Is core fuelling by pellets in helical devices as straightforward as envisaged? An overview of simulation results with the HPI2 code in TJ-II and other helical devices

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Plasma core fuelling is a key pending issue on the pathway to a nuclear fusion reactor, since deep fuelling allows for plasma density profile shaping, which is a fundamental tool to control transport and fusion burn. Cryogenic pellet injection (PI) is currently the best candidate for core fuelling, as it allows particle deposition inside the edge transport barrier. In tokamaks, pellet fuelling is now rather well understood [1]. Although some particular aspects may not be completely clear, the fact that pellet plasmoids drift down the magnetic field gradient is well understood, thereby highlighting the advantages of High Field Side (HFS) injection [2]. On the other hand, for stellarators, core fuelling is particularly critical given neoclassical predictions of core particle depletion for central microwave heating [3]. However, pellet fuelling in helical devices is not so well understood, for the advantage of HFS is not clear, *i.e.*, that plasmoid drift follows the magnetic field gradient [4, 5]. With this in mind, it also must be considered that, while ITER is a tokamak, future reactors may be based on a different concept, for instance a stellarator. Thus, stellarators need to prove themselves as a solid alternative and to solve their pending issues, such as core fuelling. Therefore, it is mandatory to increase our current understanding of underlying physical mechanisms related to PI in stellarators.

With the purpose of shedding light on pellet fuelling in helical devices, inter-device pellet comparisons have gained momentum in recent years. Here, experimental results from different non-axisymmetric devices are compared with theoretical predictions obtained using a stellarator version of the HPI2 code, a code of reference for PIs in tokamaks [6, 7]. To enable its application to the more complex geometry of helical devices, a new scheme to calculate plasmoid drift was implemented and the large TJ-II pellet database was used for its validation [8]. In addition, dedicated pellet experiments have been made on TJ-II using fast-frame cameras and its full array of diagnostics to better understand plasmoid drift. Next, data from the Wendelstein 7-X OP1.2 campaign was compared with simulations made using this HPI2 version [5]. Finally, Heliotron J and LHD have been added to this inter-device comparison. For all these devices good agreement is obtained for pellet ablation, except for W7-X HFS injections, for which pellet penetration is underestimated. On the contrary, for particle deposition such good agreement is not always attained. For instance, for TJ-II significantly good agreement is found for on-axis ECRH plasmas, while for W7-X, the expected inwards drift for HFS injections is not clearly observed. Finally, for Heliotron J and LHD, more scenarios must be considered in this study to fully understand differences between measured and HPI2 deposition profiles.

In conclusion, inter-device comparisons can help identify any missing or unknown plasmoid mechanisms related to toroidal asymmetry. This will increase confidence in pellet predictions, necessary for the development of plasma fuelling scenarios and for the design of optimized injectors.

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