

Radioisotope production using a HRR, laser-based proton source

Adrián Bembibre Fernández
adrian.bembibre.fernandez@usc.es

Acknowledgments



A. Alejo, J. Peñas, J. Benlliure
Instituto Galego de Física Altas Enerxías (IGFAE)



M. Seimetz
Instituto de Instrumentación para Imagen Molecular (CSIC-i3M)



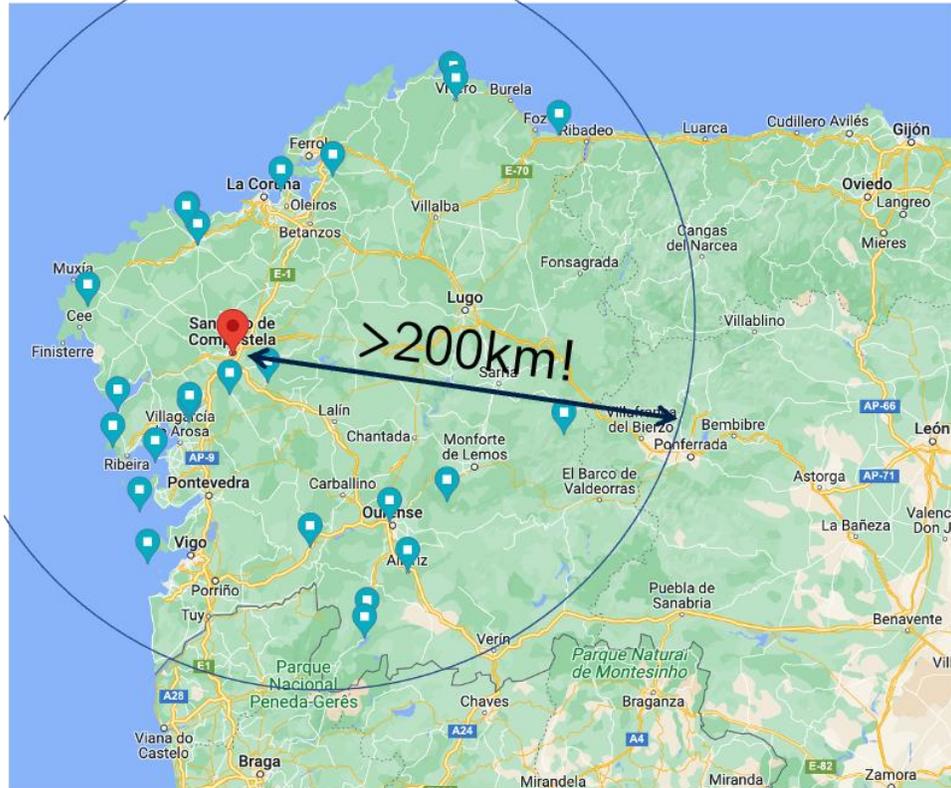
J. Apiñaniz, J.L. Henares, P. Puyuelo
Centro de Láseres Pulsados (CLPU)



M.A. Millán, C. Guerrero
Centro Nacional de Aceleradores (CSIC-CNA)



Motivation



- The centralised production of medical radioisotopes leads to the negligible use of those with short lifetimes due to the transport time.

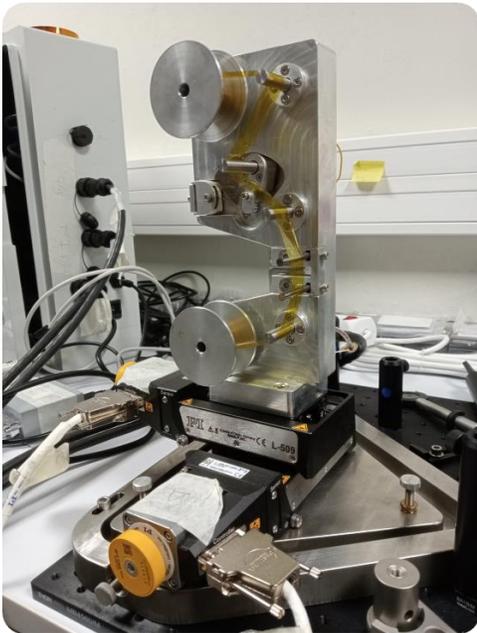
| | $T_{1/2}$ [min] |
|-----------------|-----------------|
| ^{11}C | 20.23 |
| ^{13}N | 9.97 |
| ^{15}O | 1.87 |
| ^{18}F | 109.77 |

Commonly used

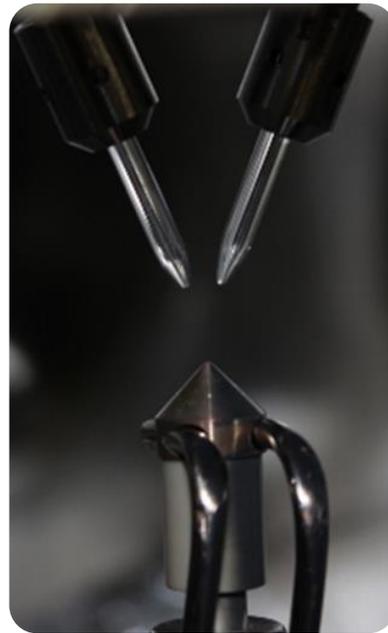
- Search for alternative methods for production \Rightarrow Laser-based proton source
 - Activity required in medical applications is hundreds of MBq \Rightarrow **Thousands of shots + high repetition rate**
- \Rightarrow Suitable target system required

