DIII-D ACCOMPLISHMENTS AND PLANS IN SUPPORT OF FUSION NEXT-STEPS

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Recent DIII-D research has provided significant new information for the physics basis of key scientific issues for successful operation of ITER and future steady-state fusion tokamaks, including control of edge localized modes (ELMs), plasma instabilities, disruptions, plasma exhaust fluxes and the development of operational scenarios.

ELM control: ELM suppression with magnetic perturbations has been demonstrated in the ITER baseline scenario with q_{95}=3.1 at the ITER pedestal collisionality utilizing an n=3 field produced by a single row of internal coils. The technique has also been extended to expand operational range and explore physics with n=2 fields. In separate studies, pellets were used to "pace" ELMs with tenfold increased rate over natural periods, leading to tenfold decreased divertor energy deposition, using injection geometry similar to that planned in ITER. Finally, non-resonant fields have been used to generate rotation shear in order to access ELM-free "QH mode" regimes with simultaneous high β, high confinement, at ITER-relevant low levels of injected neutral beam torque.

Disruption avoidance and mitigation: Real time mirror steering has enabled advanced feedback techniques to track resonant surfaces and remove or prevent tearing modes with electron cyclotron (EC) current drive, providing a basis for disruption avoidance strategies in ITER. Disruption experiments producing reproducible runaway electron beams (300 kA with 300 ms lifetimes) reveal twice the theoretically expected dissipation rates, demonstrating the possibility of full runaway ramp down with feedback control.

Preparing operation regimes for ITER and FNSF: Experiments have demonstrated the ITER baseline scenario with ITER-equivalent neutral beam injection (NBI) torque. Separate studies have shown the ability to achieve β_N~3, H_{98}~1 ITER Q=10 equivalent fusion gain with ITER-like NBI torque applied for the entirety of the discharge evolution. Turning to steady-state operation, the addition of 5 MW of off-axis neutral beams has enabled sustainment of high β plasmas with much broader current distributions removing the resonant q=2 surface from the plasma. Performance has been further optimized with somewhat more peaked current profiles ($q_{\min}$ > 1.5) to achieve, stationary discharges with β_N=3.5 for two current redistribution timescales.

Reducing plasma exhaust heat flux: A "snowflake" hexapole divertor solution has been ported from NSTX to DIII-D enabling the configuration to be sustained in stationary conditions and leading dramatic reductions in heat flux and ELM energies.

Future plans will expand access to burning plasma and steady state relevant conditions with 12 MW of gyrotrons, 12 MW off axis and 24 MW total neutral beams, enhancing 3D field and disruption mitigation to help prepare and project solutions for operation and control in the relevant regimes for next-step devices.

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