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Spherical Torus Plasma Science and Fusion Energy Development*

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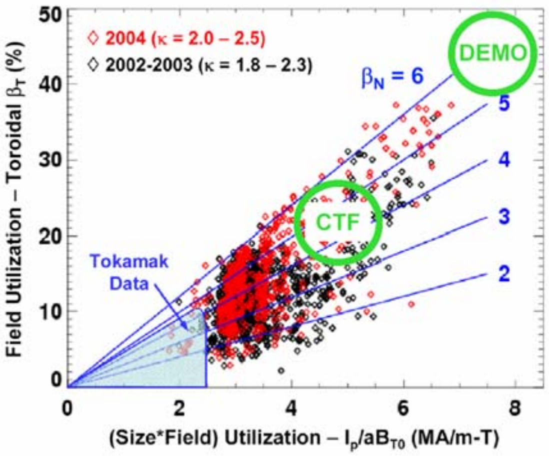
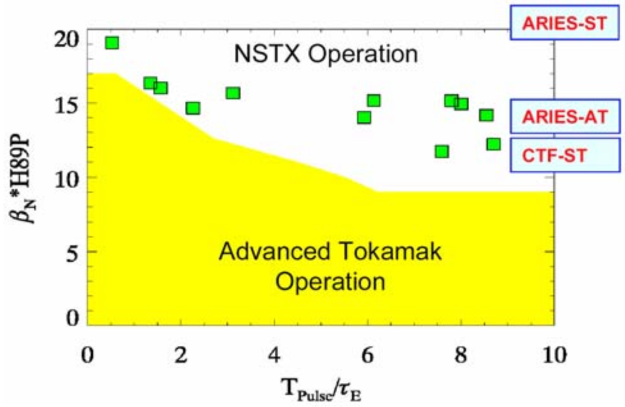
Subject Areas A, F: *Experiments, Concepts and Issues for Future Experiments*

NSTX, together with many ST experiments worldwide, have introduces opportunities to test the scientific basis of fusion plasmas extending to order-unity beta, near-sonic and Alfvénic plasma flow, supra-Alfvénic fast ions, over-dense plasmas, minimized magnetic flux content, and strong in/out asymmetry of the plasma edge. Recent progress from NSTX, taking advantage of these extended parameters, has contributed much to the understanding of: 1) the role of magnetic structure on the limits to plasma pressure; 2) the physical processes that govern the confinement of heat, momentum, and particles; 3) how energetic particles and electromagnetic waves can sustain fusion plasmas; and 4) how to control the interface between the hot plasma and its material surroundings. Factors of three expansions from normal aspect ratio data have been obtained in toroidal beta (β_T) and normalized current (I_p/aB_{T0}), leading to normalized betas (β_N) up to 6 (first figure). Substantial advancement in values of (β_N*H_{89P}) as a function of plasma pulse duration (τ_{Pulse}/τ_E) were also obtained (second figure). These results are analyzed to relate strongly to the physics of the extended plasma parameter space. Projections based on this improved understanding are made of future ST steps in the development of practical fusion energy. It is estimated that a ST-based steady-state Component Test Facility (CTF) is characterized by $R_0 = 1.2$m, a = 0.8m, $\kappa \sim 2.8$, $B_{T0} = 2$T, and $I_p \sim 8$MA. Values of $\beta_T \sim 20\%$ are calculated to be adequate for delivering a fusion power of ~ 80MW and a fusion neutral flux (W_L) of 1 MW/m^2 at the outboard power conversion and tritium-breeding blanket test modules. Values of $\beta_N*H_{89P} \sim 12$ are calculated to be adequate for achieving a fusion amplification Q of about 1.5 in CTF, if confinement times for the ions and electrons are separately estimated according to the ITER H-mode scaling. The performance requirements for DEMO are estimated to be more stringent, requiring $\beta_T \sim 45\%$ and $\beta_N*H_{89P} \sim 21$, assuming an ST characterized by $R_0 \sim 3$m, a ~ 2m, $\kappa \sim 3.2$, $B_{T0} = 1.5$T, and $I_p \sim 30$MA. For both CTF and DEMO, scientific understanding in how to generate plasma magnetic flux and helicity, through initiation, ramp-up and sustainment in the absence of central solenoid induction, is of critical importance and will need to be fully developed in the near future. The most recent results in ST plasma science and assessments in ST fusion energy development will be presented.





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