Insight into turbulent transport via measurements of the plasma flow

R. M. McDermott[1], A. Lebschy[1,2], C. Angioni[1], I. Erofeev[1], E. Fable[1], W. Hornsby[1], A. Medvedeva[1,2], D. Prisiazhniuk[1,2], U. Stroth[1,2], E. Viezzer[3] and the ADEX Upgrade Team
[1] Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany
[2] Physik-Department E28, Technische Universität München, Garching, Germany
[3]Dept. of Atomic, Molecular and Nuclear Physics, University of Seville

The core charge exchange recombination spectroscopy (CXRS) systems on ASDEX Upgrade (AUG) now provide a very high accuracy measurement of the impurity (B, N) poloidal rotation in the plasma core ($u_{pol,Z}$). This diagnostic has been used to assemble a database of $u_{pol,Z}$ measurements that covers a wide range of plasma parameters. In the edge (ρ_ϕ>0.7) $u_{pol,Z}$ is electron-diamagnetic directed, consistent with neoclassical (NC) theory. However, in the plasma core (0.2 <ρ_ϕ<0.7) $u_{pol,Z}$ is always ion-diamagnetic directed in clear disagreement with NC thoery. The measured $u_{pol,Z}$ values correlate strongly with the plasma collisionality (ν*) and the relative ion gyro-radius (ρ*), with the strongest ion-directed flows observed at the lowest ν* and the highest ρ* values. This is qualitatively consistent with an evolving balance between NC damping, which is smallest at low ν*, and a turbulent drive of poloidal rotation, which is expected to scale with ρ*.

The measurement of $u_{pol,Z}$ also provides the missing ingredient to determine the radial electric field via the radial force balance equation. This measurement has proved extremely useful for accessing the turbulent phase velocity (v_{ph}) across the linear to saturated Ohmic confinement (LOC to SOC) regimes and for clarifying the sequence of events that takes place in these plasmas. As the plasma collisionality is increased in AUG Ohmic L-mode plasmas, first a transition from the LOC to the SOC is observed. At this time, electron-directed v_{ph} is observed in the plasma edge ($\rho_{\phi\,>}$0.8). Second, the core intrinsic toroidal rotation reverses concomitant with the peaking of the electron density, which is indicative of trapped electron modes (TEM) also in the plasma core. Next, at the point of both maximum rotation reversal and density peaking, ion-directed turbulent phase velocities are observed in the plasma edge supporting the idea that the turbulence change from TEM to ITG occurs first in this region and then propagates inward. Lastly, the core toroidal rotation reverses again as the electron density profile flattens, indicating ITG turbulence also in the core.

These experimental observations show a connection between the dominant residual stress mechanisms and the electron density profile. This is inline with the results of new, non-linear, radially global, turbulence simulations of AUG Ohmic plasmas, which quantitatively reproduce the measured, hollow, rotation gradients and show that the shape of the simulated residual stress and intrinsic flow is strongly determined by the second derivative of the density profile.