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EX/P2-13: Validation of Off-axis Neutral Beam Current Drive Physics in the DIII-D Tokamak

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DIII-D experiments on neutral beam current drive (NBCD) using the new tilted beamline have clearly demonstrated off-axis NBCD in agreement with modeling. Two of the eight neutral beam sources have been modified for downward vertical steering to provide significant off-axis current drive for AT scenario development. For validation of off-axis NBCD physics, the local NBCD profile was measured in H-mode plasma and compared with modeling under a range of beam injection and discharge conditions. The full radial profile of NBCD measured by the magnetic pitch angles from the motional Stark effect (MSE) diagnostic shows a clear hollow NBCD with the peak NBCD location at rho˜0.45, which is in good agreement with the classical model calculation using the Monte-Carlo beam ion slowing down code, NUBEAM. Time evolution of the MSE signals is consistent with transport simulation with realistic current drive sources. The beam-stored energy estimated by equilibrium reconstruction and neutron emission data do not show any noticeable anomalous losses of NBCD and fast ions. The measured magnitude of off-axis NBCD is very sensitive with the toroidal magnetic field direction that modifies the alignment of the off-axis beam injection to the local helical pitch of the magnetic field lines. If the signs of the toroidal magnetic field and the plasma current yield the proper helicity, both measurement and calculation indicate that the efficiency is as good as on-axis NBCD because the increased fraction of trapped electrons reduces the electron shielding of the injected ion current. This dependency of the off-axis NBCD efficiency on the toroidal field direction is crucial to optimum use of the off-axis beams not only for DIII-D but also for ITER. A detailed NB and Electron Cyclotron Heating (ECH) power scan with variation of the ratio of beam injection energy to electron temperature (E_b/T_e) at fixed beta and with variation of beta at fixed E_b/T_e, around the anticipated ITER parameters, implies that ITER is not likely to suffer from the loss of NBCD efficiency due to additional transport from microturbulence. This work supported in part by U.S. Department of Energy under DE-AC05-00OR22725, DE-FC02-04ER54698, SC-G903402, DE-AC05-06OR23100 and DE-AC52-07NA27344.

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