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Automated RF phase adjustment for beam stabilization in the Fermilab Linac

Monday 11 August 2025 16:00 (2 hours)

The Fermilab Linac delivers 400 MeV H- beam. Variations in environmental factors and Ion Source output result in day-to-day longitudinal phase drift leading to increased beam loss. Traditionally, phase drift is corrected by manual RF cavity phase adjustments, a process that is labor-intensive and suboptimal. This work explores machine learning-based automation of drift correction using data-driven modeling of the Linac behavior. After extensive experimentation with single-layer, multi-layer, and convolutional neural networks (CNN+NN), we now adopt a prototype-based classification approach to identify optimal correction strategies. The model leverages a reduced 34-dimensional feature set comprising 7 RF cavity settings and 27 Beam Position Monitor (BPM) phase readings. To model the beam longitudinal response, we construct a 7×27 response matrix by varying the 7 cavity phases. Due to the limited set real-world data, synthetic data generation from the response matrix is also being explored to enhance model training. This enables the simulation of diverse drift scenarios and improves the generalizability of learned corrections. Finally, in addition to the prototypical loss framework, we incorporate a surrogate energy-consistent loss that penalizes inconsistencies between predicted phase corrections and changes in beam energy—estimated from the 27 BPM readings—alongside a temporal smoothness constraint that discourages abrupt prediction shifts across sequential readings.

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Yes

Would you like to submit this poster in student poster session on Sunday (August 10th)

No

Footnotes

Funding Agency

I have read and accept the Privacy Policy Statement

Yes

Author: CHICHILI, Rithish (University of Illinois Chicago)

Co-authors: VAMANAN, Balajee (University of Illinois Chicago); SULSKIS, Jason (University of Illinois Chicago); SHARANKOVA, Ralitsa (Fermi National Accelerator Laboratory); RAVI, Sathya (University of Illinois Chicago)

Presenter: SHARANKOVA, Ralitsa (Fermi National Accelerator Laboratory)

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