The high poloidal beta path towards steady state tokamak fusion

A.M. Garofalo[1], X.Z. Gong[2], S.Y. Ding[2], J. Huang[2], J. McClenaghan[1], C.K. Pan[2], J. Qian[2], Q.L. Ren[2], G.M. Staebler[1], J. Chen[2], C.T. Holcomb[3], G. Li[2], B. Lyv[2]

[1]General Atomics, San Diego, California, 92186-5608, USA
[2]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, Anhui, 230031, China
[3]Lawrence Livermore National Laboratory, Livermore, California, 94551, USA

Through coordinated research using plasma modeling and experiments at the DIII-D tokamak and the superconducting tokamak EAST, a collaboration of U.S.- and China-based magnetic fusion scientists is developing the physics basis of fully noninductive, high poloidal-beta (β_P) plasmas for application to steady-state high performance operating scenarios in ITER and CFETR. By optimizing at low plasma current and high plasma pressure, high-β_P operation reduces drastically disruption risks and requirements on external current drive, while improving the energy confinement quality through Shafranov shift suppression of turbulence. Fully noninductive sustainment for many current relaxation times has been obtained in EAST experiments with normalized pressure and confinement projected to suffice for steady state operation with 500 MW of fusion power production in CFETR (Q~5). At higher beta operation, DIII-D experiments show that very high bootstrap fraction creates multiple channels for positive feedback of turbulence suppression, leading to the formation and sustainment of a transport barrier at large minor radius. Self-consistent simulations extrapolating this regime to ITER predict steady-state Q~5 performance with day-one heating and current drive capabilities, the first-time such a result has been achieved using physics based modeling. The beneficial effects of rotation on turbulence are not needed in this scenario, overcoming the long-standing challenge that fusion reactors are projected to have low rotation. Future simulations and experiments on both EAST and DIII-D will aim at demonstrating exhaust heat and particle handling compatible with the high core plasma performance.
This talk will show how the world tokamak effort is strengthened by collaboration between facilities, and how high-β_P tokamaks provide promise for attractive fusion power reactors and excellent scientific research opportunities.

Work supported by US DOE under DE-FC02-04ER54698, Cooperative Agreement #DE-SC0010685 and Contract No. DE-AC52-07NA27344, and by the National Magnetic Confinement Fusion Program of China (No.2015GB102002, 2015GB103000)