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Advances in plasma-based beam dump modelling

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Plasma beam dumps use the large decelerating wakefields sustained by plasmas to achieve compact deceleration of spent beams. Besides the higher efficacy to absorb beam energy, plasma beam dumps are also safer if compared to conventional beam dumps. This is due to the lower production of radioactivation hazards in the low-density plasma medium. In this work, existing analytical models to estimate the beam energy loss for both passive and active beam dump schemes are reviewed. In the passive scheme, an electron beam undergoing a quiescent plasma is decelerated by its self-driven wakefield. In the active case, a beam or laser-driven wakefield enhances beam deceleration. For the passive case in particular, tailored plasma density profiles can improve beam-energy extraction by mitigating particle re-acceleration. A semi-analytical model, based on the dynamics of test-particles experiencing the existing wakefields, is presented for deceleration in the linear regime. Built upon previous models, which rely on the frozen-beam approximation, the semi-analytical model includes collective beam deformation as well as re-acceleration and defocusing of particles in the beam. This includes the formation of secondary beam density peaks due to particle re-acceleration. This information can be used to prevent decelerated beam particles from becoming highly relativistic again.

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