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BBU Thresholds and Digital Feedback Suppression for Frequency-Scaled BNL Cavities in the EIC Energy-Recovery Linac

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The Electron–Ion Collider (EIC) achieves its design luminosity by cooling the ion beam with a high-current electron beam generated in an energy-recovery linac (ERL). The baseline ERL lattice employs a BNL five-cell cavity that is frequency-scaled to 197 MHz, 591 MHz, and 1.773 GHz, raising concerns about multibunch beam-breakup (BBU) instabilities. Threshold currents for each frequency option are established with two independent BBU tracking codes, providing cross-validated operating margins that guide cavity selection. To further increase the current limit, we incorporate a digital transverse feedback (FB) system that targets the dominant higher-order modes (HOMs). Simulations show the FB raises the BBU threshold by roughly an order of magnitude: power-spectral-density analysis of the beam centroid at the linac exit confirms strong suppression of the aliased HOM peak, although some spectral growth appears at secondary frequencies. This combined study quantifies baseline BBU limits, demonstrates effective active mitigation, and charts a practical path toward robust, high-current operation of the EIC ERL.

Footnotes

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Authors: NETHTHIKUMARA, Isurumali (Thomas Jefferson National Accelerator Facility); DEITRICK, Kirsten (Thomas Jefferson National Accelerator Facility); Dr SERENO, Nicholas (Argonne National Laboratory); SETINIYAZ, Sadiq (Thomas Jefferson National Accelerator Facility)

Presenter: SETINIYAZ, Sadiq (Thomas Jefferson National Accelerator Facility)

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