Overview of activities at the Laser Laboratory for Acceleration and Applications (L2A2)

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Outlook

- → Who are we?
- → The L2A2 facility
- → What is our focus?
- → Conclusions

Who are we?

Who are we?

Scientists

J. Benlliure

(Full Professor)

A. Alejo

(RyC Fellow)

PhD Students

J. Peñas

A. Bembibre

A. Coathup

A. Reija

Technical staff

D. González

J.J. Llerena

L. Martín

Collaborators

D. Cortina

Y. Ayyad

Collaborators

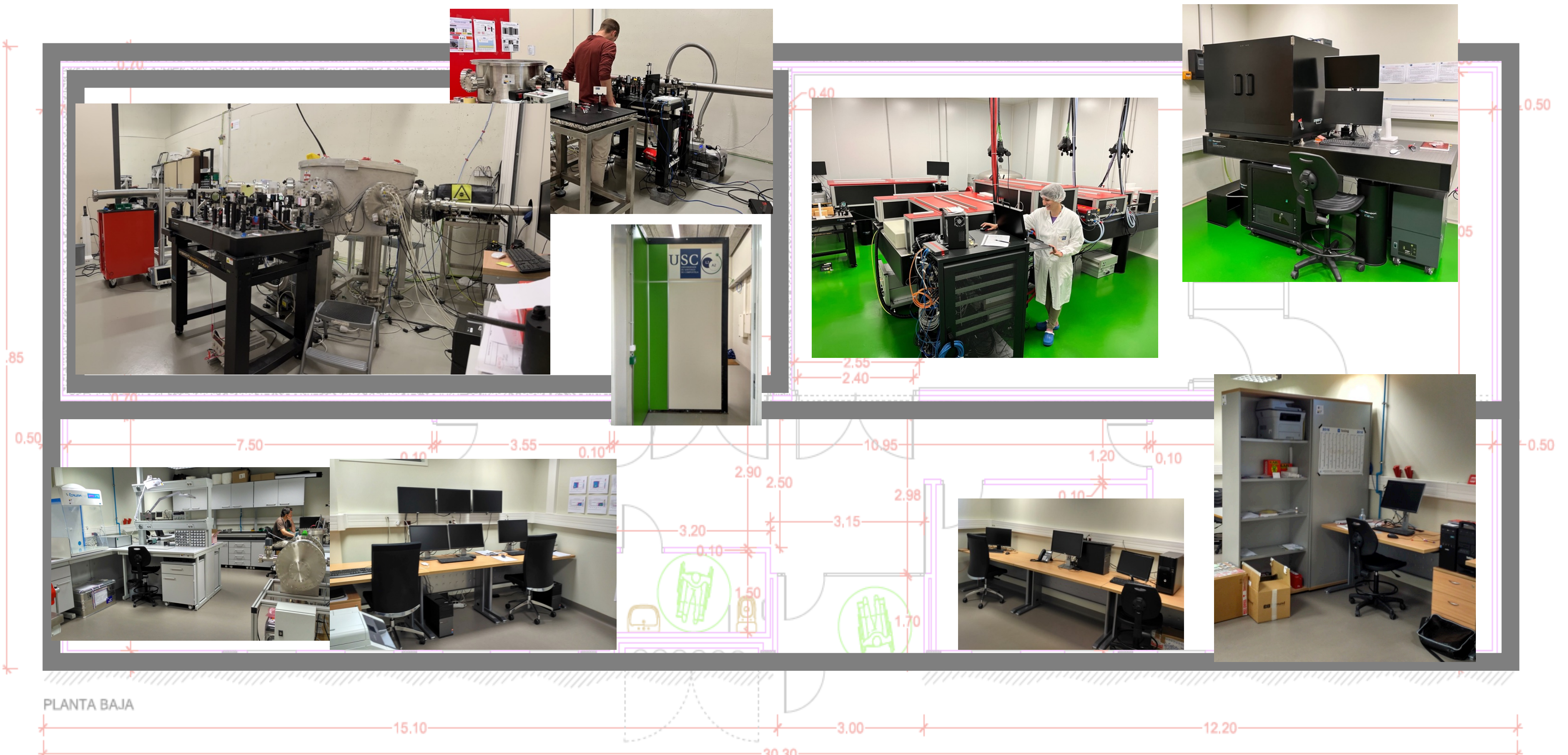
Collaborators

The L2A2 Facility

L2A2

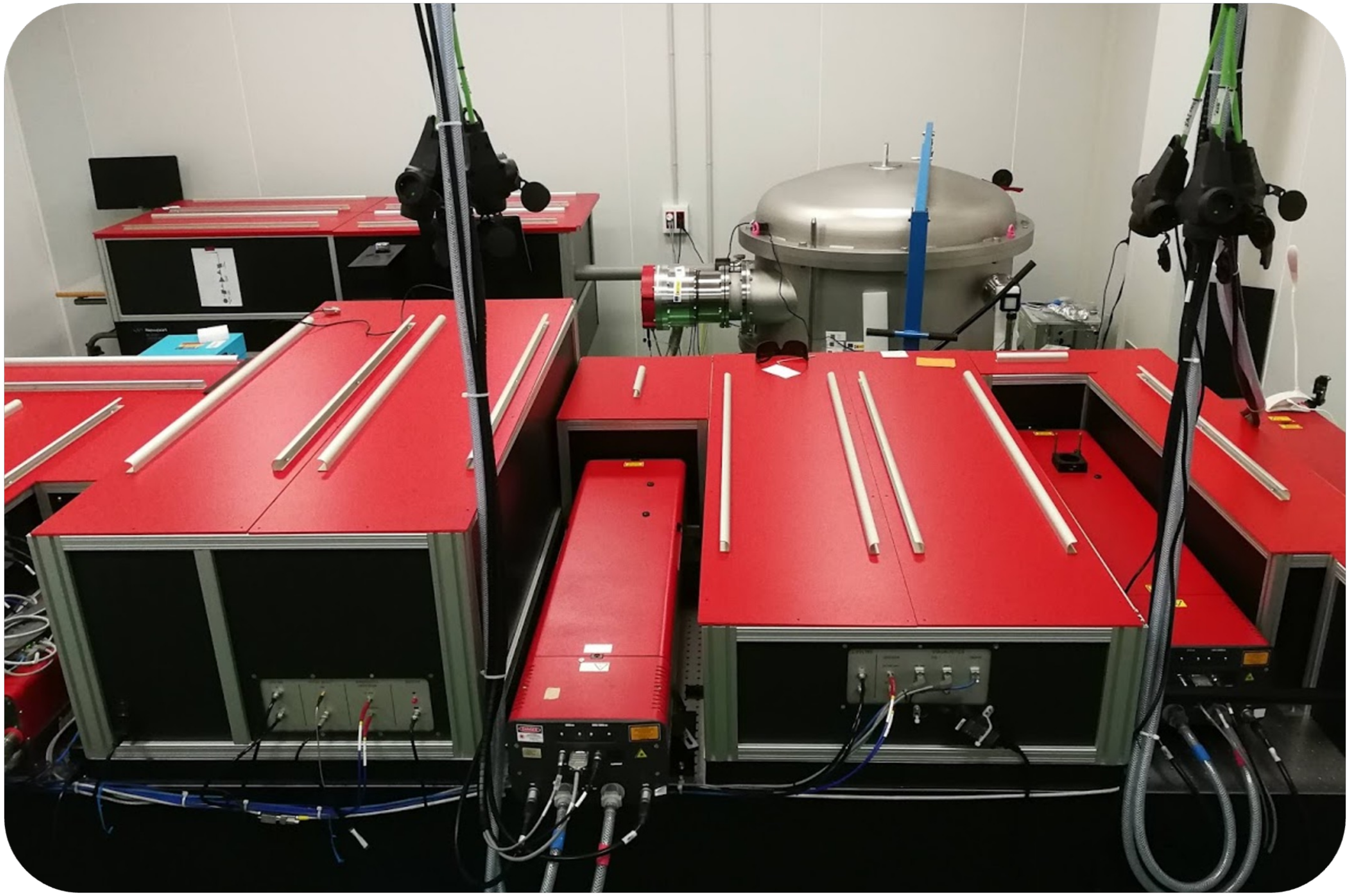
Laser Laboratory for Acceleration and Applications

