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Fast-ion energy loss during TAE avalanches in the National Spherical Torus Experiment[1]

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Increasingly, advanced operating scenarios are dependent on non-inductive control of the current profile with neutral beam injection often used as the tool to modify the current profile. It is then important to understand and predict the impact of energetic particle driven modes, such as fishbones and Alfvenic instabilities on the distribution of fast ions. The redistribution of fast ions is an inherently non-linear problem involving mode saturation physics, non-linear changes in mode structure, frequency chirping and coupling between modes. Direct 3-wave coupling and coupling of different modes through the fast ion distribution together with other non-linear behaviors are seen in the National Spherical Torus Experiment. From a database constructed of over 700 TAE avalanche events on NSTX it was found that avalanches occur only when $\beta_{\rm fast}/\beta_{\rm total}$ greater than 0.3 and mode amplitude $\delta B_\theta/B$ greater than $5\mathrm{x}10^{-4}$. The avalanches are correlated with drops in neutron rate of up to $\approx$25 percent, indicating an enhancement in fast ion transport. The fast ion transport is modeled with the ORBIT code using measured TAE frequency and mode amplitude evolution to scale the linear eigenmodes calculated with NOVA. This modeling found that the fast ion losses from the plasma were negligible at the measured mode amplitudes, however, the simulations predicted significant drops in neutron rate. The estimated transfer of energy from the fast ion distribution to the TAE, comparable to the estimated energy loss through wave damping, results in a predicted neutron rate of about half that observed. The fast ions were also moved outward in minor radius to a region of lower plasma density, accounting for the other half of the observed neutron rate drop.

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