Core Particle Transport Barriers and Turbulence Correlation Lengths in NCS Discharges on DIII–D*

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Very steep core transport barriers have been observed simultaneously in all four transport channels (particle, electron and ion thermal, and angular momentum) in recent DIII–D discharges. These highly localized (widths of a few cm), core transport barriers have to date only been observed in discharges with strongly negative central magnetic shear (NCS discharges). In contrast to previous DIII–D results [1], these discharges possess clear core pedestals in both electron density and temperature, similar to results from JT-60U [2]. Profile gradients at the location of the core ($\rho \sim 0.3$–0.4) transport barriers are similar to those observed at the plasma edge during H–mode, while profiles inside the transport barriers are flat. The spatial location of the transport barriers coincides in all four transport channels, though their temporal evolution is different – the electron particle and thermal transport barriers are created *after* the formation of the ion thermal and angular momentum barriers.

The observation of a core electron density pedestal in these discharges was made possible by a new profile reflectometer system. Simultaneous measurements of the core turbulence correlation length, Δ_r, in the transport barrier region were provided by a correlation reflectometer system. The significance of the correlation lengths is that they are representative of the step size of turbulence transport processes. The turbulence correlation length at the location of the transport barriers is reduced by a factor of ~5–10 as compared with Δ_r inside the transport barrier (a similar reduction was recently observed on JT-60U [3]). Previous measurements of core Δ_r on DIII–D, in non-ITB plasmas, show that Δ_r scales with the size of the poloidal ion gyroradius ρ_θ. The current results indicate that the correlation lengths inside the core transport barrier are consistent with this previous ρ_θ scaling, while the Δ_r at the transport barrier location are a factor of ~5–10 times smaller than the local ρ_θ (neglecting E_r orbit squeezing effects). These results are in agreement with the theory of $\mathbf{E}\times\mathbf{B}$ shear flow suppression of turbulence and transport [4], which predicts that a decrease in the turbulence correlation length should accompany transport barrier formation, as observed. Furthermore, the $\mathbf{E}\times\mathbf{B}$ shearing rate, $\omega_{E\times B}$, observed after the formation of the electron transport barriers is one of the largest yet observed on DIII–D ($> 1\times10^6$/s), and the peak shearing rate is located just inside the transport barrier radius. This suggests that obtaining improved electron particle and thermal transport may require larger $\omega_{E\times B}$ than for ions, consistent with the observation of record shearing rates in other DIII–D discharges with improved electron transport [5]. Finally, these results are consistent with the observation that strongly negative central magnetic shear (note that strong magnetic shear can also directly increase $\omega_{E\times B}$) is correlated with a reduction in core electron thermal transport on DIII–D [5,6], a reduction which may be associated with a local increase in the marginal gradient for the ETG mode [6].

[1] B.W. Rice, *et al.*, Nuc. Fusion **36**, (1996) 1271.
[2] T. Fujita, *et al.*, Phys. Rev. Lett. **78**, (1997) 2377.
[3] R. Nazikian, *et al.*, 17th IAEA Fusion Energy Conf., Yokohama, Japan, 1998.
[4] K.H. Burrell, Phys. Plasmas **4**, (1997) 1499.
[5] K.H. Burrell, *et al.*, Plasma Phys. Control. Fusion **40**, (1998) 1585.
[6] B.W. Stallard, *et al.*, Phys. Plasmas **6**, (1999) in press.

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*Work supported by the U.S. Department of Energy under Grant Nos. DE-FG03-86ER53225 and DE-FG02-89ER53296, and Contract Nos. DE-AC03-99ER54463 and W-7405-ENG-48.