Target options

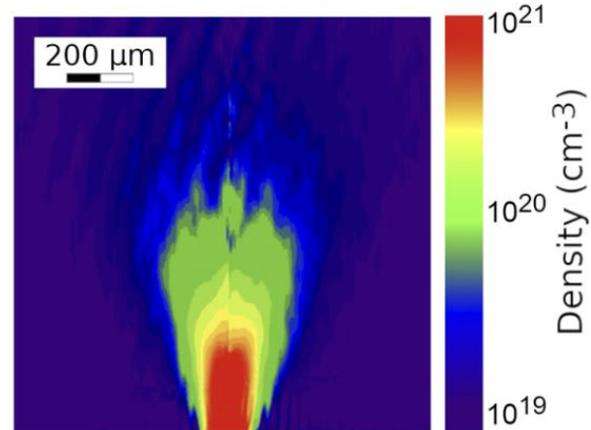
Several types of targets compatible with high repetition rate are being developed:



Tape drive



Liquid jets



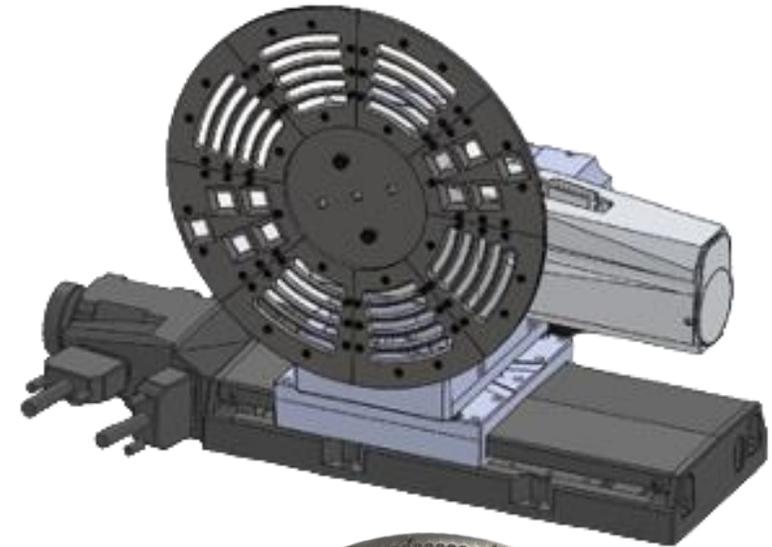
Near critical gas jets

- Cryogenic targets
- Liquid crystals
- ...
- **Rotating wheel**

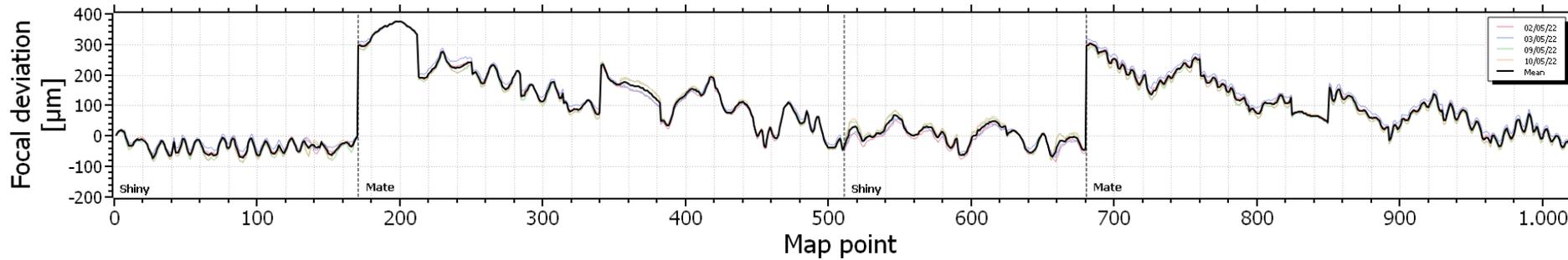
Rotating wheel

- Multi-target wheel mounted in a 3-motor system that allows to replace and position the targets at the focal plane.
- Wheel precisely manufactured to ensure maximum flatness.
- Advantages of this solution:
 - Suitable for multiple materials and thicknesses.
 - Operations at up to 10 Hz.
 - Quick target replacement.
 - Flexibility to implement in different facilities (tested at L2A2, CLPU, ELI-ALPS, ...).

Not enough!