L2A2



The STELA laser

45TW ALPHA 10/XS 800nm Ti:Sa laser



Mid-energy beamline

$E_{laser} \cong 1mJ$

$\tau_p \cong 32fs$

$P_{peak} \cong 30GW$

$f = 1kHz$

→ X-ray generation, phase contrast imaging ...

High-energy beamline

$E_{laser} \cong 1J$

$\tau_p \cong 25fs$

$P_{peak} \cong 45TW$

$f = 10Hz$

→ Ion acceleration, isotope production, ...

What is our focus?

IGFAE Instituto Galego de Física de Altas Enerxías | USC Universidade de Santiago de Compostela | XUNTA DE GALICIA

Research lines

Stable **particle acceleration** and radiation production

using high power lasers, and **applications** of these sources

Sources

Ion acceleration

X-ray sources

Secondary neutrons

HRR targetry

Target wheel

Cu disk

Tape drive

Diagnostics

Plastic scintillators

Fibre scintillators

Laser characterisation

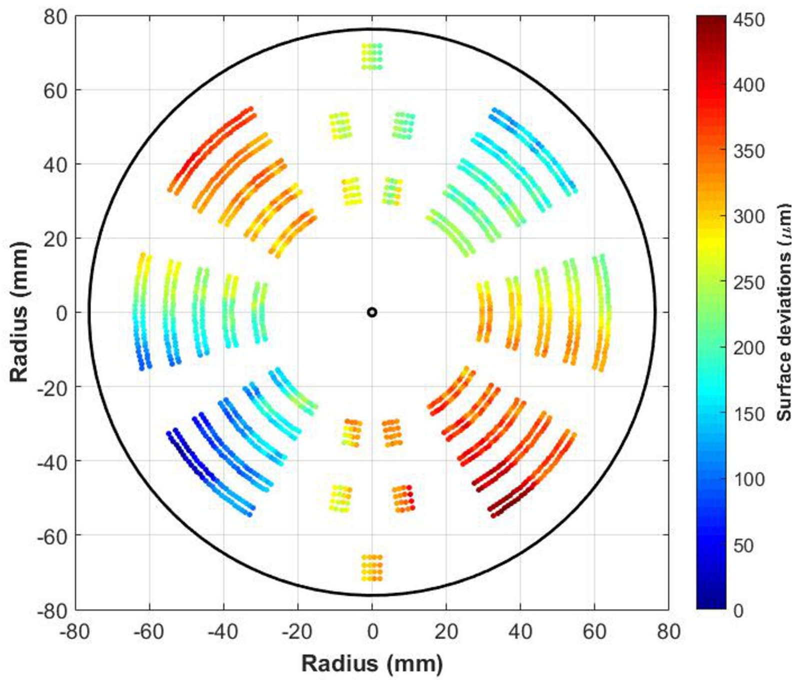
Applications

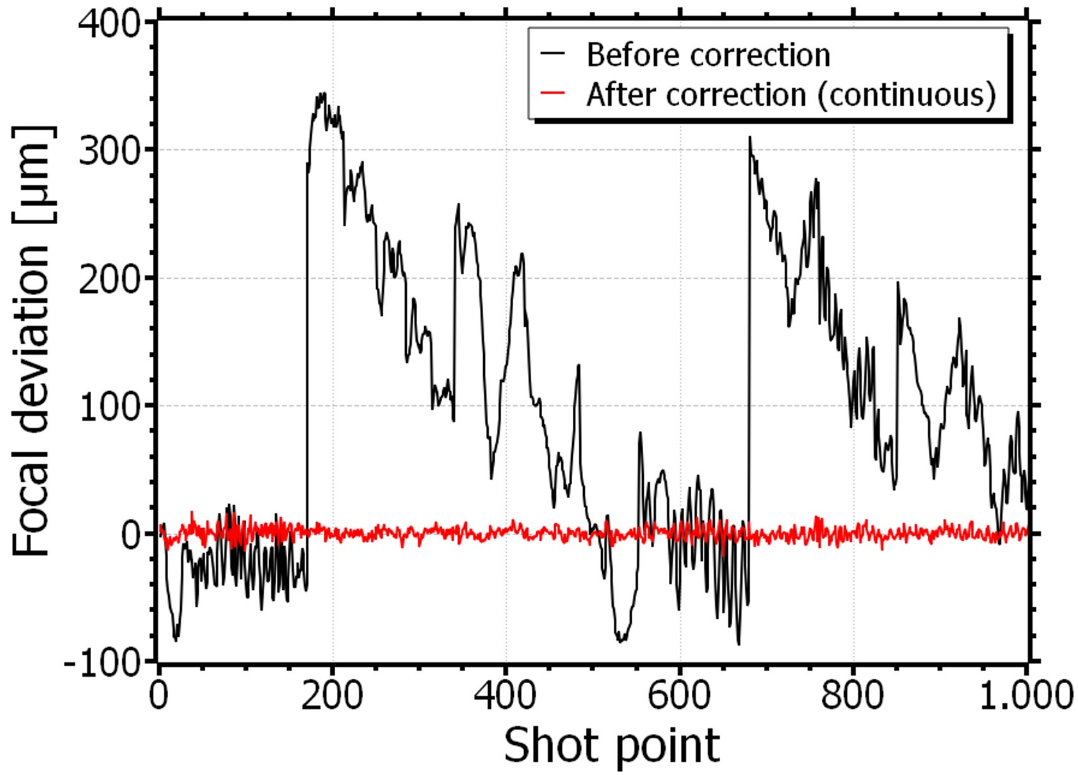
Activation

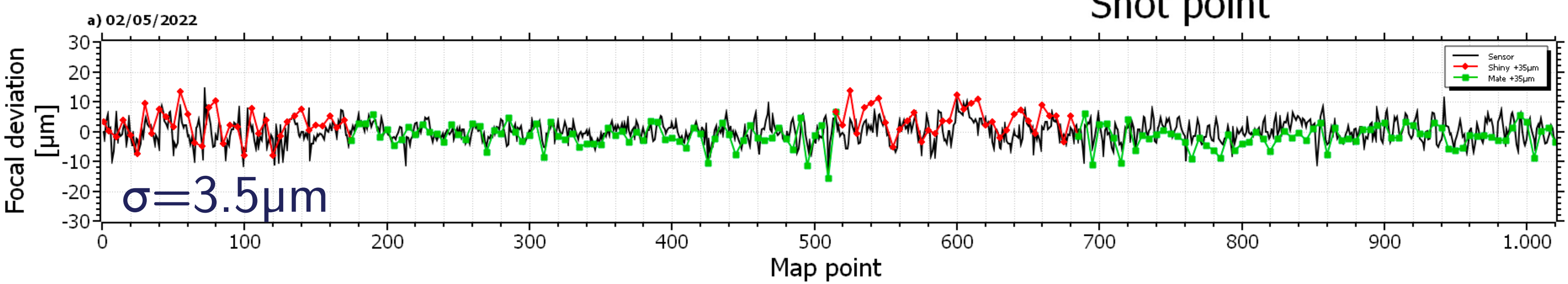
Radio-therapy

Imaging

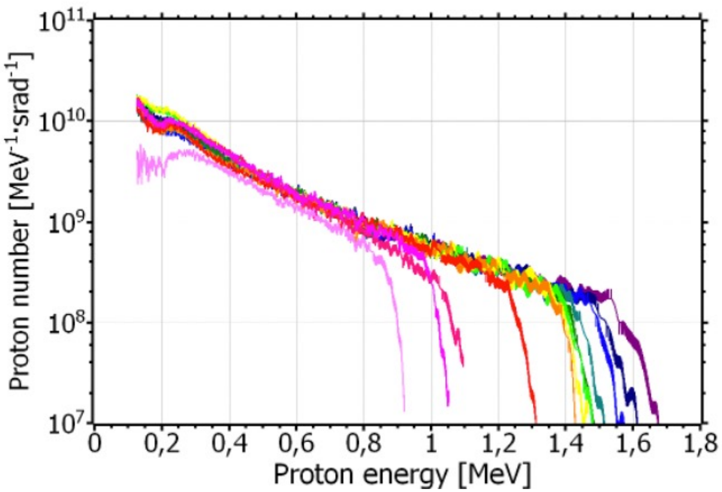
Target development (I): Wheel

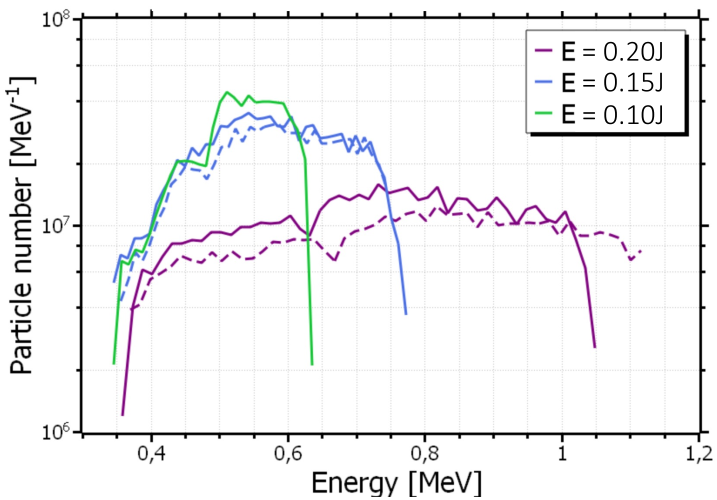






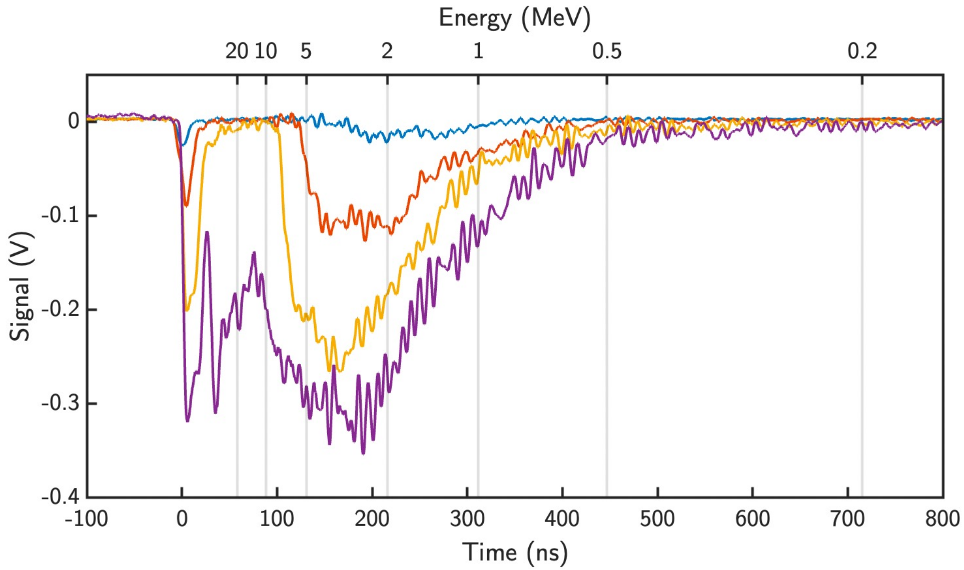
Sources (I): 10Hz Ion acceleration



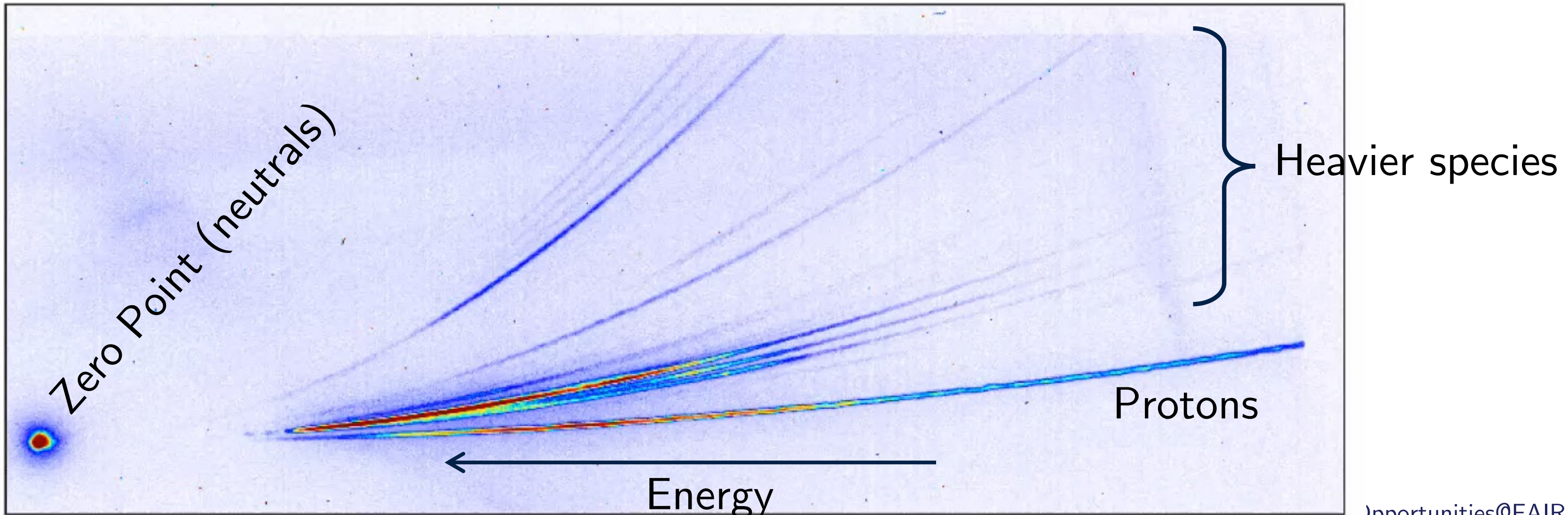


- → Tests performed at low laser energy (≲200mJ)
  - → Despite this, >1MeV ions have already been produced
- → Stable operation @ 10Hz already demonstrated experimentally
  - → ≅13% stability in maximum energy and temperature
- → Currently **upgrading laser** system to use laser energies up to 1J

