Initial Off-axis Neutral Beam Experiments in DIII-D*

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Off-axis neutral beam injection (NBI) as an effective source of torque and/or current drive is essential to plans for advanced scenarios in DIII-D and ITER. Previous results from many tokamaks validated the theoretical models of NBI for central deposition; however, results are somewhat less clear for off-axis deposition. Fast ion instabilities, and in some cases microturbulence, appear to cause significant deviations from standard model predictions.

With the goal of 5 MW of off-axis beam injection at mid-radius, two of the eight neutral beam sources on DIII-D have been modified to allow vertical steering, with the injection angle varying from horizontal to downward at an angle of 16.5 degrees. Initial experiments to assess the basic beam functionality, geometry, confinement and neutral beam current drive (NBCD) were carried out. D_α images of beam into gas and plasma yield beam neutral profiles and are key in assessing beam shape and clipping. Neutron and fast-ion D_α (FIDA) diagnostics check classical behavior of the confined off-axis beam ions in MHD-quiescent conditions. For validation of off-axis NBCD physics, the local NBCD profile was measured in H-mode plasmas and compared with modeling under a range of beam injection and discharge conditions. The radial profile of NBCD measured by the magnetic pitch angles from the motional Stark effect diagnostic clearly shows hollow NBCD profiles with the peak NBCD location at $\rho \sim 0.45$, in agreement with the classical model calculation using the Monte-Carlo beam ion slowing down code, NUBEAM.

An initial physics experiment takes advantage of the downward steered beams to vary the fast-ion gradient $\nabla\beta_f$ from centrally peaked to hollow. Systematic scans determine the stability and impact on reversed shear Alfvén eigenmodes and toroidicity induced Alfvén eigenmodes as $\nabla\beta_f$ is varied radially. Consistent with the so-called “standard drive" mechanism, these experiments show AEs are modified by off-axis injection with Alfvén eigenmodes disappearing in regions (i.e., the plasma core) where the fast ion gradient is weak or inverted, but remaining in outer regions where gradients are similar to those from on-axis injection.

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