Adjoint method and runaway electron dynamics in momentum space

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Runaway electron physics is an important aspect of the post-thermal collapse in disruptions, and is a critical area for current research. Theoretical and experimental studies have shown that various kinds of kinetic effects, including the drag force, the pitch angle scattering, and the synchrotron and bremsstrahlung radiation can change the runaway electron distribution in momentum space. In this study, we use a novel tool, the adjoint method [1], to study the runaway electron momentum space structure. The adjoint method includes all the aforementioned kinetic effects, and overcomes some of the limitations of previous methods such as the test-particle and Monte-Carlo methods. Using the adjoint method, one can obtain results like the runaway probability function and the expected slowing-down time. Theses results are consistent with previous studies, including the increase of the critical electric field for runaway electron growth due to radiation effects [2] and the runaway electron hysteresis [3]. In addition, we use the adjoint method to study the role of large angle scattering in the runaway electron population decay when the electric field is close to but less than the critical value (the marginal case). For this case, we develop a new collision operator for runaway electrons that includes both small and large angle scattering self-consistently. In contrast with the common belief that small angle scattering is much more important than large angle scattering in weakly coupled plasmas, we find that for the marginal case large-angle scattering plays an important role and cannot be ignored. Kinetic simulations with the new collision operator show an upward shift of the critical electric field value compared to previous results. These results can help us better understand the runaway electron momentum space structure, and give insights into quiescent runaway electron (QRE) experiments and runaway electron mitigation in disruptions.
This research is supported by the US Department of Energy.

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