EFFECTS OF E×B VELOCITY SHEAR AND MAGNETIC SHEAR IN THE FORMATION OF CORE TRANSPORT BARRIERS IN THE DIII–D TOKAMAK*

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Although reliable formation of core transport barriers in tokamak discharges requires some manipulation of the current density profile, the model which has evolved to understand these results includes synergistic effects of magnetic shear and E×B velocity shear. The negative or low magnetic shear allows stabilization of high n MHD modes (*e.g.* ballooning modes). In addition, the magnetic configuration with $q > 1$ everywhere stabilizes sawtooth MHD oscillations. Lack of these instabilities plus application of additional heat and, possibly, angular momentum input allows pressure and toroidal rotation gradients to build, thus increasing the radial electric field E_r and starting the feedback process discussed previously [1,2]. A local transport bifurcation can occur based on E×B shear decorrelation of turbulence as discussed by Staebler and Hinton [3,4]. As pointed out by Diamond *et al*. [5], the local transport bifurcation starts first in the plasma core because magnetic shear effects, $T_i/T_e > 1$ and the Shafranov shift all give the lowest threshold (microinstability growth rate) there. The transport barrier propagates outward into the region of increased microinstability growth rate until the local E×B shearing rate can no longer overcome the instability growth rate. Because E_r can be influenced by particle, angular momentum and heat input, various contributions to E_r through the radial force balance can be active in various machines. In TFTR, for example, the pressure gradient term is dominant and $E_r < 0$ in the plasma core while the toroidal rotation term is dominant and $E_r > 0$ in the plasma core in DIII–D.

There are a number of testable predictions which this theory makes:

1. Sawteeth and ballooning modes are turned off by the magnetic configuration.
2. Negative magnetic shear alone is not sufficient for transport barrier formation.
3. The theory is a local bifurcation theory, accordingly, there should be spatial and temporal correlation between increased E×B shearing rate, transport reduction and fluctuation decrease.
4. E×B shearing rate $\omega_{E\times B}$ should be comparable to instability linear growth rate γ_{MAX} during barrier formation and should increase more than γ_{MAX} rate after formation.
5. The $(RB_\theta)^2/B$ factor [2] will make $\omega_{E\times B}$ bigger on the low toroidal field side of a flux surface, especially in cases with large Shafranov shift; accordingly, turbulence stabilization is easier there and harder on the high toroidal field side.
6. Since the theory contains a local transport bifurcation when $\omega_{E\times B}$ is big enough, there must be a threshold in the heat, particle or angular momentum input required to create the transport barrier. This has four corollaries. First, it is the amount of input inside a given flux surface which matters, not the total power. Second, since the source has to drive pressure gradients and/or rotation, the source strength required must increase at least linearly with the local density. Third, the barrier should expand from the inside out when the source is increased and contract from the outside in when it is decreased. Fourth, destruction of the E×B velocity shear by changing the momentum input should lead to barrier collapse even at constant input power.
7. Hot ion modes should be favorable for barrier formation, since many of the key unstable modes in the plasma core (*e.g.* collisionless trapped electron modes and ion temperature gradient modes) are stabilized by increasing T_i/T_e.

Considerable experimental data from many machines confirming these predictions has been presented previously [2]. The most recent DIII–D results testing these predictions will be presented at the workshop.

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