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ITER PREDICTIONS USING THE GYRO VERIFIED AND EXPERIMENTALLY VALIDATED TGLF TRANSPORT MODEL

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The trapped gyroLandau fluid (TGLF) transport model computes the quasi-linear particle, energy, and momentum driftwaves fluxes with shaped geometry and finite aspect ratio. The TGLF particle and energy fluxes have been successfully *verified* against a large database of collisionless nonlinear gyrokinetic simulations using the GYRO code. Using a new collision model in TGLF, we find remarkable agreement between the TGLF quasi-linear fluxes and 64 GYRO nonlinear simulations with electron-ion collisions. In validating TGLF against DIII-D and JET H-mode and hybrid discharges we find the predicted temperature profiles are in excellent agreement with the measured ion and electron temperature profiles. For DIII-D hybrids, the ion energy transport tends to be close to neoclassical levels while the electron energy transport tends to be dominated by short wavelength trapped electron mode (TEM)/electron temperature gradient (ETG) modes. The high-k modes are less important in JET and ITER. ITER projections using TGLF show that the fusion gains are slightly more pessimistic than the previous GLF23 results primarily due to finite aspect ratio effects included only in TGLF. The ITER results are sensitive to the improvements in the TGLF collision model while the results for DIII-D and JET hybrids are not. A new steady-state transport code TGYRO can evolve temperature and density profiles to match power and particle sources using local flux tube nonlinear GYRO simulations or a model like TGLF. TGYRO thus provides a critical *verification* of the TGLF predictions for ITER using GYRO

The TGLF driftwave model [1,2] computes the linear growth rates due to long wavelength ion temperature gradient (ITG)/TEM and ETG modes. TGLF is a *verified* saturation rule developed to fit GYRO [3] nonlinear gyrokinetic simulations of transport fluxes. TGLF includes electron and ion trapping, finite aspect ratio, and shaped geometry from the Miller equilibrium model. Remarkable agreement was found comparing the TGLF quasi-linear fluxes against the fluxes from 83 GYRO nonlinear simulations of ITG/TEM transport without collisions [2]. Subsequent GYRO runs revealed that a new collision model was needed for TGLF. A new collision model for TGLF was then derived and fit to the nonlinear GYRO fluxes. TGLF with the new collision model (TGLF-APS09) yields better agreement with GYRO for a database of 64 simulations that included Miller geometry and collisions. The average rms errors in [χ_i, χ_e] are significantly reduced from [0.24, 0.27] using the original TGLF-APS07 collision model to [0.10, 0.13] using the new TGLF-APS09 collision model.

TGLF with original collision model (APS07) was *validated* against a profile database of 96 L- and H-mode discharges [2]. Recent work has focused on additional testing with the new collision model (APS09) against DIII-D and JET hybrid discharges. The hybrid scenario is an operating regime with a Type-1 edge localized mode (ELM) H-mode edge, suppressed sawtooth activity, mild neoclassical tearing modes (NTM), and a broad safety factor profile with $q_{\min}$ at or near unity. High performance has been obtained at reduced plasma current in stationary conditions, so the hybrid scenario has emerged as an attractive operating scenario for ITER. Therefore, gaining a predictive understanding of the transport in hybrids is warranted to confidently predict the fusion performance in ITER hybrid scenarios. Figure 1 shows the TGLF results for 96 DIII-D and JET discharges. For 30 DIII-D and 4 JET hybrids included in the database the predicted temperature profiles agree with the experimental data as well as for the conventional sawtoothing H-mode discharges. For DIII-D hybrids, χ_i tends to be near neoclassical levels while χ_e tends to be dominated by TEM/ETG modes.

