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Study of Turbulence and Radial Electric Field Transitions in ASDEX Upgrade using Doppler Reflectometry

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The radial electric field is recognised as an important factor in the performance of magnetically confined fusion plasmas. On ASDEX Upgrade microwave Doppler reflectometry has been developed to directly measure E_r profiles, its shear and its fluctuations. Here a poloidally tilted antenna selects via Bragg a specific turbulence wavenumber giving a frequency shift directly proportional to the perpendicular rotation velocity $u_\perp = v_{E\times B} + v_{\rm turb}$ of the turbulence moving in the plasma. Turbulence simulations show $v_{E\times B} \gg v_{\rm turb}$ allowing simple extraction of E_r with good accuracy. In the scrape-off-layer E_r is positive, but reverses across the separatrix due to the pedestal pressure gradient to form a negative well. The strength of the well scales directly with confinement, typically -50V/cm for ohmic/L-mode, rising to -300V/cm for H-mode and in excess of -500V/cm for improved H-modes. Without NBI $v_{E\times B} \approx v_{\rm turb}$ which allows the turbulence behaviour to be investigated. For example the core rotation reverses from ion to electron direction when plasma collisionality is raised while matched gyro-kinetic turbulence simulations show the dominant turbulence changing from TEM to ITG with corresponding $v_{\rm turb}$ reversal, which implies the core E_r reverses sign with the turbulence. Also of major importance to confinement are zonal flows and GAMs - radially localised oscillating $E \times B$ flows. E_r fluctuations directly measured by Doppler refl. reveal coherent modes in the edge gradient region where turbulence vorticity and E_r shear are largest. The mode frequency scales as sound speed over major radius but is sensitive to plasma shape and local q. So far GAMs have not been seen in H-modes, nor in the plasma core. In each topic, the synergetic combination of experiment, theory and numerical simulation aids interpretation shows E_r is interlinked with turbulence and the mean plasma profiles.

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