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Effect of the ∇B drift direction on plasma edge properties and the L-H transition in DIII-D

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INTRODUCTION

The power threshold for the L-H transition, P_{TH}, is low when the ion ∇B drift is toward the X-point and increases significantly when it is away from the X-point. In order to study the cause of this effect, we have compared lower single-null (LSN) discharges with upper single-null (USN) discharges where the ion ∇B drift direction is down in both cases. Since many plasma parameters change with input power, we have made comparisons at the same power level (P_{TOT}=2.3 MW). For these experiments, the LSN discharge is just below P_{TH} (2.7 MW) and the USN discharge is far from P_{TH} (6.8 MW). We have measured various properties of the edge plasma in an attempt to identify changes that may be responsible for the difference in P_{TH} for the two cases. The equilibrium flux surfaces and diagnostic measurement locations are shown in Fig. 1. The most pronounced difference is the reversal and the increased shear in the poloidal group velocity of the density fluctuations near the plasma edge [1]. These results complement a previous study where the plasma configuration was held fixed and the toroidal field was reversed [2]. In that study, differences in the divertor and X-point plasma were measured. In the present work, the X-point could not be located in the range of the divertor Thomson scattering diagnostic due to top/bottom symmetry issues, and those measurements are not available.

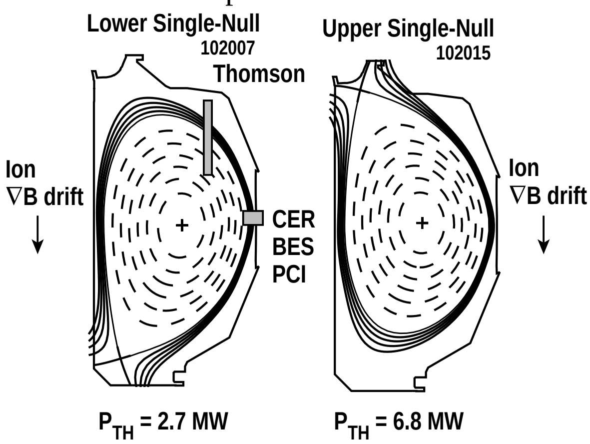

Fig. 1. Comparison of flux surface plots from EFIT for LSN and USN discharges. Also shown are the measurement locations for Thomson scattering (Thomson), charge exchange recombination spectroscopy (CER), beam emission spectroscopy (BES), and phase contrast imaging (PCI).

EDGE PROFILES

Edge profiles of density and temperature, as well as amplitudes of density and potential fluctuations were nearly identical in both cases, even though one discharge was near P_{TH} and the other was far from it. Figure 2 shows n_e, T_e, and P_e measured by Thomson scattering and carbon density, T_i and E_r measured by charge exchange recombination spectroscopy. There is very little difference in the profiles with two exceptions. The carbon density and E_r are slightly higher in the USN case. The higher carbon density is probably due to different

