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Updates to the differentiable accelerator simulation code Cheetah

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The design and operation of modern accelerators demand advanced simulation tools capable of addressing complex challenges. Differentiable simulations are particularly valuable, as they enable gradient-based optimization techniques that significantly reduce computational costs and efficiently tackle high-dimensional problems. The PyTorch-based simulation code Cheetah was developed to combine high-speed, differentiable simulations with seamless integration into machine learning workflows. In this work, we present recent updates to Cheetah, developed collaboratively by DESY, KIT, SLAC, and LBNL, which extend its capabilities and enhance its performance. Key advancements include support for vectorized execution, enabling simultaneous simulations across large parameter spaces; the addition of space charge modeling and higher-order transfer maps for more accurate beam dynamics; and expanded support for multiple particle species and additional accelerator components, broadening its applicability to other systems. By enabling faster, more precise, and scalable simulations, Cheetah is poised to become a valuable tool for meeting the growing demands of the accelerator physics community.

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