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AI-Assisted Phase Space Inference and Beam Optimization

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Reconstructing the full 6D phase space of a particle beam is a significant challenge, particularly the longitudinal (z - p_z) component, which is difficult to measure without interfering with beam operation. We explore the use of artificial intelligence to infer this hidden information from more accessible transverse projections, such as x - p_x and y - p_y phase space images. This “virtual diagnostic” approach offers the potential for non-invasive monitoring and could support more precise, real-time beam control. Initial experiments using simulated data demonstrate the feasibility of high-dimensional reconstruction and lay the groundwork for future extensions. In parallel, we propose a learning-based beam control method that integrates imitation learning and reinforcement learning in a unified framework. Instead of treating them separately, the algorithm dynamically adjusts their contributions during training—shifting from imitation to reinforcement as the policy improves. This hybrid strategy enables efficient learning in sparse-reward environments while ensuring stability. Tests in a virtual accelerator show stable convergence and improved beam intensity.

Footnotes

Funding Agency

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Yes

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