Figure 2 shows the predicted fusion power versus pedestal temperature at fixed density for an ITER hybrid scenario with I_p = 12.5 MA, P_{aux} = 33 MW and a flat density profile with a line-averaged value of 8.0x10^{19} m^{-3}. The boundary conditions are applied at ρ=0.95. TGLF-APS09 is more optimistic than TGLF-APS07 but less optimistic compared to the GLF23 model which used s-alpha geometry (infinite aspect ratio shifted circles). The TGLF results with the s-α model are similar to GLF23. Using the finite aspect ratio flux surface Miller equilibrium model in TGLF, the predicted fusion power is reduced. Due to the stiff nature of TGLF, increasing the auxiliary heating while holding the pedestal pressure fixed only slightly raises the fusion power.

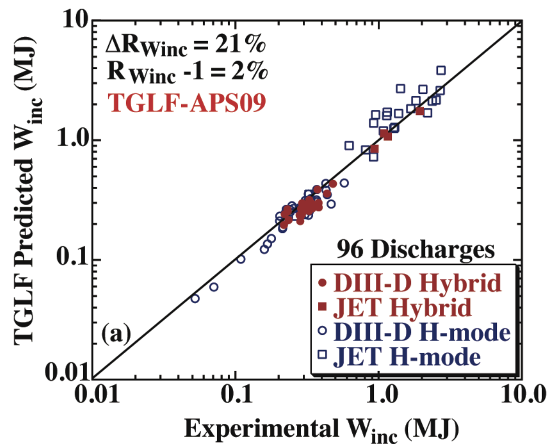

Fig. 1. Predicted incremental stored energy W_{inc} using TGLF-APS09 versus experimental W_{inc} for 30 DIII-D hybrids. 4 JET hybrids, 40 DIII-D H-modes. and 22 JET H-mode discharges.

A new steady state transport code TGYRO [4] can iterate temperature and density profiles until the transport due to multiple local flux tube GYRO simulations matches the integrated sources. A comparison of the GYRO and TGLF predictions for ITER using the TGYRO code will be made, providing *verification* of the TGLF results. Results of various sensitivity studies (e.g. particle transport, auxiliary heating, boundary conditions) on the ITER predictions will be presented. Initial results show that TGLF predicted density profile peaking increases the fusion power. The pedestal temperature requirements will also be compared to the predictions of the EPED1 model for the pedestal height and width [5].

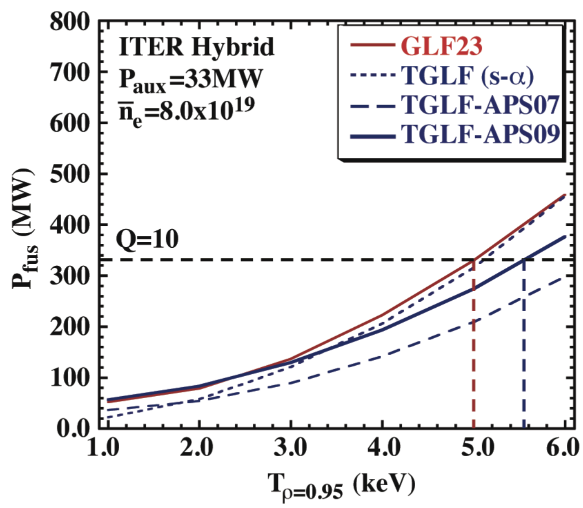

Fig. 2. Predicted fusion power versus pedestal temperature at fixed density for an ITER hybrid case with a flat density profile using the TGLF (blue) and GLF23 (red) models.

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

[2] J.E. Kinsey, G.M. Staebler, and R.E. Waltz, Phys. Plasmas **15**, 055908 (2008).

[3] J. Candy and R.E. Waltz, Phys. Rev. Lett. **91**, 045001-1 (2003).

[4] J. Candy, C. Holland, R.E. Waltz, *et al.*, Phys. Plasmas **16**, 060704 (2009).

[5] P.B. Snyder, R.J. Groebner, A.W. Leonard, *et al.*, Phys. Plasmas **16**, 056118 (2009).