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Hybrid simulations of shear Alfvén fluctuations in burning fusion plasmas

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Energetic particles (EPs) and their related physics are crucial for burning plasmas in magnetically confined fusion devices as EPs contribute significantly to the total power density. In particular, symmetry breaking collective modes excited by EPs, such as shear Alfvén wave (SAW) instabilities, could have deleterious effects on EP and thermal plasma confinement. In this work, adopting a typical divertor tokamak test facility (DTT) reference scenario, shear Alfvén fluctuations resonantly excited by reactor relevant EPs are investigated by self-consistent hybrid MHD-gyrokinetic code (HMGC) simulations, focusing on both the linear stability properties [1] as well as nonlinear saturation mechanism and fluctuation induced EP transport. [2] On the linear fluctuation spectra, it is shown that the DTT core plasmas can be schematically divided into two regions, which are characterized by low frequency reversed shear Alfvén eigenmode (RSAE) in the central core region, and by more strongly damped toroidal Alfvén eigenmode (TAE) in the outer core region. The most unstable toroidal mode number of dominant Alfvénic fluctuations is of the order of 10, consistent with the ordering of typical resonant EP orbit width. On the nonlinear dynamics, radial decoupling is shown to be a crucial element of the RSAE saturation mechanism, with convective redistribution of resonant magnetically trapped EPs. On the other hand, during the TAE saturation, diffusive transport of passing EPs are observed due to resonance overlap, resulting into cross scale transport and enhanced mode drive. This is due to the peculiar resonant structure of passing EPs and could be relevant for future burning plasma scenario.

References

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