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Role of transport versus fueling upon the pedestal density

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Fueling a future fusion reactor and the effects of fueling upon the pedestal structure is an open physics question and the U.S fusion research program has initiated a multi-institutional effort to develop a physics basis to address this question. In contrast to existing devices, future reactor-scale tokamaks the edge pedestal will be opaque to neutrals and no longer be fueled primarily by edge recycling. As both non-normalized plasma density and machine size increase, we reduce the ability of recycling or gas puff neutrals to penetrate the confined plasma and to contribute to particle sources on closed flux surfaces. We can parameterize the screening of fueling neutrals according to roughly $\delta \sim n \times a$, based on the boundary region width and this is often taken as a rule-of-thumb neutral opacity.

Recent experiments on C-Mod ($n_e \times a\ 3x10^{20} \times 0.22$) and DIII-D ($n_e \times a\ 0.9x10^{20} \times 0.67$) to investigate the role of neutral opacity go from 10 less opaque then ITER, to only a factor 2 less opaque then ITER predictions. In these experiments we observe that the density pedestal structure has moved into the SOL region for C-Mod, but that counter to prior JET and AUG results, this does not result in a degradation of the pedestal pressure. Moreover, in DIII-D, large gas puffs (up to 300 TorrL/s) to increase the opacity, resulted in an increase in the pedestal pressure up to 200 TorrL/s and degradation was only observed at 300 TorrL/s. SOLPS-ITER modeling of these DIII-D and C-Mod discharges show a decrease in neutral penetration with increased opacity and a change in the poloidal distribution of the neutrals, with a deeper penetration from the main vessel on the LFS at high opacity, versus a more uniform distribution at lower opacity.

In regular, DIII-D H-mode discharges (half the opacity of those reported above), the divertor geometry affects the density pedestal profile. A closed divertor geometry shows a reduced density gradient consistent with estimates of a reduction in pedestal fueling. This is a clear indication that changes to pedestal fueling can significantly affect the edge pedestal density structure. The implications of these results towards scaling to future tokamaks with opaque SOLs will be discussed.

While we observed a density pedestal structure in C-Mod, at the highest opacity which resulted in the highest plasma pressure, fueling through a gas puff is very inefficient. Recent DIII-D experiments and NSTX experiments show that for the same fueling rate, pellets and supersonic gas injections are much more efficient, due to deeper penetration of the fuel.

Complementary to the experimental observations, numerical models such as GENE and TGYRO, are capable of simulating plasma turbulence and transport in the steep gradient regions of the pedestal The radial fluxes predicted by the models for measured pedestal profiles are now being compared to those inferred from experiment.

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