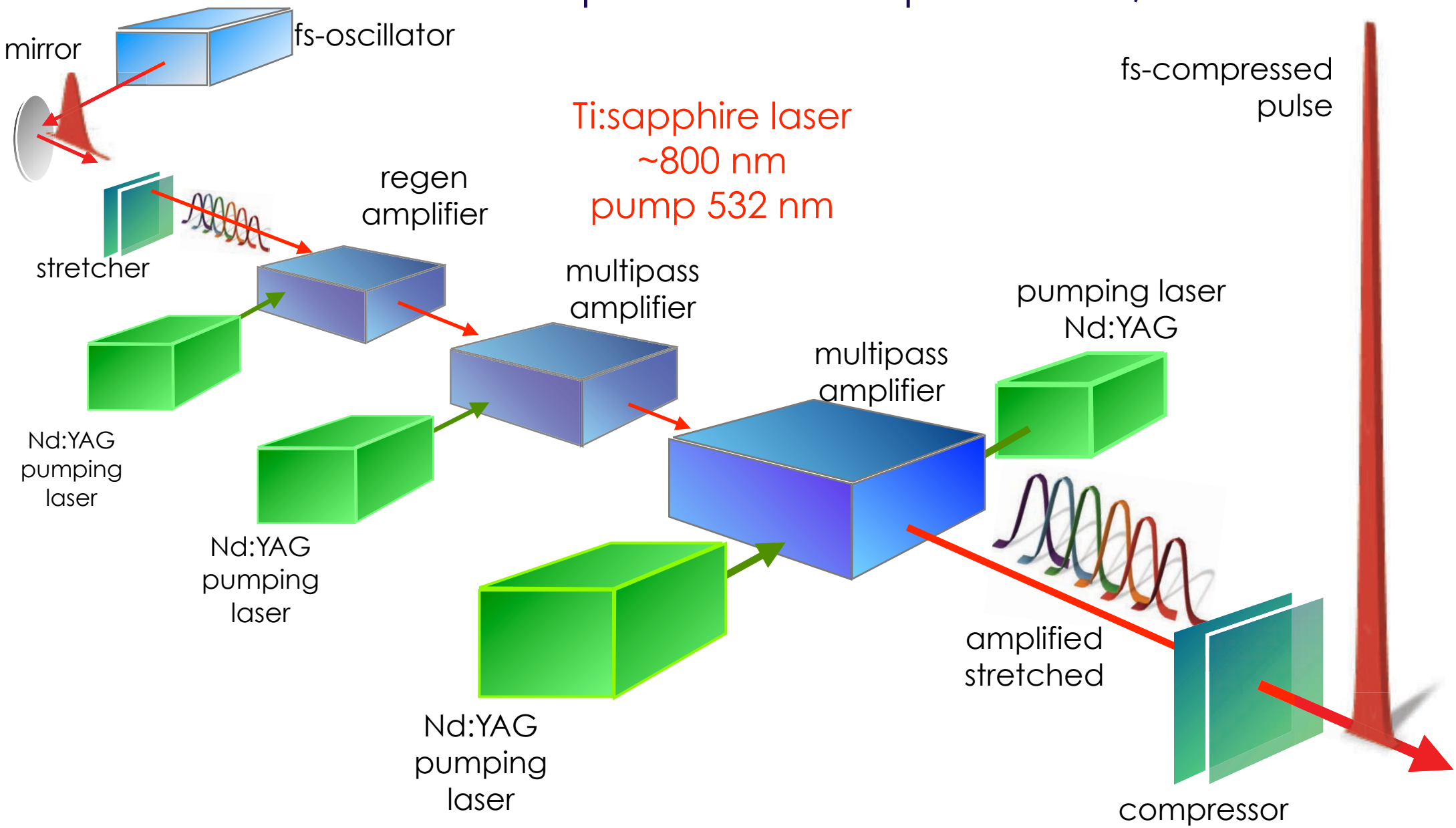
High Repetition Rate Laser-driven Proton/Ion Electron Sources

Paris, Nova
October 24th, 2016

CLPU CENTRO DE LASERES PULSADOS ULTRACORTOS ULTRAINTENSOS
Centro de Laseres Pulsados
http://www.clpu.es/

Luis Roso
Director

Chirped Pulse Amplification, CPA



Laser peak power evolution

Exawatt

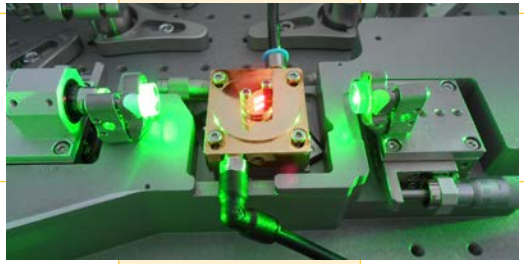
Petawatt

Terawatt

Gigawatt

Megawatt

Kilowatt

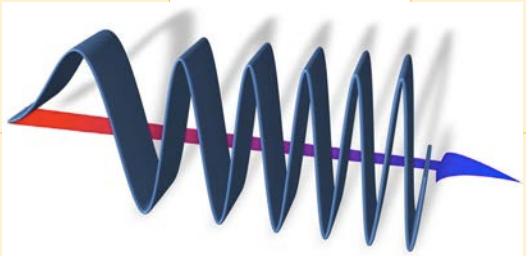


mode-locking

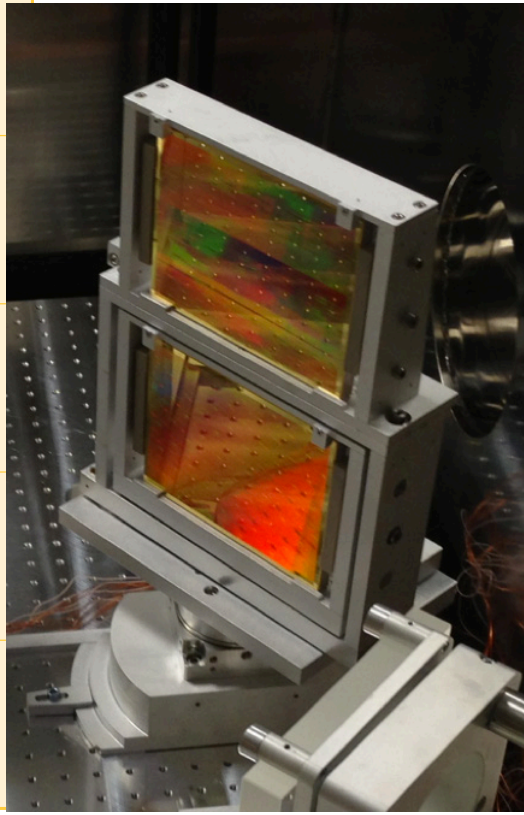
Q-switching

CPA

Chirped Pulse Amplification



10 PW



1960 1970 1980 1990 2000 2010 2020

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Petawatt

Technology
to the limit

$$PW = \frac{MJ}{ns} = \frac{kJ}{ps} = \frac{30\ J}{30\ fs} = \frac{joule}{fs}$$

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Laser acceleration

It is clear now that with a laser one can accelerate
- electrons
- protons
- ions

with a reasonable efficiency

A lot of discrepancy on the results from different labs, so many unknowns remains.

Table 2. Experimental data used in figures 38 and 40.

No.	Reference	Pulse energy W_L (J)	Pulse duration τ (fs)	Irradiance I_0 (W cm^{-2})[a]	Contrast	Target and thickness (μm)	Incidence angle (°)	Proton/ion energy $\mathcal{E}_{p(i)}$, (MeV/nucleon)
1	Snavely *et al* (2000)	423	500	3×10^{20}	1×10^{4}	CH 100	0	58
2	Krushelnick *et al* (2000b)	50	1000	5×10^{19}		Al 125	45	30
3	Nemoto *et al* (2001)	4	400	6×10^{18}	5×10^{5}	Mylar 6	45	10
4	Mackinnon *et al* (2002)	10	100	1×10^{20}	1×10^{10}	Al 3	22	24
5	Patel *et al* (2003)	10	100	5×10^{18}		Al 20	0	12
6	Spencer *et al* (2003)	0.2	60	7×10^{18}	1×10^{6}	Mylar 23	0	1.5
7	Spencer *et al* (2003)	0.2	60	7×10^{18}	1×10^{6}	Al 12	0	0.9
8	McKenna *et al* (2004)	233	700	2×10^{20}	1×10^{7}	Fe 100	45	40
9	Kaluza *et al* (2004)	0.85	150	1.3×10^{19}	2×10^{7}	Al 20	30	4
10	Oishi *et al* (2005)	0.12	55	6×10^{18}	1×10^{5}	Cu 5	45	1.3
11	Fuchs *et al* (2006)	10	320	6×10^{19}	1×10^{7}	Al 20	0 and 40	20
12	Neely *et al* (2006)	0.3	33	1×10^{19}	1×10^{10}	Al 0.1	30	4
13	Willingale *et al* (2006)	340	1000	6×10^{20}	1×10^{5}	He jet 2000		10
14	Ceccotti *et al* (2007)	0.65	65	5×10^{18}	1×10^{10}	Mylar 0.1	45	5.25
15	Robson *et al* (2007)	310	1000	6×10^{20}	1×10^{7}	Al 10	45	55
16	Robson *et al* (2007)	160	1000	3.2×10^{20}	1×10^{7}	Al 10	45	38
17	Robson *et al* (2007)	30	1000	6×10^{19}	1×10^{7}	Al 10	45	16
18	Antici *et al* (2007)	1	320	1×10^{18}	1×10^{11}	Si_3N_4 0.03	0	7.3
19	Yogo *et al* (2007)	0.71	55	8×10^{18}	1×10^{6}	Cu 5	45	1.4
20	Yogo *et al* (2008)	0.8	45	1.5×10^{19}	2.5×10^{5}	Polyimide 7.5	45	3.8
21	Nishiuchi *et al* (2008)	1.7	34	3×10^{19}	2.5×10^{7}	Polyimide 7.5	45	4
22	Flippo *et al* (2008)	20	600	1.1×10^{19}	1×10^{6}	Flat-top cone Al 10	0	30
23	Safronov *et al* (2008)	6.5	900	1×10^{19}		Al 2	0	8
24	Henig *et al* (2009b)	0.7	45	5×10^{19}	1×10^{11}	DLC 0.0054	0	13
25	Fukuda *et al* (2009)	0.15	40	7×10^{17}	1×10^{6}	CO_2+He cluster jet 2000		10
26	Zeil *et al* (2010)	3	30	1×10^{21}	2×10^{8}	Ti 2 μm	45	17
27	Gaillard *et al* (2011)	82	670	1.5×10^{20}	1×10^{9}	Flat-top cone Cu 12.5	0	67.5

Laser acceleration

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A lot of discrepancy on the results from different labs, so many unknowns remains.

