Energetic particle modes in burning plasmas

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Energetic particles (EPs), as the product of fusion reaction and auxiliary heating, play a key role in magnetically confined fusion devices. Such EPs are thermalized by Coulomb collision, which provides the energy source for a sustainable igniting fusion reactor. However, EPs can also resonantly excite collective modes such as shear Alfvén waves (SAWs) which lead to anomalous EP loss [1]. The EP induced SAWs have been investigated extensively [2]. In previous studies, the density of EPs is considered to be low (about O($\beta^{3/2}$) of the thermal ion density), especially in the analysis of inertial layer[3], where β is the ratio of plasma energy to magnetic field energy. Such condition is usually valid when only auxiliary heating is taken into account. In future tokamaks such as ITER or even fusion reactors, however, the product of D-T reaction together with power injection will probably lead to a higher proportion of EPs. Thus, it is necessary to consider the effect of higher EP proportion on the SAW excitation. For low frequency SAWs, when the EP effect is neglected in the inertial layer due to low density, the vorticity equation in inertial layer is then periodic. Here low frequency modes are at the frequency range of beta-induced Alfvén eigenmode (BAE) and kinetic ballooning mode (KBM) [4, 5]. However, if the density of EPs increases from O($\beta^{3/2}$) to O(β) of the thermal ions, the EP effect should be taken into account in the inertial layer analysis. In this work, we have presented a linear model for low frequency EPM in burning tokamak plasmas [6]. It is shown that the continuum structure is regulated by EPs and a wide-band of EPMs can be excited if the proportion of EPs is about O(β). Compared with the analysis before [7], the EP drive can excite the EPMs without overcoming the continuum damping. And the EPMs become more unstable than discrete eigenmodes. Moreover, a switch or even an oscillation between discrete eigenmodes and wide-band EPMs can possibly be detected in future experiments and simulations. As illustrated in Figure 1, the switch of phases between wide-band EPMs and discrete SAWs can become a quasi-periodic oscillation, which can possibly be detected in experiments and simulations.

References

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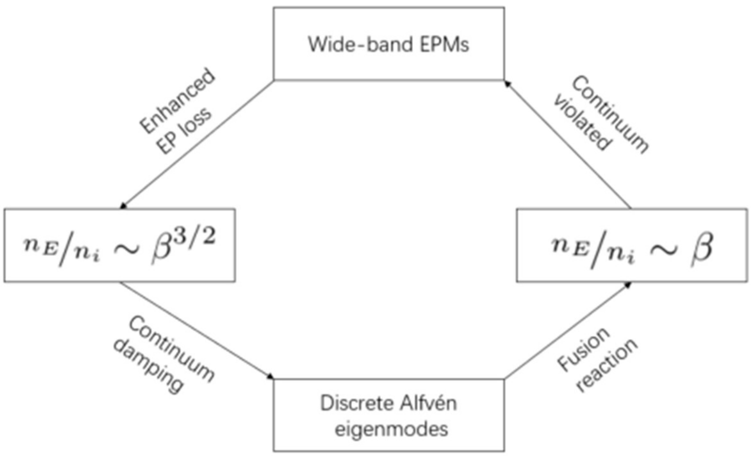

Figure 1. The illustration of the oscillation mechanism.