Prospect on the application of subluminal pulses as drivers for plasma-based acceleration of non-relativistic muons

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Just as electrons, muons are fundamental particles. Thus, their full energy is available in collisions, in contrast for example to protons. A 14 TeV muon collider with sufficient enough luminosity would provide a similar discovery reach as a 100 TeV proton-proton collider [1]. Furthermore, muons' decay represents a potential laboratory source of one of the most abundant but at the same time mysterious elements of the Standard Model: the neutrinos.

Taking inspiration from what happens in the earth's atmosphere, muons can be produced through the interaction of protons with the nuclei of a dense target. This will generate pions, finally decaying into muons. In this three-step process, the muons are mostly produced with non-relativistic energies, excluding the possibility to accelerate them with well-established plasma-based acceleration techniques, such as LWFA [2] or PWFA [3]. State-of-the-art techniques to sculpt the spatio-temporal spectrum of electromagnetic wave-packets leading to pulses with arbitrary group velocities have been recently developed [4]. These pulses are able to propagate with a subluminal group velocity, making them suitable candidates to drive acceleration wakes for heavier particles.

In this work, we propose a plasma-based acceleration technique for non-relativistic particles using pulses with non-relativistic group velocities and discuss the role of the evolution of these pulses in a plasma on the acceleration. Moreover, a study of the propagation of subluminal pulses in the plasma, that has never been investigated before, will be carried on. As a first step, we investigated the acceleration using an external field with a non-relativistic group velocity analytically and in 2D particle-in-cell simulations using OSIRIS [5]. Subsequently, the evolution and wakefield properties using optical space-time wave-packet drivers, traveling with group velocities smaller than the speed of light were explored. We have found that these pulses are able to drive plasma wakes that travel slower than the speed of light that can accelerate non-relativistic particles.

References

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