GA–A27795

POTENTIAL IMPROVED ITER PERFORMANCE VIA ZONAL FLOW STABILIZATION

by
J. CANDY, R.V. BUDNY, G.M. STAEBLER, E.A. BELLI, and X. YUAN

JUNE 2014

GENERAL ATOMICS

DISCLAIMER

GA–A27795

POTENTIAL IMPROVED ITER PERFORMANCE VIA ZONAL FLOW STABILIZATION

by
J. CANDY, R.V. BUDNY,* G.M. STAEBLER, E.A. BELLI, and X. YUAN*

This is a preprint of the synopsis for a paper to be presented at the Twenty-Fifth IAEA Fusion Energy Conf., October 13-18, 2014 in Saint Petersburg, Russia.

*Princeton Plasma Physics Laboratory, Princeton, New Jersey.

Work supported by
the U.S. Department of Energy
under DE-FG02-95ER543096 and DE-AC02-09CH11466

GENERAL ATOMICS PROJECT 03726
JUNE 2014

Potential improved ITER performance via zonal flow stabilization

J. Candy(1), R.V. Budny(2), G.M. Staebler(1), E.A. Belli(1) and X. Yuan(2)
(1) *General Atomics, San Diego, California, USA*
(2) *Princeton Plasma Physics Laboratory, Princeton, New Jersey, USA*

Abstract In this work, we show that improvements in predicted ITER performance may be realized by carefully accounting for stabilization from self-generated zonal flows. Prior transport modeling has shown that, generally speaking, production of acceptable fusion power in ITER requires that ion and electron energy fluxes in the core plasma be on the order of a single gyroBohm (or less); that is, $Q_e/Q_{\rm GB}, Q_i/Q_{\rm GB} \simeq 1$, where $Q_{\rm GB} \doteq \rho_s^2 c_s/a$ is the gyroBohm unit of energy flux, and ρ_s is the ion-sound gyroradius of deuterium. This implies proximity to the linear threshold, and gyrokinetic simulations with GYRO [1] show that nonlinearly-generated zonal flow activity can play a significant role in reducing the steady-state flux in this regime in comparison with TGLF levels. Specifically, we have previously observed [2] that for steady-state ITER profiles as predicted by TGLF [3], GYRO [1] simulations exhibit complete turbulence quenching by self-generated zonal flows.