Sources (II): 1PW Ion acceleration

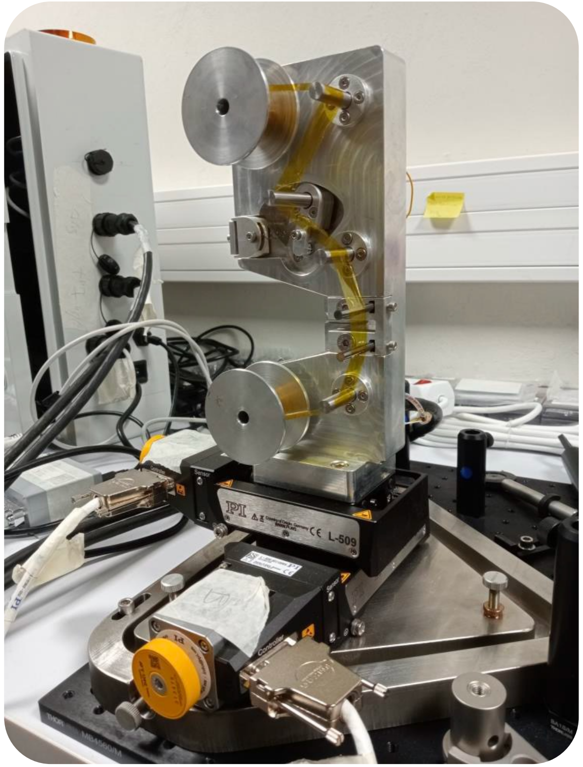


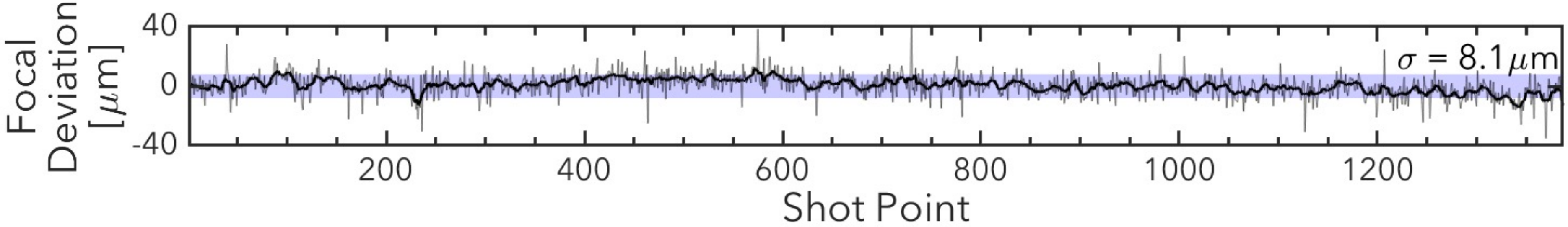
- → Due to the extreme power, significantly larger craters and post-irradiation deformation would be produced ⇒ **modified target wheel design**
- → Successfully accelerated ions at rates of up to 1Hz and laser energies up to 30J
- → Versatility of the wheel design shown by stable ion acceleration at these energies



Target development (II): Tape

- → The target wheel significantly increases the rep rate and number of shots with respect to most alternatives.
- → However, the maximum number of shots needs to be further increased
- → A tape target is currently being developed that would allow for continuous ion production for extended (hours) periods of time



