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Acceleration of positrons in plasmas with high energy efficiency

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Accelerating particles to high energies with high efficiency and beam quality is crucial in developing accelerator technologies. While particle acceleration in plasmas has made important progress for electrons, identifying a reliable plasma acceleration technique for positrons would pave the way to a linear collider for high-energy physics applications.

Here, we show that a tradeoff between energy efficiency and beam quality needs to be established in the presence of a positron load in the plasma [Phys. Rev. Research 3, 043063 (2021)]. This tradeoff is intrinsically related to the quick response of plasma electrons within the positron bunch, a response which becomes stronger at higher positron charge and energy efficiency. In linear plasma wakefields, it is found that the main limitation for the beam quality lies in the uncorrelated energy spread that the positron bunch acquired during acceleration in the plasma. Different schemes are discussed, and the results demonstrate that when the plasma response is driven in a moderately nonlinear regime, one can achieve simultaneously energy transfer efficiencies exceeding 30% and uncorrelated energy spread below 1%. A strongly nonlinear wake produced by a donut-shaped driver is more suitable for high-charge, high-gradient acceleration, at the cost of a degraded efficiency and beam quality.

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