ≥ 10^{11} J/m^3, equivalent to **pressure ≥ 1 Mbar (10^{11} Pa)**

Core of the Sun: 10^{16} J/m^3 ; NIF peak compression: ~2 10^{16} J/m^3

Paradigm Shift – High-Repetition-Rate Experiments

Inferring free free opacities from functional optimisation at VUV FEL

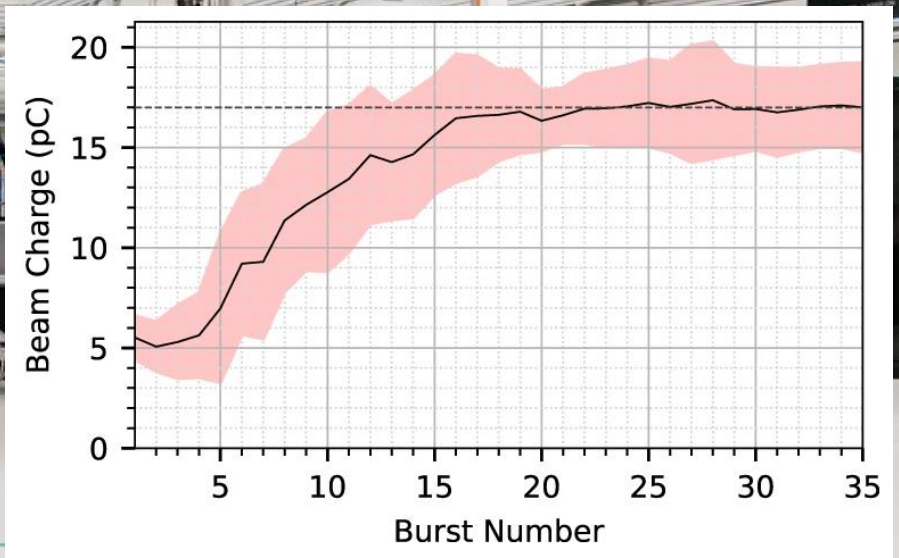




Functional optimization approach used to extract the opacity as a function of electron temperature and density by constraining it to the dataset of integrated transmission measurements

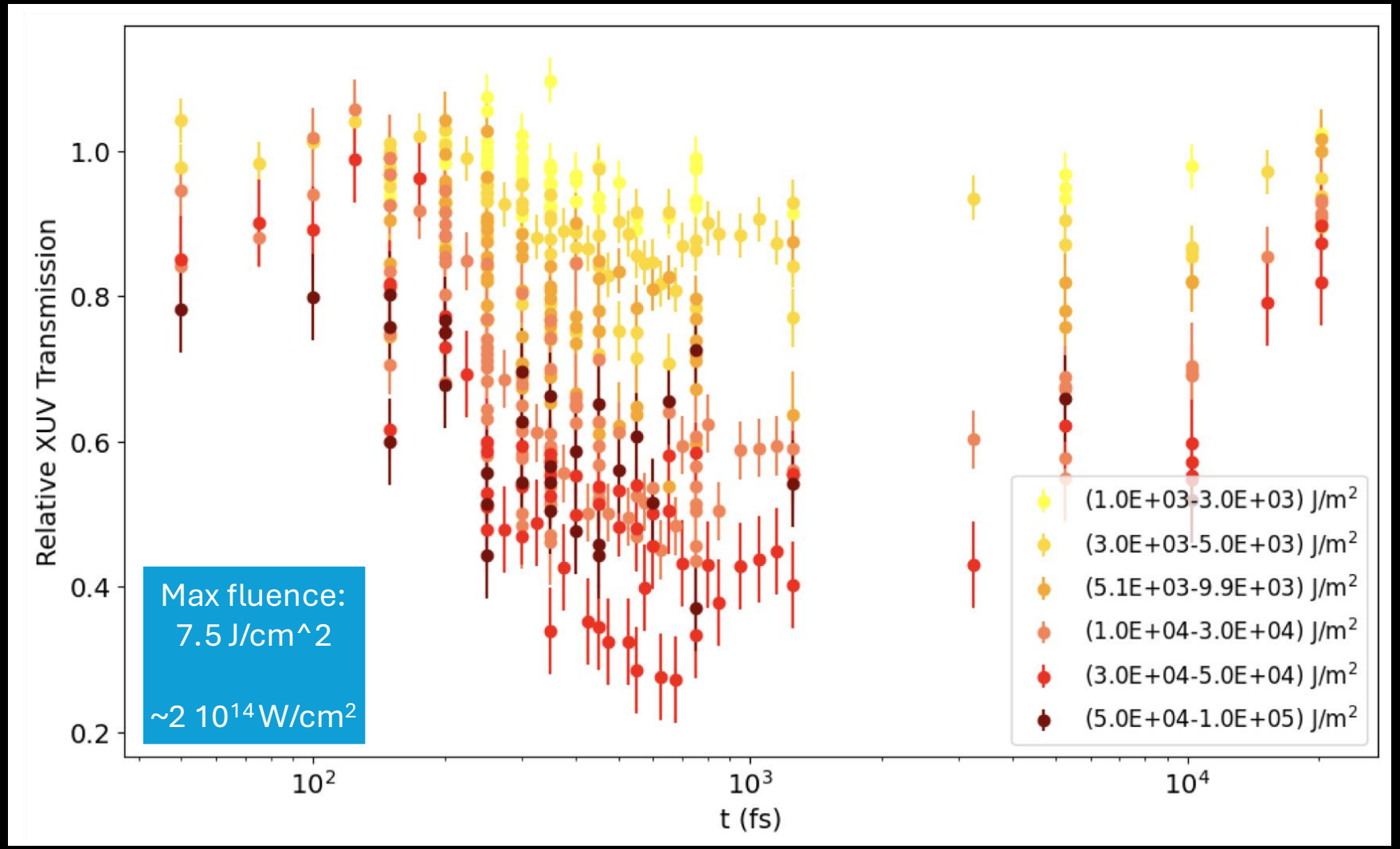
S. Vinko et al, Phys. Rev. Lett. (2020)

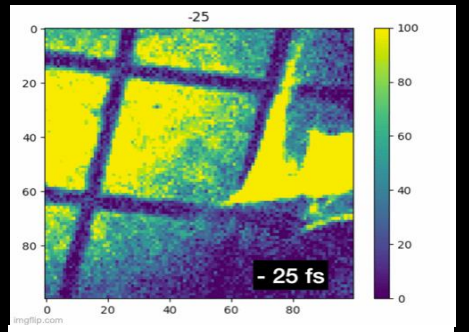
Machine learning for source optimization