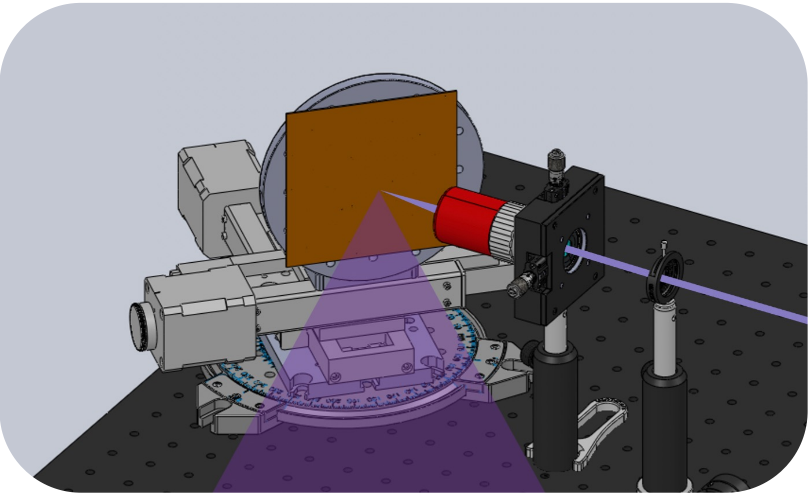


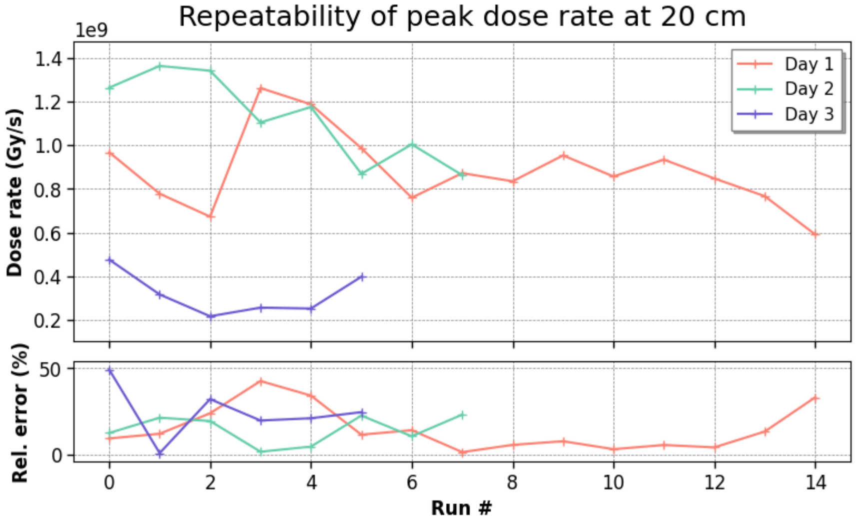
Sources (III): X-Ray generation

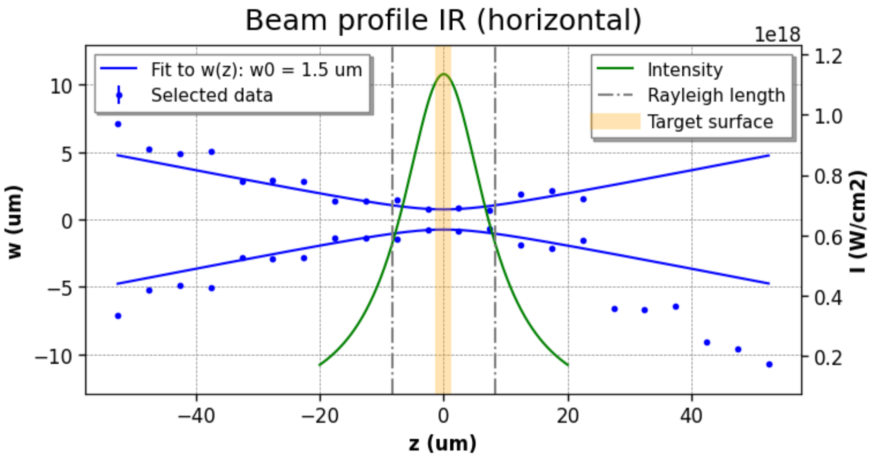
→ Generation of a **stable** X-ray source operating at **high repetition rate** (1kHz)

→ The mid-energy beamline is focused onto a rotating Cu target using a microscope objective

→ The target needs to be replaced continuously while remaining within the Rayleigh range of the laser



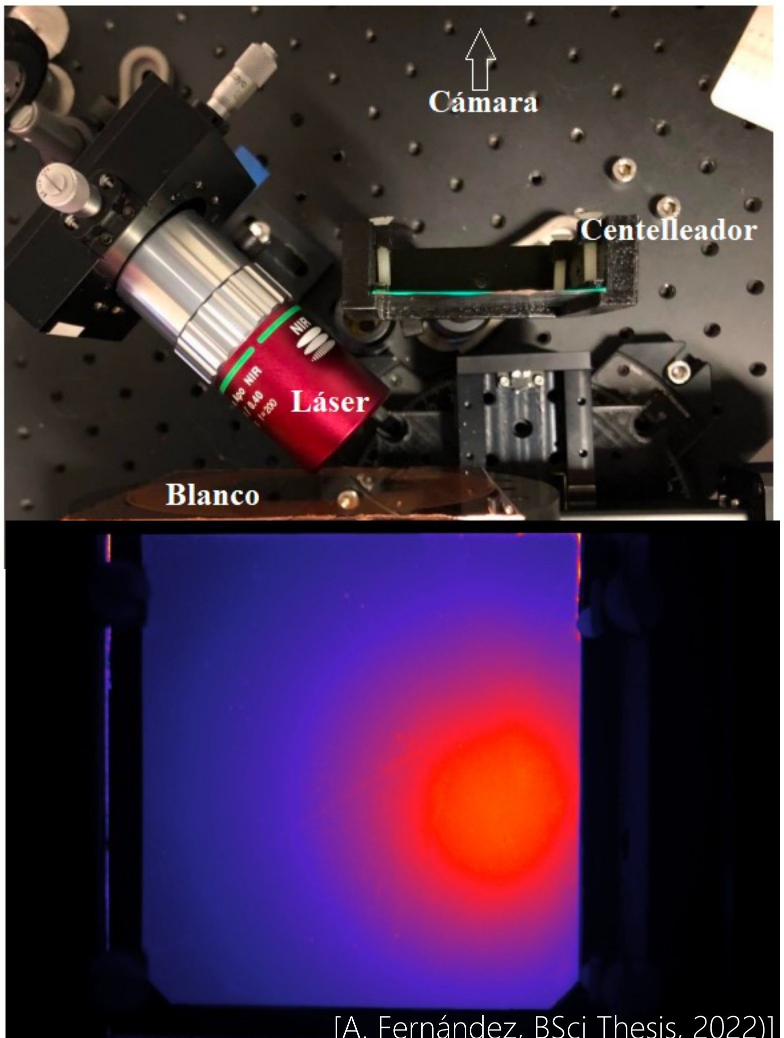




Peak dose rate ∝ $10^9\ Gy/s$ (within pulse)

