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Quasilinear Gyrokinetic Modeling of Reduced Transport in the Presence of High Impurity Content, Large Gradients, and Large Geometric α_{MHD}

C. D. Stephens[1], D. R. Hatch[1], M. Kotschenreuther[1], S. M. Mahajan[1], J. Citrin[2,3], and C. Bourdelle[4]

[1]University of Texas at Austin, TX 78712-1192, United States of America
[2]DIFFER - Dutch Institute for Fundamental Energy Research, Eindhoven, The Netherlands
[3]Science and Technology of Nuclear Fusion Group, Eindhoven University of Technology, Eindhoven, The Netherlands
[4]CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France

Email: cole.stephens@austin.utexas.edu

Transport barriers in tokamak discharges are often characterized by large gradients that can destabilize electrostatic microinstabilities, thereby driving anomalous turbulent transport [1]. However, large gradients can also lead to large geometric α_{MHD}, a stabilizing parameter in certain regimes [2]. The resulting transport is inherently constrained to be ambipolar; in effect, these large gradients can make this flux constraint impossible to satisfy, resulting in stabilization and the reduction of turbulent transport [3]. Due to the high computational cost of nonlinear gyrokinetic simulations, using a reduced turbulent transport model is ideal for predictive modeling. However, reduced models tailored for the tokamak core can become unreliable in transport barrier regimes, thus necessitating model development and improvement. We test the extent to which the gyrokinetic quasilinear code QuaLiKiz [4] can reliably predict anomalous transport in transport barrier discharge regimes to determine parameters that lead to turbulent transport reduction. We use the gyrokinetic code GENE [5], based on first principles, as a point of comparison for QuaLiKiz. Unlike GENE, QuaLiKiz uses many approximations to ensure computational tractability. In particular, QuaLiKiz assumes a Gaussian eigenfunction, uses $s - \alpha_{\text{MHD}}$ geometry, and only captures electrostatic fluctuations. To ensure accurate predictions in transport barrier discharge scenarios, we improve the approximations made for trapped particles, and thus the trapped electron mode (TEM), by incorporating the bounce-averaged electrostatic eigenfunction [6, 7]. The Gaussian ansatz allows us to analytically estimate this bounce-averaging effect with sufficient accuracy. We also improve the approximate methods used to solve for the mode structure in order to accurately calculate bounce-averaging effects.

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