DPP15-2015-000892

Abstract for an Invited Paper
for the DPP15 Meeting of
the American Physical Society

Progress Toward Steady State Tokamak Operation Exploiting the high bootstrap current fraction regime[1]

Q. REN, ASIPP

Recent DIII-D experiments have advanced the normalized fusion performance of the high bootstrap current fraction tokamak regime toward reactor-relevant steady state operation. The experiments, conducted by a joint team of researchers from the DIII-D and EAST tokamaks, developed a fully noninductive scenario that could be extended on EAST to a demonstration of long pulse steady-state tokamak operation. Fully noninductive plasmas with extremely high values of the poloidal beta, $\beta_p \geq 4$, have been sustained at $\beta_T \geq 2\%$ for long durations with excellent energy confinement quality ($H_{98y,2} \geq 1.5$) and internal transport barriers (ITBs) generated at large minor radius (≥ 0.6) in all channels (T_e, T_i, n_e, V_{Tf}). Large bootstrap fraction (f_{BS} ~80%) has been obtained with high β_p. ITBs have been shown to be compatible with steady state operation. Because of the unusually large ITB radius, normalized pressure is not limited to low β_N values by internal ITB-driven modes. β_N up to ~4.3 has been obtained by optimizing the plasma-wall distance. The scenario is robust against several variations, including replacing some on-axis with off-axis neutral beam injection (NBI), adding electron cyclotron (EC) heating, and reducing the NBI torque by a factor of 2. This latter observation is particularly promising for extension of the scenario to EAST, where maximum power is obtained with balanced NBI injection, and to a reactor, expected to have low rotation. However, modeling of this regime has provided new challenges to state-of-the-art modeling capabilities: quasilinear models can dramatically underpredict the electron transport, and the Sauter bootstrap current can be insufficient. The analysis shows first-principle NEO is in good agreement with experiments for the bootstrap current calculation and ETG modes with a larger saturated amplitude or EM modes may provide the missing electron transport.

[1]Work supported in part by the US DOE under DE-FC02-04ER54698, DE-AC52-07NA27344, DE-AC02-09CH11466, and the NMCFP of China under 2015GB110000 and 2015GB102000.