Fusion Research Progress and Plans on DIII-D*

Richard Buttery on behalf of the DIII-D team

General Atomics, PO Box 85608, San Diego, CA 92186-5608, USA

The DIII-D tokamak has addressed key issues to advance the physics basis for burning plasmas for ITER and future steady-state fusion devices. Preparation for ITER remains the highest priority, where strong progress has been made on disruption mitigation and ELM control: it is possible to tune shattered pellet disruption mitigation techniques to optimize thermal and current quench properties by varying impurity content (Fig. 1). A new gamma ray imaging camera validates runaway electron generation and dissipation models at high energies, but identifies increased dissipation at low energy. The physics of ELM suppression by 3D fields is found to be associated with excitement of an edge current driven mode. The technique has been extended to the metal walled ASDEX Upgrade with good performance and impurity flushing, in work that identifies a crucial role played by plasma triangularity in the plasma response to the 3D fields. A new low torque variant of QH mode leads to high performance ELM stable operation, while non-linear simulations account for the saturation of edge MHD that regulates this regime. Probing ITER baseline scenarios with external 3D fields identifies increased plasma response prior to onset of tearing modes, identifies increased response as plasma tearing instability is approached, indicating a relationship to ideal MHD and a potential control tool, although further effort is needed to develop more robust techniques for stability control with suitable performance in low collisionality and low torque variants of the ITER baseline scenario.

DIII-D is also identifying key trends and validating models for transport, energetic particle behavior, pedestal optimization and L-H access to understand behavior in ITER: beam fueling is found to play a role in density peaking. H mode access is facilitated by the occurrence of dual band turbulence associated with increased velocity shear. Observations of core rotation reversal are matched gyro-kinetic simulations; combined with measurements of intrinsic rotation scaling, simulations project significant rotation in ITER. Work validated integrated first principles core-pedestal transport models that predict ITER will achieve its Q=10 goal.

DIII-D is also developing the path toward a steady state advanced tokamak reactor with an integrated core-edge solution. Robust 3D field induced ELM control is found compatible with high confinement in fully non-inductive steady state ‘hybrid’ plasmas (Fig. 2), benefiting from increased plasma response to the 3D fields at high $\beta_N$. Energetic particle losses are explained by multiple overlapping Alfvén eigenmodes, and can be avoided by modifying the current profiles or deploying electron heating, understood to act through changes to the GAM frequency. Divertor studies have identified the critical role of drifts in particle and heat transport, while studies in Helium have isolated gaps in divertor simulation capabilities, pointing to the need for improved molecular radiation models and better accounting of midplane-to-divertor transport.

Significant enhancements to DIII-D are planned in 2018 and beyond to improve device flexibility and performance, with heating power rises and reconfiguration to access high $\beta_N$, and new divertor structures to test the physics and optimize the approach for an integrated core-edge solution for future fusion energy devices.

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