Two progress lines:
- single shot to study the acceleration dynamics
- multishot to get a real accelerator.

Key Point

High Repetition Rate

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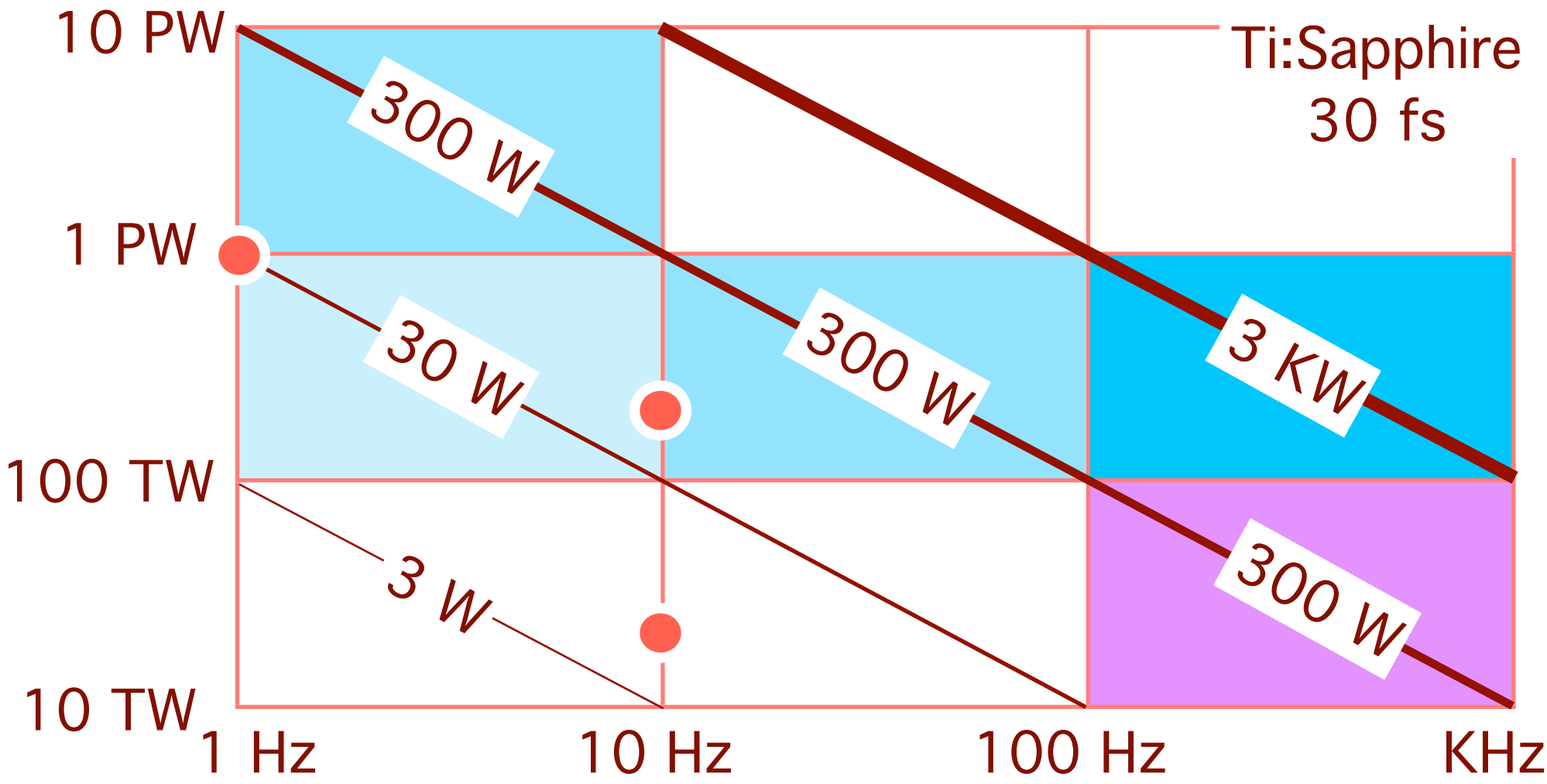
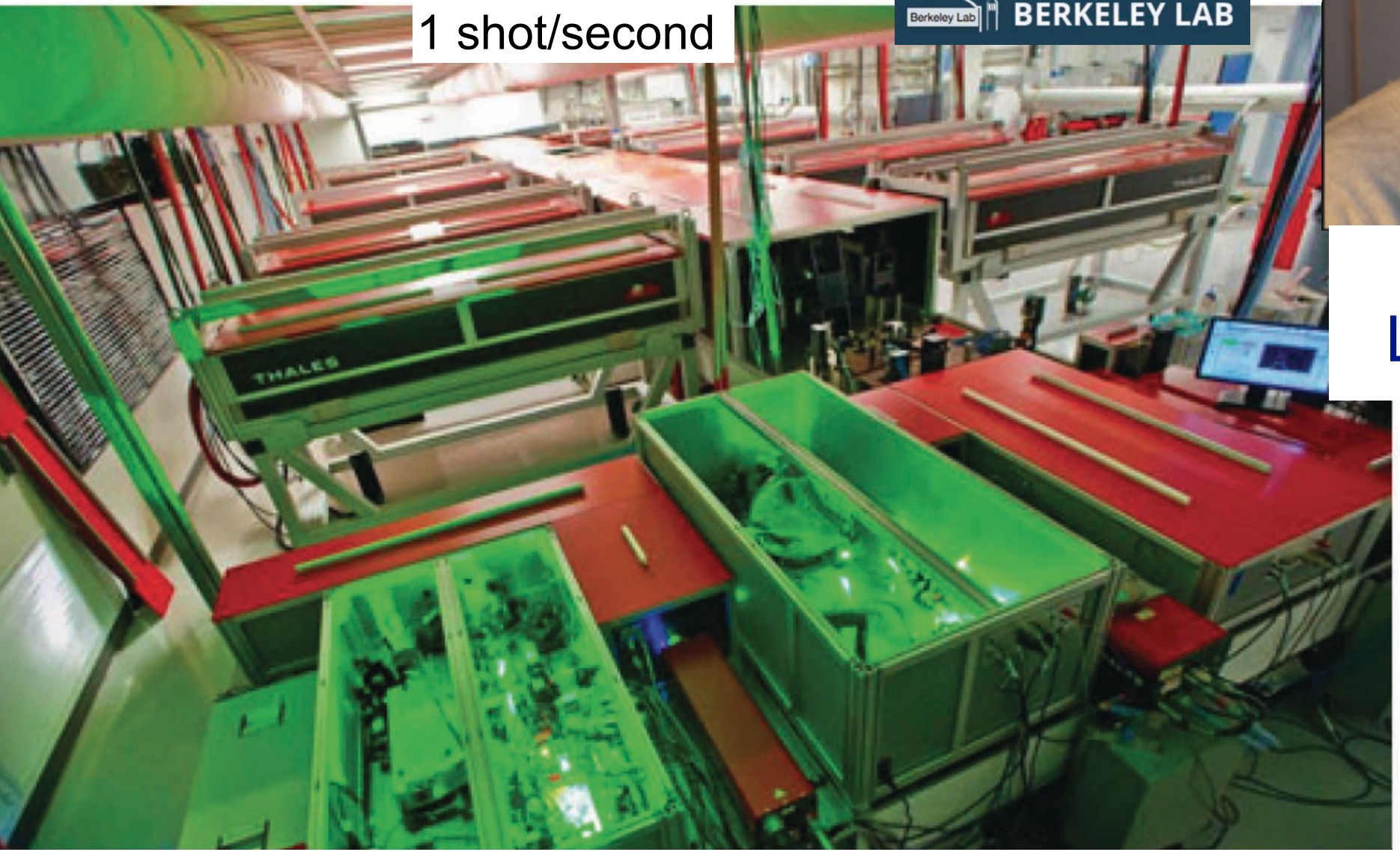
Average power



BELLA, Berkeley, USA

1 shot/second

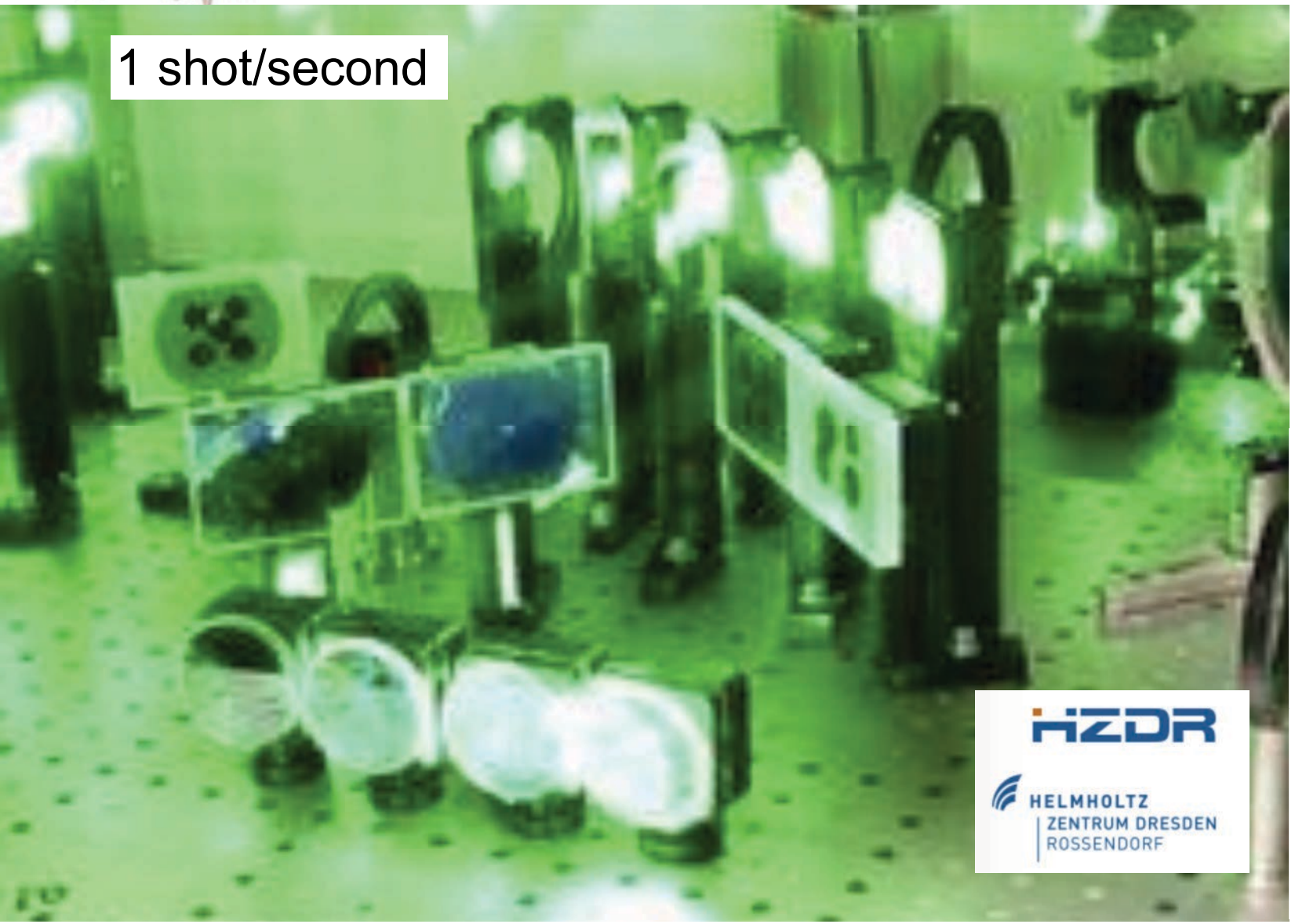


Berkeley Lab BERKELEY LAB

Wim Leemans

CLPU CENTRO DE LÁSERES PULSADOS ULTRACORTOS ULTRAINTENSOS

DRACO, Dresden, D



Ulrich
Schramm

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VEGA The Spanish PW

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Spanish ICTS

MAP OF UNIQUE SCIENTIFIC AND TECHNICAL INFRASTRUCTURES (ICTS)

