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A local gyrokinetic study of turbulent transport in a negative triangularity DEMO

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Experiments on TCV [1] and DIII-D [2] have found that tokamak equilibria with negative triangularity (i.e. δ <0) can achieve significantly better energy confinement than the conventional positive triangularity magnetic geometry. Moreover, they were found to have a higher L-H power threshold, potentially enabling a negative δ plasma to be heated to burning conditions while remaining in L-mode. Thus, a negative δ reactor operating in L-mode may still be able to achieve high fusion gain [3]. Importantly, this would avoid the material survivability issues caused by the powerful ELMs that are expected in reactor-scale H-mode plasmas.

The goal of this work is to compare turbulent transport in DEMO-relevant plasmas with positive and negative triangularities. This is important, not only to complement experimental studies, but to investigate how behavior extrapolates to a burning plasma. Without a large dedicated negative triangularity tokamak, theory and computation provide the primary tools for assessing the feasibility of a negative triangularity reactor. Accordingly, we performed local nonlinear gyrokinetic simulations of positive and negative δ equilibria derived from EU DEMO scenarios. Multiple equilibria were considered, characterized by different values of the total plasma current I_p, but Ion Temperature Gradient (ITG)-driven turbulence was found to be dominant in all. Additionally, since triangularity does not penetrate well to the magnetic axis, several radial locations were studied to understand the impact of the strength of triangularity on performance.

Preliminary GENE simulations of these equilibria indicate that negative δ shaping reduces the heat flux relative to positive δ *when holding the plasma profiles fixed* (see Fig. 1). This is consistent with previous simulations of Trapped Electron Mode (TEM) turbulence in TCV [4,5] and fluctuation measurements in TCV [6]. Moreover, although the ion heat transport was dominant, switching to negative δ reduced the fraction of energy carried by the electrons (see Fig. 1). Interestingly, for the nominal parameters of these DEMO equilibria, switching the background plasma profiles between the positive and negative cases had just as big of an effect as switching the plasma shape (see Fig. 1). Moreover, the magnitude of the change caused by swapping either the plasma profiles or the magnetic geometry is found to increase with minor radius. This is intuitive as the triangularity is stronger further out. Lastly, the stiffness of the temperature profiles was found to be similar between positive and negative δ at the minor radial locations considered (see Fig. 2), which is consistent with past numerical studies of the TEM turbulence in TCV [7,8].

References

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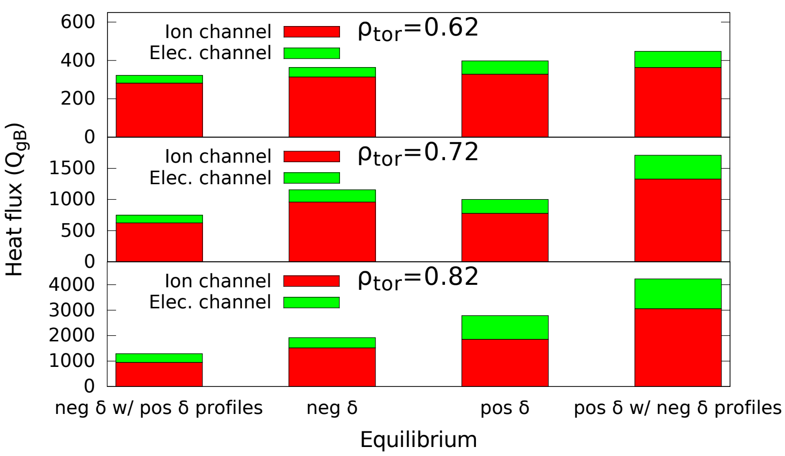

Fig. 1. Ion and electron heat fluxes at three different minor radial positions in four different equilibria: one positive δ, one negative δ, and the two equilibria generated by exchanging the plasma profiles.

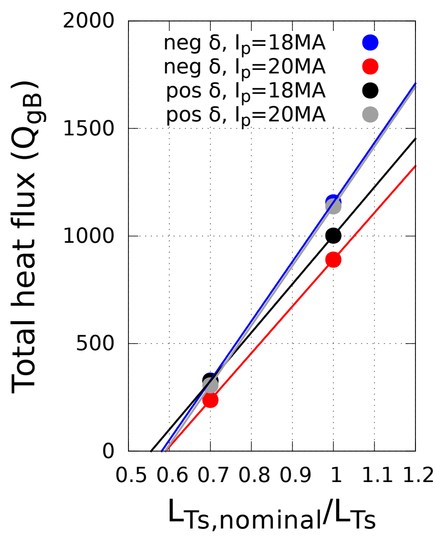

Fig. 2. The stiffness of two negative δ equilibria compared to their corresponding positive δ equilibria at a minor radius of $\rho_{tor} = 0.72$.