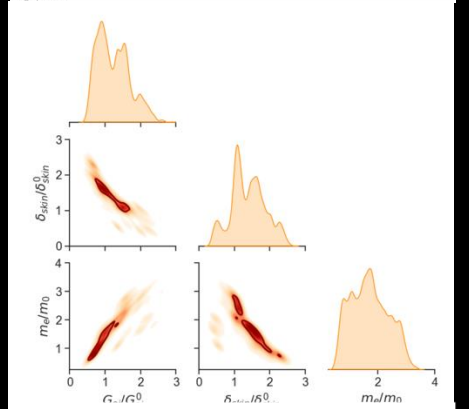


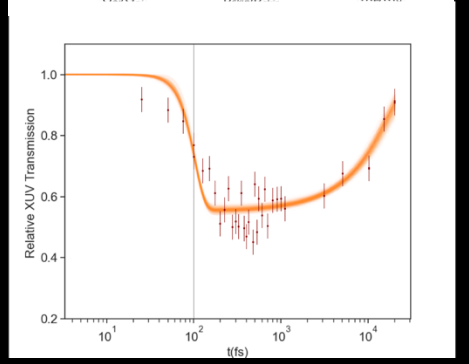
Shalloo, R.J., *et al. Nat Commun* **11**, 6355 (2020

Recovering time-dependent opacity in the EUV from large datasets

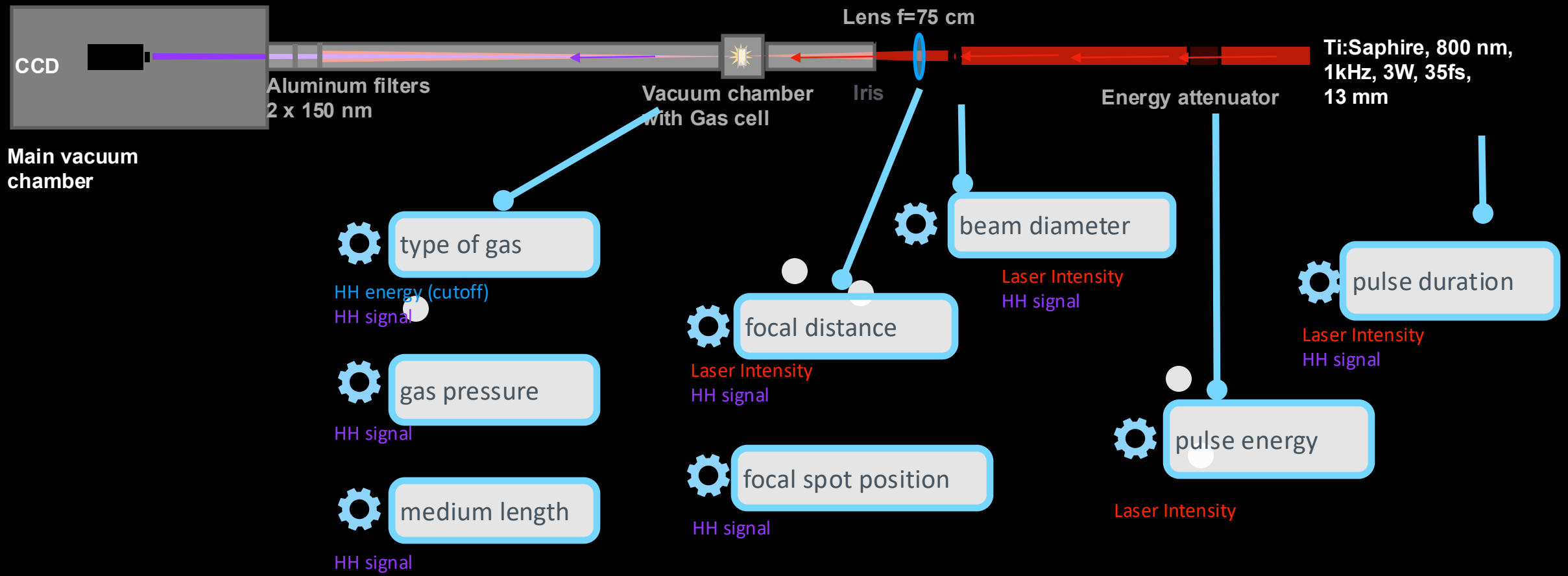








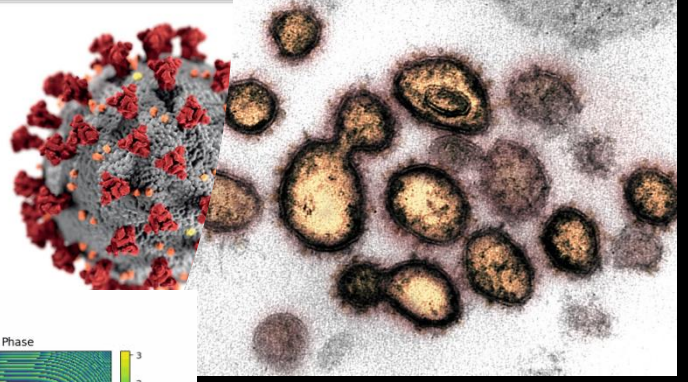
How to optimize High Harmonic Generation in the lab?

