Validation of On- and Off-axis Neutral Beam Current Drive Against Experiment in DIII-D*

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Neutral beam current drive (NBCD) experiments in DIII-D using vertically shifted plasmas to move the current drive away from the axis have clearly demonstrated off-axis NBCD. Time-dependent measurements of magnetic pitch angles by the motional Stark effect diagnostic are used to obtain the evolution of the poloidal magnetic flux, which indicates a broad off-axis NBCD profile with a peak at about half the plasma radius. The measured off-axis NBCD profile is consistent with calculations using an orbit-following Monte-Carlo code for the beam ion slowing down including finite-orbit effects, provided there are no large-scale MHD activities such as AE modes or sawteeth. Agreement is found between the measured pitch angles and those from simulations using transport-equilibrium codes. The fast-ion density profile is inferred from neutron and fast-ion D_alpha diagnostics. As expected, prompt losses are larger (smaller) for off-axis (on-axis), perpendicular (tangential), or counter-current (co-current) injection. Some evidence of non-classical transport is observed. Off-axis NBCD is planned for ITER, so detailed comparison of theoretical models with experimental measurements is needed for accurate projections. Steady-state, high beta_N tokamak scenarios require current drive that is maximum off-axis. The magnitude of off-axis NBCD is sensitive to the alignment of the beam injection relative to the helical pitch of the magnetic field lines. If the signs of B and I yield the proper helicity, both measurement and calculation indicate that the efficiency is good, even better than for on-axis NBCD because the increased fraction of trapped electrons reduces the electron shielding of the injected ion current, in contrast with electron current drive schemes where the trapped electrons degrade the efficiency.

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