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Wide divertor heat-flux width in ITER from self-organization between the neoclassical and turbulent transports across the separatrix surface

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A serious concern for ITER operation is the ability for the divertor to withstand the steady plasma exhaust heat that will be deposited on the divertor surface along a narrow toroidal strip. A simple, data-based regression from experimental measurements in present devices shows we would have λq⊠1mm for ITER operation at Ip=15 MA. However, it is questionable if such a simple extrapolation is valid as there may be differences in fundamental edge physics between ITER plasmas and those in present devices. Therefore, any extrapolation from present experiments to ITER needs to have a solid physics basis, which is one of the goals of the gyrokinetic edge code XGC1. Prediction for λq by XGC1 has been validated on several representative C-Mod, DIII-D, NSTX, and JET plasma conditions. However, when the same code is applied to a model ITER plasma at Ip=15MA, surprisingly, λq≈6mm is obtained [1]. Another abnormality is noticed from high current, high triangulariry NSTX-U model plasma simulations. A substantial new understanding has been obtained after the 2016 IAEA-FEC for physics behind the enhanced divertor heat-flux width. XGC1 data reveals an interesting competition effect between the neoclassical and turbulent transports. In the "conventional"tokamaks that obey the Eich scaling [2], a "blob-type"edge turbulence exists across the magnetic separatrix Ψn>0.97. On the other hand, in ITER, a "streamer-type turbulence"extends to Ψn>0.97 due to the small ρ_i/a effect. The streamer-type turbulence is much more efficient in the radial transport across the magnetic separatrix surface, with the pressure and potential perturbation being highly off-phase, than the blob-type turbulence is. We note here that even with ρ_i/a, the X-point orbit loss and a strong spontaneous co-rotation in the edge plasma supports a reasonably strong pedestal in ITER that is ~2X wider than the MHD predicted width.
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[1] C.S. Chang et al., IAEA-FEC 2016, TH/2-1; Nucl. Fusion 57 (2017) 116023
[2] T. Eich et al., Nucl. Fusion 53 (2013) 093031

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