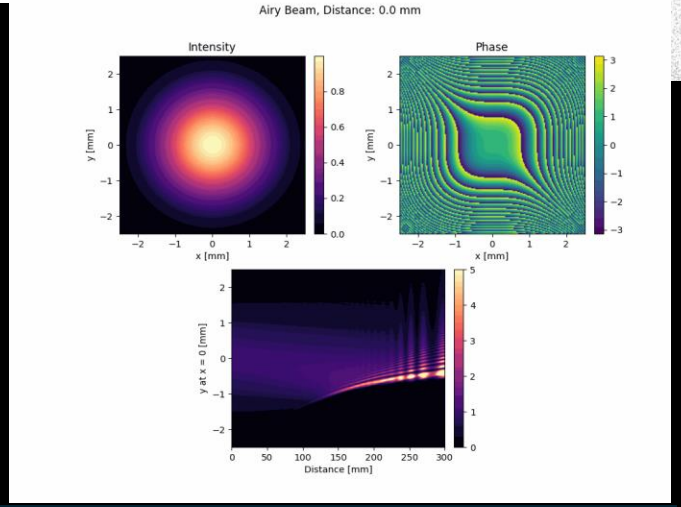


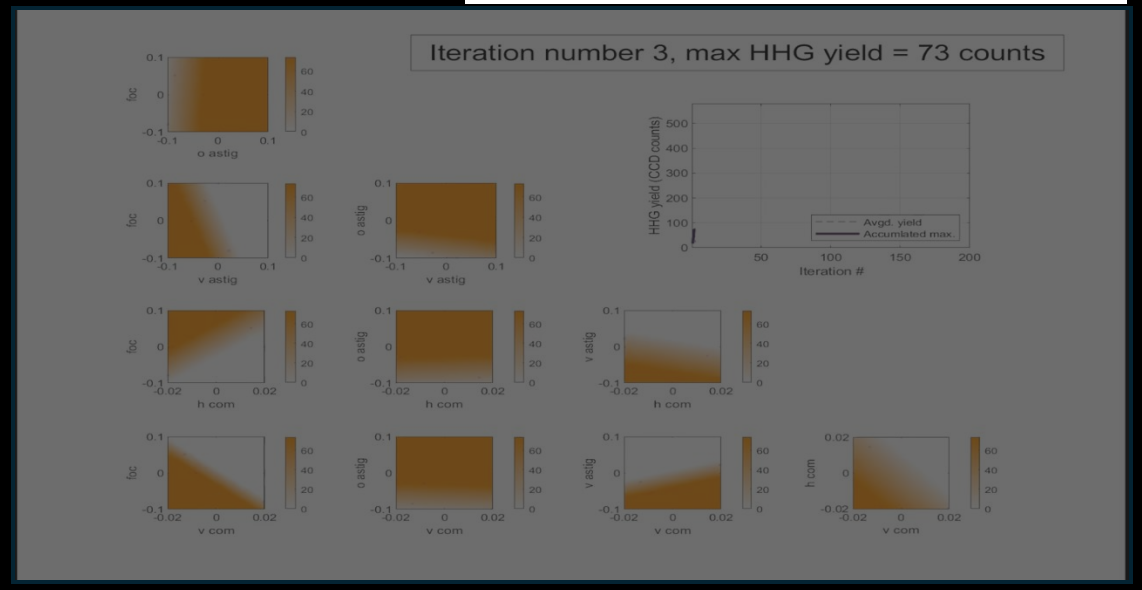
Laser Intensity affects HH energy (cutoff) and HH signal (ionization)