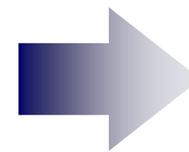
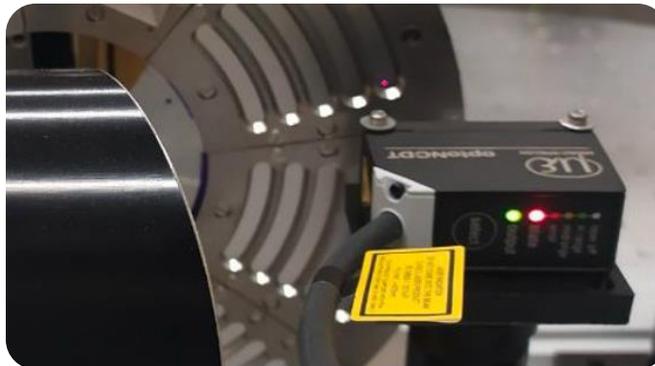


Rotating wheel. Surface pre-mapping

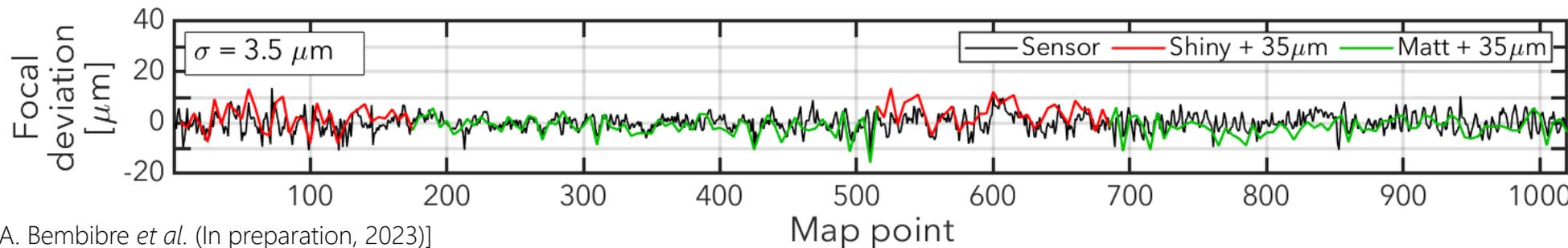
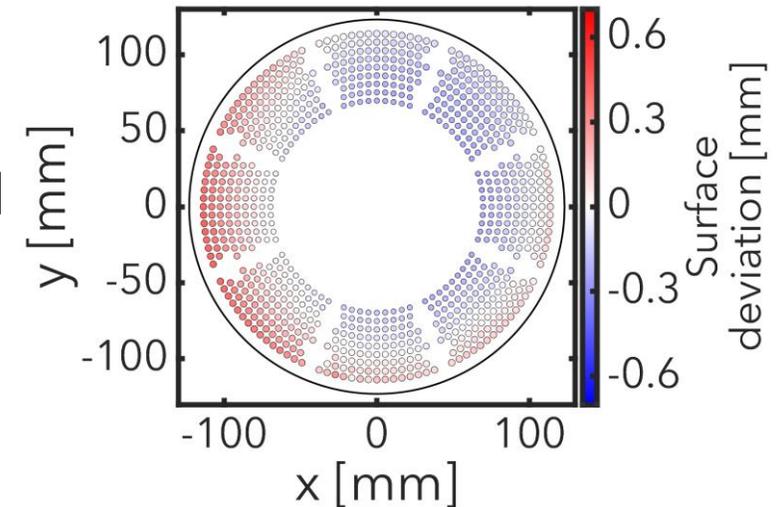


Dispersion ($600 \mu\text{m}$)
 \gg
 Rayleigh length (few μm)

