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Effect of anisotropic fast ions on internal kink mode stability in DIII-D negative and positive triangularity plasmas

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Recent DIII-D experiments show that sawteeth can be strongly affected by anisotropic fast ions from Neutral Beam Injection (NBI) in both negative and positive triangularity plasma configurations. Fast ions from co-current NBI are stabilizing for the sawtooth stability, resulting in longer sawtooth periods. On the other hand, fast ions from counter-current NBI are destabilizing, leading to small and frequent sawteeth. The relative change in the sawtooth period and amplitude can be more than 50%. The observation appears to hold in both plasma shapes. Non-perturbative toroidal modeling, utilizing the magnetohydrodynamic-kinetic hybrid stability code MARS-K, reveals an asymmetric dependence of the stability of the (1,1) internal kink mode on the injection direction of neutral beams, being consistent with the experimentally observed sawtooth behavior. The MARS-K results suggest that anisotropic fast ions strongly affect the mode growth rate and frequency through both adiabatic (fluid) and non-adiabatic (kinetic) contributions. The asymmetry of the (1,1) kink mode instability relative to the beam injection direction is mainly due to the non-adiabatic contribution of passing fast ions, which stabilize (destabilize) the internal kink with the co-(counter-) current beam injection. The mode growth rate of the internal kink mode with co-(counter-) current beam injection can be increased (decreased) by a factor of 2 compared with the fluid limit. Trapped particles are always stabilizing due to precessional drift resonances. Modeling also shows that fast ions affect the n = 1 internal kink in a similar manner in both negative and positive triangularity plasmas, albeit being more unstable in the negative triangularity case. This similarity is mainly attributed to the fact that the mode is localized inside the q=1 flux surface, with very similar eigenmode structures in both negative and positive configurations. Furthermore, MARS-K modeling indicates that other factors, such as the plasma rotation, the plasma resistivity, or the presence of a resistive/ideal wall, have much weaker effects on the mode stability as compared to that of the drift kinetic resonance effects of fast ions in DIII-D.

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