NanoXCAN

Prix Tremplin Mariano Gago
Académie des Sciences

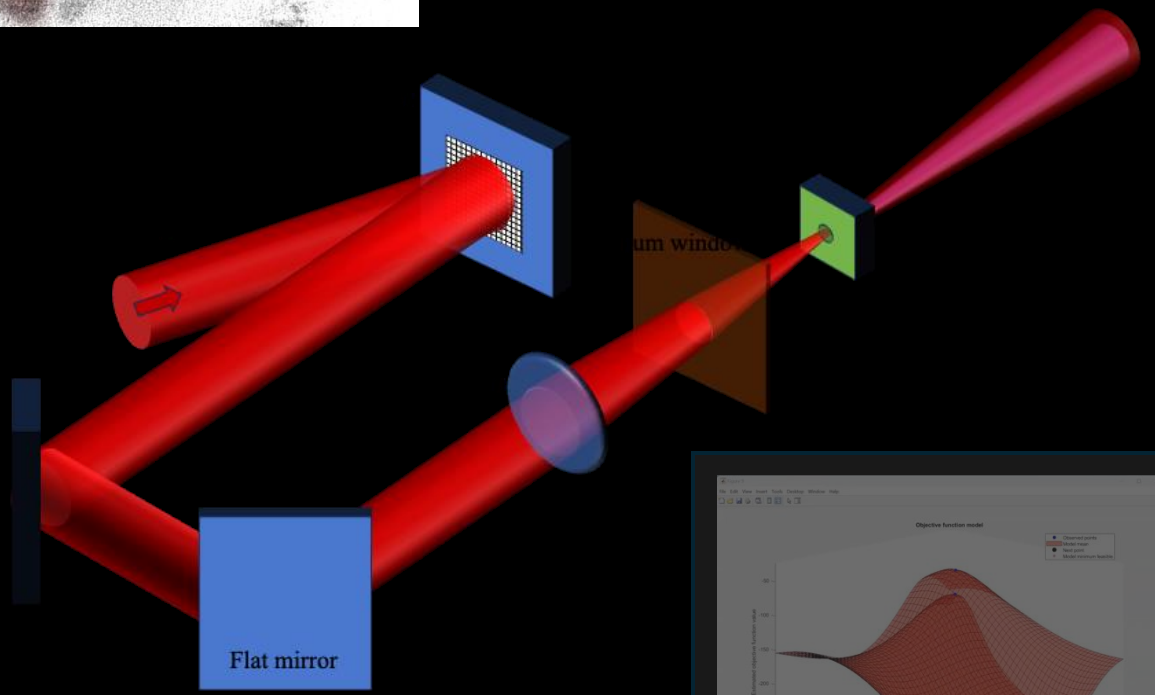


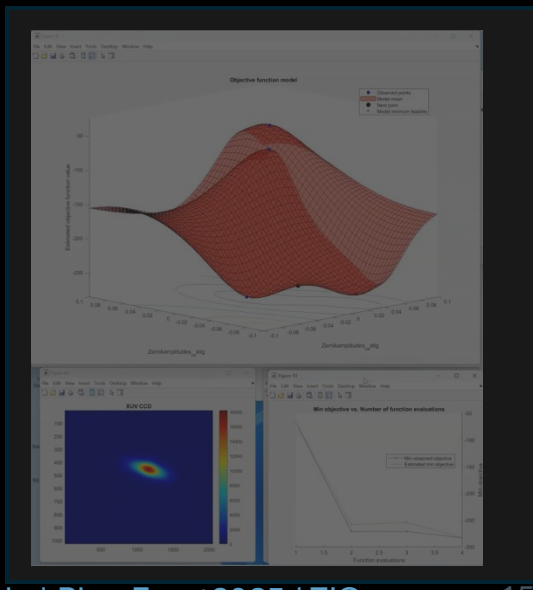




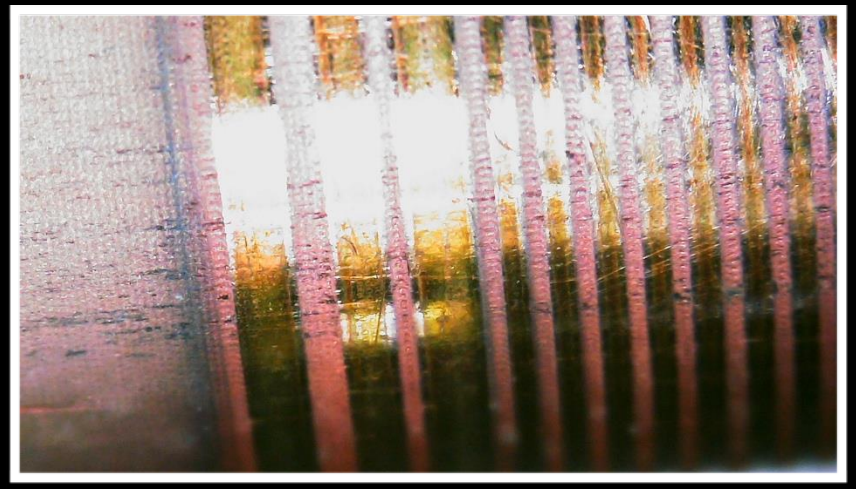
VOXEL

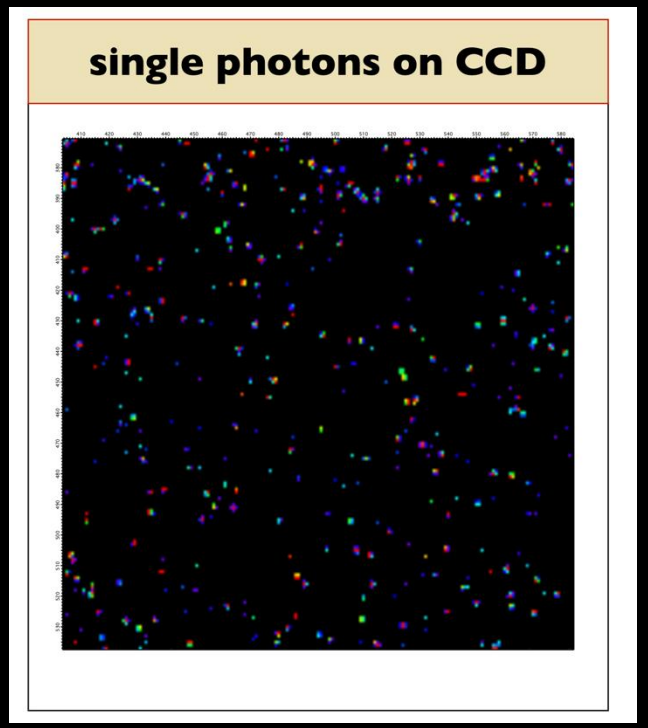
Automated source optimization

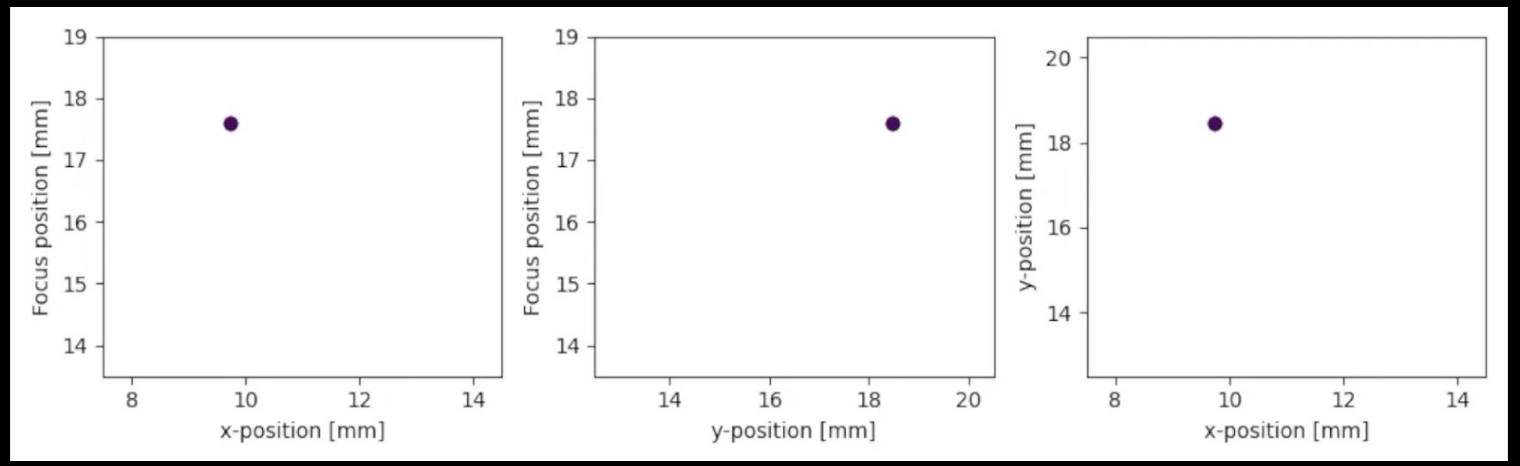


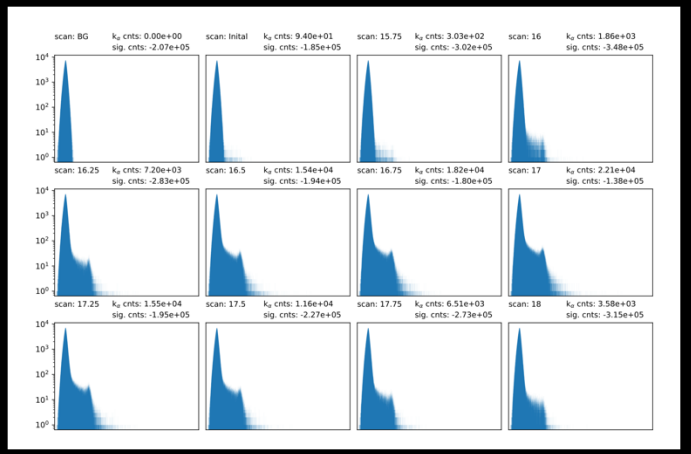


X-ray optimization

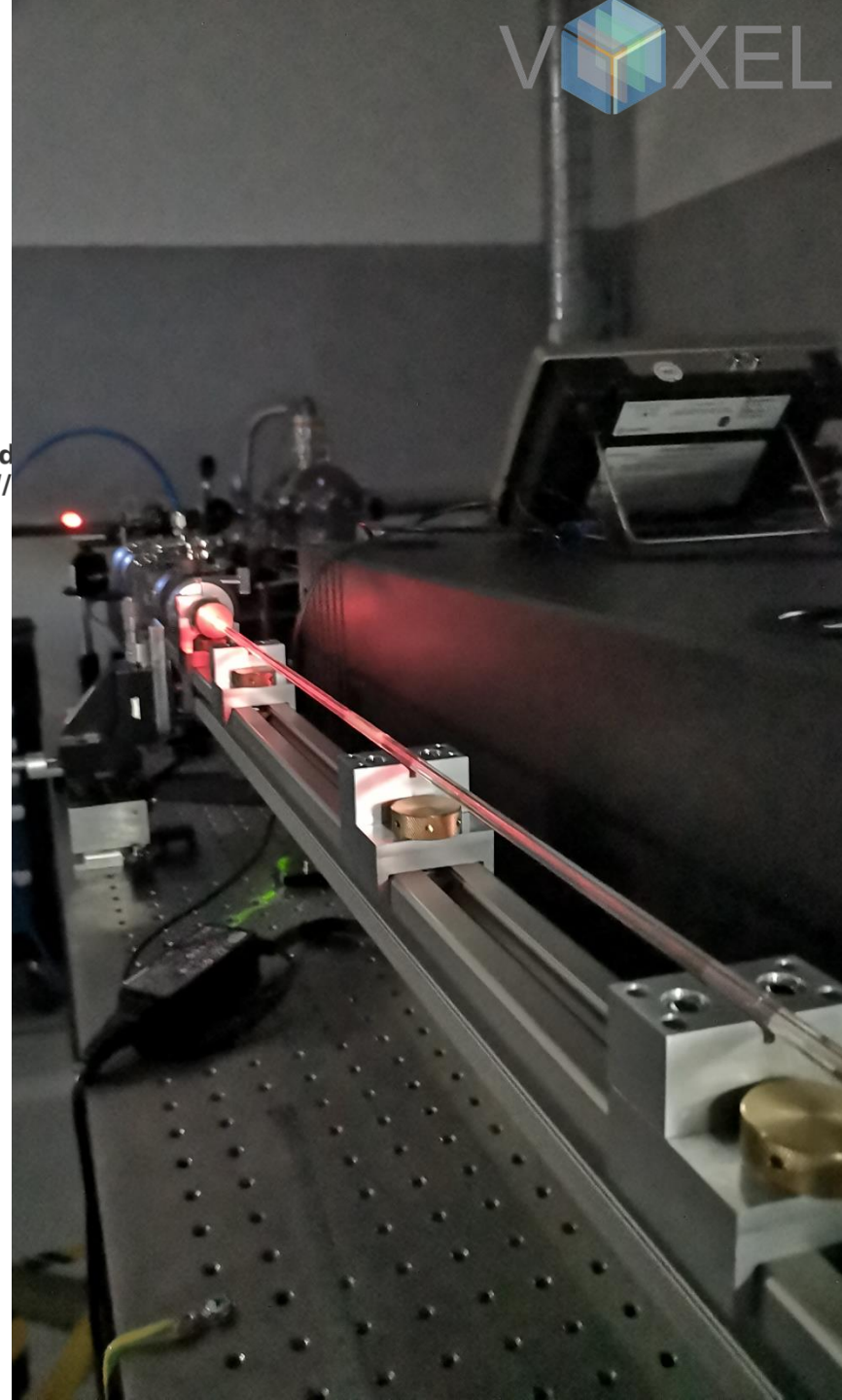








What's next?



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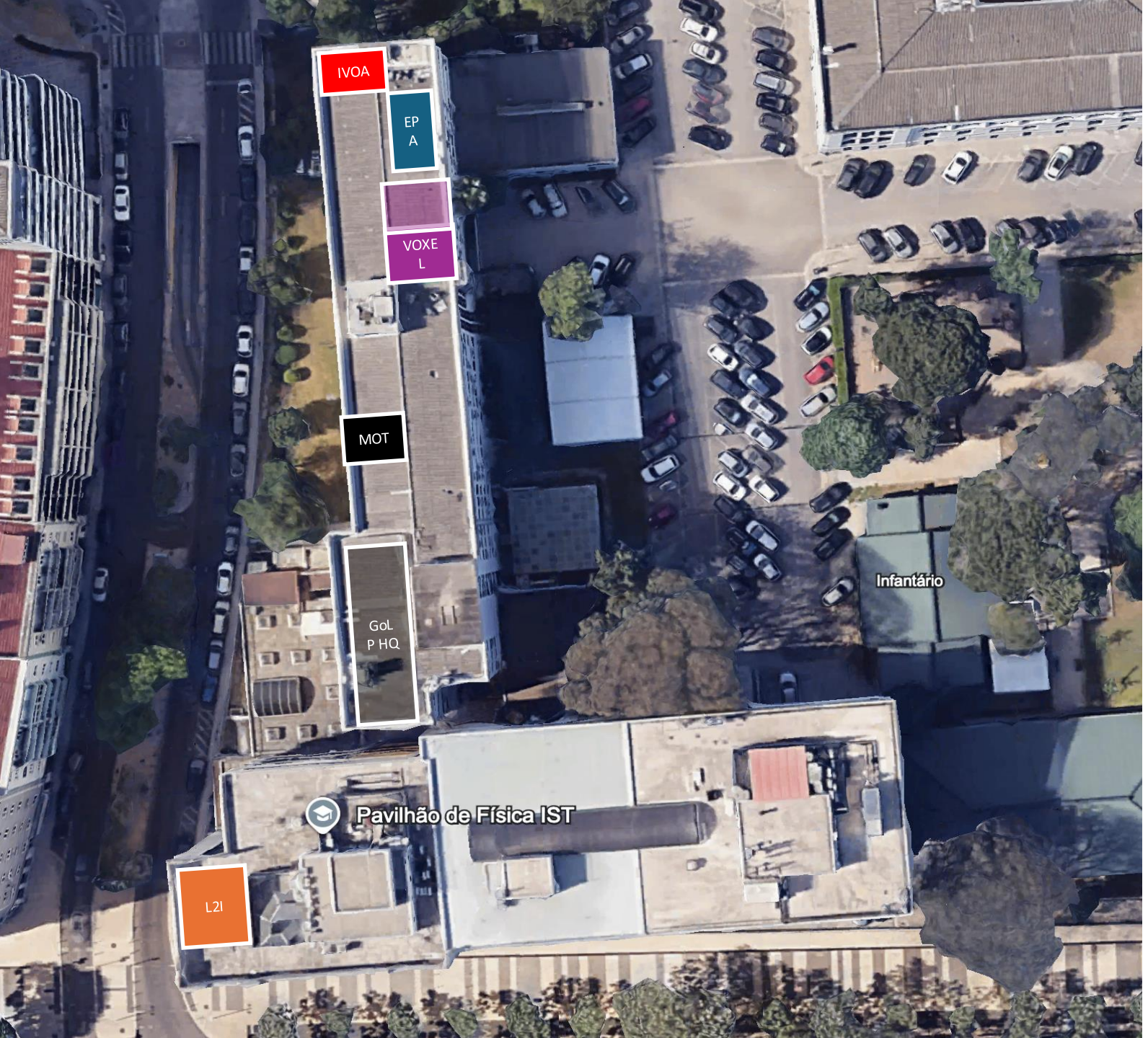
2030 Lisboa PROGRAMA REGIONAL DE LISBOA

Cofinanciado pela União Europeia



golp

EPA	Plasma acceleration lab
VOXEL	IR laser-plasma interaction
MOT	Cold atom facility
L2I	Novel lasers at 3 μm and applications
HPC	Accelerates HPC Cluster
IVOA	Industrial & Vision Optics Applications

https://golp.tecnico.ulisboa.pt/

GoLP-IN (Grupo de Lasers e Plasmas' Internship Program)

6 months duration, every semester, open to all degrees & all years

-Started in 2022/2023, now on its 7th edition (calls for 8th will open mid P1)

-Recognized by the Scientific Council of IST (01/06/23) for 3 ECTS credits.

