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Impact of inward turbulence spreading on energy loss of edge-localized modes[1]

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BOUT++ six-field Landau-fluid simulations show that an ELM crash has two phases: fast initial crash of ion temperature profile on the order of Alfven time scale near the peak gradient region and slow electron inward turbulence spreading from the ELM crash event. Both of them contribute to the ELM energy loss. However, the conducted ELM energy loss dominates over the convected ELM energy loss, which remains almost constant after the initial crash. The total ELM energy loss is mainly determined by the MHD turbulence spreading when the pedestal temperature height is large. The inward front propagation of electron temperature perturbation spreads into the linearly stable zone, while the ion perturbation front has much less spreading. The electron temperature fluctuation peaks on the rational surfaces and the front jumps gradually inwards towards neighboring rational surfaces. The electron wave-particle resonances via Landau closure provide a relatively strong parallel damping effect on the electron temperature perturbation and induce a large cross-phase shift of about $\pi/2$ angle between ExB velocity and the ion temperature, which yields almost no spreading for ion temperature and density fluctuation. When pedestal temperature height increases, the cross-phase shift of electron decreases and is close to $\pi/4$ angle which yields a large turbulence spreading and generates the large electron conducted energy loss. The front propagation stops at the position where the radial turbulent correlation length is shorter than the magnetic surface spacing. The energy burst of an ELM is controlled by the magnetic shear profile, the characteristic front propagating velocity and the turbulence correlation time. The inward turbulence spreading is mainly driven by (1) a series of micro-crashes due to a localized steepening of profile and (2) the magnetic flutter. The impact of other kinetic effects, such as full FLR effect and toroidal resonance, will be presented via simulations of a newly developed electro-magnetic Gyro-Landau-Fluid extension.

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