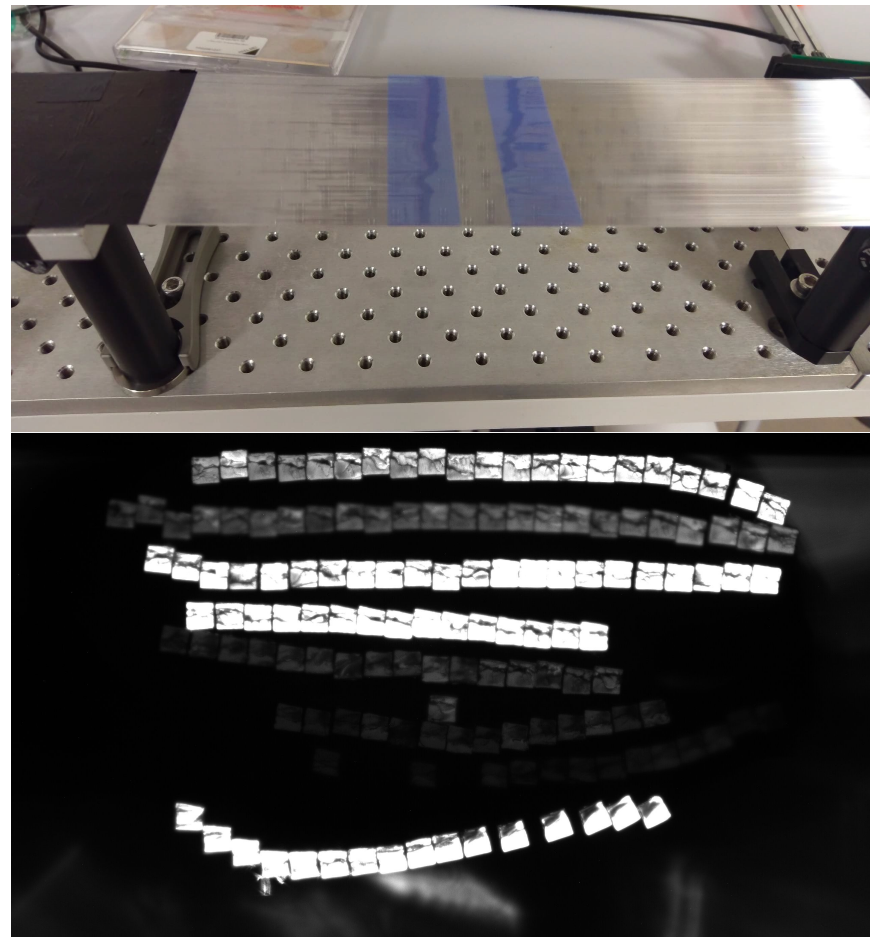
Diagnostic development

Stacks of scintillators



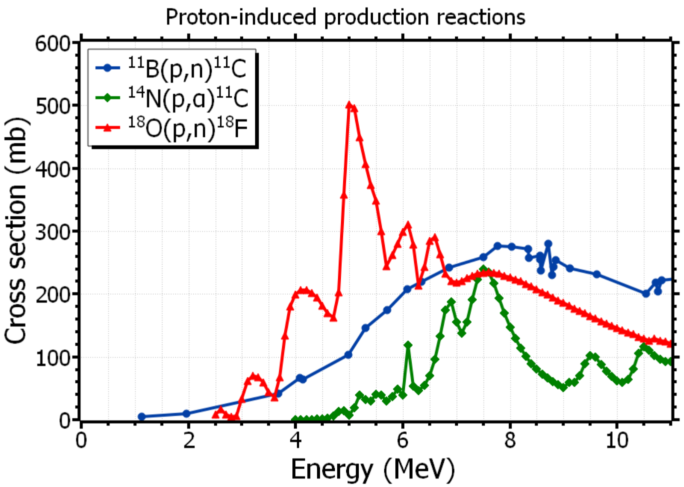
[A. Fernández, BSci Thesis, 2022)]

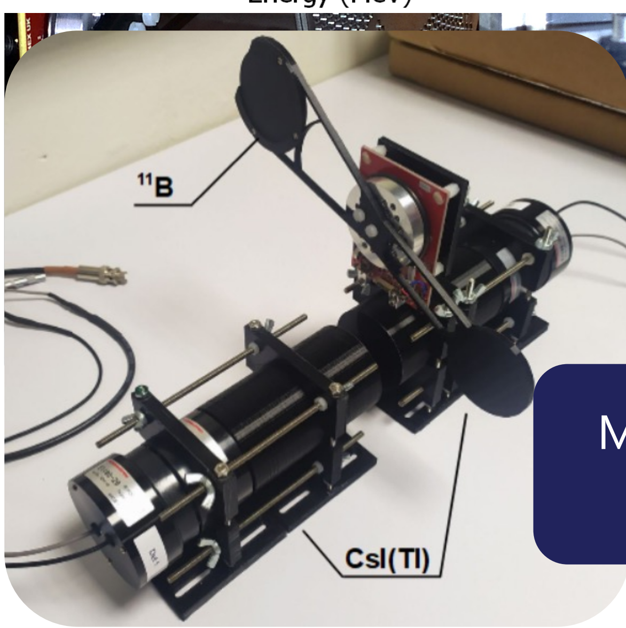
Scintillating fibers



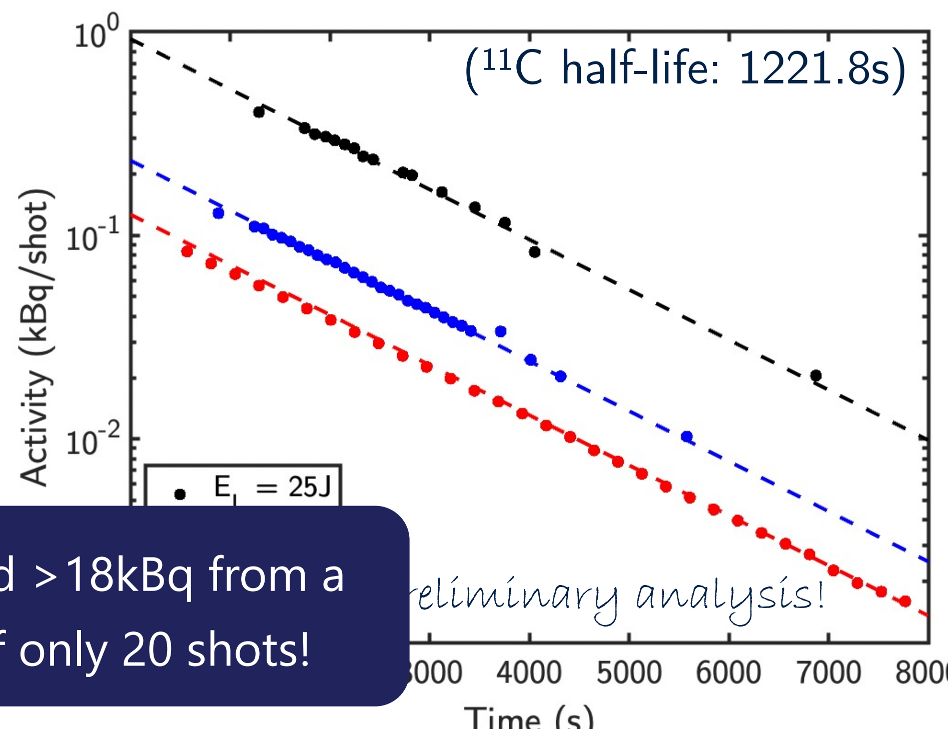
[C. Nogueira, Summer internship – Technical Report, 2022)]