GOBIERNO DE ESPAÑA

MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Infraestructuras Científicas y Técnicas Singulares

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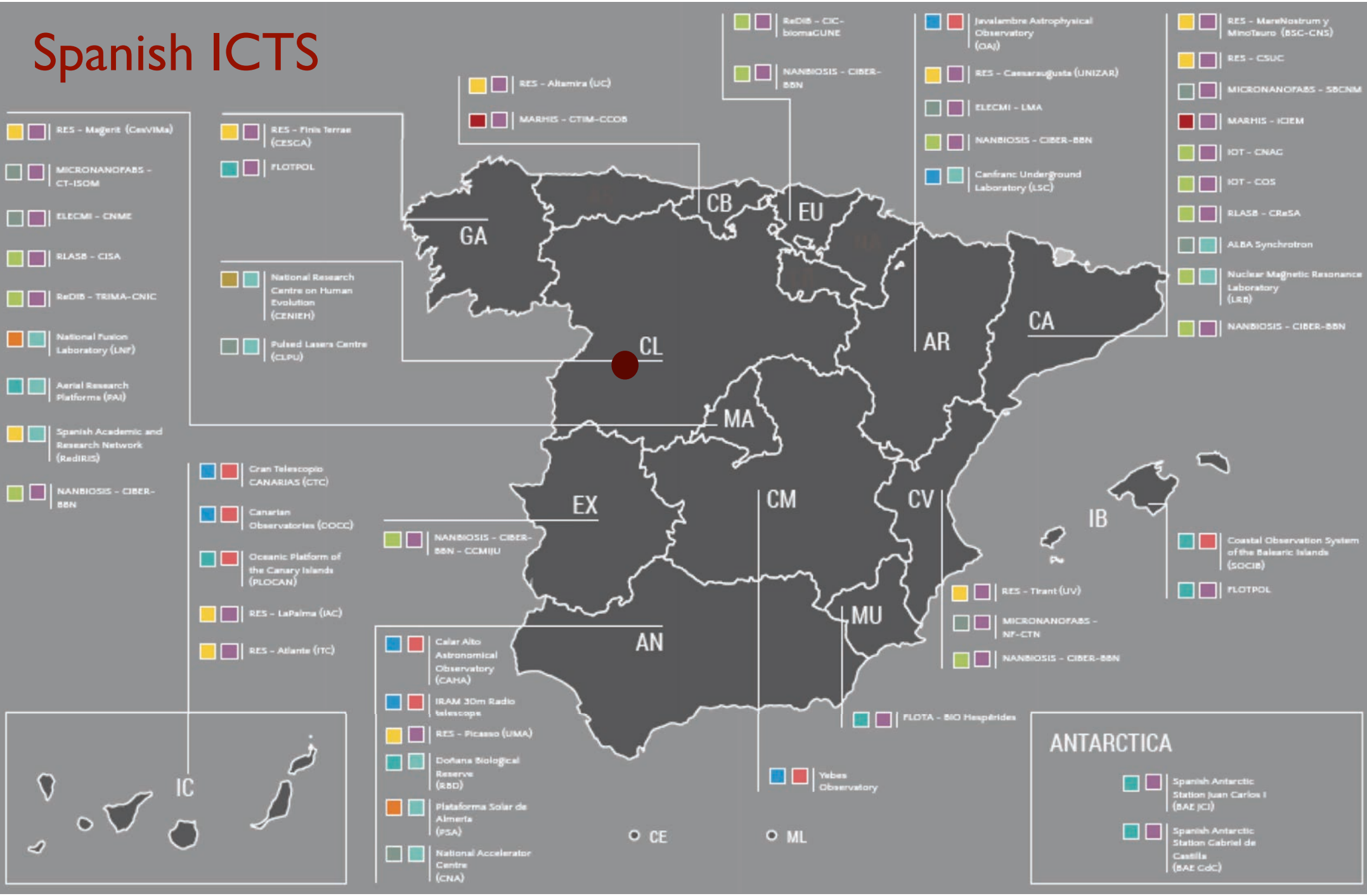
Spanish ICTS



Centro de Láseres Pulsados ... The Spanish PW Pulsed Lasers Centre, Salamanca

Spanish Government	50 percent
Castilla y León Regional Gov	45 percent
University of Salamanca	5 percent

Public Consortium established Dec 2007

CLPU CENTRO DE LÁSERES PULSADOS

MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Junta de Castilla y León

VNiVERSiDAD D SALAMANCA

Established
in 1218

VNiVERSiDAD
D SALAMANCA
CAMPUS DE EXCELENCIA INTERNACIONAL

CLPU CENTRO DE LÁSERES PULSADOS ULTRACORTOS ULTRAINTENSOS

Established
in 1218

VNiVERSiDAD
D SALAMANCA

CAMPUS DE EXCELENCIA INTERNACIONAL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Calle del Adaja
Calle del Adaja
Camino del Gudino
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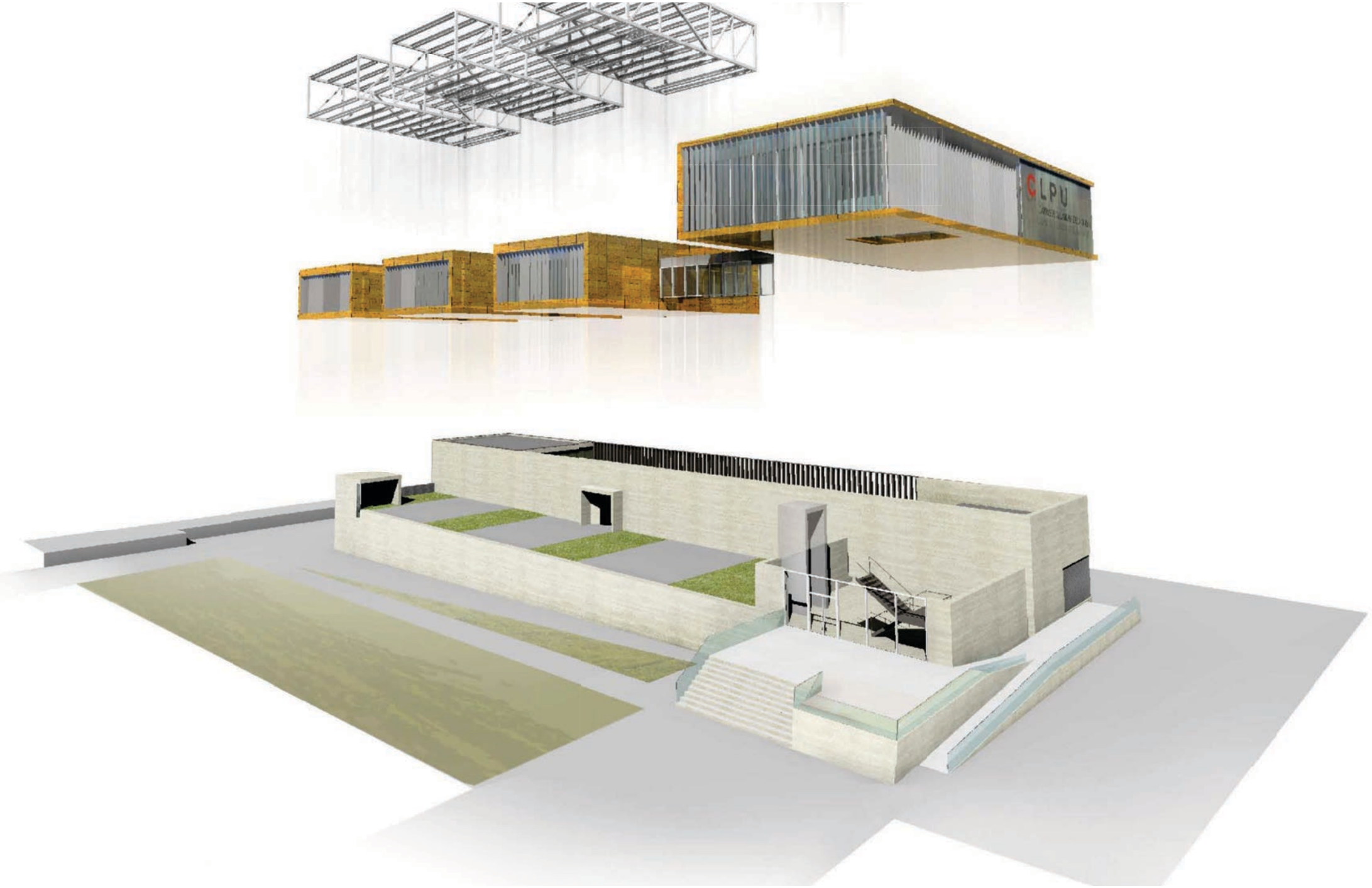
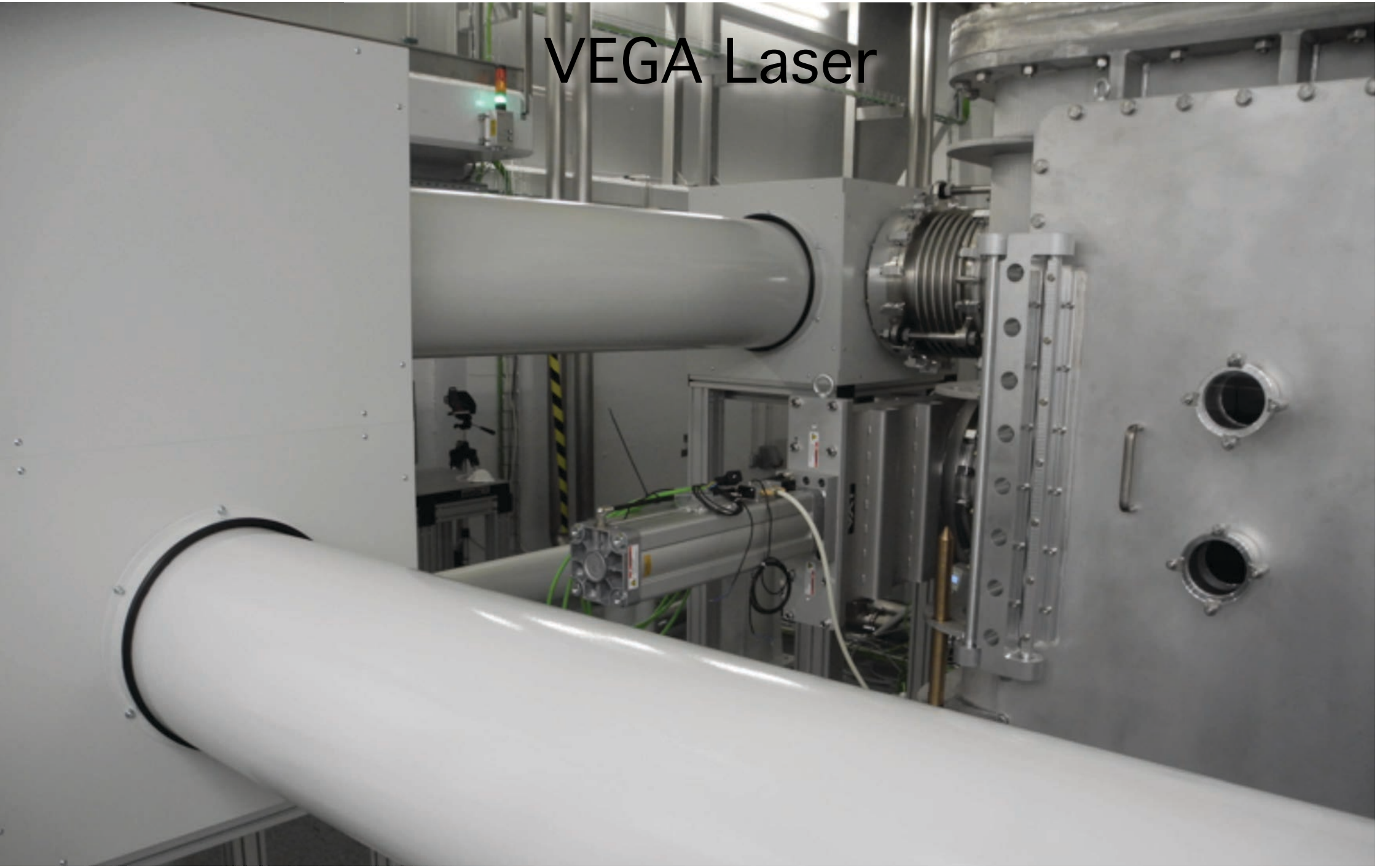
CM-547
PARQUE CIENTÍFICO
UNIVERSIDAD D. SALAMANCA

