

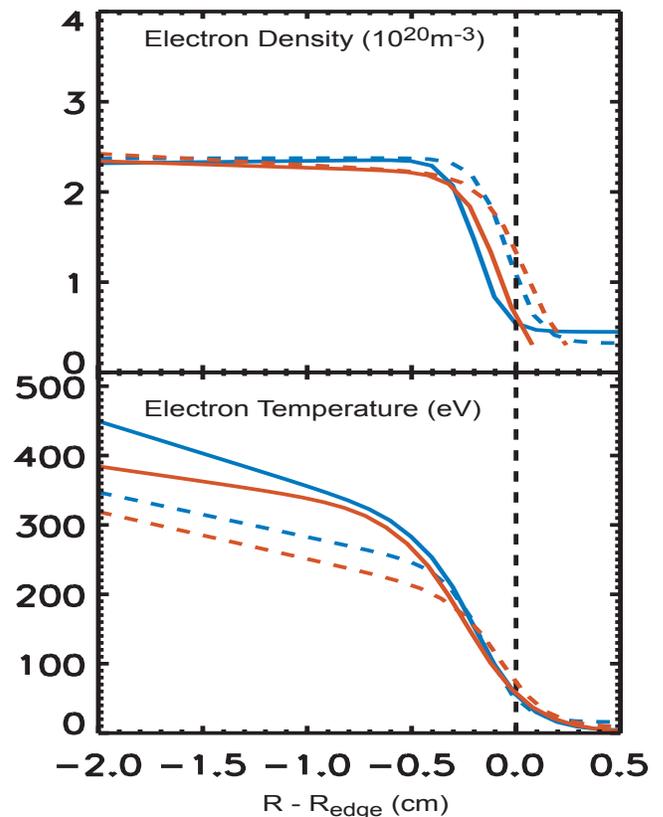
New Insights on Transport in a Dense Tokamak Plasma Edge

Plasma and neutral transport physics are found to be intimately linked in determining the width of the thermal insulation layer that forms at the edge of a high density tokamak plasma.

The device with the greatest potential to confine plasmas at fusion-relevant temperatures is the tokamak, a chamber in which strong magnetic fields are used to trap plasma in a well-confined torus. Under certain circumstances, a tokamak plasma can transition from standard confinement to a high-confinement mode, or *H-mode*, the result of a narrow region of reduced plasma transport present at the H-mode edge, which serves as an “insulating layer” for the confined plasma. In crossing this edge barrier, which is typically a few percent of the total extent of the torus, plasma density and temperature can each jump by a factor of ten or more, giving rise to an enhanced edge *pedestal* in either quantity. These pedestal values have a strong effect on core energy confinement, and predictions of performance on future burning plasma experiments rely on assumptions about the pedestal. However, despite a history of pedestal observations on various tokamaks, there is no clear answer to the question: What factors set the width and height of the edge barrier?

Research on the Alcator C-Mod tokamak has shed some new light on this key question of edge pedestal physics, through experiments combined with neutral transport modeling. Spatially resolved measurements of plasma temperature and density and neutral density are obtained in order to characterize the edge barrier region, which on C-Mod is less than a centimeter in extent. Previous models of neutral interaction with edge plasma have suggested that the density pedestal width is determined by the characteristic ionization length of fueling neutrals. Yet, contrary to this expectation, results on C-Mod indicate that the pedestal is instead governed by the transport physics of the plasma species. Indeed, the application of additional neutral gas during typical C-Mod H-modes has little effect on either the height or width of the density pedestal. This is in sharp contrast with results from other tokamaks, which operate at considerably lower densities than C-Mod.

Recently, detailed modeling of neutral transport physics has provided a potential resolution of these seemingly contradictory results. Due to the higher plasma densities in C-Mod, the rate at which collisions occur between fueling neutrals and hot plasma ions is higher. This decreases the neutral penetration and ionization inside the barrier region. When the ion-neutral interaction is weakened by lowering overall density, the previous simpler model, which is able to simulate the density pedestal in low density machines, again becomes valid. The implication is that the exchange of energy and momentum between plasma and neutral particles should be considered carefully when modeling transport on future tokamaks with high plasma densities.



Sample plasma density and temperature pedestals with (dashed curves) and without (solid curves) additional gas puff. Density pedestal height remains fixed despite perturbation to neutral source.