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Low Temperature Kinetic Plasma Simulations for New and Future Supercomputer Architectures

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Kinetic simulations for low-temperature plasmas are widely applicable to many modern plasma applications, including materials processing and etching, plasma switches, and spacecraft electric propulsion. At the Princeton Plasma Physics Laboratory we are developing simulation tools to enable engineering prototyping of low-temperature plasma devices. One of our tools, based on the standard particle-in-cell method, has been written from the ground up to take advantage of modern supercomputing architectures. This includes targeting the multi-level parallelism inherent to new chips, as well as heterogeneous architectures such as CPU-GPU systems. Specific challenges inherent to low-temperature plasma kinetic codes include the increasing importance of Monte-Carlo collision algorithms, as well as the challenges associated with solving the elliptical Poisson equation on very large simulation grids. Here we explore these challenges, and offer some ideas on how they can be handled on modern supercomputers, particularly those with CPU-GPU architecture. We also present profiling results which demonstrate the advantages of writing algorithms which can specifically target these new and future supercomputers.