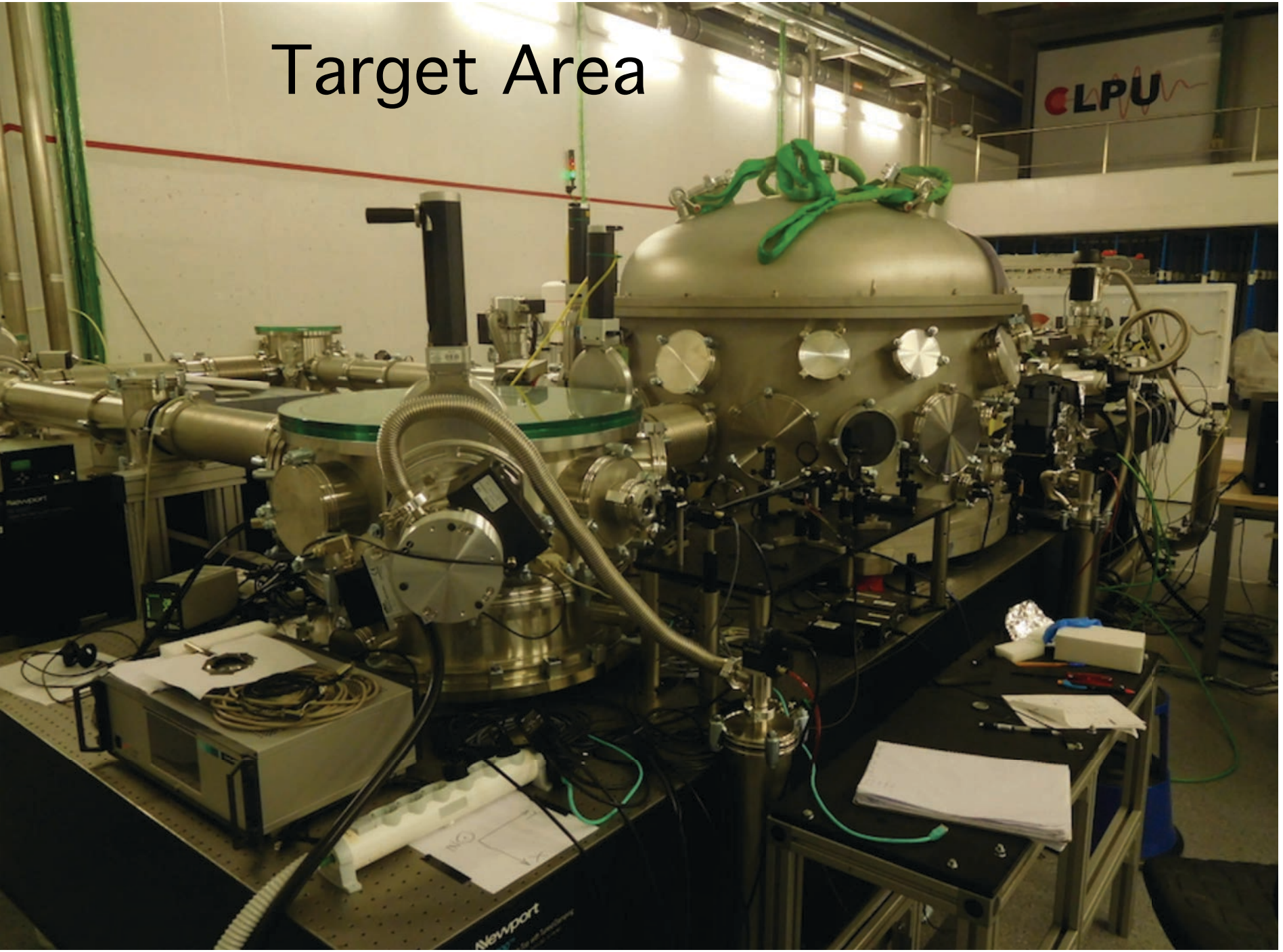
CLPU is a user facility
opened to the domestic and international
community through competitive access


CLPU

VEGA Laser


VEGA Laser

Target Area



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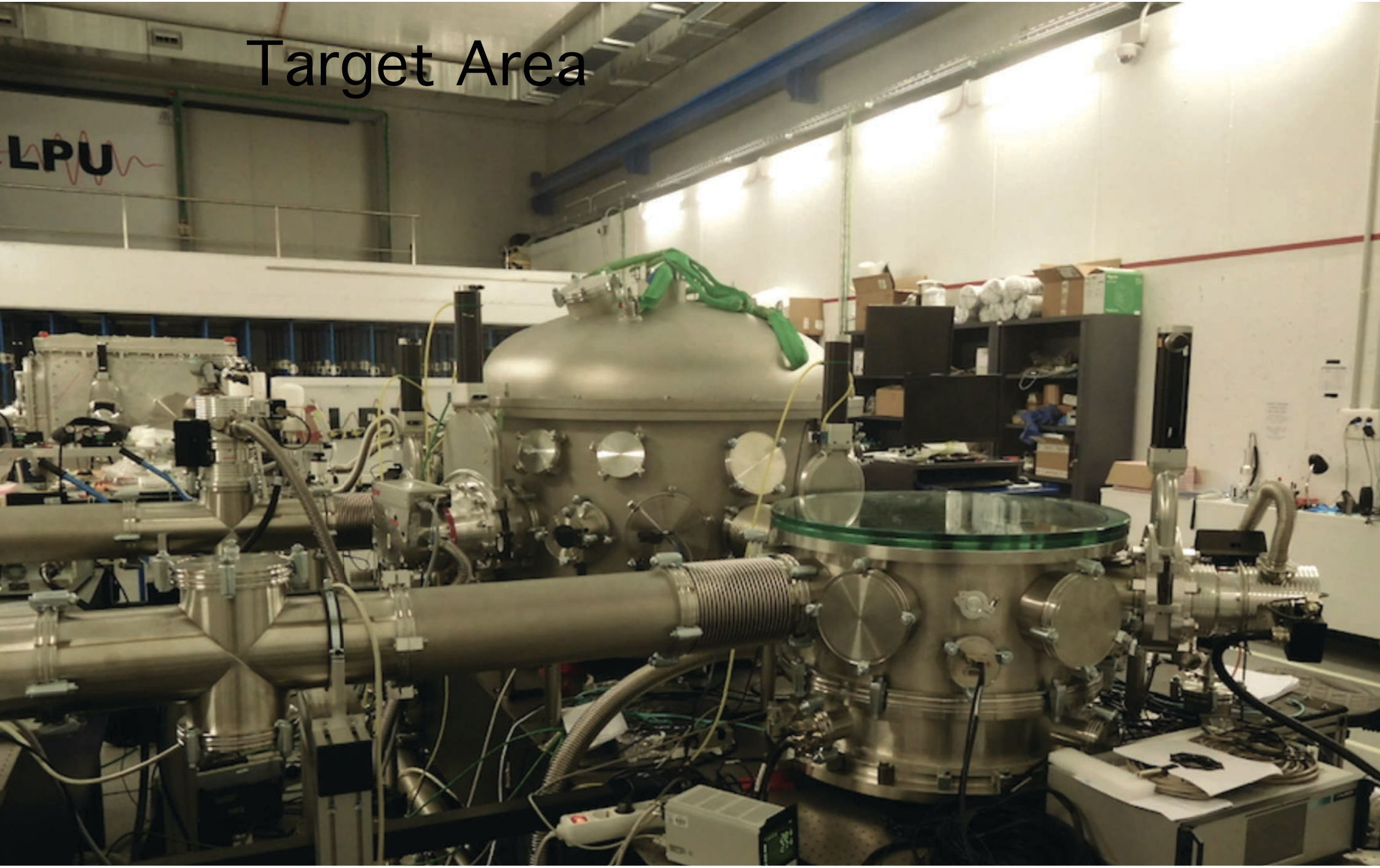
Target Area



