Positron acceleration in a plasma channel with multi-Petawatt-class lasers

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The electron-positron colliders of the future will measure tens of kilometres and cost billions of euros. The alternative offered by plasma accelerators is promising since they can sustain accelerating fields which are orders of magnitudes higher than these conventional radio-frequency accelerators, providing relativistic beams in shorter distances and for reduced costs. Experiments have already shown that positron wakefield acceleration is possible when the wake structure is driven by a single and long positron beam [1], and numerical investigations indicate that positron wakefield acceleration is possible either using a Laguerre-Gaussian laser pulse driver [2] or a hollow plasma channel [3]. It is worth noting that all the mentioned numerical studies assume an idealised positron beam injection. Multi-Petawatt lasers are now expected to be able to both, create and accelerate positrons [4]. This is predicted for a 90 degree collision between a multi-PW laser and a GeV-class electron beam, where positrons are created via the multi-photon Breit-Wheeler process and are then accelerated on a short distance by the laser in vacuum.

In this work, we suggest a new scheme based on the propagation of a multi PW pulse in a preformed plasma channel. It stands out from previous attempts since it addresses the three key steps of creation, injection and acceleration of the positrons within a single 3D self-consistent numerical framework. In this setup, positrons generation takes place at the focus of a multi-PW laser and is stimulated by a perpendicularly propagating electron beam via the inverse Compton and Breit-Wheeler processes. Although positrons are created in the same direction as the incident electrons, a fraction of them is deflected by the laser pulse toward its propagation axis and injected in the plasma channel. The positron acceleration takes place in the plasma channel over a distance of 400 μm. The fields focusing positrons on the channel axis are mediated by a dense central electron beam, formed self-consistently along the pulse propagation. Although unexpected at lower laser power, such focusing and accelerating fields for positive charges have already been observed in numerical simulations but where never exploited for positron acceleration [5, 6]

References

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