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High Efficiency Uniform Positron Acceleration in Plasma Wakefield Accelerator

Shiyu Zhou[1], Jianfei Hua[1], Weiming An[2], Warren B. Mori[3], Chan Joshi[3], Jie Gao[4] and Wei Lu[1]
[1] Department of Engineering Physics, Tsinghua University, [2] Department of Astronomy, Beijing Normal University, [3] University of California Los Angeles, [4] Institute of High Energy Physics, Chinese Academy of Sciences
e-mail(speaker): zhoushiyu@tsinghua.edu.cn

Next generation high energy electron-positron colliders are highly desirable for precision studies of the Higgs Boson and discovering physics beyond the standard model [1]. Current radio-frequency accelerators are limited by the accelerating gradients due to breakdowns, thus advanced acceleration schemes with high gradient, high efficiency and great beam quality are in demand.

One of the most Plasma wakefield accelerator (PWFA) has achieved several breakthroughs in electron beam acceleration to provide large acceleration gradients and high energy transfer efficiency while maintaining excellent beam quality [2]. Most groundbreaking results to date have been obtained using an intense electron bunch to excite a nonlinear wake that accelerates a witness electron bunch. However, it is not effective for positron acceleration because the volume at the very back of such wakes where the wakefield is both accelerating and focusing for positron is extremely small.

Because of the uniform accelerating field in transverse planes and zero focusing force inside channels, wakes in hollow plasma channels produced by electron beams have been suggested for positron acceleration [3]. We investigate a new positron beam loading regime in the hollow plasma channel that can obtain high-efficiency uniform positron acceleration by overlapping the electron and positron beam. However, the misalignment of the drive and/or trailing bunches would induce a strong beam-breakup instability that leads to beam emittance growth and ultimately loss of positrons. In response to this, we utilize the interaction between the hollow plasma channel and the asymmetric driving electron beam to create a stable wake structure that is viable for positron acceleration [4]. Through self-consistent effect of the positron beam and the plasma boundary electrons, a high-efficiency and uniform acceleration of the positron beam is realized. 3D particle-in-cell simulations show that an several tens of percent energy extraction efficiency from the wake to the positrons and a 1% level energy spread can be simultaneously obtained.

References

[1] X. Lou, Nat. Rev. Phys. 1, 232 (2019).
[2] C. Joshi *et al.*, Phys. Plasmas 27, 070602 (2020)
[3] S. Gessner *et al.*, Nat. Commun. 7, 11785 (2016).
[4] S. Zhou *et al*., Phys. Rev. Lett. 127, 174801 (2021).

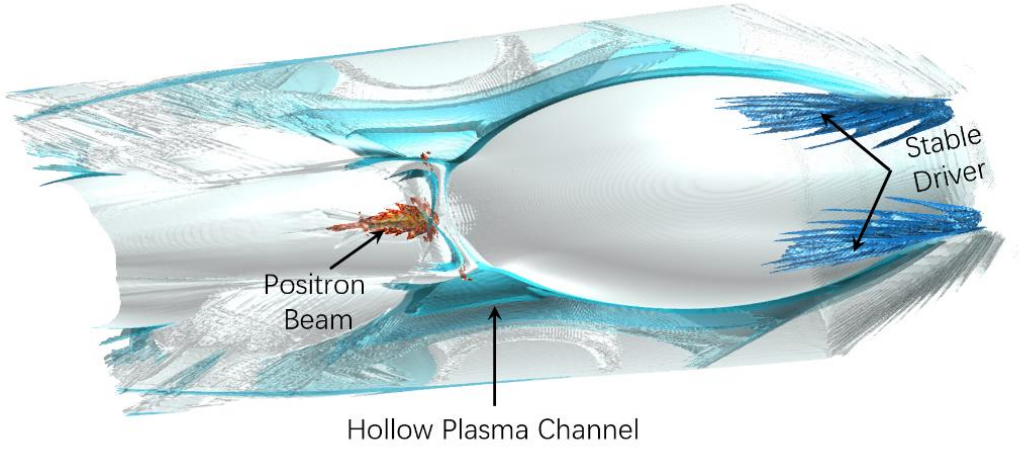

Figure 1. Schematic diagram of stable, efficient, uniform positron acceleration in a hollow plasma channel