Pre-map of the target surface

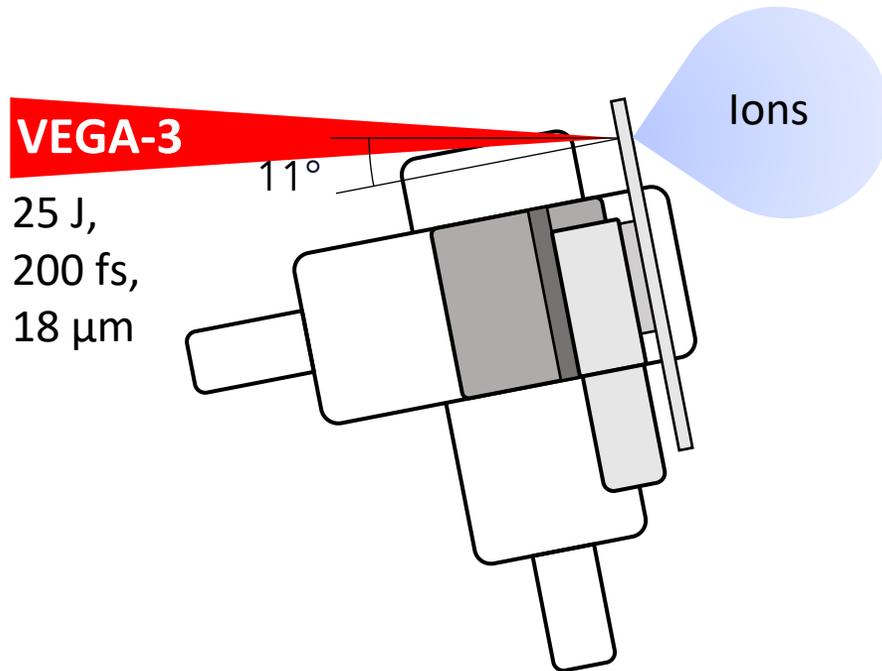


Automatised movements



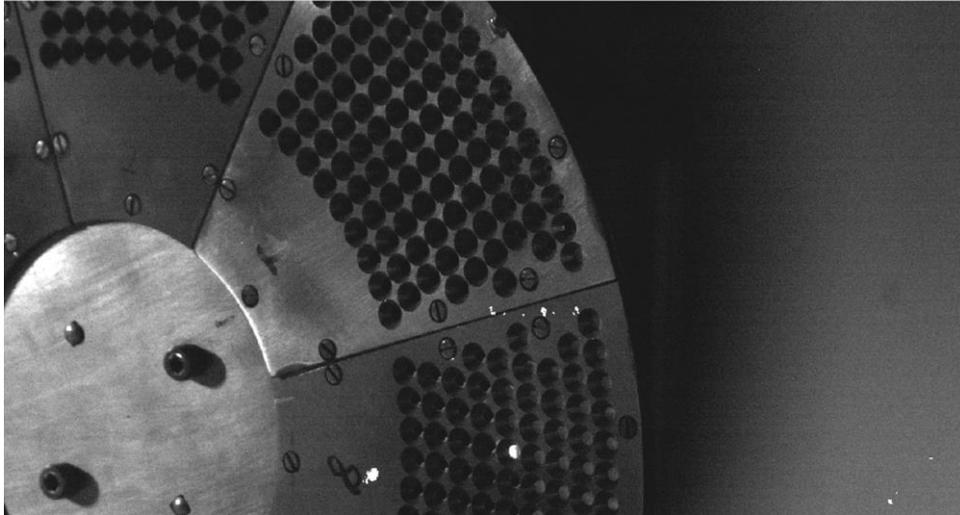
Automatic positioning
 with $\sigma = 3.5 \mu\text{m}$

1 Hz acceleration using a PW laser

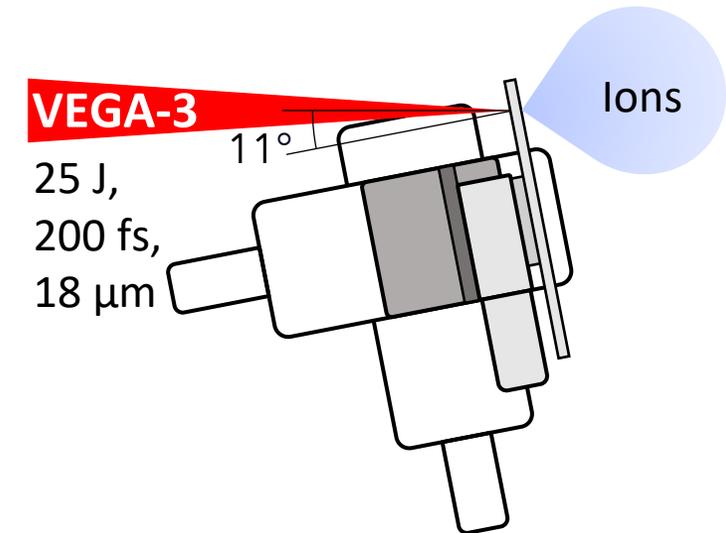
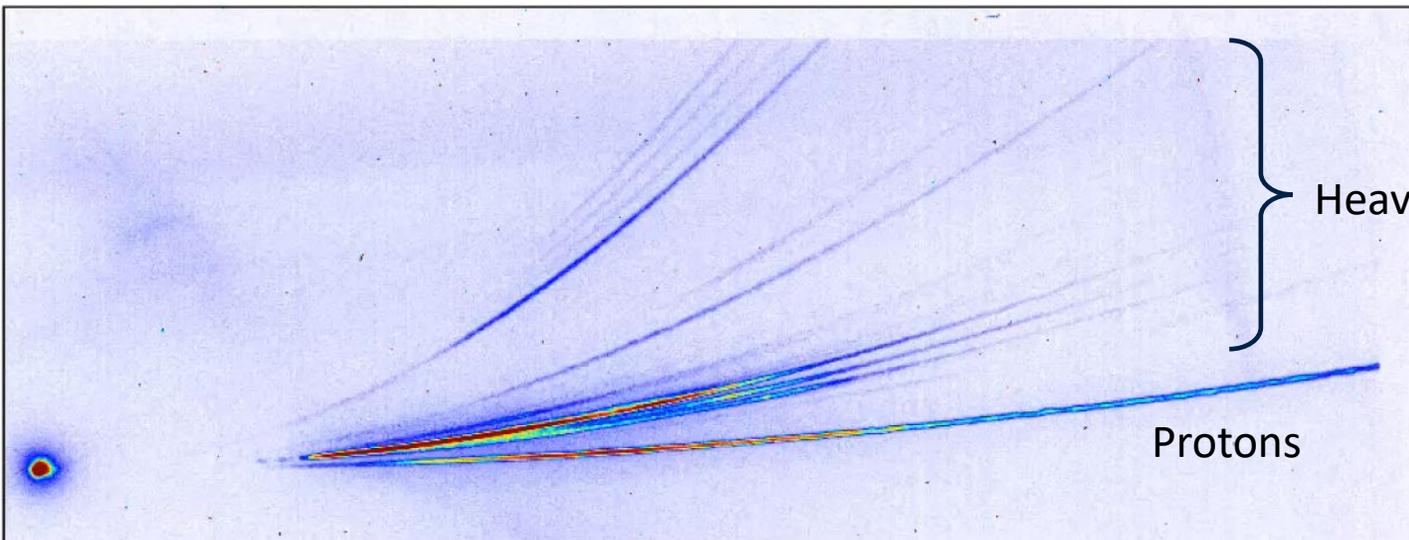


- The wheel system has been used at CLPU with VEGA-3 PW laser.
- Ions accelerated via the TNSA mechanism and characterised using Thomson Parabola Spectrometer.