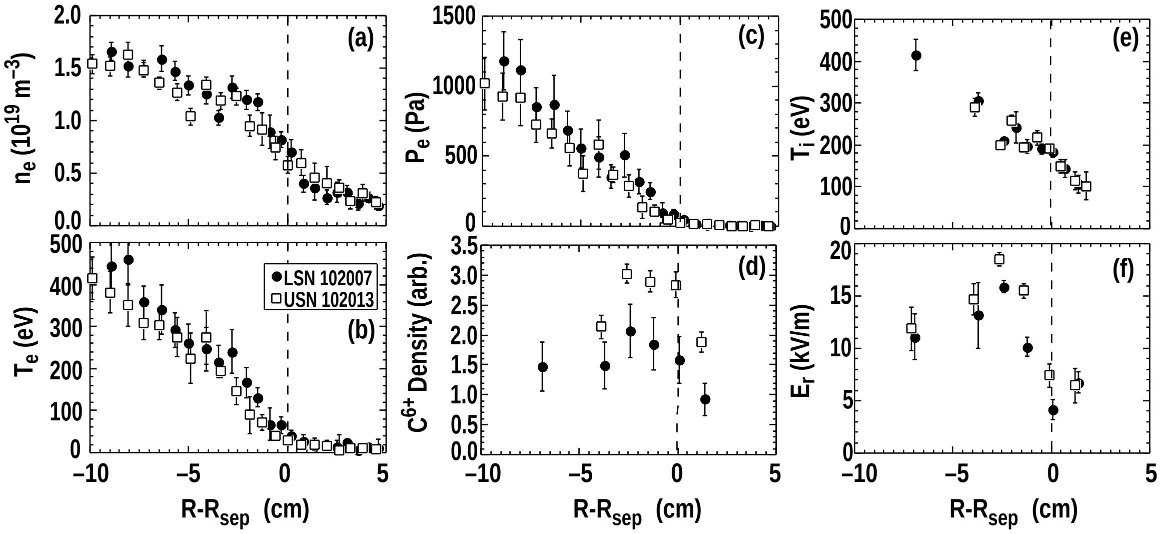

Fig. 2. Edge profiles of (a) n_e, (b) T_e, and (c) P_e measured by Thomson scattering, mapped to the plasma midplane, and (d) C^{6+} density, (e) T_i and (f) E_r measured by CER. Closed symbols are for the LSN case and open symbols are for the USN case. The points represent an average of 16 Thomson and 8 CER measurements during a 200 ms steady portion of a single discharge and the error bars represent the standard deviation. P_{TOT}=2.3 MW in both cases.

conditioning properties of the carbon surfaces in the top and bottom divertor. We have measured much greater variations in the carbon density for LSN configurations without P_{TH} changing, indicating that P_{TH} is not very sensitive to the carbon level at these small values. The slightly higher E_r just inside the separatrix may be important, but we have not found a consistent value of E_r or its shear as a requirement for the L-H transition. The lower values of E_r are associated with the LSN case, which has the low P_{TH}. These results indicate that the specific values of midplane edge temperature, beta, or their gradients as independent parameters are probably not playing key roles in determining P_{TH}. However, these parameters may be linked with other plasma properties that influence the L-H transition.

EDGE FLUCTUATIONS

Spatially resolved edge density fluctuation measurements from beam emission spectroscopy [3] and correlation reflectometry show a change in the poloidal group velocity, $V_{\theta gr}$, of the fluctuations when the ∇B drift direction was changed. High (low) shear in $V_{\theta gr}$ is associated with the low (high) P_{TH}. Unlike usual core fluctuation measurements, the poloidal group velocity differs from the $V_{E\times B}$ near the plasma edge. Figure 3 shows $V_{\theta gr}$ measured with BES and $V_{E\times B}$ determined from CER measurements. The change in the shear in $V_{\theta gr}$ at R–R_{SEP} = –3 cm is much greater than the modest change in the shear in the $V_{E\times B}$ between the two cases. We speculate that shear in $V_{\theta gr}$ may stabilize turbulent transport similar to $E_r \times B_T$ shear stabilization. Figure 4 shows a reduction in the radial correlation length, $L_{c,r}$, in the shear region for the LSN case as compared with the USN case. A power scan shows that the shear in $V_{\theta gr}$ increases with the heating power, consistent with the velocity shear being important for the L-H transition.

Density fluctuations near the midplane separatrix measured with phase contrast imaging [4] (sensitive only to k_θ~0 modes) show that the turbulence is dominated by radially

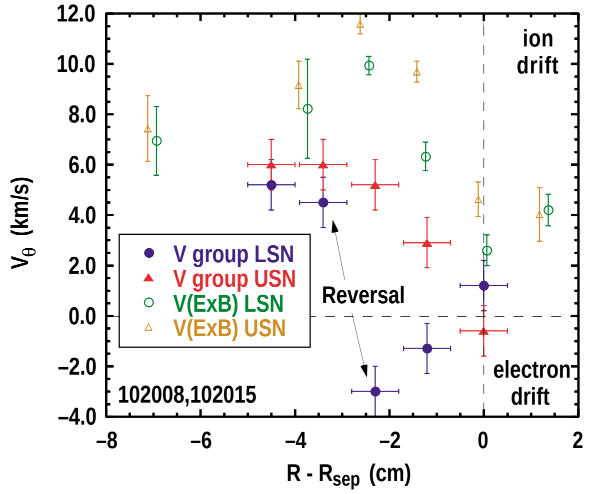

Fig. 3. Poloidal group velocity of the density fluctuations measured by BES and $E_r \times B_T$ velocity determined from CER measurements.

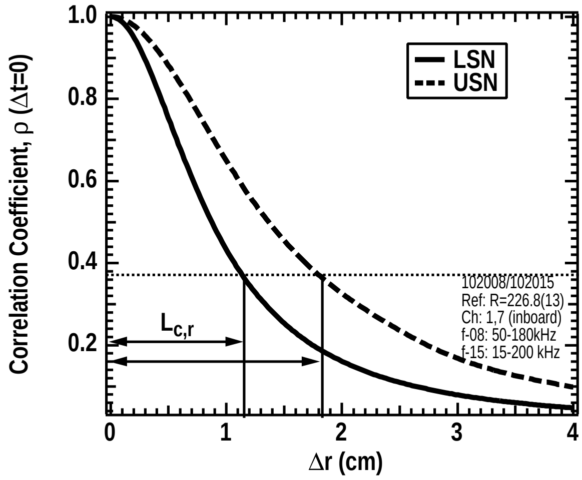

Fig. 4. Radial correlation function of the density fluctuations measured by BES in the region R-R_{SEP}=–3 cm.

outward k_r modes when the ion ∇B drift is away from the X-point, and is roughly balanced between outward and inward modes when the ion ∇B drift is toward the X-point (Fig. 5). The significance of inward versus outward propagating modes is not understood and is an area for further study.