CLPU results on electron acceleration

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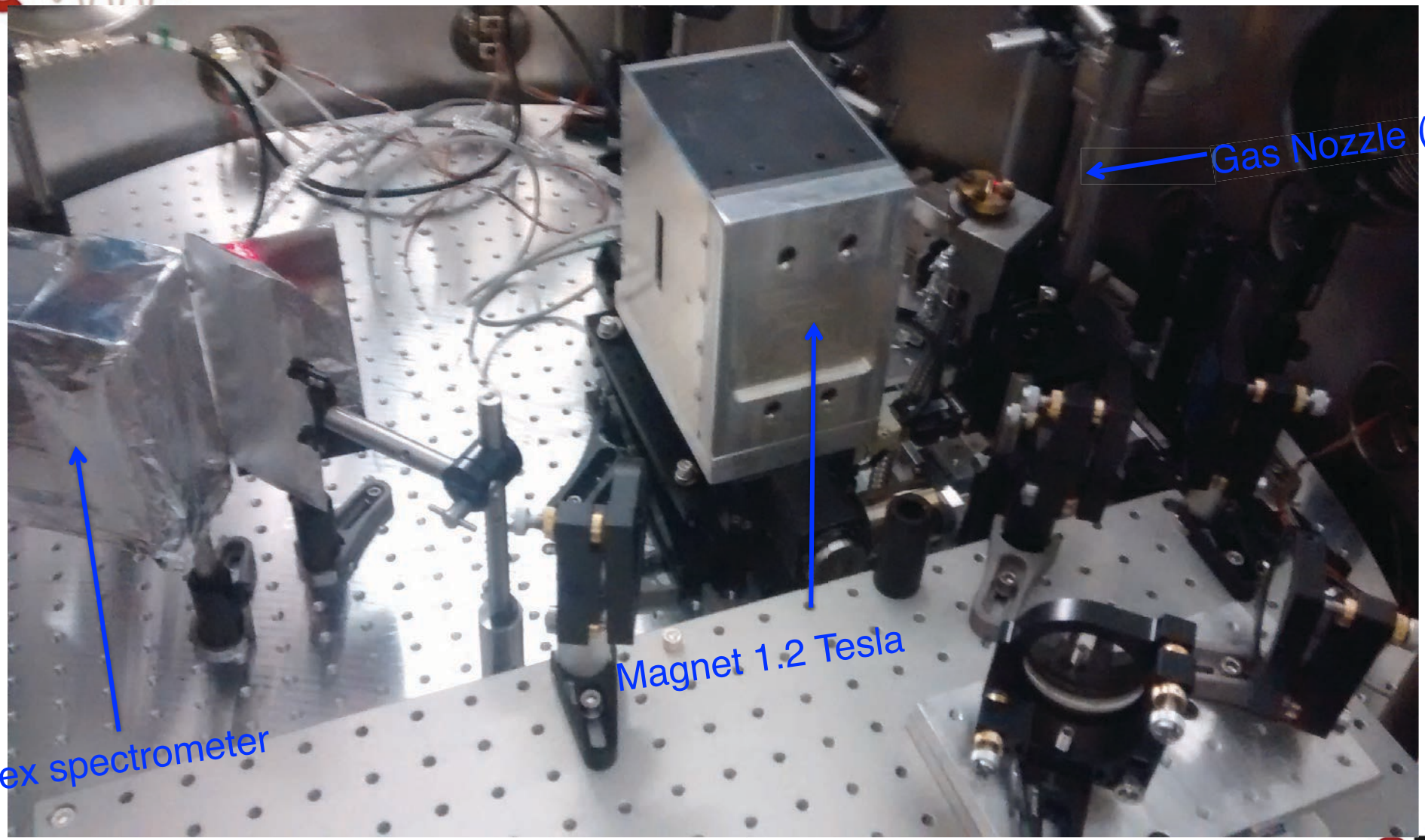
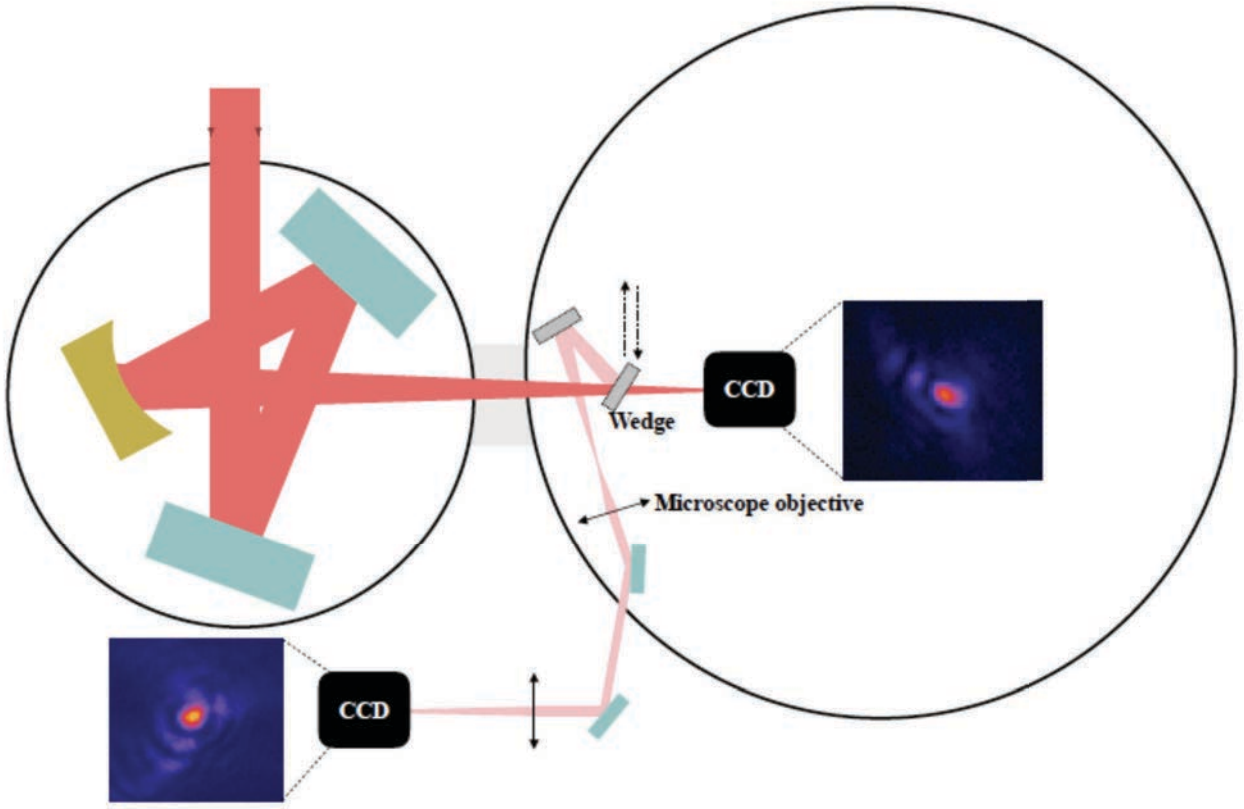
Experimental Set-up (VEGA-2, 200 TW, 30 fs)

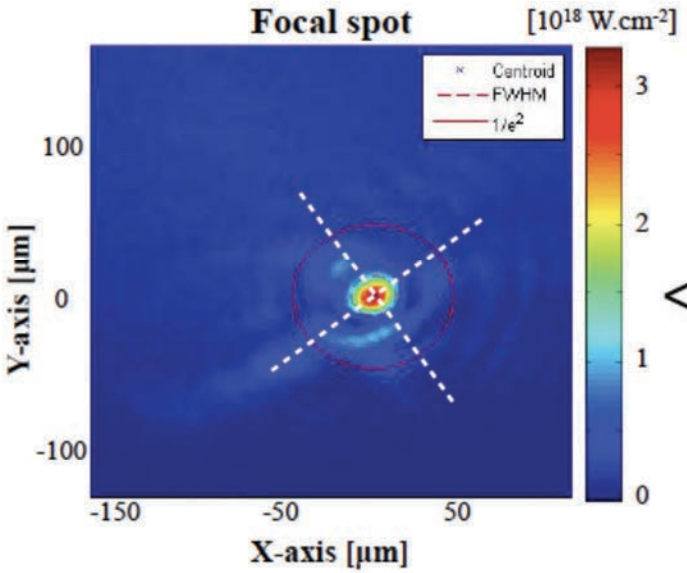


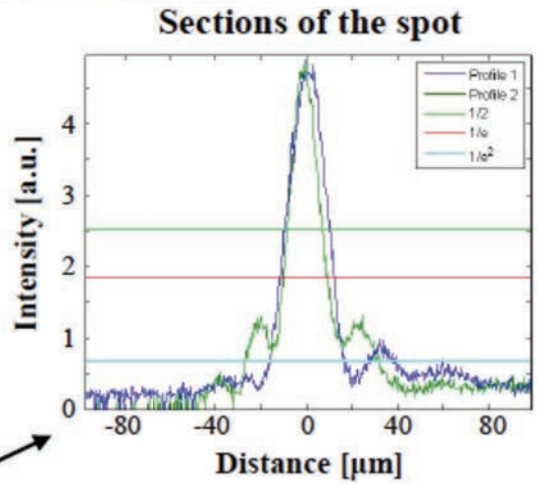
Laser spot characterization: focal spot

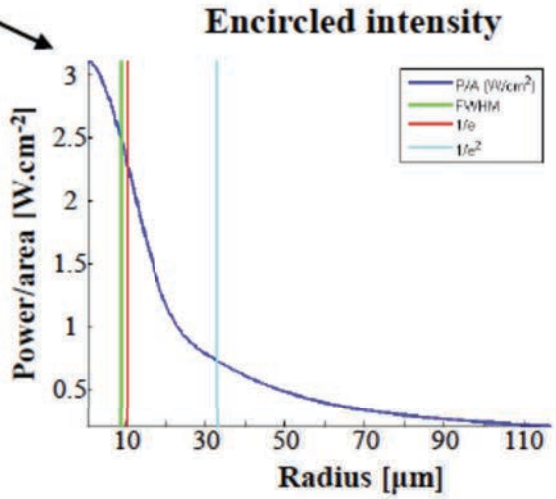


- An image of the focal spot is acquired in vacuum before each shot sequence using a “wedge” on a translation stage
- The image was compared with a direct measurement using a CCD at TCC

