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Beam envelope measurements using beam position monitors for low-beta superconducting linear accelerator

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Accurate monitoring of beam dynamics in superconducting linear accelerators (linacs) is important for minimizing beam losses and maintaining stable operation. In superconducting sections, however, destructive diagnostics must be avoided to prevent issues such as particulate contamination and outgassing, which makes direct beam envelope measurements particularly difficult. This work introduces a non-destructive approach that leverages beam position monitors (BPMs) to infer the transverse beam envelope by measuring the quadrupole moment of the beam profile. Although the principle was initially proposed in the 1980s, its adoption—especially for hadron beams—has remained limited due to insufficient signal sensitivity and the geometric limitations of conventional BPM designs. To address these challenges, we utilized BPMs with a cos(2θ) electrode structure, which provide enhanced sensitivity to quadrupole components and are particularly effective for low-β heavy ion beams. This technique was implemented in the superconducting RIKEN linac (SRILAC), where data from eight BPMs were combined with transfer matrix modeling and supplementary wire scanner measurements. The estimated beam envelopes showed good agreement with results from standard quadrupole scans, validating the proposed method as a practical tool for non-destructive, routine beam diagnostics in superconducting accelerator systems.

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Footnotes

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