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Beam quality preservation by loading of a preceding electron beam in proton driven plasma wakefield acceleration

Proton-driven plasma wakefield acceleration has been demonstrated in simulations to be capable of accelerating electrons to the energy frontier in a single plasma stage. However, the achieved beam quality especially the normalized emittance is still far from applications. This is because the transverse plasma wakefield acting on the witness electron bunch is nonlinear to the radius, and it varies along the bunch and in time as well, regardless of whether the operation regime is nonlinear or not. In addition, the longitudinal electric field is nonuniform along the radius, which causes the energy spread to increase during the acceleration. In this paper, we propose to load another electron bunch ahead of the witness bunch. This preceding electron bunch completely expels the plasma electrons away from the witness bunch and sustains a local plasma electron free "bubble" within the accelerating structure. In the "bubble", the witness bunch sees a radially linear focusing and a transversely uniform accelerating field, which preserves the normalized emittance and maintains low energy spread of the witness beam. Studies show that for the preceding electron beam, the initial energy needed is only ~550 MeV for a 1 TeV proton driver. Also it is initially placed close to the zero-field region, so it doesn't extract much energy from the wakefield. Interestingly, all the obtained energy will eventually contribute to the wake excitation in the later stage. At the end of the accelerating stage, the witness bunch reaches the energy frontier with high beam quality.

Working group

Theory and computation

Primary author: LI, Yangmei (University of Manchester/Cockcroft Institute)

Co-authors: XIA, Guoxing (University of Manchester); ZHAO, Yuan (University of Manchester); APSIMON, Oznur (The University of Manchester)

Presenter: LI, Yangmei (University of Manchester/Cockcroft Institute)

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