Laser spot characterization: focal spot analysis







Spot FWHM
18.1 µm

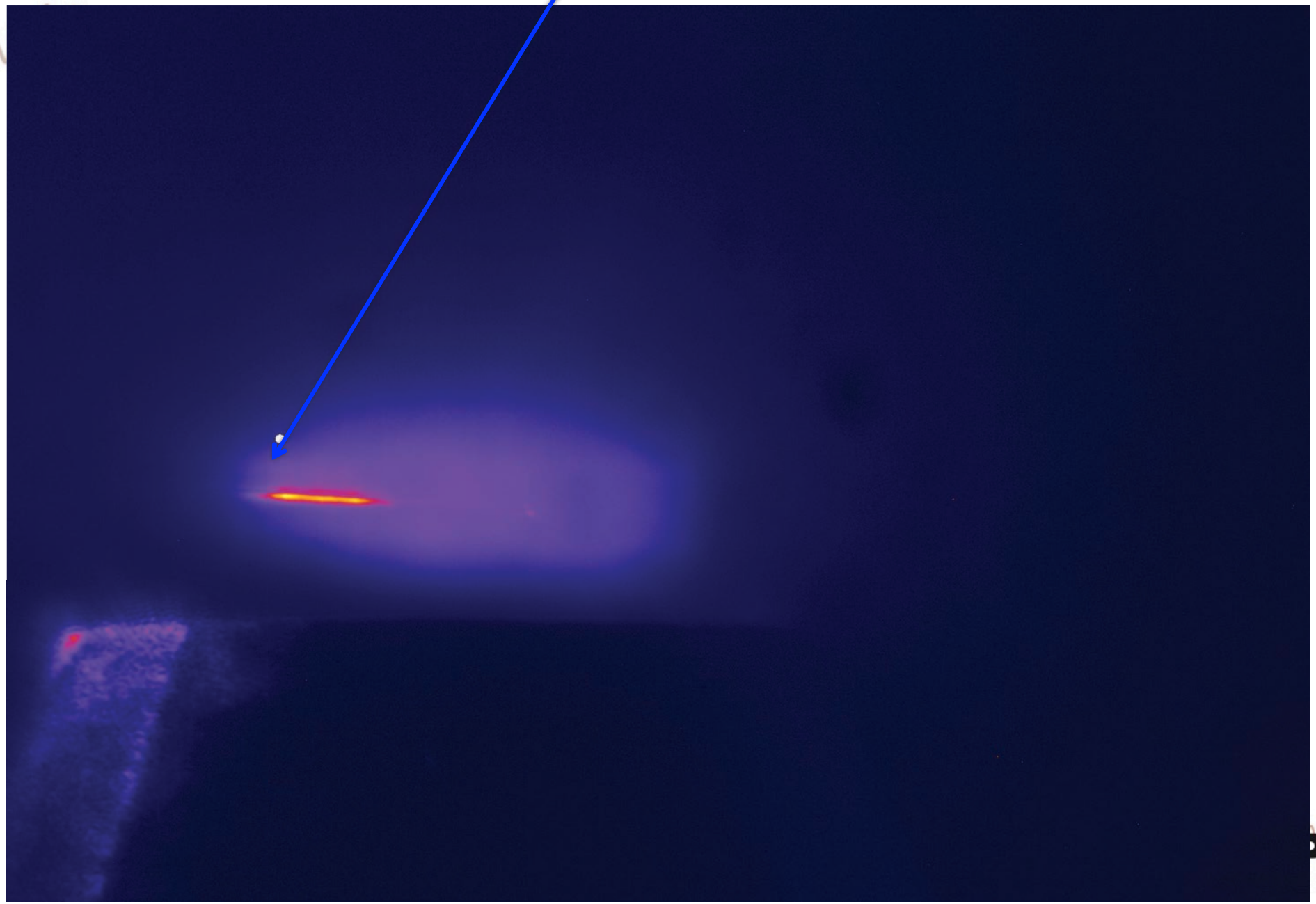
1/e2 width
66.5 µm

I at FWHM
2.4x10^{18} W/cm^{-2}

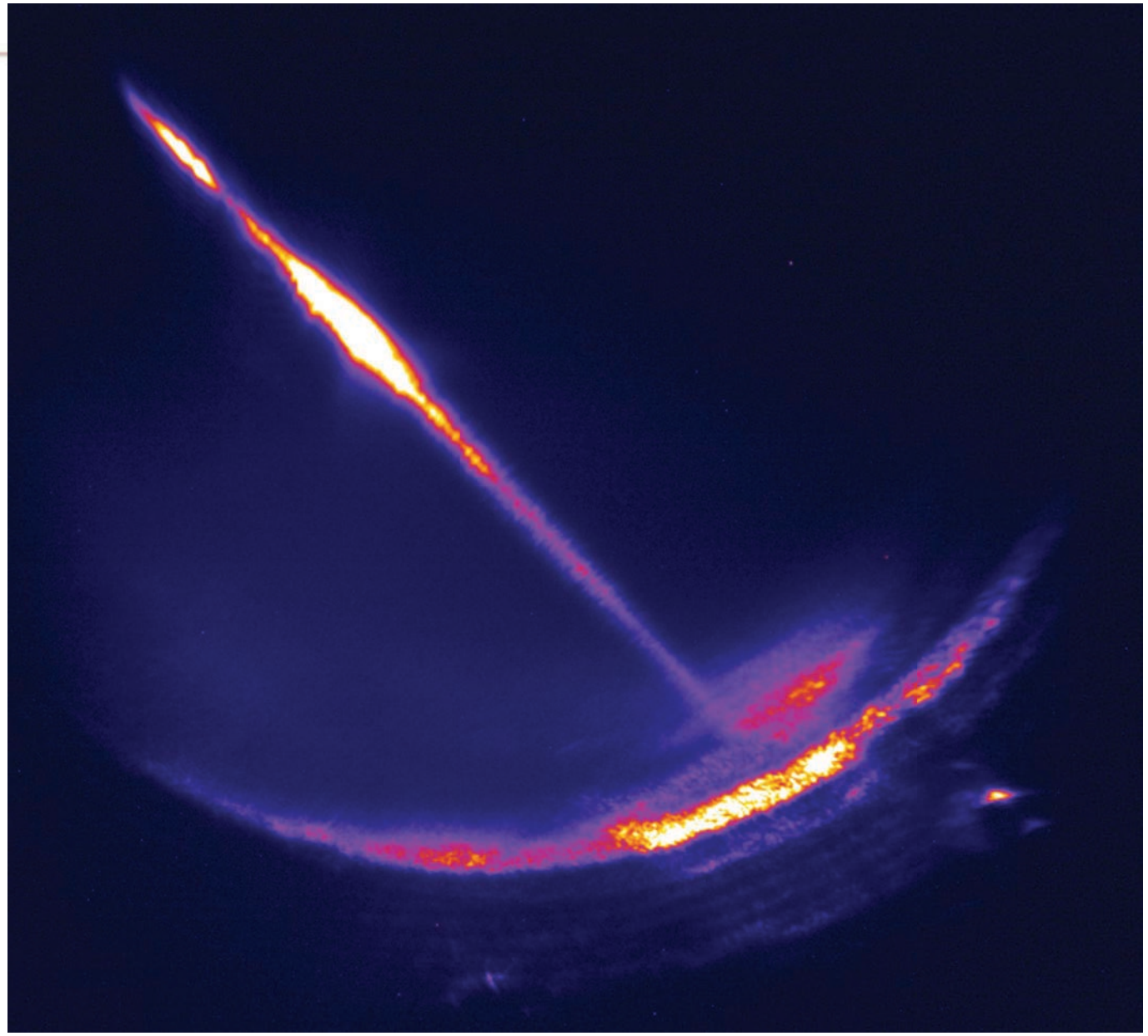
% of energy contained in FWHM
5%

% of energy contained in 1/e^2
19%

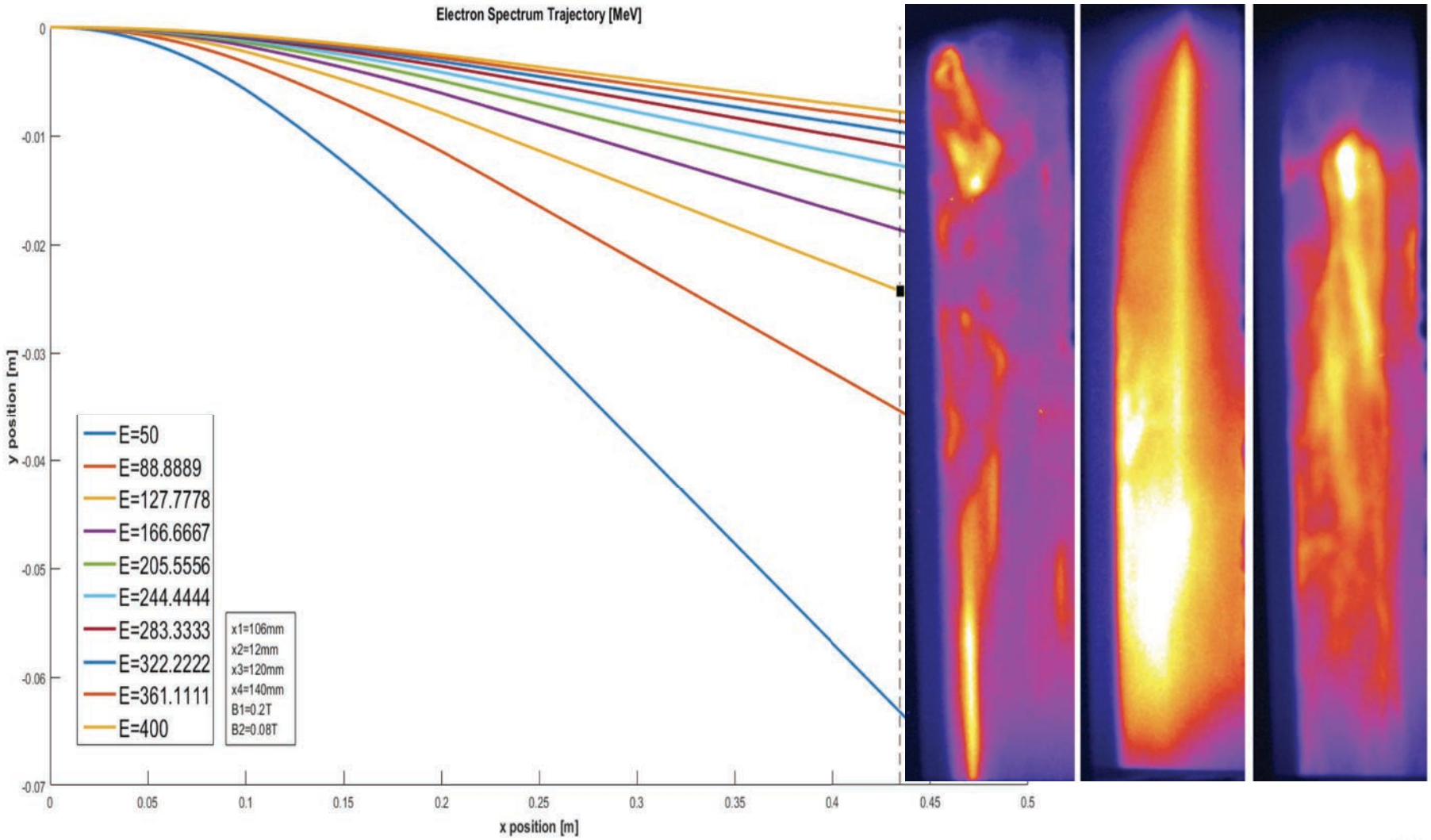
Gas jet filament (side view)



