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. By leveraging plasmas, we can reach unprecedented high acceleration gradients, and with this prospect plasma-based accelerators are now considered as a promising future technology [1]. While important progress has been made in plasma-based electron acceleration in recent years, identifying a reliable acceleration technique for the positron counterpart in plasma would pave the way to a linear collider for high-energy physics applications.
In this work, 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 [2]. 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 electron-driven linear plasma wakefields, it is found that the bunch quickly evolves towards an equilibrium with limited emittance growth, and the main limitation for the beam quality lies in the uncorrelated energy spread that the positron bunch acquired during its acceleration in the plasma. Different plasma acceleration 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%. On the other hand, 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.
The presentation will be concluded with perspectives and future directions for reaching collider-type parameters for the positron beam using plasma accelerators, and with a new vision of the possible physical limitations when trying to reach such parameters.

[1] C. Adolphsen, et al. European Strategy for Particle Physics -- Accelerator R&D Roadmap, arXiv:2201.07895
[2] Hue et al., Phys. Rev. Research 3, 043063 (2021)