

DPP13-2013-000775

Abstract for an Invited Paper
for the DPP13 Meeting of
the American Physical Society

The Dynamics of Turbulence and Shear Flow Across the L-H Transition on DIII-D¹

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Comprehensive 2D turbulence and flow measurements demonstrate that a rapidly increasing turbulence-driven shear flow is generated ~ 100 microseconds prior to the L-H transition and appears to trigger the transition. Understanding the details of this L-H transition triggering mechanism and the physics behind the power threshold scaling is critical for fusion research, since burning plasmas will require H-mode operation to achieve their performance goals. Using 2D turbulence imaging data acquired with Beam Emission Spectroscopy and applying velocimetry analysis techniques to quantify turbulent flow patterns, a rapid evolution of turbulence and flow shear is observed 1-2 cm inside the separatrix immediately before the L-H transition. Measurements show that in plasmas with injected power just above the L-H power threshold, the inferred turbulent Reynolds stress increases rapidly, as does the poloidal flow shearing rate. The energy transfer rate from turbulence to the flow peaks during this rapid evolution prior to the transition and exceeds the effective turbulence recovery rate. Visualizations of turbulence demonstrate a strong shearing of the turbulent eddies during this final phase. In plasmas with injected power below the L-H power threshold, the measured Reynolds stress, shear flow and energy transfer are lower and the shearing rates are below the decorrelation rate. These observations suggest that increasing power flux leads to increased turbulence, turbulent Reynolds stress, shear flow development and a rapidly increasing poloidal flow that triggers the transition. Similar analysis is applied to measurements at different toroidal fields and densities to help understand the underlying physics behind the empirical L-H transition power threshold.

¹Supported by US DOE under DE-FG02-08ER54999 & DE-FC02-04ER54698.