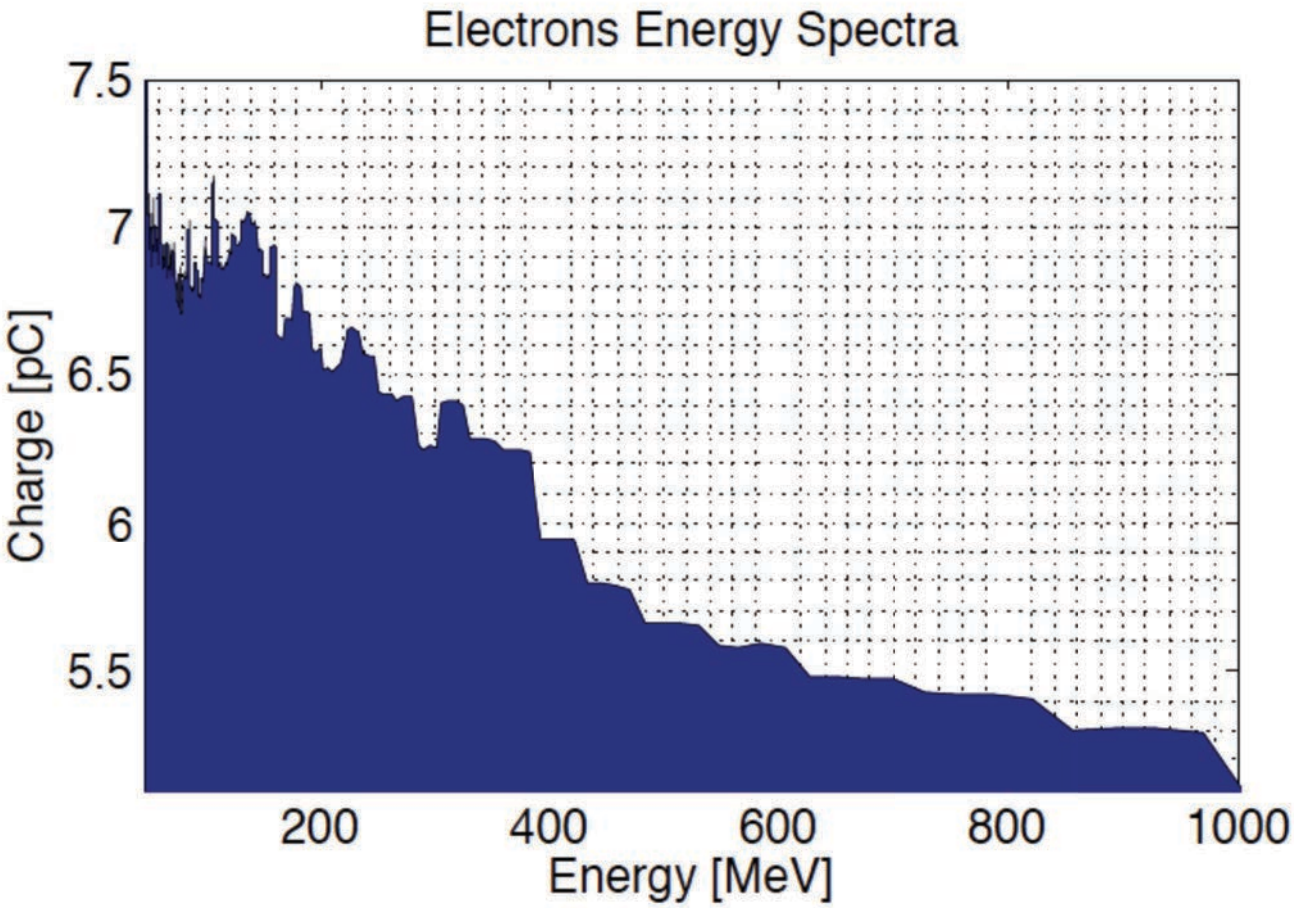
Gas jet filament (top view)

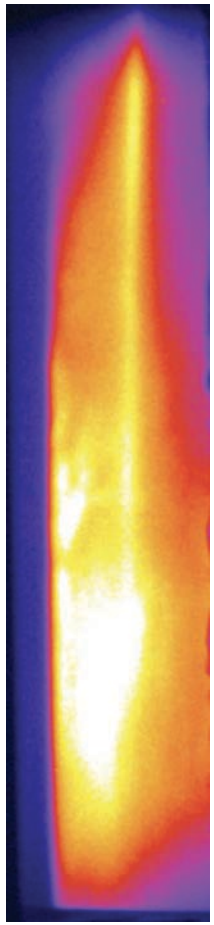


Electrons trace in Lanex spectrometer



Electrons trace in Lanex spectrometer (single shot)





Key Point
High Repetition Rate
- Laser
- Target

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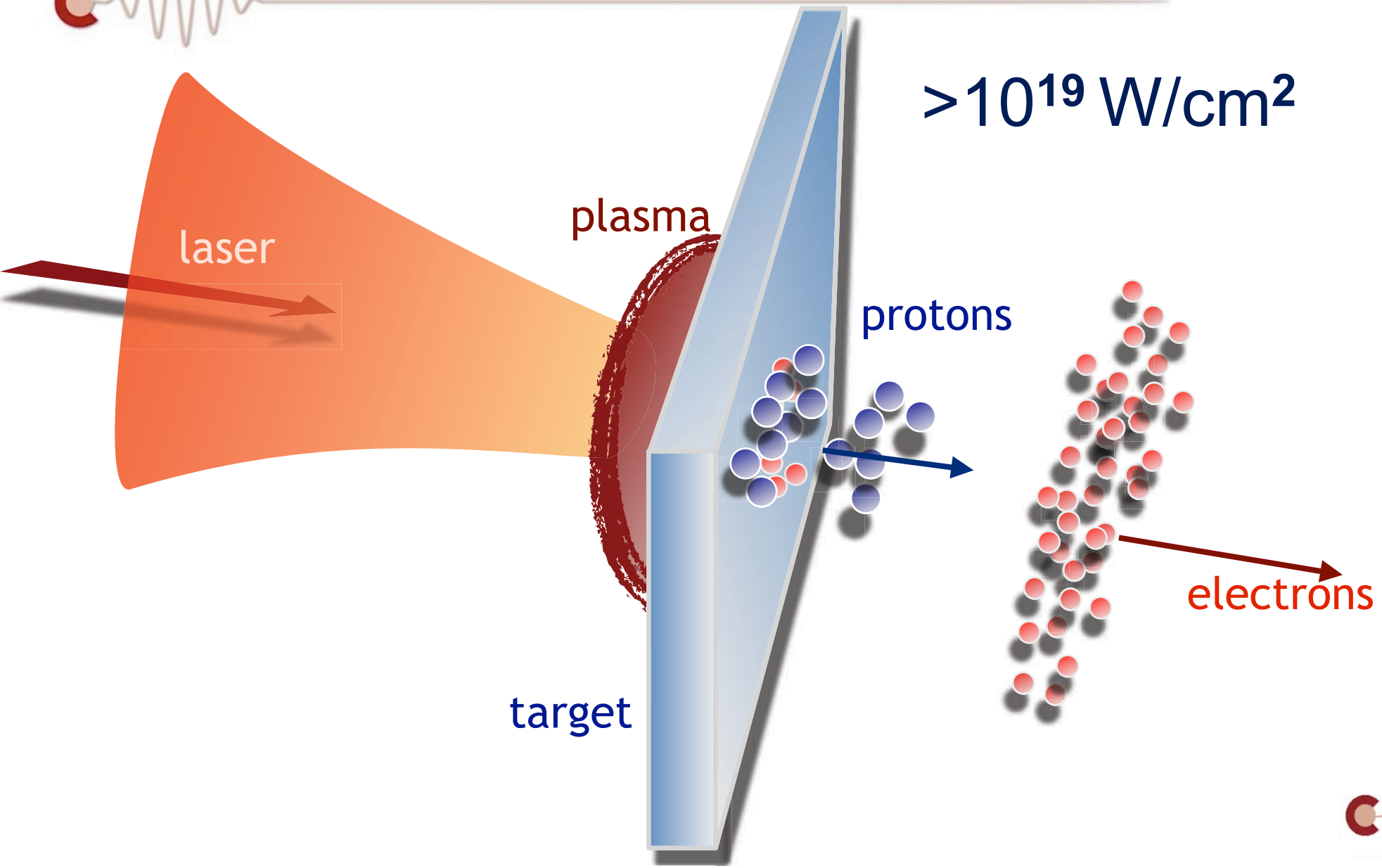
Plasma laser acceleration



CLPU CENTRO DE LÁSERES PULSADOS

Targets

Need of further research on continuous cheap targets able to work in the Hz to KHz regime

For TNSA proton acceleration ... **near solid density**

SourceLab gas target (François Sylla)
Solid Hydrogen targets (Jean Paul Perrin, CEA Grenoble)
Thin film targets

and many more

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For TNSA proton acceleration ... **near solid density**

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and many more
some of them too complicated (too nanostructured) for multishot cheap operation