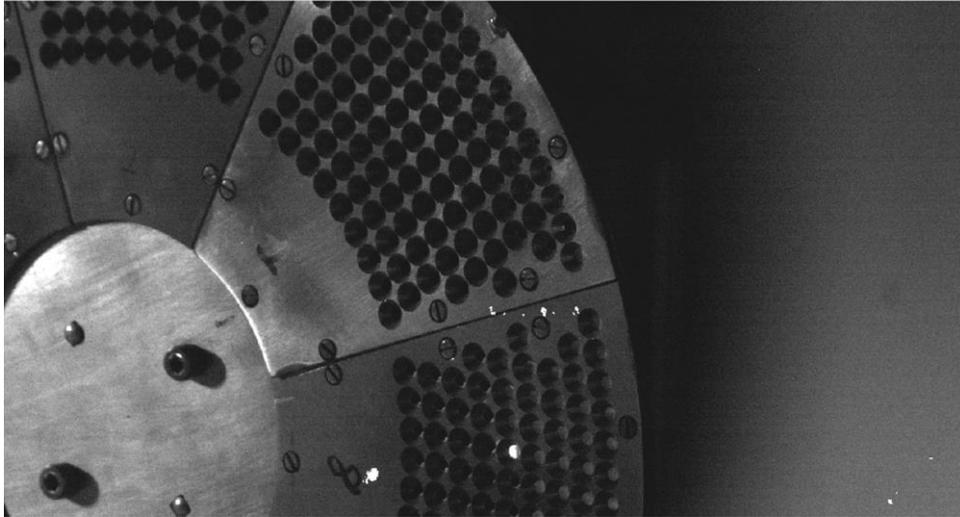
1 Hz acceleration using a PW laser



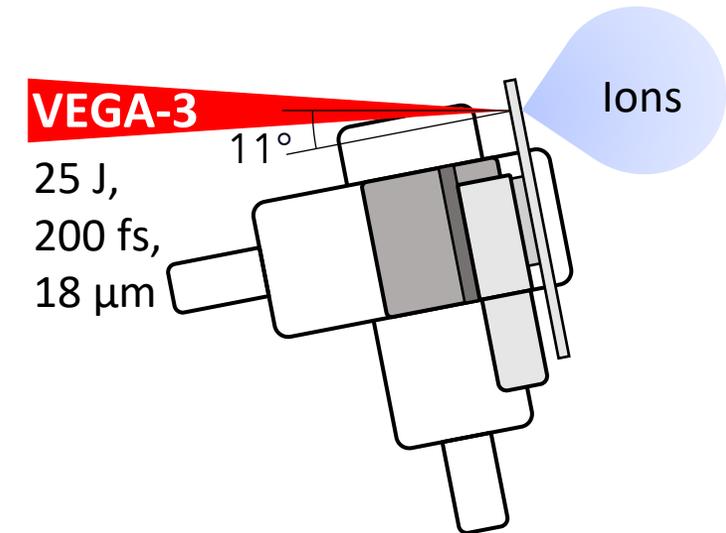
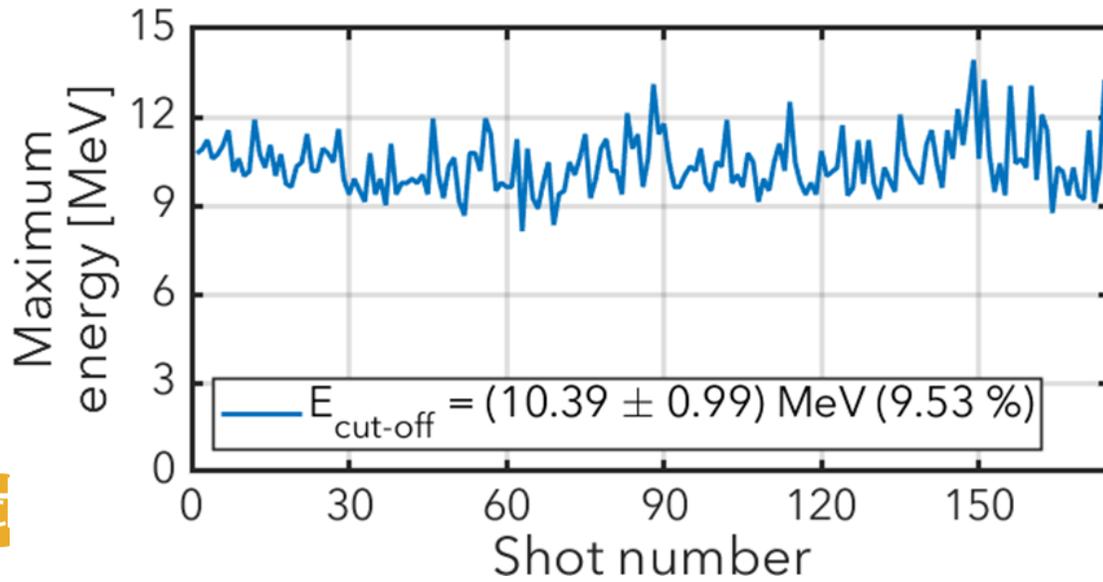
- The wheel system has been used at CLPU with VEGA-3 PW laser.
- Ions accelerated via the TNSA mechanism and characterised using Thomson Parabola Spectrometer.
- Cut-off energies up to 15 MeV with stability better than 10 % were observed.



