8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

Confinement improvement of negative triangularity L-mode tokamak configurations from first-principles global gyrokinetic simulations

G. Di Giannatale[1], A. Balestri[1], S. Brunner[1], M. Murugappan[1], L. Villard[1]

[1]École Polytechnique Fédérale de Lausanne (EPFL), Swiss Plasma Center (SPC), CH-1015 Lausanne, Switzerland

e-mail (speaker): giovanni.digiannatale@epfl.ch

One critical parameter affecting confinement performance in a fusion device is plasma shaping and in particular the triangularity. Negative triangularity (NT) configuration has gained significant interest in last decade since it has been shown, through intensive experimental campaigns (e.g. [1, 2, 3]), to increase the confinement time compared to the traditional positive triangularity (PT) configuration in L-mode operation.

In this work, we explore the effects of triangularity on turbulent transport employing both global temperature gradient-driven and flux-driven gyrokinetic simulations performed with the ORB5 code. A comprehensive theoretical understanding of the experimental findings remains elusive. Specifically, questions remain about how NT confinement improvement can extend to the core where triangularity is minimal, and whether these improvements can scale to larger devices.

In the first part of our analysis we focus on global gradient-driven simulations employing collisionless dynamics. Our analysis sheds some light on the differences between positive and negative triangularity, and it predicts that the relative improvement, $(\chi_{NT} - \chi_{PT})/\chi_{PT}$, is not limited to small machines or fluctuations size: the ρ^* scan displayed in Figure 1 shows that the relative improvement does not scale with the system size [4]. This system size scan has been performed considering a hybrid electron model, where only the trapped electrons give a kinetic response to the quasi-neutrality equation. However, simulations with fully kinetic electron response, performed for a single ρ^*, confirm the qualitative results achieved with the hybrid model and quantitatively increase even more the gap between the two configurations. The simulations were conducted in a turbulent regime of interest: a mixed ITG-TEM regime. Collisional effects have also been investigated using both global and flux-tube approaches. A general picture is emerging and our observations *partially* (i.e. on the electrons channel) agree with Y. Camenen et al.'s [1] experimental work, which noted the stabilizing effect of collisions on the TEM, with consequent reduction of the difference in electron heat diffusivity between PT and NT. On the other hand, the ion heat flux does increase with collisionality, and NT maintains its advantage over PT, especially in the ion channel. This confirms that negative triangularity improvement is not limited to the TEM regime but extends to ITG or mixed ITG-TEM regimes as well, as already observed in other recent papers using global [4] or flux tube [5] simulations.

Flux-driven simulations confirm that NT can indeed sustain higher temperature gradients compared to PT when heated with the same input power. This appears to be true in both collisionless and collisional (TCV collisionality) dynamics. Differences between gradient-driven and flux-driven will be highlighted. Flux tube simulations have been carried out considering the gradients of the profiles obtained in global, flux-driven simulations run at the same power for the two triangularities, with good agreement at $\rho_{pol} = 0.75$.

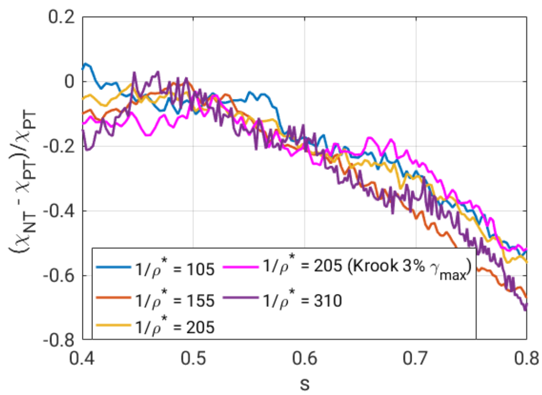

Figure 1: relative transport reduction for different ρ^*

References

[1] Camenen Y et al. 2007 *Nucl. Fusion* **47** 510
[2] Fontana M et al 2017 *Nucl. Fusion* **58** 024002
[3] Austin M E et al 2019 *Phys. Rev. Lett.* **122** 115001
[4] Di Giannatale G et al 2024 *Plasma Phys. Control. Fusion* **66** 095003
[5] Balestri A et al 2024 *Plasma Phys. Control. Fusion* **66** 075012