Applications (I): Activation





- → Energies are high enough for production of ^{11}C by irradiating a ^{11}B sample, via $^{11}B(p,n)^{11}C$
- → Succesfully measured the activation levels and decay for different laser energies
- → Up to **1kBq/shot** for highest laser energy



Measured >18kBq from a burst of only 20 shots!

Applications (IV): Radiation Therapy

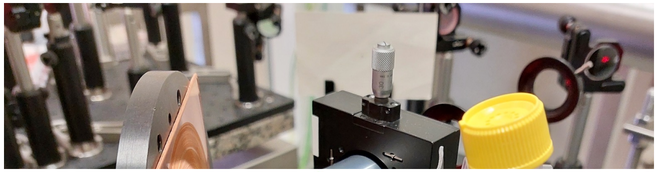
→ FLASH therapy has attracted significant attention

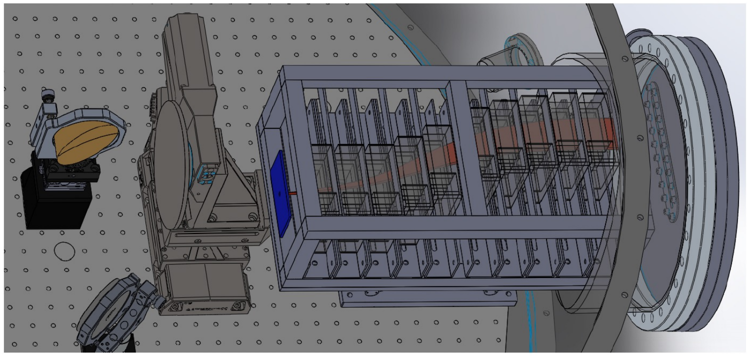
- → Short irradiation times using ultra-high dose rates
- → Less damaging for healthy tissue, widening the therapeutic window

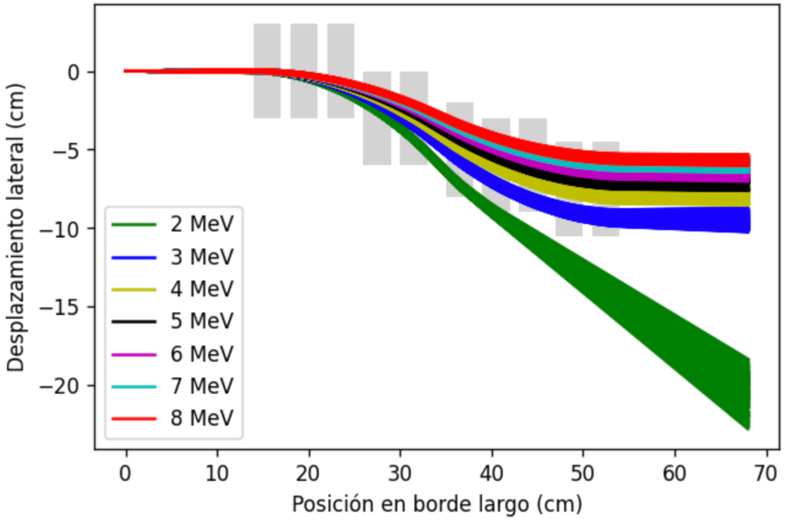
→ Goal: Using laser-driven ion beams to combine the benefits of Bragg peak and FLASH effects

→ Currently focusing on FLASH effects by using the laser-driven X-ray source

→ In parallel, building an ion energy selector for the next step



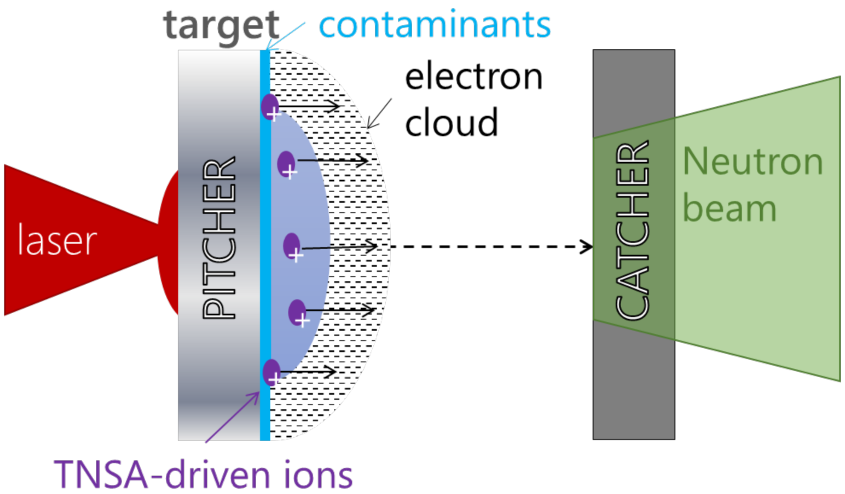


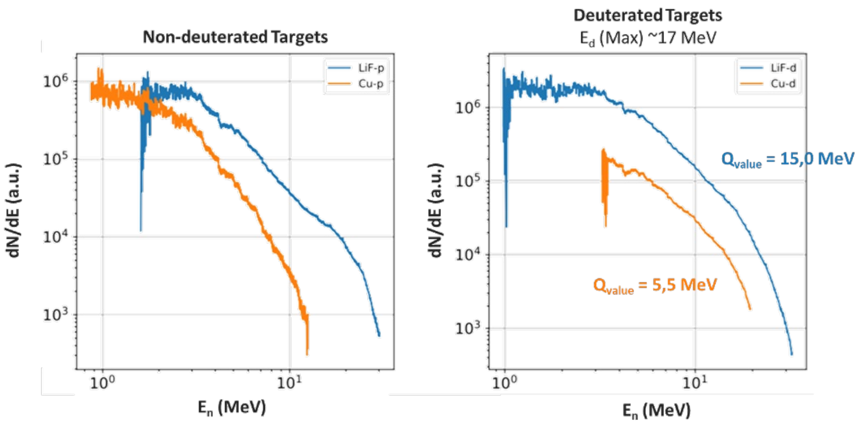


A. Torralba *et al*. *Quantum Beam Sci*. **2022**, *6*(1), 10

Applications (II): Neutrons

- There is a significant interest on use of neutrons for applications, however bottleneck is the limited number of facilities
- Laser-driven ion beams can be used as drivers for neutron production
  - Advantages such as ultra-short duration, high flux, high energy, compactness...
- First experimental campaign at DRACO (Dresde, Germany), focusing on source optimization and detectors
- Follow-up campaign on CLPU testing the first proof-of principle experiments





