Performance of Discharges with High Elongation and β in NSTX and Near-Term Paths Toward Steady State.

S.P. Gerhardt
Princeton Plasma Physics Laboratory
sgerhard@pppl.gov

Spherical Torus configurations for plasma material studies, a nuclear component testing facility (CTF), and eventually fusion power generation, will need strong shaping, high-beta, excellent confinement and (possibly) external current drive in order to operate in steady state. Recent experiments in NSTX have demonstrated high-β, high-κ operation over a range of normalized currents in support of these needs. High-β_P scenarios with non-inductive fractions $f_{NI} \approx 70\%$, elongation of 2.7, normalized beta $\beta_N=5$, normalized current $I_N=I_P/aB_T=2.4$, have been reliably demonstrate with minimal large-scale MHD activity, and have NSTX record low loop voltages. The density in these discharges ramps to a Greenwald fraction of ~1, such that the neutral beam current fraction f_{NBCD} drops from ~25% early in the discharge to 15% at later times; the bootstrap fraction ramps up as the density increases, achieving maximal values of f_{BS}=55%. These scenarios were then extended to higher normalized current I_N= 4.2 and toroidal beta of β_T up to 30%. All of these scenarios benefited from lithium conditioning of the plasma facing components, and achieved confinement comparable to or better than ITER H-mode scaling. n=3 non-resonant error field correction, and n=1 dynamic error field correct and resistive wall mode feedback were critical in maintaining reliability at this high-β_N.

Predictive modeling with the TRANSP code has been used to find near term means to increase f_{NI} beyond 70%, starting from the parameters of the high-β_P discharges discussed above. A 25% decrease in the plasma density, as predicted to be possible with the recently installed liquid lithium divertor (LLD), coupled to a 18% increase in the temperature ($\tau_E \propto n_e^{0.4}$), increases the neutral beam current at the expense of the bootstrap current, and leaves the total non-inductive fraction unchanged. If, however, the temperatures vary inversely with the density, an increase in the non-inductive fraction to 85% may be anticipated. If the densities remain fixed, a 40% increase in T_e and T_i is sufficient to achieve f_{NI}=1; reducing Z_{eff} from 3 to 2 allows reduced the required temperature increase to 25%. This increase in temperature might be provided by increased confinement with LLD, or via core fast wave heating in addition to that from neutral beams.

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