Preparatory simulations with FLASH of a laboratory astrophysics experiment on the NIF laser-facility

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Cosmic rays are very energetic particles accelerated during violent astrophysical phenomena. Shocks in particular are likely to be accelerating structures for cosmic rays via processes such as those presented by Fermi in 1949 [1]. Due to the impossibility of in situ measurements, laboratory astrophysics experiments are necessary to study the acceleration processes of cosmic rays [2]. One way to do laboratory astrophysics is to use high power lasers like the National Ignition Facility (NIF) in the United States of America or LMJ in France, i.E. megajoule class laser facilities.

In particular to obtain high Mach number shocks high power lasers must be used [3]. This year there will be shots at the NIF to study for the first time in the laboratory non-thermal ion populations generated by magnetized high-Mach-number quasi-parallel (magnetic field parallel to the shock velocity) collisionless shocks. To prepare this experiment hydrodynamic simulation with the code FLASH [4] have been performed. The main goal is to estimate what maximum collisional shock velocities (i.e. Mach number) can be reached experimentally. The collisional shock characteristics are required as input for kinetic plasma simulations that can model the development of the collisionless shock and the associated particle acceleration. The analysis of the FLASH simulation results will be presented, and the transition towards the kinetic simulations will be discussed.

Shots on the OMEGA laser facility were also performed to prepare the experiment on NIF. To analyse the results of these shots, additional FLASH simulations were run. The analysis of these additional simulations will be presented, as well as the scaling of the collisional shock velocity as a function of the main laser and target parameters.

[1] E. Fermi, Physical Review, vol 75, no. 8, April (1949)
[2] F. Fiuza et al., Nature Physics, vol. 16, no. 9, (2020)

[3] D.B. Schaeffer et al, Physics of Plasma, vol. 24, no. 12 (2017)

[4] B. Fryxell et al., Astrophys. J. Suppl.Ser., vol 131, no. 1 (2000)