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RF Design and Optimization of the High-Energy Linac for the FCC-ee Injector Complex

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The high-energy linac of the Future Circular Collider electron-positron (FCC-ee) injector complex requires high-performance RF accelerating structures to efficiently accelerate beams up to 20 GeV while ensuring operational stability. This study presents an analytical approach to the RF design of traveling-wave structures, incorporating a pulse compression system to enhance power efficiency and meet the demanding FCC-ee specifications. By utilizing lookup tables and analytical models, we systematically explored a broad parameter space to determine the fundamental mode at 2.8 GHz and analyze Higher Order Mode (HOM) characteristics. The structure's geometry, particularly the iris parameters, was optimized to maximize effective shunt impedance, minimize peak surface fields, and implement HOM detuning for wakefield suppression. Additionally, we investigated the bunch-to-bunch energy spread minimization including the impact of transient beam loading, with a focus on top-up operation, where bunch charges vary dynamically among four bunches. To accommodate these variations, we introduce the concept of the "golden"RF pulse, an optimized input RF waveform

that averages the solutions for fully loaded and unloaded conditions. While this method does not eliminate energy deviations entirely, it provides a practical compromise, reducing energy spread across all possible charge distributions. Finally, comprehensive thermal and mechanical simulations were performed to evaluate the structural integrity and operational performance of the HE linac under 100 Hz repetition frequency, ensuring long-term reliability.

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