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GPU Accelerated Weak-Strong Simulations of Beam Quality Degradation Mechanisms due to Strong Head-on Beam-beam Interactions and Application to the FCC-hh

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The beam-beam interaction is one of the most severe limitations on the performance of circular colliders, as it is an unavoidable strong nonlinear effect. As one aspires for greater luminosity in future colliders, one will simultaneously achieve stronger beam-beam interactions. We study the limitations caused by strong incoherent head-on beam-beam interactions, using a new GPU-based code (CABIN) allowing for a detailed description of the long term particle trajectories in 6D phase space. The evolution of the beam emittance and beam intensity has been monitored to study the impact quantitatively, while frequency map analysis has been performed to understand the impact qualitatively. Results from CABIN has shown good quantitative agreement with dedicated experiments in the LHC. Schemes devised to cancel beam-beam driven resonances, by use of specific intermediate phase advances between the interaction points, work very well with zero crossing angle. Due to lack of symmetry, these schemes have an almost negligible impact with a significant crossing angle. The hourglass effect has been found to reduce the detrimental effects caused by the chromaticity and vice versa. The optimal level of the hourglass effect has been achieved when β^* is 1.5 times greater than the RMS bunch length. With the FCC baseline parameters, based on LHC tunes, a realistic maximum total beam-beam tune shift has been found at approximately 0.02. Alternatives to reach the ultimate goal of 0.03 are discussed.

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