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Transport Theory for Energetic Alpha Particles and Superbananas in Tokamak Fusion Reactors with Broken Symmetry

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Error fields or magnetohydrodynamic (MHD) activities break toroidal symmetry in real tokamak fusion reactors, e.g., ITER. It has been shown in a comprehensive theory for neoclassical toroidal plasma viscosity for tokamaks that broken symmetry enhances particle, momentum, and energy transport. The enhanced energy transport increases with increasing energy. Because fusion-born alpha particles have energy significantly higher than that of fuel ions, the enhanced energy loss for alpha particles can be an issue for reactors if their energy transport loss rate is faster than the slowing down rate. In that case, the fusion energy gain factor Q will be significantly impacted. To quantify the tolerable magnitude for the error fields or MHD activities, transport theory for energetic alpha particles is developed. The theory is a generalization of the theory for neoclassical toroidal plasma viscosity. The superbanana plateau and superbanana regimes are the most relevant regimes for fusion-born alpha particles. The transport theory for energetic alpha particles developed is extended to the limit where the slowing down operator dominates and to allow for the finite value of the radial electric field.

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