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Particle-In-Cell Modeling for MegaJoule Dense Plasma Focus[1]

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Megajoule scale dense plasma focus (DPF) Z-pinches with deuterium gas fill are compact devices capable of producing 10^{12} neutrons per shot but past predictive models of large-scale DPF have not included kinetic effects such as ion beam formation or anomalous resistivity. We report on progress of developing a predictive DPF model by extending our 2D axisymmetric collisional kinetic particle-in-cell (PIC) simulations from the 4 kJ, 200 kA LLNL DPF to 1 MJ, 2 MA Gemini DPF using the PIC code LSP. These new simulations are by far the most detailed and computationally intensive DPF simulations run to date. They incorporate electrodes, an external pulsed-power driver circuit, and model the plasma from insulator lift-off through the pinch phase. To accommodate the vast range of relevant spatial and temporal scales involved in the Gemini DPF within the available computational resources, the simulations were performed using a new hybrid fluid-to-kinetic model. This new approach allows single simulations to begin in an electron/ion fluid mode from insulator lift-off through the 5-6 μs run-down of the 50+ cm anode, then transition to a fully kinetic PIC description during the run-in phase, when the current sheath is 2-3 mm from the central axis of the anode. Simulations are advanced through the final pinch phase using an adaptive variable time-step to capture the fs and sub-mm scales of the kinetic instabilities involved in the ion beam formation and neutron production. An anode shape scan as well as a scan in stored energy/charging voltage has been performed. A comparison of MJ performance for different drivers will be presented. Validation assessments are being performed, comparing against experimental measurements of neutron yield, neutron anisotropy and plasma density.

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