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L-H Transition Trigger Physics in ITER-Similar Plasmas with and without Applied n=3 Magnetic Perturbations

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Quantitative proof is presented that the ion polarization current [1] dominates the evolution of the radial electric field E_r across the L-H transition, and needs to be properly taken into account in Ohm's law. This is an important step towards developing a physics-based reduced L-H transition model, which in addition needs to include at a minimum the poloidal momentum balance, and evolution equations for the turbulence intensity and the pressure gradient [2]. The observed isotope dependence of the threshold power P_LH in ITER-similar H, He and D plasmas [3] can then be qualitatively understood: in D and He, where the Reynolds stress [2-4] dominates the neoclassical bulk viscosity and thermal ion orbit loss, P_LH is relatively low. In hydrogen plasmas, where the Reynolds stress is marginal and comparable to the neoclassical bulk viscosity and thermal orbit loss current, P_LH is much higher. The observed increased transition time to full turbulence suppression in hydrogen plasmas can also be quantitatively understood using this model.
Resonant magnetic perturbations (RMP) may have to be applied before the L-H transition in ITER to safely suppress the first ELM. In ITER-similar plasmas in DIII-D the increase of P_LH with n=3 RMP is most pronounced with ECH, with P_LH increasing with decreasing plasma collisionality [P_LH~(nu_star)^-0.3]. Two-fluid modeling with the M3D-C1 code [5] shows that the normalized L-mode radial density gradient a/L_n is toroidally modulated and periodically increased on the outboard midplane with applied RMP. Non-axisymmetric modifications with RMP include increased local long-wavelength turbulence (measured via BES) and reduction of the E_r well and ExB shear. We conjecture that the increase in threshold power with RMP results from locally enhanced instability drive (however without simultaneously increased Reynolds stress) and reduced ExB shear.
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