Direct Laser Acceleration of Bethe-Heitler positrons in a plasma channel

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Plasma-based technology offers an advantageous solution to produce accelerating fields of 100 times higher amplitude than in conventional accelerator facilities. While electron acceleration is well-explored both theoretically and experimentally, hardly any solutions have been established to accelerate positrons [1].

It is worth noting that all previous attempts rely on acceleration in plasma wakefields, whereas in our case, the accelerating field is the laser itself. It was recently proposed to create and accelerate positrons in vacuum during the interaction of an intense laser pulse and a relativistic electron beam in a $90\circ$ geometry [2]. In light of this, we proved that the positron beam can be further guided and accelerated if we place a plasma channel on the laser propagation axis [3]. The main limit of that scheme is that a high laser power of 80 PW is necessary to create positrons via the Breit-Wheeler process and inject them into the guiding structure.

In this work, we propose to overcome this limit and investigate the direct laser acceleration of positrons with laser power in the range of 5 to 10 PW. Positrons are created by the Bethe-Heitler process during the interaction of the laser pulse with a thin foil placed in front of the plasma channel. Our main result is that direct laser acceleration of positrons is possible with a laser power of 5 to 10 PW. We identified what conditions are necessary with quasi-3D particle-in-cell simulations conducted with the OSIRIS framework [4]. We also present analytical estimates for the acceleration process accounting for the static field created by the dense and self-loaded electron beam. Finally, we provide guidelines on choosing the laser pulse, the thin foil, and the plasma channel to witness and optimize this new acceleration process for positrons.

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