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PARTICLE TRANSPORT RESULTS FROM COLLISIONALITY SCANS AND PERTURBATIVE EXPERIMENTS ON DIII-D

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The critical issues of particle transport behavior with collisionality and resonant magentic perturbation (RMP) application have been studied in recent experiments on the DIII-D tokamak. First, the collisionality scaling of particle transport and turbulence in L-mode plasmas was investigated using similarity techniques (e.g. [1]); the collisionality, ν^*, was varied by a factor of 3–5, but little change was observed in the density profile peaking, and only modest changes in transport rates and turbulence, Fig. 1, in agreement with GYRO predictions. Second, we have obtained the first direct confirmation of an increase in particle diffusion coefficient, D, and reduction in inward pinch velocity, V, with RMP application, in both L- and H-mode plasmas, changes which extend beyond the pedestal into the plasma core [2], see Fig. 2. This increase in core transport is consistent with an increase in measured turbulence levels and decreased **ExB** shear, and also with calculations by the TGLF transport model.

Particle transport experiments on DIII-D have addressed a range of important issues: First, they contribute to the development of a predictive capability for electron particle transport, through validation (or not) of the capabilities of state-of-the-art transport models and simulations such as TGLF and GYRO. Second, the experiments address key issues for ITER, such as the collisionality scaling of particle transport and density peaking, which will directly impact fusion power production and impurity accumulation. In addition, the experiments address the important issue of the causes of the core density pump-out sometimes observed with RMP application, which occurs independent of ELM suppression [3]. While the reduction in edge density with RMP application is a large contributor to the ELM stabilization process by reducing the edge pressure gradient below the peeling-ballooning stability limit [4], a reduction in core density with RMP or ECH application is undesirable as leading to a reduction in fusion performance on ITER.

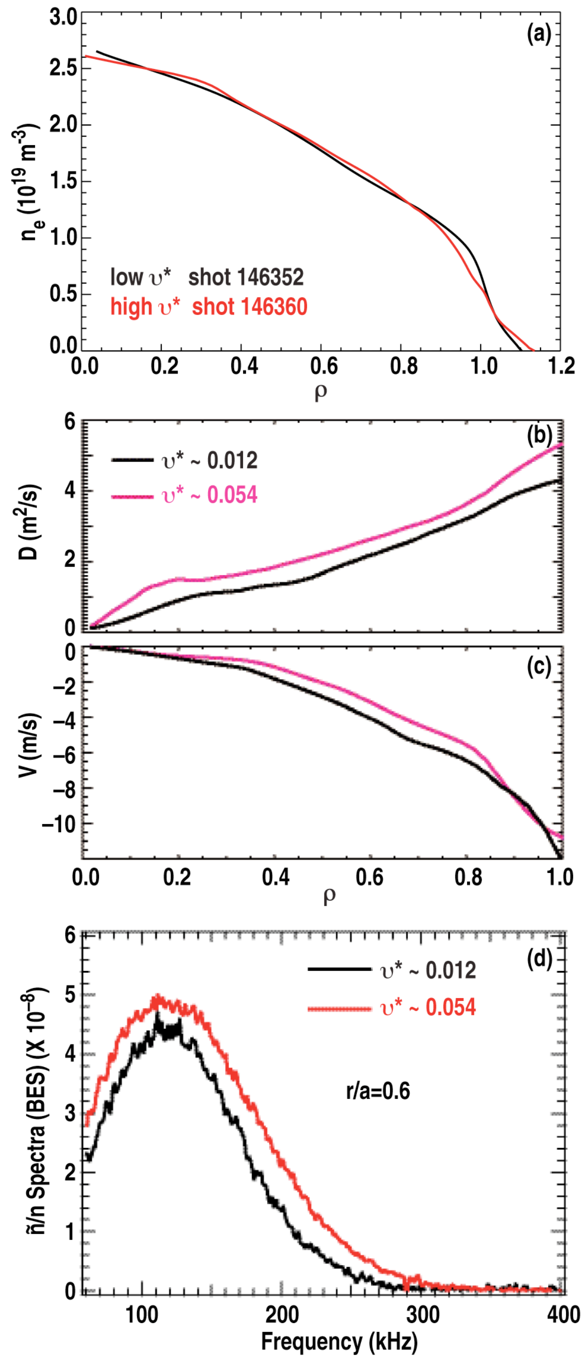

Fig. 1. (a) Density profiles for matched low and high collisionality L-mode discharges, showing no change within measurement error. (b,c) Measured perturbed D, V, again showing little change with collisionality. (d) Measured density fluctuation amplitudes at ρ=0.55 from BES system, showing modest increase in turbulence with collisionality. These observations are consistent with GYRO predictions.