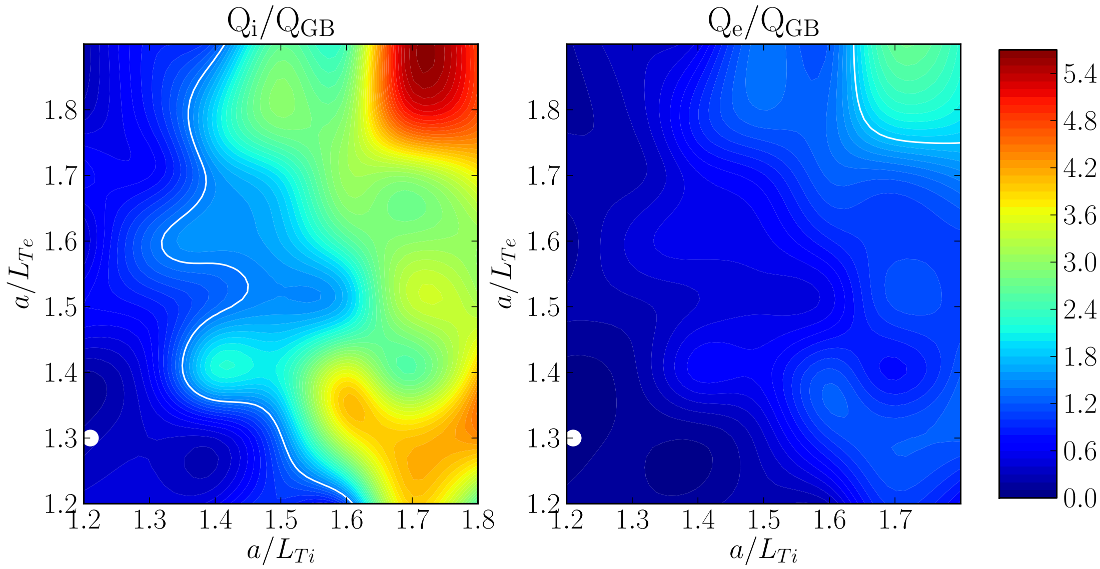

Figure 1: *Contour map of GYRO fluxes, at* $r/a = 0.8$*, as a function of* a/L_{Te} *and* a/L_{Ti} *for ITER hybrid scenario described in the text. White contour line shows the critical values of* $Q_i/Q_{\rm GB} = 1.4$ *(left) and* $Q_e/Q_{\rm GB} = 1.8$ *(right) predicted by TGYRO to obtain net power balance. White dots show TGLF gradients at which this balance is obtained. The implication is that GYRO would predict markedly higher gradients (especially the electron gradient), to produce the same turbulent fluxes required to achieve power balance.*

This observation suggests that accounting for zonal-flow stabilization in TGLF prediction of ITER may lead to improved performance estimates. In this work, we report on quantitative assessments of the performance improvement expected when stabilization from nonlinear flows is added via gyrokinetic re-tuning of TGLF in the near-threshold regime. We also describe the performance impact of two potentially important secondary effects: ETG transport and electromagnetic fluctuations. In particular, ETG transport may be enhanced in this regime since ITG activity, known to inhibit ETG transport, will be reduced. Also, we have observed that for ITER-like plasmas, transverse electromagnetic coupling stabilizes the ITG branch, whereas compressional electromagnetic coupling stabilizes the TEM branch, indicating other possible mechanisms for improved performance.

ITER Scenario Simulations are based on an ITER hybrid DT scenario with approximately 45 MW of total auxiliary NBI and RF power, and a hollow q-profile with $q_{\min} = 1.5$ at $r/a = 0.3$. The plasma contains roughly equal amounts of D and T, and a helium ash fraction with $n_{He}(0)/n_D(0) \sim 1/3$. Various impurity (Ar, Be, W) and energetic ion populations are also considered in the baseline scenario.

Transport Modeling For TGYRO [4] modeling we use some simplifications to the baseline scenario in order to keep the number of ions manageable. Specifically, we consider only 3 kinetic ions: D, T and ^{4}He, but have verified that results do not change significantly when additional impurities and/or fast-ion dilution are retained. Rotation is taken to be at the diamagnetic level and thus rotation shear stabilization is ignored. Alpha heating to electrons and ions, collisional exchange, and electron radiation loss are computed self-consistently. Neoclassical transport for all species is computed directly by NEO [5] with no approximation. Given these assumptions, TGYRO-TGLF predicts core temperature of $T_e(0) \sim 25\,\mathrm{keV}$ and $T_i(0) \sim 17\,\mathrm{keV}$. Typical fluxes observed in the steady-state prediction are $Q_i/Q_{\mathrm{GB}} \sim 1$ at $r/a = 0.7$. TGYRO-GYRO simulations of the steady-state TGYRO-TGLF scenario show that turbulence is nonlinearly quenched across the entire simulation range $0.1 \leq r/a \leq 0.8$, with the implication that steeper gradients and therefore improved performance is expected after accounting for these effects in TGLF. Revisions of ITER performance using such a recalibrated TGLF will be summarized.

Acknowledgements This work was funded by US Department of Energy under DE-FG03-95ER54309 and DE-AC02-09CH11466.

References

[1] J. Candy and R.E. Waltz, J. Comput. Phys. **186**, 545 (2003).

[2] J.E. Kinsey and G.M. Staebler and J. Candy and R.E. Waltz and R V. Budny, Nucl. Fusion **51**, 083001 (2011).

[3] G.M. Staebler and J.E. Kinsey and R.E. Waltz, Phys. Plasmas **14** 055909 (2007).

[4] J. Candy and C. Holland and R.E. Waltz and M.R. Fahey and E. Belli, Phys. Plasmas **16** 060704 (2009).

[5] E.A. Belli and J. Candy, Plasma Phys. Control. Fusion **54**, 015015 (2012).