Energetic Ion Transport and Neutral Beam Current Drive Reduction Due to Microturbulence in Tokamaks*

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Energetic ion transport due to microturbulence can significantly broaden the fast ion pressure profile with consequences for energetic particle driven instabilities and non-inductive current drive from neutral beam injection. Experiments on the DIII-D tokamak reveal the incremental beam ion transport driven by microturbulence, particularly in ITER-relevant scenarios where off-axis current drive is used by tilting one beamline for injection at a normalized minor radius of r/a=0.5. Anomalous fast ion transport in MHD-quiescent plasmas is investigated using spectroscopic measurements that probe the beam ion distribution, providing radial profiles of beam ion density. These measurements are compared to synthetic diagnostic simulations in which the classical (i.e., non-turbulent) beam ion distribution is calculated by the Monte Carlo neutral beam code NUBEAM. Differences between these two profiles indicate the presence of non-classical transport effects. These plasmas are further modeled by the new energy and pitch angle dependent anomalous diffusivity feature of NUBEAM, with the turbulent diffusivities calculated self-consistently using the gyrokinetic code TGYRO/TGLF. It is also possible to define analytic expressions for the anomalous diffusivity based on existing theoretical models. Microturbulence-induced beam ion transport decreases neutral beam current drive (NBCD) efficiency, especially for off-axis beam injection where the ions are deposited in regions with stronger turbulence. Instances of NBCD up to 30% below expected values based on neoclassical predictions occur in conditions where strong microturbulence driven thermal transport is inferred. The ability to model and predict the impact of microturbulence in off-axis NBCD scenarios will be presented.

*Supported by the US DOE under DE-FC02-04ER54698.