Predicting Internal Transport Barriers with the TGLF Model[*]

G.M. Staebler[1], L.L. Lao, B.A. Grierson[2], C. Chrystal[2], and J.E. Kinsey[1]

[1] *General Atomics, PO Box 85608, San Diego, CA 92186-5608, USA*

[2]*Princeton Plasma Physics Laboratory, PO Box 451, Princeton, NJ 08543-0451, USA*

Transport barriers have been observed and studied in most of the world's magnetic confinement devices. It is well established that the suppression of drift-wave turbulence by $E \times B$ velocity shear plays an important role in this phenomena. The recent development [1] of a high accuracy "spectral shift" model of the $E \times B$ shear turbulence suppression, based on nonlinear gyro-kinetic simulations, enables meaningful validation tests of the gyrokinetic theory with the quasilinear trapped gyro-Landau fluid (TGLF) code. An example of an internal transport barrier (ITB) discharge [2] in the DIII-D tokamak is shown in Fig. 1. This discharge has negative magnetic shear and strong fast ion dilution inside of r/a 0.35. Both of these are strongly stabilizing to the ion temperature gradient mode. In addition, the toroidal velocity shear suppresses but does not turn off the gyrokinetic turbulence.

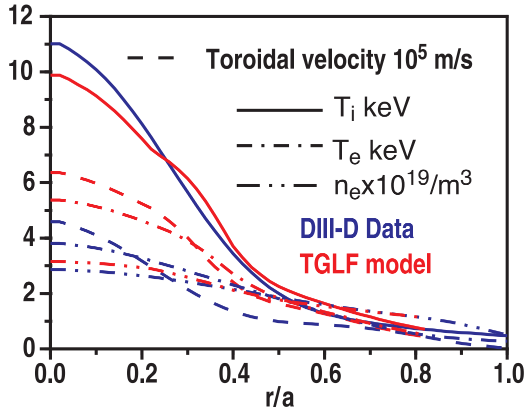

Figure 1: TGLF+NEO simulation (red) and curve fit to data (blue) for DIII-D discharge 84736 at 1300 ms [2]. Electron density and temperature, ion temperature and ion toroidal velocity are evolved to a transport steady state.

In previous modeling of this same discharge with the GLF23 model [3], it was found that the reduction in electron and ion energy transport was in reasonable agreement with experiment but that the toroidal momentum and particle transport was predicted to be much lower than observed. The TGLF model improves its fidelity to the gyro-kinetic theory in many ways compared to GLF23. Of particular importance to transport barriers are improvements in the calculation of electron temperature gradient modes (ETG) and Kelvin-Helmholtz (KH) instabilities. The new spectral shift model for $E \times B$ velocity shear in TGLF allows the calculation of the momentum pinch Reynolds stress. It is found that the KH mode reduces the suppression effect of the $E \times B$ velocity sufficient to provide the momentum transport in an ITB. This effect of the KH mode also provides particle and electron energy transport far above the small neoclassical levels. The ETG mode is a major contributor to electron energy transport within the ITB. The state of the art neoclassical code NEO was used in this simulation and kinetic carbon 6 was included in TGLF and NEO. The agreement with the DIII-D data is excellent for the ion temperature and density profiles. The electron temperature and toroidal rotation are higher than measured for this case. Comparison of the NEO predicted neoclassical poloidal rotation with direct measurement in recent ITB discharges on DIII-D will be shown. There are clear signs of interchange mode driven transport near the axis of some negative central shear discharges but the transport in the steepest gradient region is well predicted by TGLF+NEO.

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