Advances in understanding the impact of the isotope mass on pedestal structure and transport

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The H-mode pedestal, a narrow region of reduced transport at the plasma edge, sets the boundary condition for core plasma performance. Therefore, understanding the physics of pedestal structure and dynamics and predicting its performance in future fusion reactors is key to reducing the uncertainties associated with the realization of burning plasma conditions. ITER and future fusion reactors will operate with mixed Deuterium-Tritium plasmas. The greatest challenge to date related to understanding the impact of hydrogen isotope mass on plasma transport lies in the processes governing the plasma edge region and H-mode pedestal.

This presentation will review recent progress (via experiments, theory and numerical modelling) in understanding the impact of isotope mass on pedestal structure and inter-ELM transport.

Recent T and D-T experiments on JET have confirmed a strong mass dependence on the pedestal density and provided new and unique results. For example, T pedestals exhibit different characteristics from those in H and D plasmas as a function of neutral gas fuelling [1]. State of the art pedestal diagnostics were employed to measure the pedestal structure in D, D-T and T and the most advanced theoretical models were used to identify the physics mechanisms linked to the dependence of pedestal stability and inter-ELM transport on isotope mass [2]. Furthermore, changing the isotope mass in experiment served as a powerful actuator to guide refinement of predictive pedestal models [3].

A key question for full prediction of the pedestal density is the relative role of neutral penetration vs pedestal particle transport. The competing level of turbulent and neoclassical transport with varying isotope mass has been quantified using the gyrokinetic code GENE for selected JET pedestals [4]. However, progress in this area is typically hindered by the difficulty to obtain accurate measurements of the edge particle source. Recently, the isotope dependence of neutral fuelling in the H-mode pedestal region was examined quantitatively in DIII-D experiments using direct spectroscopic measurements of neutral hydrogen (H and D) penetration [5].

Projecting to D-T plasmas in future reactors, which will be opaque to neutrals, the impact of isotope mass dependence of edge neutral fuelling will be negligible, while the pedestal density structure will depend primarily on its transport properties, in turn affecting pedestal stability.

[1] P Schneider et al., Nucl. Fusion **63** (2023) 112010
[2] L Frassinetti et al., Nucl. Fusion **63** (2023) 112009
[3] S Saarelma et al., Nucl. Fusion **64** (2024) 076025

[4] I Predebon et al., Nucl. Fusion **63** (2023) 036010

[5] R Chaban et al., Nucl. Fusion 64 (2024) 046008