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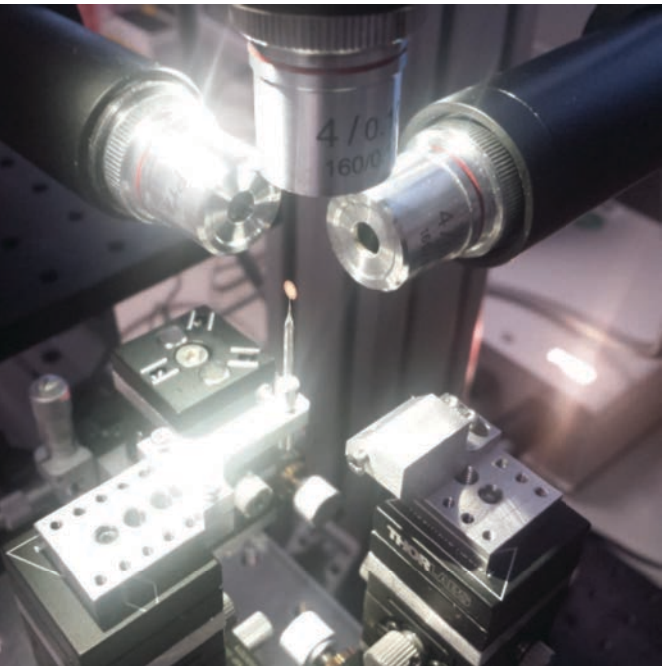
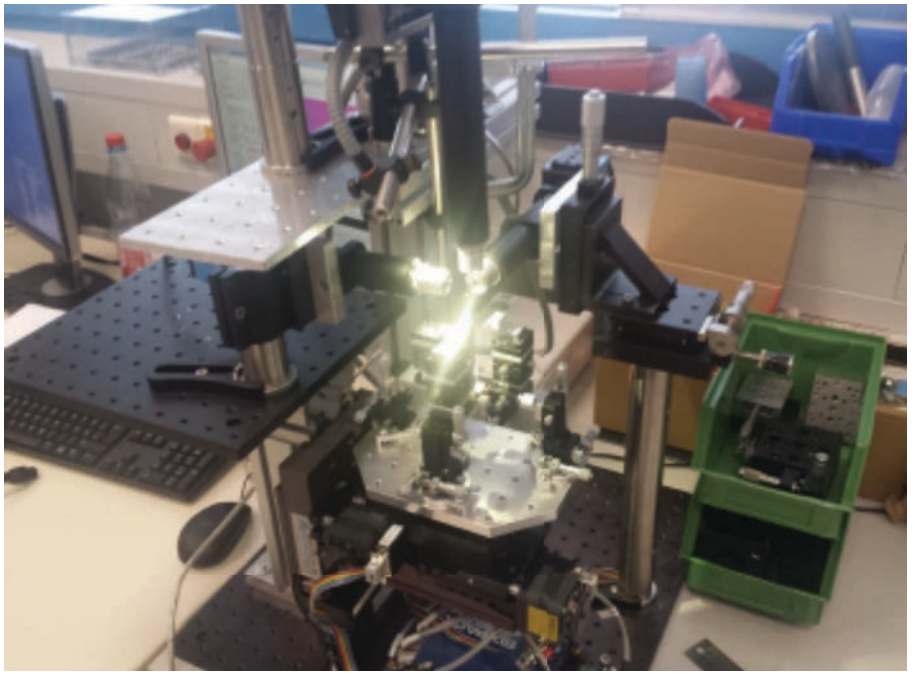
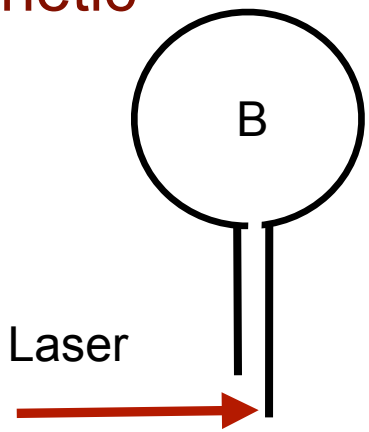
Coils to enhance the magnetic field

Kilo-tesla level using ultra-intense and ultra short laser pulses and to study the physics underlying this process of magnetic field generation by laser.

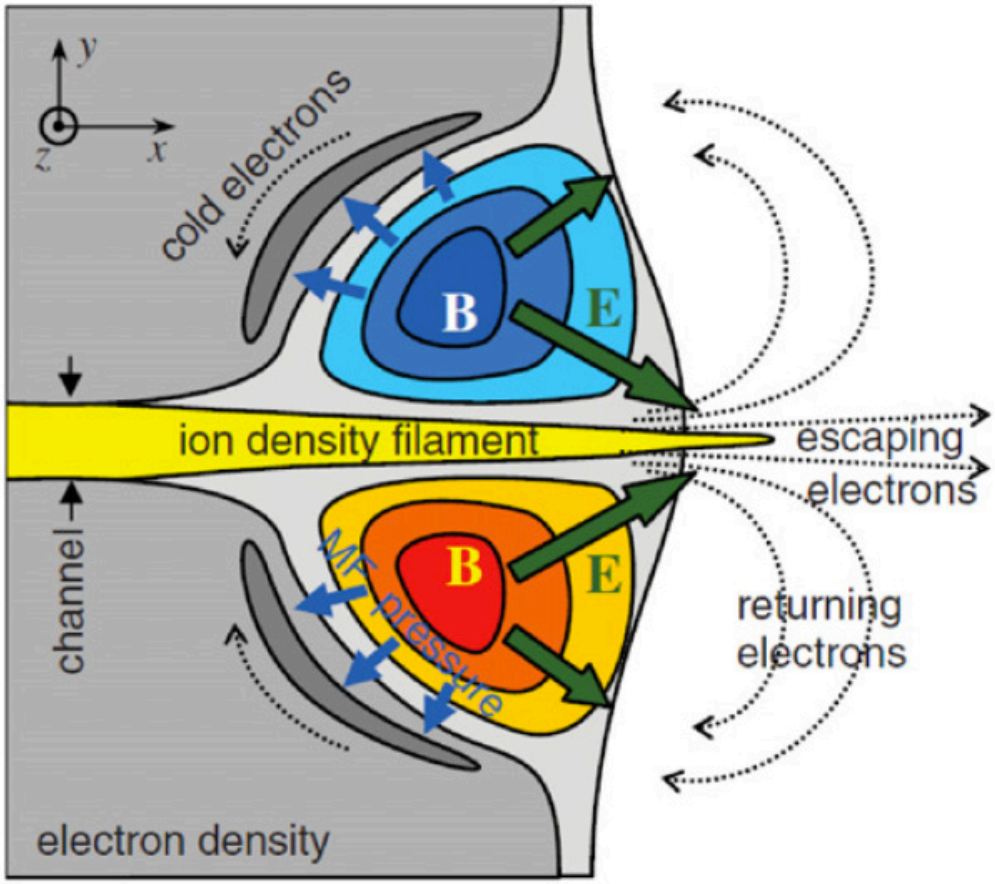






Jon Apiñaniz, CLPU, user at GSI

Laser induced acceleration



Daido et al, Rep Prog Phys, 75 (2012) 056401

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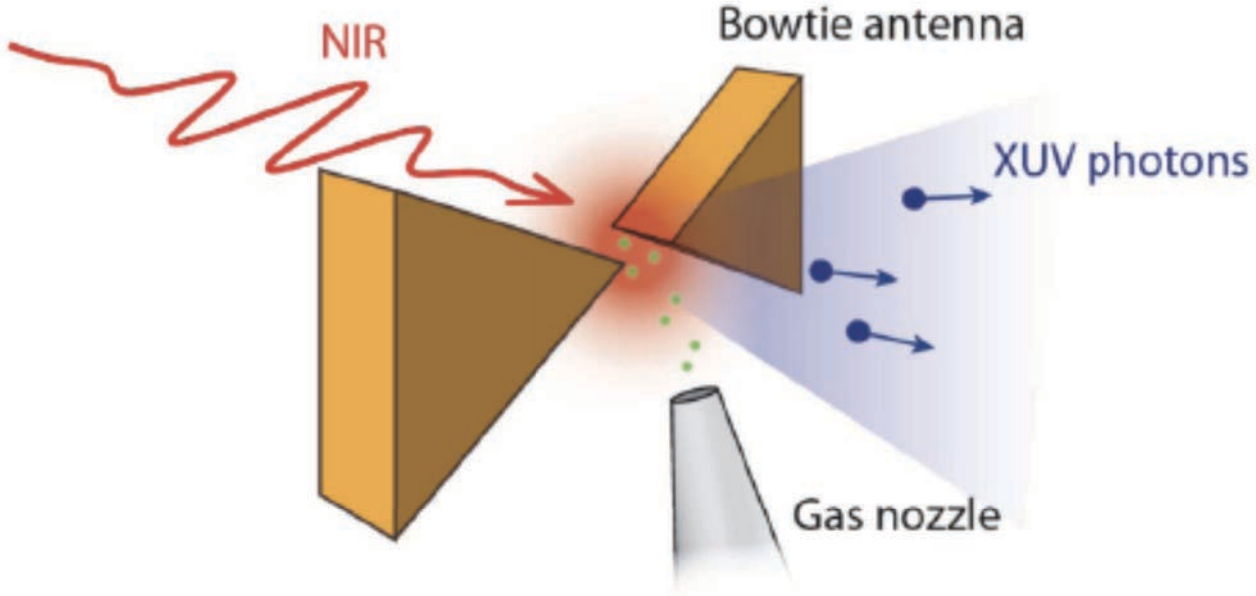
Attosecond nanophotonics

Attosecond physics at the nanoscale

Ciappina, Pérez-Hernández, ... Krausz, and Lewenstein
Invited to Reports on Progress in Physics (Arxiv)



Conclusion

Laser development maybe OK
Target development too slow

Need extra effort on 10 Hz targets that really work

Targetry Meeting
Salamanca 21–23 June 2017

Wednesday 21 to Friday 23, June 2017 | Hospedería Fonseca (Salamanca, Spain)

Co-chairs:

- Paul Bolton (München University)
- Luca Volpe (Salamanca University)
- Luis Roso (CLPU)

Organized by:

Spanish Pulsed Laser Centre, CLPU

Salamanca - SPAIN

Contact: lvolpe@clpu.es

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The **PALMA** project funded by Spanish MINECO

Laser **P**roton **A**cceleration for **M**edical **A**pplications

Ultrafast Radiotherapy: What happens when
the dose is received over a very short time

CLPU + Univ Salamanca
CIEMAT
Univ Aveiro, Portugal
Univ Maryland, USA
Univ Alberta, Canada

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The TEAM ...

Giancarlo Gatti, Head of the CLPU Scientific Division
Xavier Vaisseau, José Antonio Pérez-Hernández,
Jon Apiñaniz, Carlos Salgado, Francisco Valle,
Marine Huault, Ghassan Zeraouli, Sophia Malko,
and **Luca Volpe,**
Plasma Chair at the University of Salamanca

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VNiVERSiDAD D SALAMANCA

Cruz Méndez, Head of the CLPU Laser Team
Oscar Varela, Enrique Garcia, Jose David Pisonero,
Javier García,Irene Hernández, Jose Luis Sagredo

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Thanks !!!

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