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Improving Accelerator Surrogate Models with a Knowledge of Physics

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Physics-based simulation tools are essential to the design and operation of modern particle accelerators. Although accurate, these tools tend to be expensive to evaluate, aren't always compatible with modern implementations of automatic differentiation, and have a hard time incorporating data from real-world machines. Surrogate models have the potential to solve these problems by turning simulated data (or measurements) into quick-to-evaluate and differentiable functions though machine learning techniques. In this work, we improve on the way surrogate models are trained by "teaching"them about the already known laws of physics that govern charged particle beams. By training models of a toy particle accelerator with an additional "physics-informed neural network"loss term based on the Vlasov equation, we demonstrate significantly lower error (by more than a factor of two) in our models compared to those trained on simulated data alone. This research paves the way for accelerator physics to bridge the gap between purely data-driven models and physics-based simulation tools by introducing physics-informed priors for surrogate modeling.

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digital twins

Secondary Keyword

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Tertiary Keyword

surrogate model architectures

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