1 Hz acceleration using a PW laser

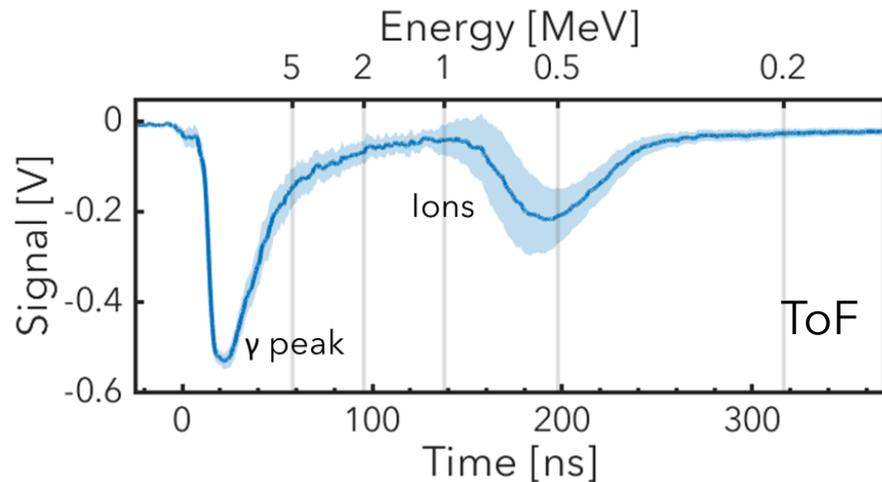


- The wheel system has been used at CLPU with VEGA-3 PW laser.
- Ions accelerated via the TNSA mechanism and characterised using Thomson Parabola Spectrometer.
- Cut-off energies up to 15 MeV with stability better than 10 % were observed.

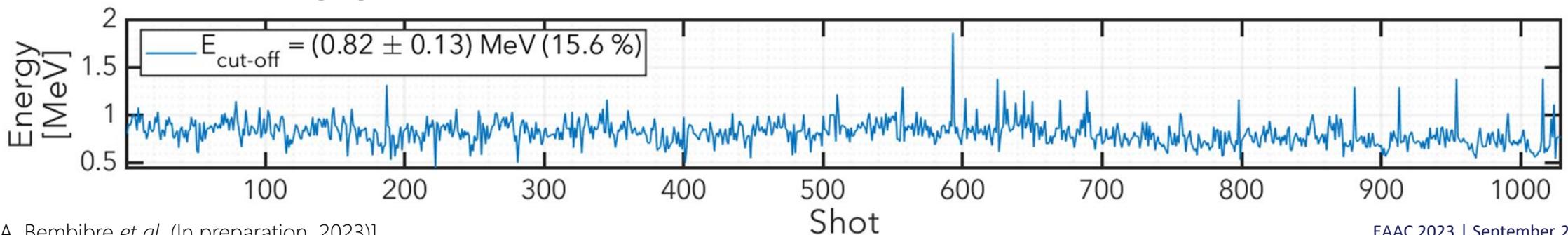


10 Hz demonstration

- Operation at 10 Hz requires a purpose-made wheel \Rightarrow **>5000 shots**.
- Acceleration at 10 Hz demonstrated using the 45 TW laser at *Laboratorio Láser de Aceleración y Aplicaciones (L2A2)*.