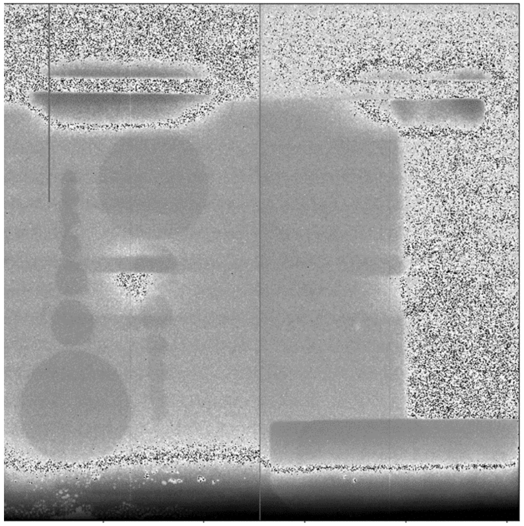
Applications (III): Phase-Contrast

→ Conventional X-ray imaging is based on measuring transmitted intensity (imaginary part of refractive index). This is a problem for imaging of parts with similar attenuation

→ **Phase-contrast imaging** exploits the real part of the index of refraction to improve contrast or recognition of objects in an image

→ Requirements: small source size, large fluence. Available on laser driven sources

→ Currently using the developed X-ray source to optimize the imaging system



Conclusions

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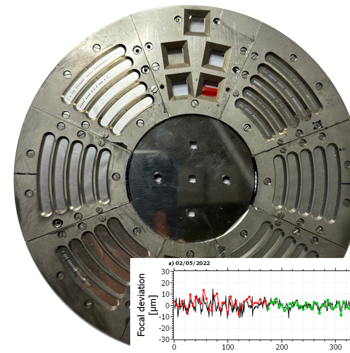
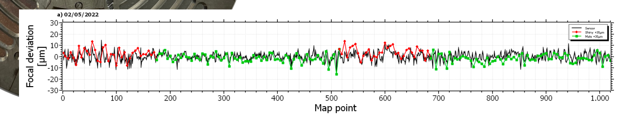
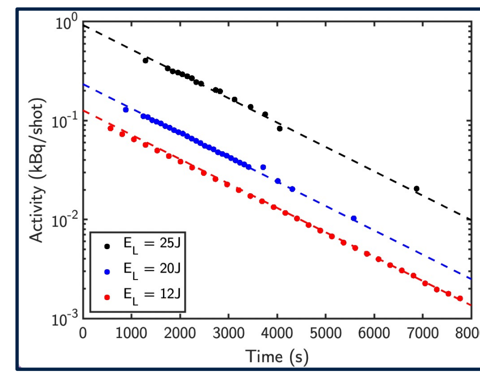
- → We are a medium-sized group based in Santiago de Compostela
- → Developing work with a several national and international collaborators

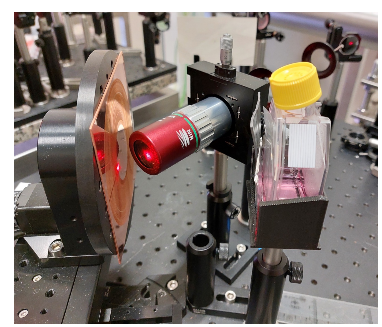
(and we are keen on new collaborations!)

- → High-power laser available at L2A2, local facility at USC
- → Working on laser-plasma Physics, focusing on particle acceleration and applications of these sources









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Acknowledgments

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L2 A2
iMATUS
CLPU CENTRO DE LÁSERES PULSADOS
CNA Centro Nacional de Aceleradores
idis INSTITUTO DE INVESTIGACIÓN SANITARIA SANTIAGO DE COMPOSTELA
i3M Instituto de Instrumentación para Imagen Molecular
VNIVERSIDAD D SALAMANCA CAMPUS DE EXCELENCIA INTERNACIONAL
UNIVERSIDAD COMPLUTENSE MADRID
LAIA
QUEEN'S UNIVERSITY BELFAST
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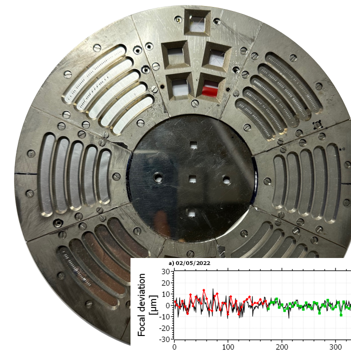

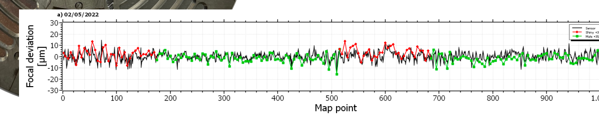

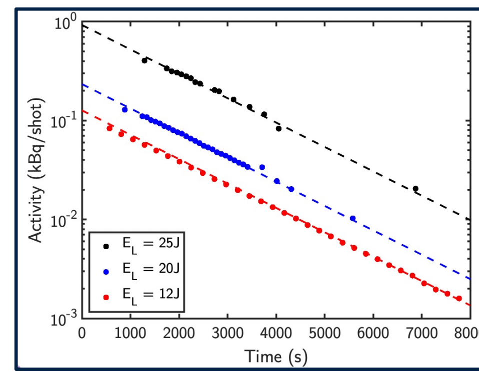

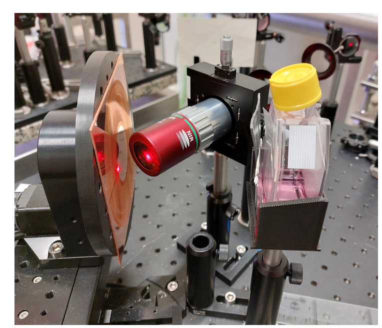

Thank you!

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