A multi-shot target-wheel assembly for high-repetition-rate, laser-driven proton acceleration

A. Bembibre†,[1] J. Peñas†,[1] D. Cortina-Gil,[1] L. Martín,[2] A. Reija,[1] C. Ruiz,[3] M. Seimetz,[4] A. Alejo,[1,*] and J. Benlliure[1]

[1] *Instituto Galego de Física de Altas Enerxías, Universidade de Santiago de Compostela, Santiago de Compostela, Spain*
[2] *Laboratorio Láser de Aceleración y Aplicaciones, RIAIDT, Universidade de Santiago de Compostela, Santiago de Compostela, Spain*
[3] *Instituto Universitario de Física Fundamental y Matemáticas y Dpto. de Didáctica de la Matemática y de las Ciencias Experimentales, Universidad de Salamanca, Salamanca, Spain*
[4] *Instituto de Instrumentación para Imagen Molecular (I3M), CSIC-Universitat Politècnica de València, Valencia, Spain*

(Dated: February 22, 2024)

REFERENCE STABILITY OF THE LASER-DRIVEN PROTON SOURCE

In order to ensure that the variation of the ion energies observed when using the automatic alignment method is indeed not related to the method itself, a reference measurement of the ion energy stability was performed. To do so, a significant number of shots were taken under the same laser and target conditions (Al targets mounted on the wheel, and similar laser pulse energy, spot size and pulse duration), but in this case each target was manually aligned by the operator. After finding the focal plane of the laser beam with the focal spot camera, each target was accurately brought to the same reference plane by using the focal spot camera as imaging system, with micron-level precision. The ToF flight signal was used to calculate the maximum ion energy for each shot. The results for ~ 70 shots manually aligned are shown in Fig. S1. In this case, an average energy of $\sim$700 keV was obtained, and a standard deviation of $\sim$100 keV, corresponding to a standard deviation of $\sim 15\%$, analogous to that obtained when using the automatic alignment system.

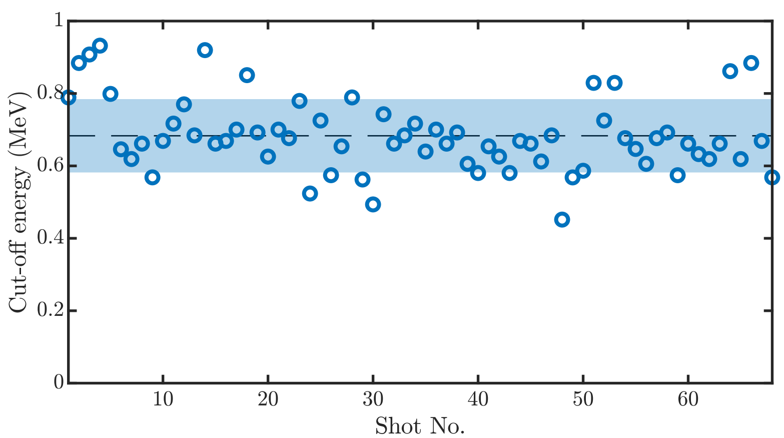

Figure S1. Proton cut-off energies obtained from manually aligned targets.

With the aforementioned, these results support that the variability observed is indeed not related to the operation of the target system but rather caused by some other effect affecting the laser-plasma interaction and the acceleration, and we judged the laser parameters to be the most likely candidate, albeit such dependence could not be directly measured for the data presented in the text.

* aaron.alejo@usc.es

ON THE FLEXIBILITY OF TARGET THICKNESS AND MATERIAL

The presented target wheel design is particularly advantageous with respect to other alternatives, such as tape-drive systems, for its flexibility, compatible with the hosting of a broad range of target materials and thicknesses. Albeit the data presented in the manuscript focusses on the use of Al foils, the target wheel operation has been demonstrated for plastic and metallic foils with thicknesses between $\sim 2\,\mu$m up to tens of microns. Furthermore, the use of nanometric foils relevant in the context of novel acceleration mechanism is currently being actively studied. Mounting of plastic targets as thin as $\sim$300 nm on the presented holder has been successfully achieved, without the target being damaged by surface tension. Modifications of the holder could allow to extend its use to even thinner targets, in order to prevent damage by the tension. Additional studies are required to confirm the long-term stability of the targets when operated at high rates, considering potential damage by the debris.

Beyond the hosting of the targets, the difference on the target reflectivity could pose a major limitation regarding the pre-map generation due to potential limitations of the distance sensor. For this reason, the capabilities of the sensor to measure transparent and diffuse materials has been studied, as shown in Fig. S2. Consistent results can be achieved for the entire working distance range of the sensor, even in the case of transparent thin mylar foils, demonstrating the flexibility not only of the target but also of the alignment method. Furthermore, the functioning of the sensor in more extreme conditions is currently being studied, but early measurements indicate that the surface of the few hundred nanometer formvar targets, and even the surface of optical-quality glass with AR coating, can be equally characterise with the current sensor under normal conditions.

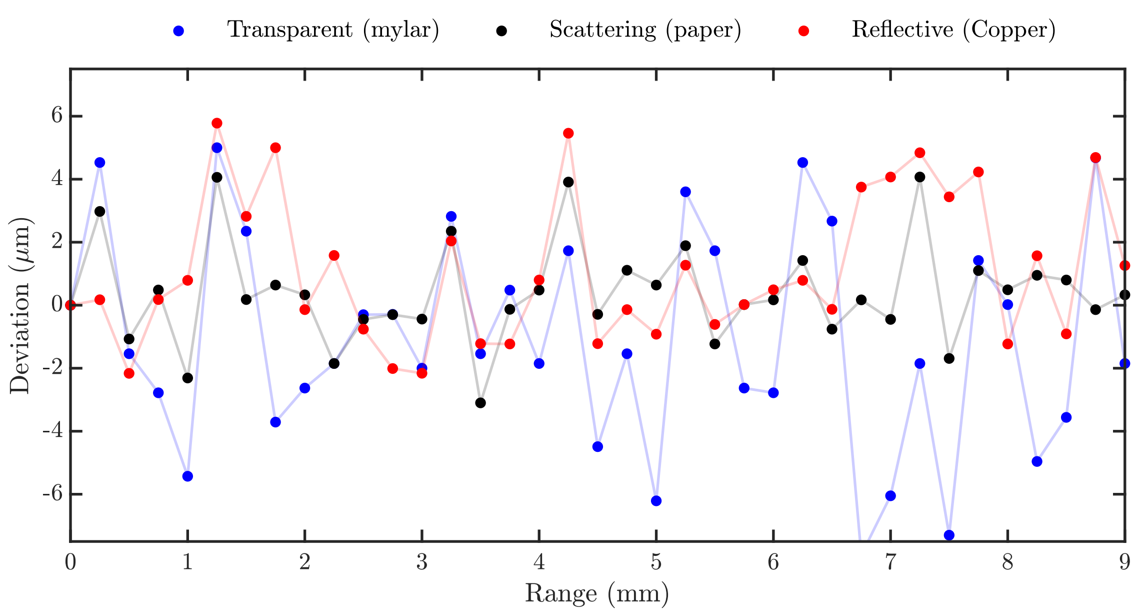

Figure S2. Characterisation of different materials using the distance sensor.