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Gyrokinetic study of plasma transport and global profile evolution in stochastic magnetic fields

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Particle and energy transport in the presence of stochastic magnetic fields is the key physics issues that underlies the rapid thermal quench observed in a naturally occuring tokamak major disruption. First-principles-based calculation of plasma transport in stochastic magnetic fields has been developed using a global gyrokinetic model to confront specific challenges of thermal quench transport issues in tokamak disruption modeling. We emphasize the consistent coupling of electron and ion dynamics through transport ambipolarity induced electric field which plays a critical role in determining plasma transport in such systems. The gyrokinetic Poisson equation is directly solved in 3-dimension to capture the complicated plasma potential structure associated with the stochastic magnetic fields. The Poisson equation is also extended to including the vacuum permittivity, which enables to calculate the sheath potential between plasma and material wall. Further, a novel delta-f particle approach is developed to handle the particle loss to the wall and corresponding nonlinear evolution of the global plasma profiles in the stochastic magnetic fields with lower computational cost and higher accuracy. It is shown that the electric fields slow down and enhance the parallel transports of the electrons and ions, respectively. At the same time, the established potential in the stochastic layer produces strong radial ExB transports comparable or even stronger than radial parallel transports. The resulting ambipolar rarefaction waves form a complicated filament-like structure and propagate into the core region across the stochastic layer. The ExB transports also pump out the core plasma within the good closed magnetic surfaces to the stochastic layer region as the rarefaction wavefront reaches the boundary between them. As a result, we observed a rapid collapse of the global plasma profile within several milliseconds that agrees with the typical time scale of the thermal quench.