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Multi-Time-Scale Energetic Particle Dynamics in JT-60U Simulated with MHD Activity, Sources and Collisions

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The dynamics of Alfven waves and fast ions in JT-60U plasmas driven by powerful Negative-ion-based Neutral Beams (N-NB) are studied for the first time using long-time simulations, which include N-NB sources, collisions, MHD and wave-particle interactions self-consistently. The simulations are able to reproduce experimentally observed bursts of MHD activity, which chirp down and up in the frequency range 40-60 kHz and occur at intervals 5-15 ms. The underlying modes are identified as resonant wave-packets known as Energetic Particle Modes (EPM) with dominant toroidal mode number n=1. The EPM bursts modify the fast ion distribution significantly, which means that self-consistent simulations as performed here are needed for accurately computing fusion rates, heating and current drive. The successful reproduction of chirping bursty modes in JT-60U validates the new tools for predictive simulations of future experiments, such as JT-60SA and ITER. On the physics side, the self-consistent simulations enable us to study the important meso-time-scale dynamics that connect slow and fast processes. For instance, it is found that the large Larmor radius of N-NB ions together with resistive dissipation play a key role for the intermittency of the bursts. The JT-60U plasmas studied are also subject to Abrupt Large Events (ALE), which are characterized by short intense magnetic fluctuation signals and subsequent drops in the plasma core neutron rates. Efforts are underway to reproduce these relaxation events with the long-time simulations in order to unravel the underlying physical processes, such as the trigger mechanism. The self-consistent simulations are complemented with conventional simulations, where the plasma response is probed starting from a suitable initial condition. It is shown that EPMs with toroidal mode numbers n>1 may be excited by particles that have energies about 100-200 keV below the N-NB ion birth energy (400 keV). The ALE period is comparable to the time needed for a particles to slow down into that energy range, which indicates that n>1 modes are important for ALEs. Furthermore, EPMs are subject to convective amplification and different harmonics interact via scattering of resonant particles. These nonlinear effects may play a role for triggering relaxation events, like ALEs. Further analyses are in progress and will be reported at the conference.

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