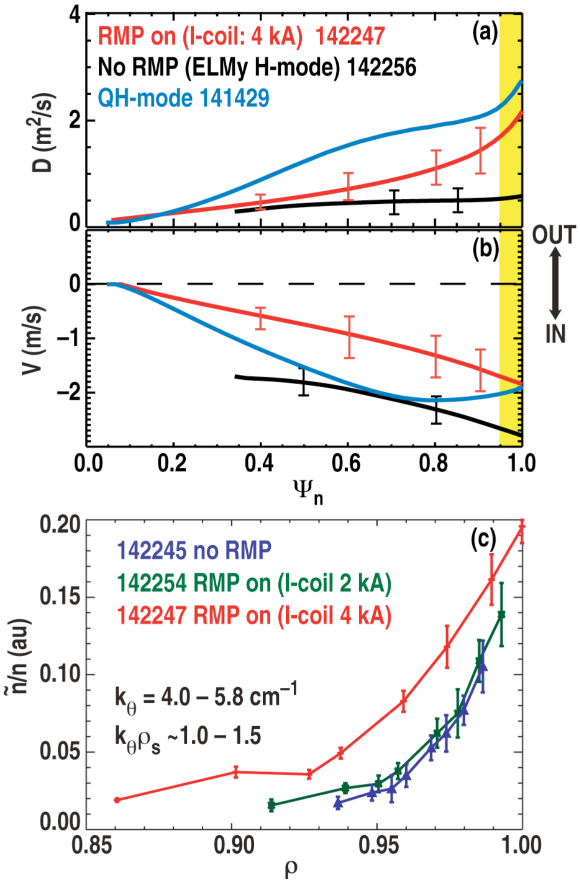

Fig. 2. (a) Particle diffusion coefficient D, and (b) inward particle pinch velocity V, for three discharges; a conventional ELMing H-mode discharge (black), an equivalent ELM-suppressed discharge with RMP applied (red), and a QH-mode discharge (blue). (c) Measured intermediate-k turbulence levels as a function of radius, showing a clear increase with RMP amplitude.

Recent GYRO simulations have predicted that particle flux, as a function purely of collisionality, should show a strong increase at low collisionality, but with little change above a critical value, $\nu^* \sim 0.01$ [5]. To investigate this prediction, an L-mode experiment was performed employing similarity techniques [1] to vary collisionality, i.e. the magnetic field strength and heating power were varied, while matching parameters such as relative gyroradius, beta and safety factor. In the experiment, B_T was varied from 2.1 to 1.65 T, resulting in a change in ν^* from ~0.01 to 0.05. Over this range of collisionality, little change was observed in the density profile, profile peaking, measured D, V, (obtained using perturbative techniques [6]), or measured fluctuation levels, see Fig. 1. These observations are in agreement with GYRO predictions made prior to the experiments; TGLF and GYRO simulations of the actual experimental discharges are underway. In a second set of experiments, perturbative transport techniques using oscillating gas puffs were utilized to measure D and V in conventional ELMing H-mode, ELM-suppressed RMP and QH-mode regimes, as well as L-mode. These experiments provide the first direct measurement confirming an increase in D and decrease in V with RMP application. Figure 2 (a) and (b) provide a direct comparison of D and V for two comparable discharges, with and without RMP application, and also for a QH-mode discharge under somewhat different conditions. One important feature of the measurements is that the changes in D and V with RMP application extend deep into the plasma core, past the edge region where the applied RMP fields are expected to directly impact the magnetic field topology. In the plasma core, clear increases in plasma turbulence levels are observed, Fig. 2(c), consistent with TGLF modeling, while **ExB** shear decreases to a level below the linear growth rate [2].

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[1] C.C. Petty and T.C. Luce, Phys. Plasmas **6**, 909 (1999).
[2] S. Mordijck, et al., submitted to Phys. Plasmas (2011).
[3] T.E. Evans, et al., Nucl. Fusion **48**, 024002 (2008).
[4] P.B. Snyder, et al., Nucl. Fusion **47**, 961 (2007).
[5] G.M. Staebler, private communication (2011).
[6] H. Takenaga, et al., Plasma Phys. Control. Fusion **40**, 183 (1998).