Turbulent transport of energetic particles in gyrokinetic simulations and impact on the excitation and nonlinear saturation of global instabilities

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Turbulence and energetic particles are ubiquitous elements in tokamak plasmas. On the one hand, turbulence increases the energy and particle transport leading to a decrease of energy confinement time. On the other hand, energetic particles coming from nuclear reactions and/or external heating can excite instabilities leading to a loss of confinement of the energetic particles themselves and therefore resulting in an extra loss of confinement. When these two elements coexist, the analysis of their mutual interaction is essential on the route towards the steady state production of energy. Progress in this direction has been done in recent gyrokinetic simulations using the GYSELA code, showing the nonlinear excitation of turbulence by means of energetic-particle driven geodesic acoustic modes (EGAMs) [1]. In those simulations, no energetic particle transport was taken into account in the radial direction. This transport can impact the excitation and nonlinear saturation of EGAMs due to the redistribution of energetic particles in real space. Also, transport in the velocity space around the resonance might have an impact on the excitation and saturation. The redistribution in velocity space can be due to both turbulence and EGAMs, whereas the distribution in the radial direction can only be due to turbulence. How the interaction between energetic particles and turbulence is modified when the transport of energetic particles is taken into account remains an open issue that will be addressed in this talk via gyrokinetic simulations.
As a first step in this context, energetic particles have been implemented in the multispecies gyrokinetic particle-in-cell code NEMORB [2]. The excitation of EGAMs in the absence of turbulence has been successfully benchmarked against previous gyrokinetic simulations with GYSELA [3,4], proving the robustness of the results. An overview of these results is presented here, focusing on the impact that the nonlinear behavior of EGAMs in terms of saturation [4] and interaction with turbulence [1] can have on the performance of fusion devices.
NEMORB, as a multispecies particle-in-cell code, represents the most appropriate tool to analyse at the same time the excitation of global instabilities like EGAMs and the transport of energetic particles in the presence of turbulence. For this purpose, an energetic particle source has been implemented in NEMORB, able to modify the background distribution function in order to excite EGAMs in the presence of turbulence. Analysis of the transport of resonant energetic particles both in real and velocity space is presented, focusing on how this transport affects the excitation of EGAMs and the subsequent interaction with turbulence. Possible extension to electromagnetic simulations is also presented.

References:
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