5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Neoclassical transport due to resonant magnetic perturbations in DIII-D

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Non-axisymmetric magnetic field perturbations known as resonant magnetic perturbations (RMPs) are applied to mitigate or suppress the instabilities present in the plasma also known as edge localized modes (ELMs) which arise as a result of the steep pressure gradient at the edge in H-mode plasmas. The application of RMPs often leads to a decrease in the plasma density, referred to as density pump-out, which can significantly affect fusion performance. Here we investigate the role of neoclassical transport in density pump-out and heat flux in the presence of RMPs. In this study, the drift kinetic code NEO [1] with the enhanced capability to handle non-axisymmetric magnetic geometry is used to evaluate the neoclassical transport properties in DIII-D plasmas where RMPs are applied. The magnetic field given as an input to NEO is calculated using extended magnetohydrodynamic code M3D-C1 [2] and includes the nonlinear resistive plasma response in realistic geometry and with realistic values of resistivity. Because resistivity is included in the response model, the perturbed field also includes magnetic islands and regions of stochasticity. In order to ensure that integrable surfaces are provided to NEO, everywhere, we use isotherms of electron temperature calculated by M3D-C1 to represent the magnetic surfaces.

The study performed here indicates a dramatic increase of the neoclassical particle and energy fluxes in the presence of the RMPs and is on the same order as in same range as the diffusive particle fluxes calculated in the ELMing discharges in DIII-D [3], suggesting that neoclassical transport plays an important role in edge transport in such cases. The calculated neoclassical fluxes in DIII-D plasmas are found to be closely correlated with the observations of density pump-out over a range of RMP spectra (see Figure 1). Also, these calculations show that that even at modest RMP levels, the linear plasma response can lead to overestimation of the neoclassical fluxes near the pedestal region, and that nonlinear MHD simulations are essential at high RMPs to satisfactorily model the perturbed magnetic geometry in the pedestal region.

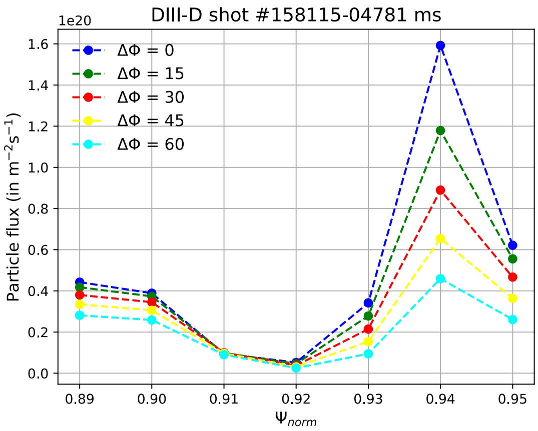

Figure 1: Neoclassical particle flux for ions calculated by NEO using equilibrium calculated by nonlinear M3D-C1 for DIII-D shot #158115 for time slot 4781 ms at RMP = 4 kA for different phasing ($\Delta\phi$). $\Delta\phi$= 0 (in blue), $\Delta\phi$= 15 (in green), $\Delta\phi$= 30 (in red), $\Delta\phi$= 45 (in yellow), and $\Delta\phi$ = 60 (in cyan)

References:

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