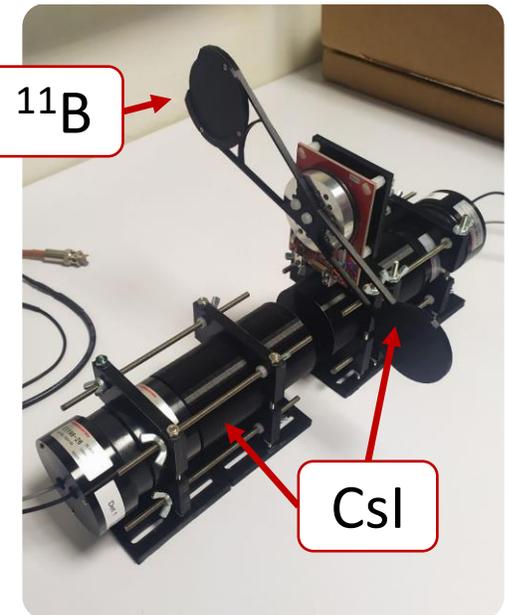
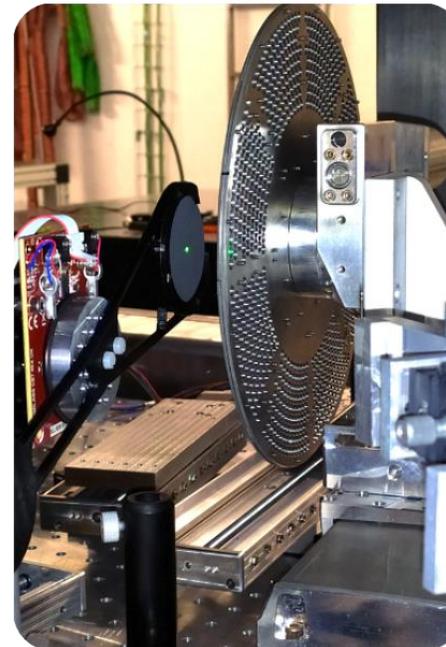
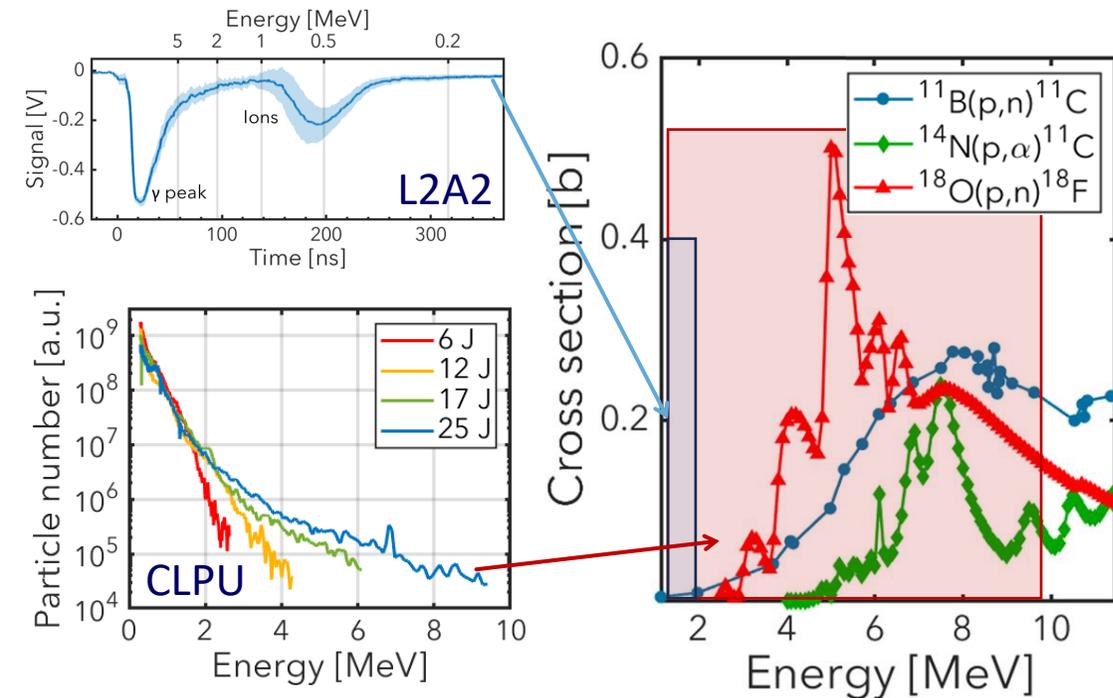
- Ions characterised using Time-of-Flight technique.
- The measurements show a stability in proton cut-off energy of **15.6 %**, limited by laser specs.



