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Program for Finding the Upper Bound on Unstable Alfvén Mode Induced Fusion Alpha Transport Losses*

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Previous GYRO simulations have shown that reactor-scale fusion alpha transport from thermal plasma instabilities like ITG/TEM is likely to be insignificant [1]. Recent simulations of fixed gradient alpha transport induced by alpha driven local (very low-$k_\theta \rho_s$ but high-n for low-ρ_*) Alfvénic TAE/EPM turbulence embedded in very strong (moderate-$k_\theta \rho_s$) ITG/TEM turbulence showed nonlinearly saturated states can exist at energetic particle (EP) pressures up to perhaps twice the TAE/EPM stability threshold with quasi-linear (and likely intermittent) relaxation of the driving EP pressure gradient appearing at stronger EP drive [2]. However, even the pre-relaxation level of EP transport is not significantly higher than the ITG/TEM induced level below the local linear TAE/EPM threshold EP pressure gradient $-dP_\alpha^{loc-lin}/dr$. Since the global linear stability threshold will always exceed that for the local, $-dP_\alpha^{loc-lin}(r)/dr$ should provide an *upper bound on unstable Alfvén mode induced fusion alpha transport losses:* Given the MHD equilibrium and thermal plasma profiles, it is straightforward to calculate the local fusion energy deposition rate $Q_{alpha}(r)$ [MeV/sec/m^3], the classical slowing-down fusion alpha density profile $n_\alpha^{class}(r)$, and the effective alpha temperature profile $T_\alpha^{class}(r)$ (which has a very weak gradient). Since $-T_\alpha^{class} dn_\alpha^{class}(r)/dr$ will be less than $-dP_\alpha^{loc-lin}(r)/dr \sim -T_\alpha^{class} dn_\alpha^{loc-lin}/dr$ beyond some outer radius, $n_\alpha(r) = n_\alpha^{class}(r)$ for $r > r_b$. Integrating $-dn_\alpha(r)/dr = [-dn_\alpha^{class}(r)/dr, -dn_\alpha^{loc-lin}(r)/dr]_{\min}$ inward from $r = r_b$, the maximum $n_\alpha(r)$ will be less than $n_\alpha^{class}(r)$for $r < r_b$. Since the effective alpha temperature should not deviate from $T_\alpha^{class}(r)$, the minimum fusion energy deposition rate to the thermal plasma is $[n_\alpha(r)/n_\alpha^{class}(r)]Q_{alpha}(r)$ from which an upper bound on alpha transport losses can be inferred. Physically accurate gyrokinetic $-dP_\alpha^{loc-lin}(r)/dr$ profiles from TGLF projected ITER plasma profiles are easily obtained [3].

[1] C. Estrada-Mila, J. Candy, and R.E. Waltz, “Turbulent transport of alpha particles and helium ash in reactor plasmas,” Phys. Plasmas **13**, 112303 (2006).
[2] E. M. Bass and R.E. Waltz, “Gyrokinetic simulations of mesoscale energetic particle-driven Alfvénic turbulent transport embedded in microturbulence,” Phys. Plasmas **17**, 112319 (2010).
[3] J.E. Kinsey, G.M, Staebler, J. Candy, R.E. Waltz, and R.V. Budny, “ITER predictions using the GYRO verified and experimentally verified TGLF transport model,” submitted to Nucl. Fusion 2010.

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