Cross-field plasma transport in divertor and divertor plasma detachment

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Detached (or partially detached) divertor regime is currently considered mandatory for ITER and future tokamak-reactors [1]. Its realization relies on intensive power loss by impurity radiation from divertor volume [2]. In tokamaks with carbon PFCs the main radiation loss is usually due to carbon, sputtering of which is virtually uncontrollable. In tokamaks with metal walls (e.g. JET) radiation loss with impurity generated by sputtering of the PFCs is relatively small. In order to reach divertor detachment, one has to inject impurities (e.g. nitrogen or neon). As a result, the amount of impurity becomes a controllable parameter. However, impurity localization and, therefore, the radiation loss in divertor volume is determined by an interplay of drifts and classical parallel and anomalous cross-field transport. While there are some experimental data on and theoretical models of the physics of anomalous cross-field plasma transport in the main chamber of the SOL, the information on anomalous cross-field plasma transport in divertor volume is very limited.

Meanwhile our numerical simulations clearly demonstrate that cross-field transport in the divertor volume plays a very important role in setting the conditions for impurity radiation. For example, if the energy flows are arranged in such a way that some part of energy is dumped from the most loaded flux surfaces to their neighbours in the radiation zone upstream and then returned back downstream, this would reduce the temperature gradient and expand the radiation zone, Fig. 1. To shed some light on the impact of cross-field plasma transport in the divertor volume on the impurity dynamics, radiation loss and divertor detachment, we perform scoping studies using the SOLPS4.3 code suite [3] as the test bed. We vary the electron and ion cross-field heat conductivity, as well as the anomalous diffusivity, within the inner and outer divertor volumes and consider their impact on the impurity radiation loss and the detachment physics. We also compare our results with theoretical predictions [4].

References


![Fig. 1 Impurity (neon) radiation losses, $Q_{\text{imp}}$, energy source due to radial heat transport, $-\nabla q_r$, and plasma temperature, $T_e$, plotted along one of the flux tubes in the outer divertor.](image-url)