Experimental Tests of Causality: Role of E×B Shear in Causing Turbulence and Transport Changes in Magnetic Fusion Plasmas*

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A prime goal in physics research is the development of theories which have the universality needed to explain a wide range observations. Developed over the past decade, the model of turbulence decorrelation and stabilization by sheared E×B flow has the universality needed to explain the turbulence reduction and confinement improvement seen in the edge and core of a wide range of magnetic confinement devices. As has been discussed previously,[1] this concept has the universality needed to explain the edge transport barriers seen in limiter and divertor tokamaks, stellarators, and mirror machines in the H–mode. In addition, the model can explain the further confinement improvement from H–mode to VH–mode seen in some tokamaks[2–4] where the edge transport barrier becomes wider. Finally, this paradigm explains the core transport improvement created in plasmas with negative or low magnetic shear.[1,5–8]

Because the E×B shear, turbulence, and transport are all intimately intertwined in multiple feedback loops, devising experiments to test whether E×B shear causes a change in turbulence and transport has been a major challenge for experimentalists. Over the past five years, there have been at least four clear demonstrations of causality performed in tokamak plasmas, both at the plasma edge on DIII–D[4,9–10] and TEXTOR[11] and further into the plasma core on DIII–D[3,4,12] and TFTR.[13] The main goal of the present paper is to discuss these causality tests in detail. Comments will also be made on other results[14,15] which, while not inconsistent with causality, did not allow a clear causality test to be made.

Discussing these causality results at present is particularly timely, since recently a number of theories of the L to H transition have appeared which ignore the role of E×B shear in triggering the L to H transition.[16–18] Based on the experimental evidence that changing E×B shear can cause turbulence reduction and confinement improvement, its seems clear that these theories are missing a key portion of the physics of the transition.

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*Work supported by U.S. Department of Energy under Contract No. DE-AC03-99ER54463.

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