New Mechanisms for Improved Confinement with Isotopic Mass

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The ion mass dependence of the electron collisionality parameter $\nu_e R/c_s \propto A^{1/2}$ introduces a strong and favorable ion mass dependence in the nonlinear upshift of the TEM critical density gradient and the associated transport stiffness. The effective critical density gradient for onset of TEM turbulent transport, associated with zonal flow dominated states just above the linear instability threshold, significantly exceeds the TEM linear stability threshold by an amount that increases strongly with collisionality[1,2]. Several hundred nonlinear GENE and GS2 simulations have been carried out to study the parameter dependence of the upshift in scans of R/L_n, $\nu_e R/c_s$, and safety factor. The mass scaling via electron collisionality is reproduced by an analytic model of the TEM nonlinear critical density gradient upshift[3]. The model describes the quasi-periodic energy exchange between zonal flows and primary instability, as driven by secondary instability. The resulting scalings inherit strong variation with T_e/T_i, Z_{eff}, $\nu_e R/c_s$, magnetic shear, flow shear, trapped particle fraction, etc. from the linear TEM growth rate. The new density gradient driven TEM mechanism is relevant when $T_e \geq T_i$ and density profiles are peaked, or near the top of the H-Mode pedestal where R/L_n is large and $T_e \sim T_i$. This new mechanism could also resolve a longstanding conundrum in which TFTR D-T supershots with reversed inner core magnetic shear displayed little isotope effect, while normal shear cases displayed a nonlinearly strong isotope effect due to ExB shear.[4]

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