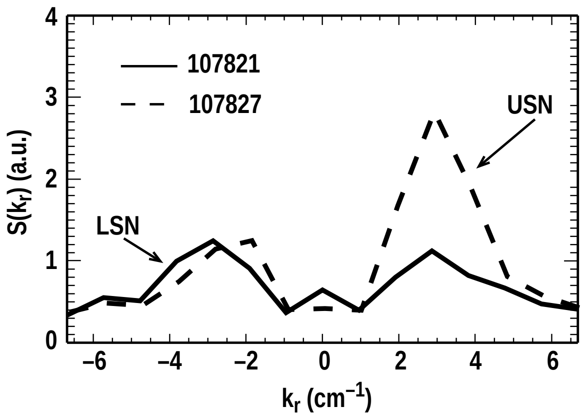

Fig. 5. S(k) of the edge density fluctuations (10 kHz < f < 100 kHz) measured by PCI near the outboard midplane separatrix.

MODELING

We have begun modeling similar discharges using a three dimensional, non-local electromagnetic turbulence code called BOUT, which models the boundary plasma using fluid equations for plasma vorticity, density, electron and ion temperatures and parallel momenta [5]. Preliminary results (Fig. 6) show that the edge turbulence can drive substantial poloidal velocities of the density fluctuations. Strong shear in this velocity exists near the separatrix when the ion ∇B drift is toward the X-point but not for the case when the ion ∇B drift is away from the X-point, qualitatively in agreement with the experimental results.

SUMMARY

The experimental results suggest that specific values of mid plane edge temperature, beta, or their gradients are probably not playing key roles in determining P_{TH}. However, shear in the edge poloidal group velocity of the turbulence may be important for obtaining H-mode and determining P_{TH}. Simulations of the edge plasma have begun and the results may eventually lead to improved understanding of the source of the edge velocity shear.

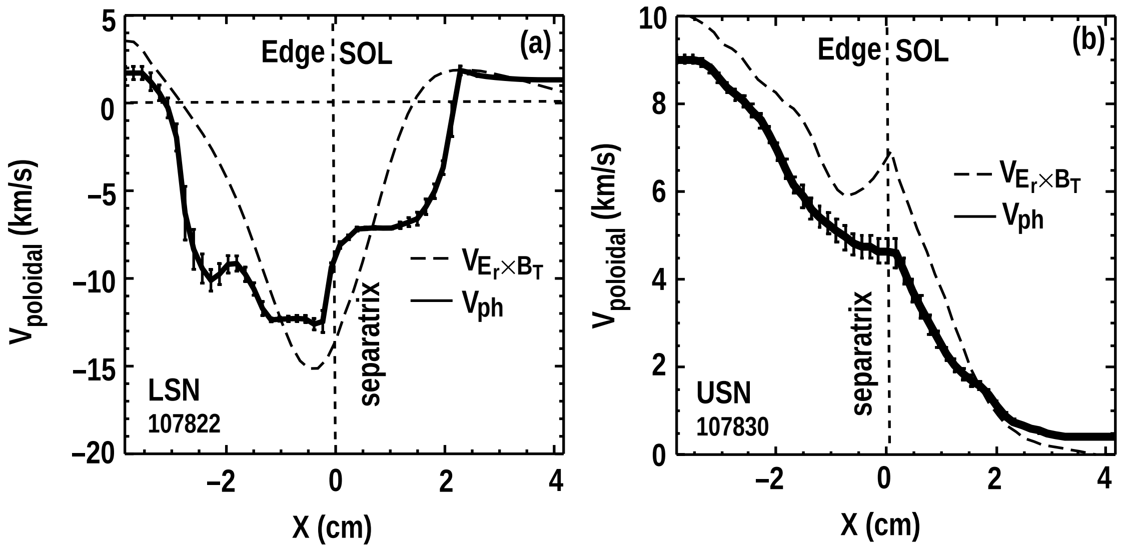

Fig. 6. Poloidal phase velocity of the density fluctuations and the and $E_r \times B_T$ velocity from the BOUT code for (a) LSN and (b) USN configurations.

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