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Physics-Informed Priors for Sample Efficient Models of Beam Transport with Intense Space Charge

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Highly accurate simulation tools have become a staple in the design and operation of high-brightness particle accelerators. These tools are not without limitations, however. They are often computationally expensive. Many codes are incompatible with automatic differentiation (for machine learning). It can also be unclear how to include real-world measurements in a way that improves the model. Many of these problems are solved with a data-driven approach. Surrogate models are fast to evaluate, differentiable, and treat data from simulations and particle accelerators uniformly. Unfortunately, surrogate models often require a large amount of (possibly expensive) training data for their creation. In this work, we bridge the gap between purely data-driven models and physics-based simulation tools by introducing physics-informed priors for accelerator surrogate modeling. By coaxing our models to obey the physical laws that govern charged particles in an accelerator, we can improve sample efficiency while maintaining the benefits of surrogate models. We present our initial results that directly compare the accuracy of conventional and physics-informed models trained with few samples.

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