-So far: 142 applicants, 76 research topics, 49 concluded (certificates issued)

GoLP_IN website:
golp.tecnico.ulisboa.pt/wp/opportunities/golp-internship/

See previous work at:
golp.ist.utl.pt/wp/opportunities/golp-internship/golp_in-alumni/

Onboarding presentation (5th edition)

Interns and supervisors (5th edition)

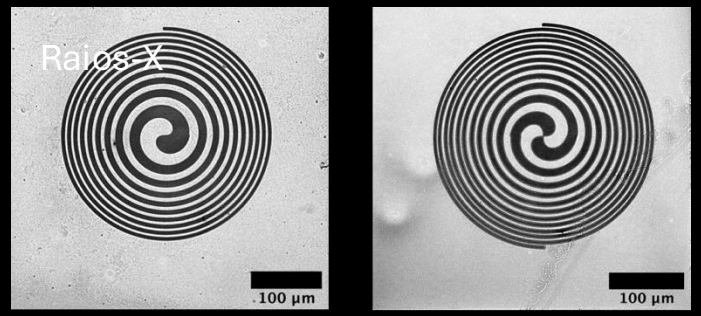
Certificate award (3rd edition)

GROUP OF LASERS AND PLASMAS

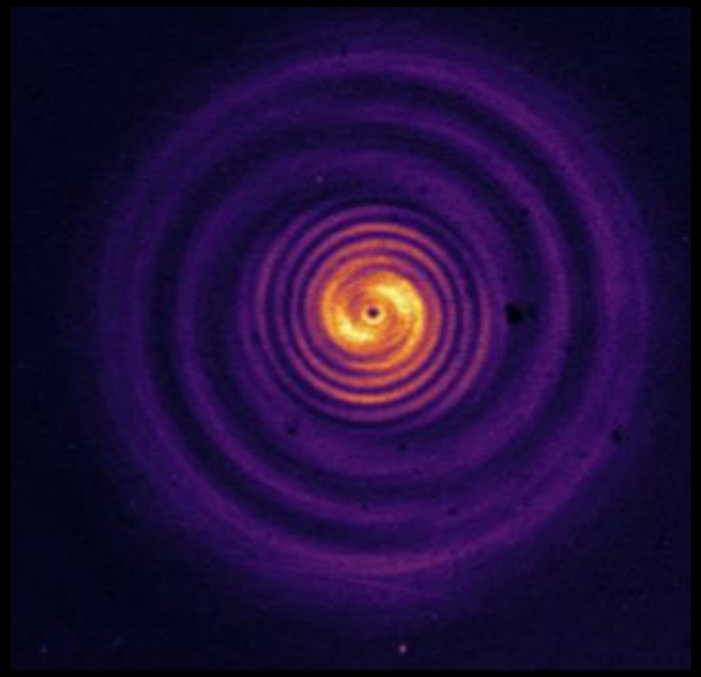
Committed to continuously raising the bar

