Whistler wave instabilities of runaway electrons in tokamaks

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Highly energetic runaway electron beam can be generated in tokamak disruptions, which can be destructive to the device. The runaway electron beam has a bump-on-tail and anisotropic distribution due to parallel acceleration and radiation reaction, thus can be susceptible to kinetic instabilities. In this work the whistler wave instabilities associated with runaway electron beam is investigated using a newly-developed simulation model, and the anomalous dissipation and the fast pitch angle scattering of runaway electrons in low energy are explained[1].

The interaction of runaway electron avalanche and the kinetic instabilities are studied self-consistently using quasilinear model. Results show that excited whistler waves can cause electrons to be scattered to large pitch angle (Fig. 1) and form vortices in momentum space, creating a new energy loss channel, and enhance the radiations. This explains the higher-than-expected critical electric field and the loss of runaway electron population in low energy regime identified experimentally[2]. The whistler waves excited in runaway electron experiments have recently been measured in both flattop phases[3] and post-disruption stages, which is consistent with the simulation results. The fast growth of electron cyclotron emission (ECE) signals observed in experiments is reproduced by a synthetic diagnostic tool. In addition, the oscillations of the ECE signals is explained through the nonlinear interactions between the excitation of whistler waves and the scattering of electron distribution function.

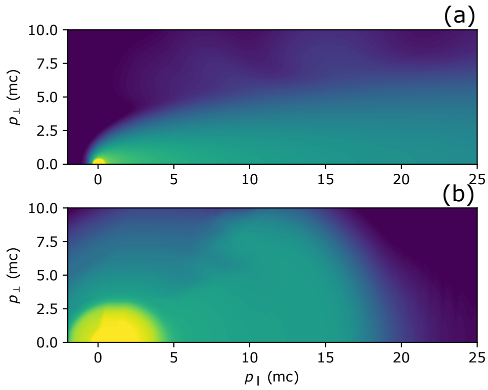

Figure 1: Compared to the case without kinetic instabilities (a), the electrons scattered by whistler waves has broader distribution in pitch angle (b).

References

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