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Critical fast ion distribution in phase space for the synchronized sudden growth of multiple Alfvén eigenmodes and the global transport of fast ions

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Alfvén eigenmodes (AEs) driven by fast ions in tokamak plasmas and the fast ion distribution formed with the AEs, neutral beam injection (NBI), and collisions are investigated with hybrid simulations for energetic particles and a magnetohydrodynamic (MHD) fluid [1]. The multi-phase simulation [2], which is a combination of classical simulation and hybrid simulation, was applied for various beam deposition power (P_NBI) and slowing-down time (t_s). In the classical simulation, energetic particle orbits are followed in the equilibrium magnetic field with NBI and collisions while the MHD perturbations are turned off. The physical parameters other than P_NBI and t_s are similar to those of a TFTR experiment [3]. For P_NBI=10MW and t_s=100ms, which are similar to the TFTR experiment, the AE bursts take place with a time interval 2.7ms and the maximum amplitude of radial MHD velocity normalized by the Alfvén velocity vr/vA=3x10^-3, which are close to the TFTR experiment. With increasing volume-averaged classical fast ion pressure, the fast ion confinement degrades monotonically due to the transport by the AEs. The fast ion pressure profile resiliency, where the increase in fast ion pressure profile is saturated, is found for the cases with the AE bursts. In this work, we have clarified the physical process of the AE burst in toroidal plasmas. Before the AE bursts occur, multiple AEs become unstable, and grow to low amplitude. The low-amplitude AEs gradually and locally flatten the fast ion distribution in phase space leading to the formation of a stepwise distribution. The stepwise distribution is a "critical distribution"where the further beam injection leads to the higher AE amplitude, the broadening of the locally flattened regions, and their overlap. This resonance overlap of the multiple AEs [4] brings about the AE burst, the global transport of fast ions, and the saturation of the distribution.

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