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Muons acceleration in plasma-based accelerators

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Muon colliders are being currently considered as a next step for HEP [1]. Since muons, as electrons, are fundamental particles, their full energy is available in collisions, in contrast to protons. Nonetheless, the finite mean lifetime of muons (2.2 μs at rest) means that the muons must be collected, cooled, and rapidly accelerated before a significant number of them decay. Plasma accelerators could in principle accelerate muons to relativistic energies much faster than traditional RF accelerators, thereby greatly reducing the loss of muons. Already well established and studied plasma-based acceleration methods [2,3] are applicable only to particles whose velocities are close to the speed of light (relativistic particles). Heavier particles, e.g. muons, are thus excluded from the acceleration mechanism. 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. 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. If this innovative approach for the acceleration of muons is successful, this work may become a step towards a plasma-based injector for a future muon collider.

References

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