Quantum beamstrahlung: a platform to precisely probe strong-field QED

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Beamstrahlung in leptonic collisions can lead to severe energy loss of colliding beams [1]. High-luminosity collisions between dense and high-energy (10s GeV to a few TeV) beams planned for future colliders, including advanced collider concepts through high-gradient plasma based accelerators, will place beamstrahlung in the quantum regime. The self fields of colliding beams are ideally suited to test strong-field QED predictions: the fields are static and quasi-uniform and thus providing a highly controllable platform, as compared with laser-based configurations and beam-plasma interactions [2]. We show that in the low disruption limit, the beamstralhung can be computed with the one-photon spectrum and pair production remains negligible [3]. A characteristic spectral peak close to the beam energy is identified, as a signature predicted by strong field QED theory. The dependence of the spectral peak on the beam parameters is also determined. Ultra-bright colliding gamma-ray beams are produced in the collision and the possibility of using the radiation for a photon-photon collider has been envisaged decades ago [4]. In the low disruption limit, we show that the gamma-ray beam is highly collimated along the propagation direction of the emitting beam and the brightness can reach 10^{30} photons/(s mm^2 mrad^{2}0.1%BW) for initial 100 GeV electron beams. All the theoretical results are confirmed by self-consistent 3-dimensional QED particle-in-cell simulations.

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