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Particle and Impurity Transport in JET and ASDEX Upgrade: Experimental Observations and Theoretical Understanding

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Cross-field transport in tokamak plasmas determines the peaking of both the density and the impurity profiles, with important consequences on both plasma stability and confinement. Experiments indicate that, in most conditions, a turbulent (non-neoclassical) particle pinch is needed to explain the observed peaking of electron and impurity density profiles. Theory has shown that several turbulent mechanisms contribute to the formation of a pinch velocity. For the first time, an empirical scaling for density peaking in H-mode plasmas is presented, by combining data from two different devices, AUG and JET. Correlations among plasma parameters are reduced, and collisionality is identified as the statistically most relevant plasma parameter in multiregression analyses. On the basis of this scaling, the density profile in a burning plasma is predicted to be peaked. The empirically determined dependence on collisionality is found to be consistent with the predictions of the gyrofluid model GLF23, namely with the collisional reduction of the turbulent particle pinch. However, the most advanced gyrokinetic models are found in quantitative disagreement with the experiments, since they predict the reduction of the pinch to take place over a range of collisionality which is well below the lowest collisionality experimentally achieved. Observations in JET and AUG indicate that auxiliary electron heating is the most efficient method to suppress heavy impurity accumulation and impurity pinches reversing the direction from inwards to outwards in response to localized auxiliary electron heating are observed. Such a reversal is not explained by neoclassical effects. A newly identified mechanism of turbulent pinch, which does not vanish for highly charged impurities and which reverses its direction as a consequence of the reversal of the direction of propagation of the turbulence is proposed as the best candidate to explain the experimental observations.