IAEA FEC 201

Contribution ID: **664** Type: **Oral**

Turbulence and Sheared Flow Structures Behind the Isotopic Dependence of the L-H Power Threshold and H-L Back Transition on DIII-D

Thursday 20 October 2016 09:10 (20 minutes)

Measurements of long wavelength (K_perp Rho_I<1) density fluctuation characteristics in the edge of both Deuterium (D) and Hydrogen (H) plasmas across the L-H transition on DIII-D demonstrate the existence of single or double bands of low-wavenumber turbulence observed near the edge of H and D plasmas, which are strongly correlated with the L to H-mode transition power threshold (P_LH) and can help explain the isotopic and density dependence of P_LH, and how the P_LH difference is reduced at higher density. Understanding and accurately predicting the L-H power threshold is critical to operating and achieving high confinement in burning plasmas such as ITER. Above about n_e~4e19 m^-3, P_LH is seen to converge for the H and D, and increases for both with higher density. Surprisingly, the P_LH increases significantly at low density in H but not in D plasmas. Two distinct frequency bands of density fluctuations are observed in the D plasmas at low density, n_e~1.2-1.5e19 m^-3, but not in H plasmas with similar density, which appears to be connected to the much lower power threshold in D at low density. Consistently, E×B shear near region of r/a~0.95-1.0 is larger in D plasmas than in H plasmas at low density; as the P_LH increases with increasing density, the dual mode structure disappears while E×B shear becomes similar and small for both D and H plasmas at higher density, n_e~5e19 m^-3, where P_LH is similar for both D and H plasmas. In the H-L back transition the ELM like bursts preceding the back transition can eliminate the large transient heat load to the divertor. The size of the bursts is reduced with lower rotation. The power difference (delta_P=P_LH-P_HL) between the L-H transition and H-L back transition increases with increasing density in D plasmas, but reduces in H plasmas, indicating stronger hysteresis in D plasmas as density is increased. The increased edge fluctuations, increased flow shear, and the dual-band nature of edge turbulence correlating with lower PLH can explain the strong isotope and density dependencies of PLH and support current L-H transition theories but suggest a complex behavior that can inform a more complete model of the L-H transition threshold.

Country or International Organization

United States of America

Paper Number

EX/5-1

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Session Classification: Transport & LH Transition

Track Classification: EXC - Magnetic Confinement Experiments: Confinement