Radioisotope production

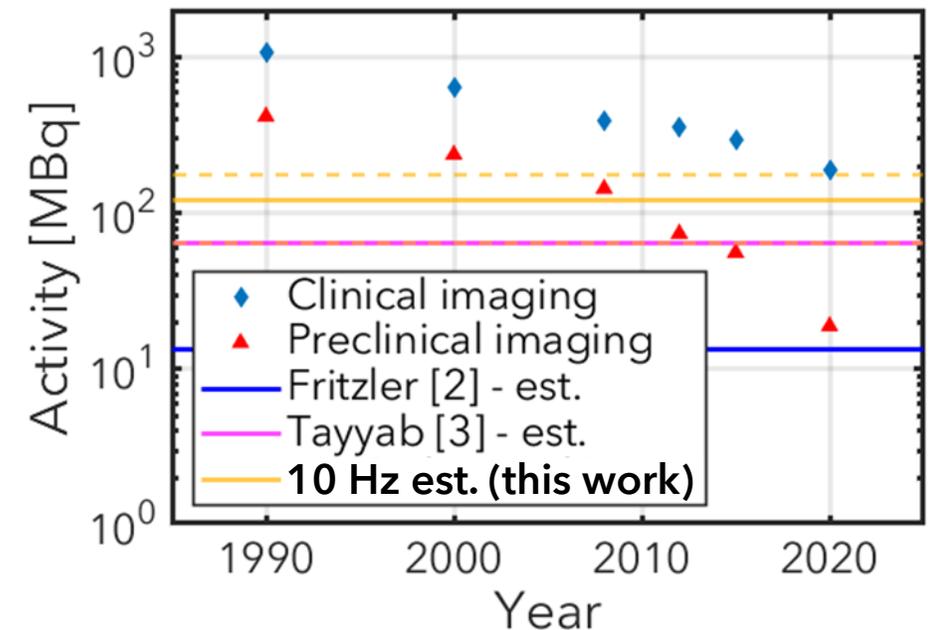
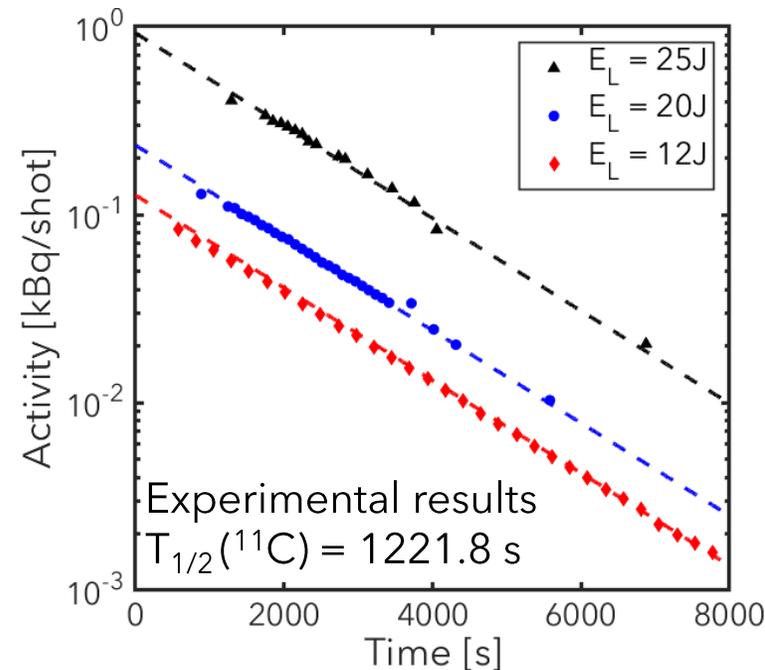
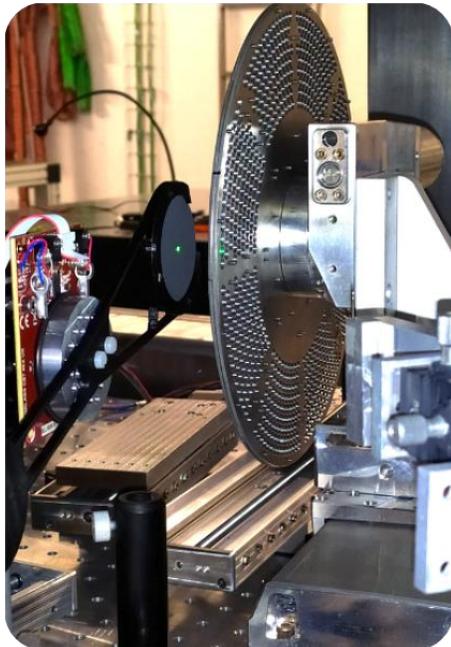
- Radionuclides are produced through activation of a secondary target with the accelerated particles.

- Activity diagnostics developed in-house for in-vacuum irradiation and detection, based on two CsI scintillators working on coincidence.



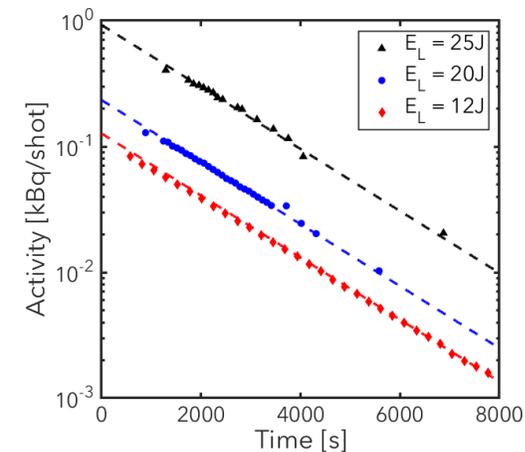
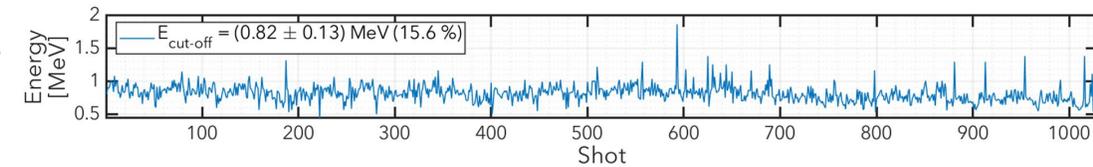
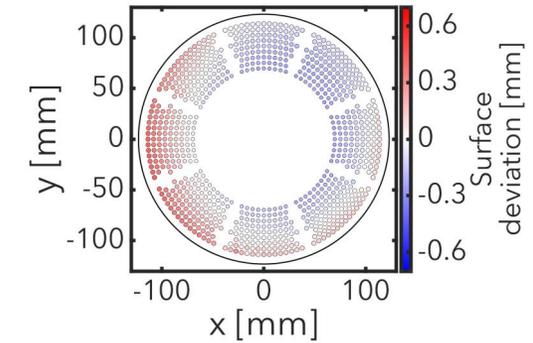
Radioisotope production

- Generation of ^{11}C with activities >230 kBq from a burst of only 20 shots.
- Potential to reach preclinical levels already with current configuration.
- Simulations predict that clinical levels could be produced with 10 Hz operation.



Take-home messages

- A HRR-ready wheel target has been developed, based on an automatised alignment system.
- Ion acceleration at rates up to 10Hz demonstrated using the wheel.
- Generation of ^{11}C with activities $>12\text{kBq/shot}$, compatible with potential pre-clinical studies.



Thank you!