Simulation of the chromatic focusing phenomenon in laser-driven proton acceleration experiments

M. Bardon[1], L. Perrachon[1], J. G. Moreau[1], F. Lubrano[1], O. Cessenat[1]

[1] *CEA-CESTA, Le Barp 33114, France*

A new scheme of the proton post-acceleration and collimation was proposed recently [1] by researchers from the Queen's University of Belfast (QUB). A solenoid, connected at one end to a thin metallic target, and, at the other end, to the ground, is used to flow the discharge current induced by the charge ejection from the target. This system generates an ElectroMagnetic Pulse (EMP) around the proton beam produced by the Target Normal Sheath Acceleration (TNSA) mechanism. A Lorentz force is then applied to the proton beam. Finally, this device can simultaneously: accelerate, focus, and energy select the proton beam generated by the interaction of a short-pulse laser with a TNSA target.

An experiment [1] was conducted, at low laser pulse energy, on the ARCTURUS laser, at Heinrich-Heine University in Dusseldorf (Germany). The results of the experiment were compared with a numerical modeling conducted this year at the CEA-CESTA (France). These simulations have allowed, for the first time, reproducing the physical phenomenon (called "chromatic focusing phenomenon") in this new compact laser-driven accelerator concept. Figure 1 presents an example of the simulation conducted with the code SOPHIE developed at the CEA. SOPHIE is a 3D, Particle-In-Cell (PIC), Finite Difference in Time Domain (FDTD) code that solves Maxwell's equations for the fields and Vlasov's equations for particles in a large volume and with arbitrary boundary conditions. It is a highly parallelized code perfectly adapted to run on the new TERA-1000 cluster of the CEA/DAM. In the example presented in Figure 1, the mesh is made up of 10^9 cells and 10^7 macro-particles have been used. The calculation is run on the TERA-1000 CEA/DAM cluster with 1024 processors. Propagation of the proton beam and the current pulse can be represented simultaneously. In this particular example, the simulation was initiated by the ejection of electrons and protons from the rear side of the target. Figure 1 represents the proton beam propagation, at the time t=200 ps, with a color bar corresponding to the proton kinetic energy and also the electric field magnitude along the coil. The proton focusing observed is in agreement with the experimental results.

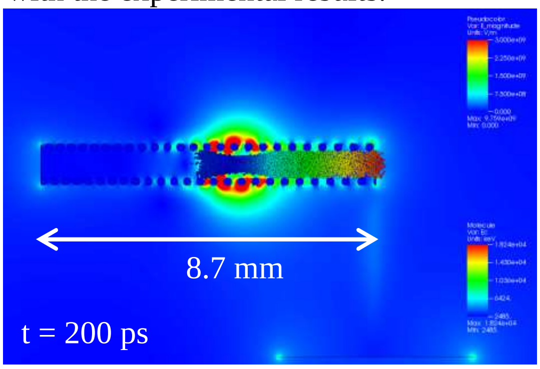

Figure 1: Chromatic focusing phenomenon reproduced by numerical simulation (SOPHIE code).

These simulations allow us to optimize the ion ejection and acceleration structures. New optimized devices will be tested on LULI 2000 facility in March 2019.

[1] "Guided post-acceleration of laser-driven ions by a miniature modular structure", S. Kar et al., Nature Com. 10792 (2016)