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EX/1-5: Fully Noninductive Scenario Development in DIII-D Using New Off-Axis Neutral Beam Injection

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New off-axis neutral beam injection (NBI) capability on DIII-D has expanded the range of achievable and sustainable current and pressure profiles of interest for developing the physics basis of steady-state scenarios in future tokamaks. Fully noninductive (NI) scenarios are envisioned to have broad current and pressure profiles with elevated minimum safety factors (q_min), high normalized beta (beta_N), and a large fraction of the plasma current I_P sustained by the bootstrap current. Using off-axis NBI, plasmas have been produced with q_min between ~1.3 and ~2.5 to evaluate the suitability for steady-state operation (f_NI≡I_NI/I_P=1). Nearly stationary plasmas were sustained for two current profile relaxation timescales (3 s), with q_min=1.5, beta_N=3.5, f_NI=70%, and performance that projects to Q=5 in an ITER-size machine. The duration of the high beta_N phase is limited only by the available NBI energy. Low-order tearing modes are absent and the predicted ideal-wall n=1 kink beta_N limit is >4. To achieve higher f_NI, higher beta_N is needed to increase the bootstrap current, and higher q_min will decrease the required external current drive near the axis. Experiments to produce plasmas with q_min>2 showed that the use of off-axis NBI results in higher sustained q_min, with q_min at a larger radius (i.e. a broader current profile), and a broader pressure profile. These changes increased the predicted ideal-wall n=1 kink mode beta_N limit from below to above beta_N =4. These plasmas achieved a maximum beta_N=3.2 limited by the available NBI power and reduced confinement (H_98~1) relative to similar plasmas with lower q_min. beta_N=4 with q_min>1.5 was transiently obtained albeit with only 2 out of 5 MW of off-axis NBI available. Off-axis fishbones and low-order tearing modes were observed in the course of the q-profile scan. These studies indicate that obtaining a sustained, high performance, f_NI=1 scenario involves a number of trade-offs related to the choice of q-profile. This work was supported by the US Department of Energy under DE-AC52-07NA27348, DE-FC02-04ER54698, DE-FG02-04ER54761, DE-AC02-09CH11466, DE-FG02-08ER85195, DE-FG02-08ER549874, DE-AC05-00OR22725, and SC0G804302.

Country or International Organization of Primary Author

USA

Author: Mr HOLCOMB, Christopher T. (USA)

Presenter: Mr HOLCOMB, Christopher T. (USA)

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