Manipulamos as nossas fontes e desenvolvemos novos diagnósticos

P. Estrela: Fuzilli de Raios-X

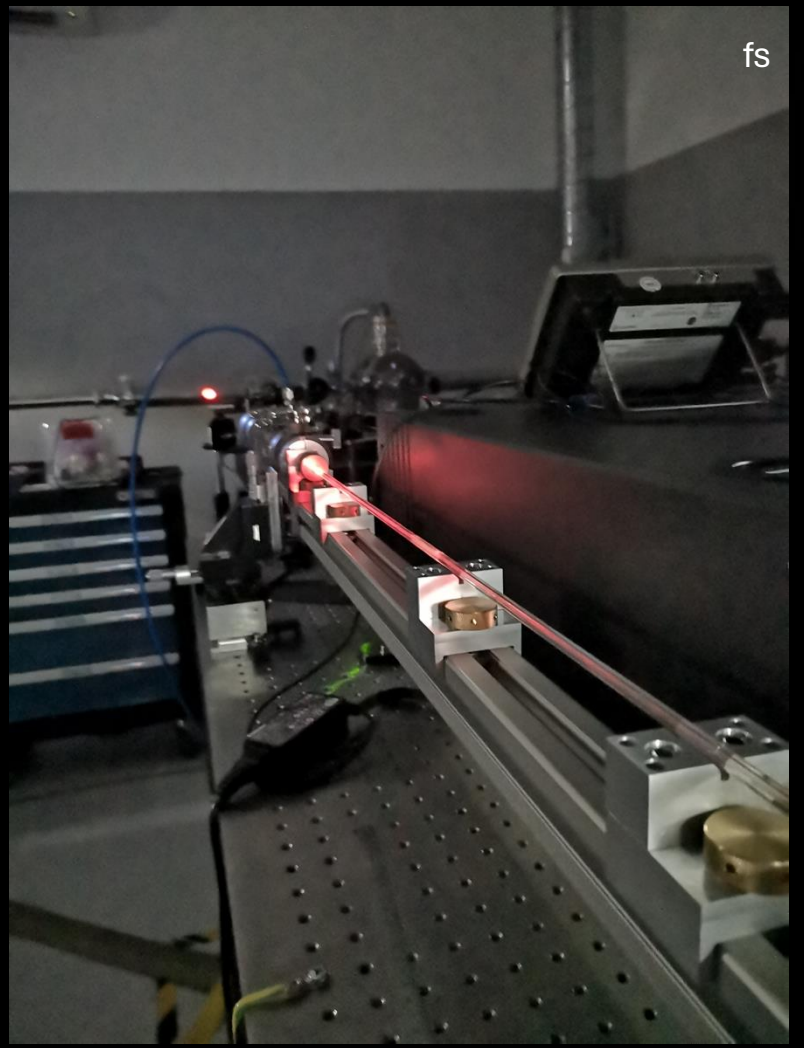


microscope images of SZP lenses fabricated at INESC MN



sphere ULTRAFAST PHOTONICS

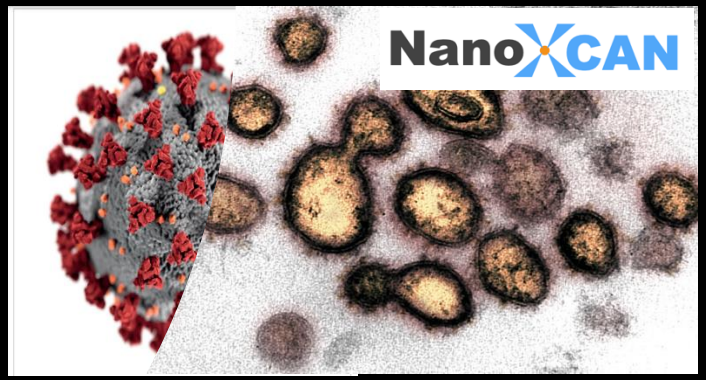
M. Silva: Impulsos de 3.8 fs

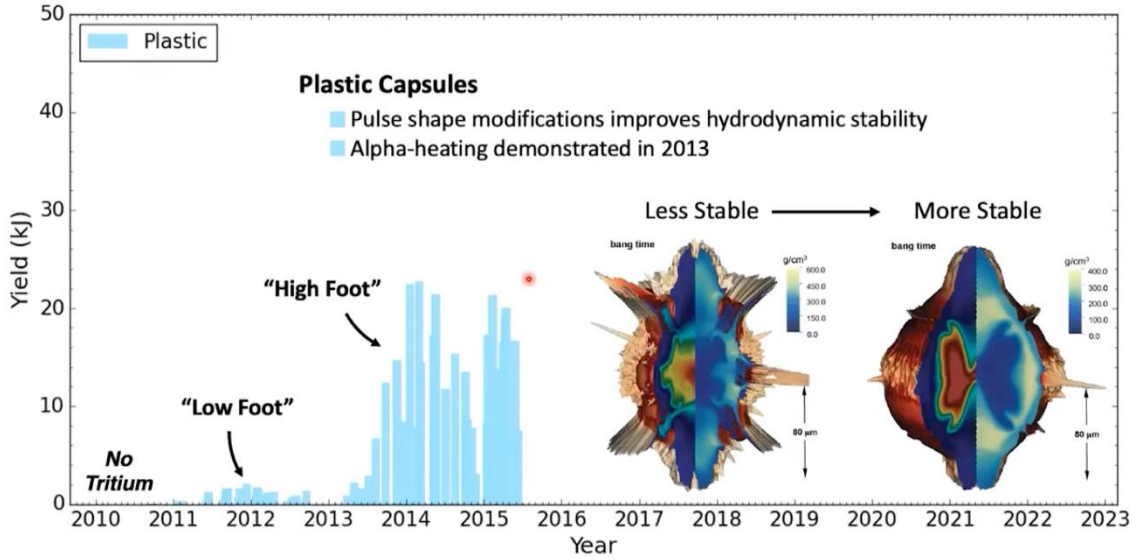


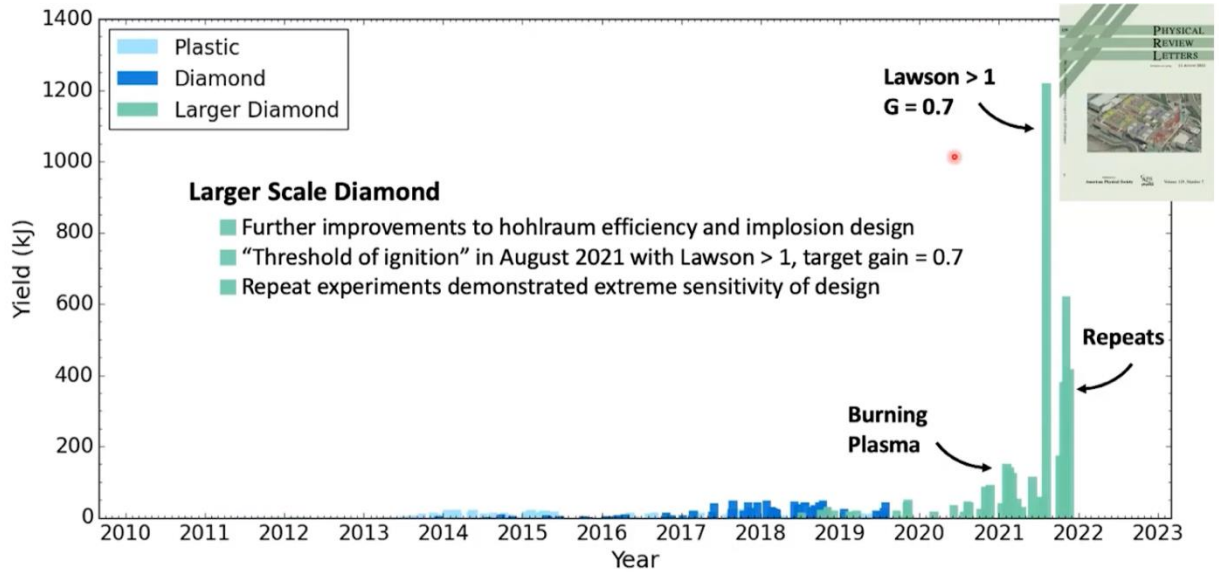
VOXEL

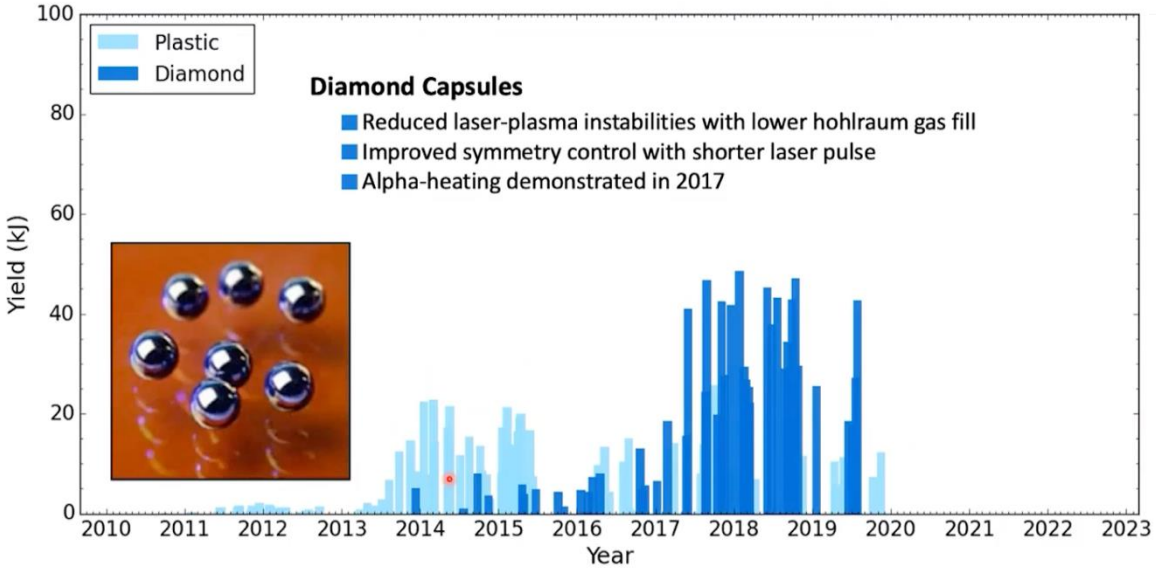
EUROfusion

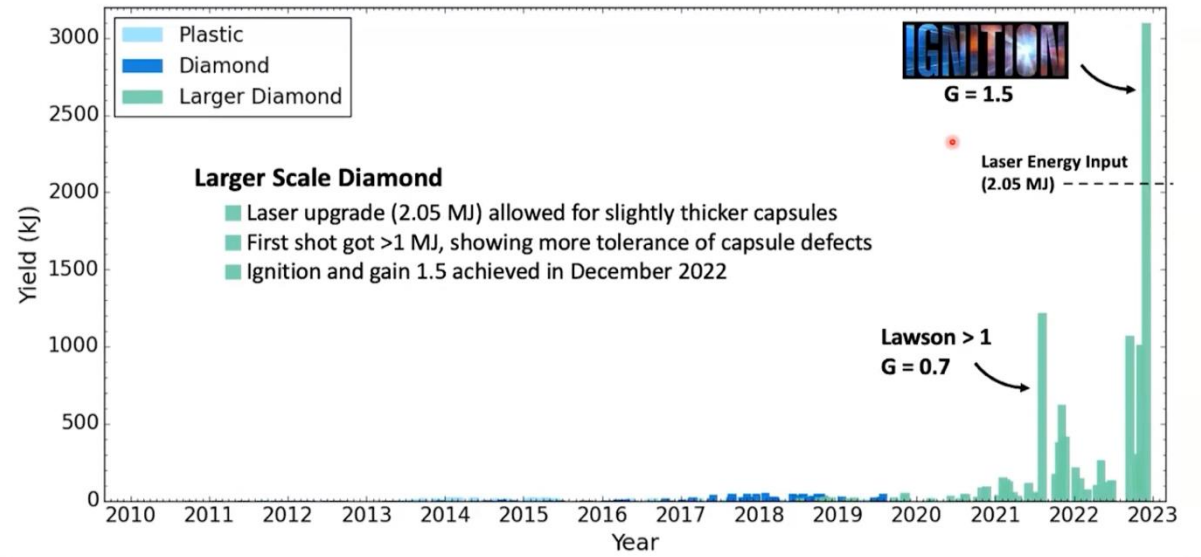
IMPULSE



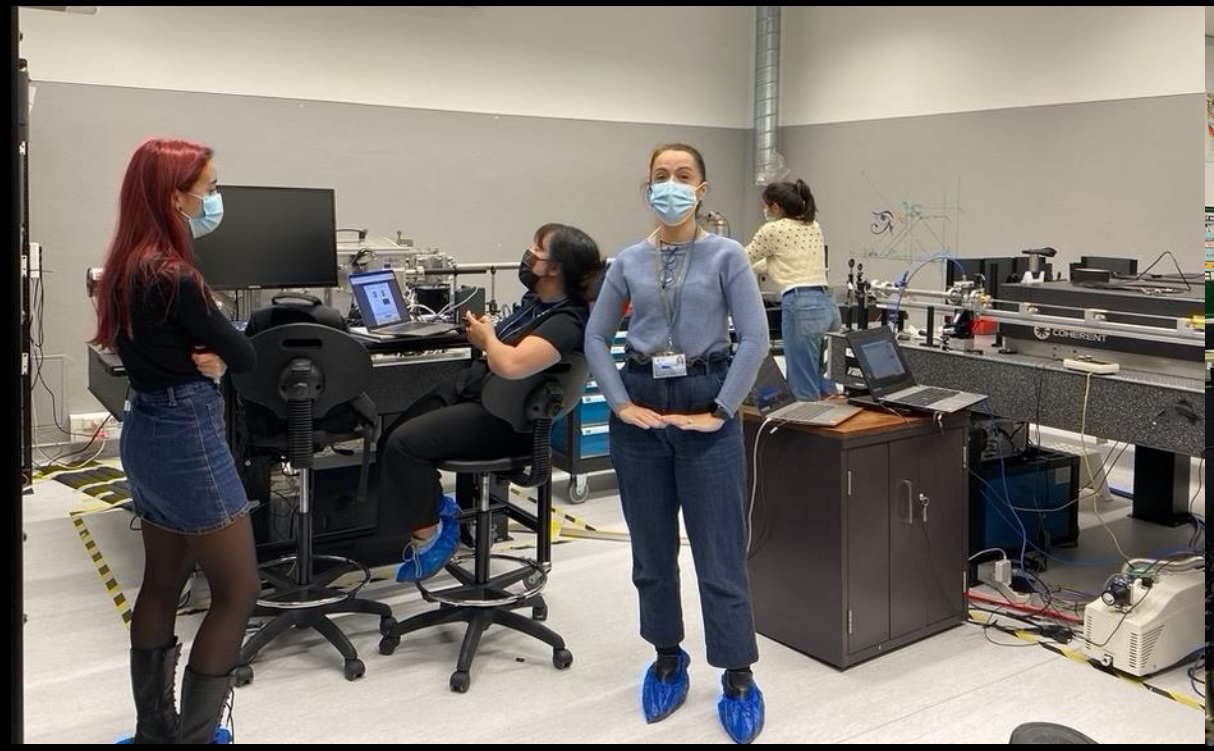

Plastic
Plastic Capsules
Pulse shape modifications improves hydrodynamic stability
Alpha-heating demonstrated in 2013
Less Stable
More Stable
"High Foot"
"Low Foot"
No Tritium
bang time
bang time
80 μm
80 μm
Yield (kJ)
Year


Plastic
Diamond
Larger Diamond
Larger Scale Diamond
Further improvements to hohlraum efficiency and implosion design
"Threshold of ignition" in August 2021 with Lawson > 1, target gain = 0.7
Repeat experiments demonstrated extreme sensitivity of design
Lawson > 1
G = 0.7
Repeats
Burning Plasma
PHYSICAL REVIEW LETTERS
Yield (kJ)
Year


Plastic
Diamond
Diamond Capsules
Reduced laser-plasma instabilities with lower hohlraum gas fill
Improved symmetry control with shorter laser pulse
Alpha-heating demonstrated in 2017
Yield (kJ)
Year


Plastic
Diamond
Larger Diamond
IGNITION
G = 1.5
Laser Energy Input
(2.05 MJ)
Larger Scale Diamond
Laser upgrade (2.05 MJ) allowed for slightly thicker capsules
First shot got >1 MJ, showing more tolerance of capsule defects
Ignition and gain 1.5 achieved in December 2022
Lawson > 1
G = 0.7
Yield (kJ)
Year

A equipa X-GoLP opera dois laboratórios laser de alta potência



VOXEL

Plasmas Densos, Raios-X, Machine learning

L2I Novos lasers