A new quasi-isodynamic stellarator configuration with good fast-ion confinement and reduced turbulent transport

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The stellarator is an attractive concept for magnetic confinement fusion reactors, as it offers some advantages over the tokamak. Whereas in tokamaks part of the magnetic field is produced by driving a large inductive current in the plasma, the magnetic field of the stellarator is generated by external coils, avoiding the risk of current-driven instabilities and making steady-state operation easier. However, the lack of axisymmetry of the stellarator implies that good confinement is not guaranteed but requires careful tailoring (optimization) of the magnetic configuration. Wendelstein 7-X (W7-X) is the first large stellarator whose magnetic configuration has been obtained using numerical optimization, and its reduced neoclassical transport of thermal species has been recently demonstrated [1]. However, the confinement of energetic particles, which is crucial for a reactor and improves with β in W7-X, is not expected to be good enough at β~4-5% [2]. Furthermore, the first experimental campaigns in W7-X have shown that turbulent transport limits its performance in most plasma regimes.

In this conference contribution, we present a new quasi-isodynamic (QI) stellarator configuration that improves in fast ion confinement and turbulent transport with respect to W7-X while keeping all its other good properties [3]. In the new configuration, with four periods and aspect ratio A~10, the confinement of fast ions is excellent not only for reactor-scale plasmas with β~4% but also for moderate values of β~1.5%, which can be transiently necessary for the operation of a reactor. The effective ripple is smaller than 0.5% in the plasma core, and a significant magnetic well ensures the Mercier MHD stability in the whole plasma volume. Ballooning stability up to β=5% has also been confirmed. A preliminary evaluation allows us to foresee a small bootstrap current for β values up to 4%, as expected for QI devices. As an expected by-product of the QI optimization at finite beta, the new configuration exhibits reduced Trapped Electron Mode (TEM) turbulent transport. A preliminary set of filamentary coils capable of generating this configuration will also be presented.

[1] C. Beidler et al. Nature 596, 221 (2021).
[2] M. Drevlak et al. Nucl. Fusion 54, 073002 (2014).
[3] E. Sánchez et al. Nucl. Fusion. Submitted, 2023 (https://arxiv.org/abs/2212.01143).