Extending enhanced-performance scenarios in the stellarator TJ-II after pellet injections

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Recent progress in helical devices and the demonstration of optimization reflects continued interest in stellarators as an alternative fusion approach. However, steady-state operation requires developing long-pulse scenarios, thus plasma fuelling is a critical issue. Whilst studies are performed on large devices to develop feasible fuelling scenarios, complementary studies on mid-sized machines can provide insights into underlying physics issues. In the Heliac TJ-II, a reproducible bifurcation-like transition to a high-performance branch, as measured by the triple product, $n_e \cdot T_i \cdot \tau$, is achieved by pellet injection during in NBI heated plasmas. This pellet-enhanced phase exhibits confinement well beyond stellarator ISS04 scaling expectations and β's well above Sudo predictions [1, 2]. It is maintained without additional heating until NBI switch-off by tailoring the pellet sequence. Discharges are characterized by a peaked density profile, stronger negative E_r's from the edge region to the core, and by increased post-injection ion temperatures, the latter being attributed to reduced ion heat diffusivity and improved ion energy confinement. These findings have stimulated intermachine comparisons of similar phenomena [3]. In addition, reduced density and plasma potential fluctuations are seen together with high E_r shear in the density gradient region. The latter may be associated with a low-order rational located in the same region, suggesting an important role for MHD turbulence in the formation of transport barriers [4]. Significant theoretical and experimental efforts are underway to identify the dominant instabilities that are suppressed when this enhanced phase is created. In the paper, an overview of experimental results for different magnetic topologies, pellet types and the pellet injection sequence is given and the role of instabilities in triggering a transport barrier in the gradient region is discussed.

[1] I. García-Cortés et al. *Phys. Plasmas 30* (2023) 072506.
[2] K. McCarthy et al. *in revision Nucl. Fusion (2024)*
[3] A. Dinklage et al., *29th Fusion Energy Conference, London* (2023).
[4] L. García et al., *Phys. Plasmas 30* (2023) 092303.