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# First-Principle Simulations Reproduce Multiple Cycles of Abrupt Large Relaxation Events in Beam-Driven JT-60 Plasmas

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Using the high-performance supercomputer Helios and advanced numerical methods, first-principle simulations of fast-ion-driven magnetohydrodynamic (MHD) modes have, for the first time, reproduced multiple cycles of so-called "Abrupt Large Events (ALE)" as observed in beam-driven high-beta JT-60 tokamak experiments. This is a major milestone because, unlike experiments, such simulations can provide us with physical information at arbitrary levels of detail. This is required for clarifying the mechanism that triggers ALEs as well as for the development and verification of reduced models that are urgently needed for predictive simulations of fast ion dynamics in burning-plasma-relevant experiments (such as JT-60SA and ITER) and power plant design (DEMO). In this paper, we describe the numerical methods used, validate the results against experimental data from JT-60, and present first new physics insights that were obtained from the analysis of the simulation results. For instance, it is shown that ALEs occur when multiple fast-ion-driven modes with different toroidal wavelengths grow to large amplitudes while interacting nonlinearly. This multi-wavelength-nature of ALEs was subsequently confirmed experimentally, which demonstrates the predictive capability of these simulations. Moreover, it is shown that these long-time simulations yield more accurate and detailed predictions for the fast ion density profile and velocity distribution, even in the presence of strong Alfven mode activity.

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