Tritium experiments in JET-ILW in support of JET and ITER D-T plasmas

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After several years of extensive preparations and large investments, in 2021 JET has exploited its unique capability for using T as the main fuel in an ITER-like wall environment with dedicated T experiments, culminating in a sequence of experimental campaigns encompassing all three hydrogen isotopes. Key isotope studies range from technological and operational aspects, such as isotope change-over and tritium inventory and removal, to understanding the dependence of particle, heat and momentum transport on isotope mass, required for predicting ITER's burning plasmas. Furthermore, the impact of isotope mass on the integrated performance of high I_P and of high β ELMy H-modes has been investigated in T vs D counterpart discharges in preparation for JET D-T high fusion power plasmas.

T plasmas have a lower L-H power threshold, but previous results of $P_{L\_H} \sim 1/A$ ($A = m_i/m_p$) are confirmed only for the net power across the separatrix, i.e. with bulk radiation subtracted, highlighting the relevance of this term in the Be/W wall environment and thus the need to include it when predicting H-mode access in ITER. On the other hand, the operating space for steady ELMy H-mode is reduced compared to D, for similar auxiliary heating and gas fuelling rates. Tritium H-modes, explored at I_P ranging between 1.4 and 3.5 MA, are characterised by a slower build-up of the core density profile after the L-H transition, lower ELM frequency and increased pedestal density (likely due to reduced inter-ELM particle transport with increasing isotope mass) compared to D. These properties, combined with the higher W sources measured in T (both inter-ELM, due to the larger Be-sputtering, and intra-ELM, due to the increased W-sputtering by main fuel with increasing A) facilitate rapid increase of W radiation. As a consequence, H-mode entry, its steady sustainment and H-mode exit without disruption had to be reoptimized for T plasmas.

In controlled type I ELMy H-mode experiments, higher thermal pressure is observed in T than in D. While at medium heating power / β (low fast ion content), similar core confinement is found with both isotopes if the pedestal pressure is matched, at higher heating power / β, tritium H-modes have enhanced core confinement compared to D, for similar pedestal pressure. Although the heat fluxes and toroidal rotation are similar, plasma β, collisionality and fast ion content are different in these T and D plasmas. Flux driven core transport predictive modelling with quasi-linear models cannot explain the core confinement in the high beta regime, highlighting missing physics connected to non-linear fast-ion and electro-magnetic stabilization of core turbulence and their coupled effects in such models. T plasmas with H ELM-pacing pellets are beneficial to the formation of H-modes with T_i and n_e internal transport barriers and low pedestal density, an unexpected and not yet understood result. First measurements of core main ion intrinsic rotation in comparative H, D and T Ohmic plasmas show a clear isotope dependence, which was not predicted by theory.

In summary, the recent T experiments in JET demonstrate that isotope studies in H and D alone are not sufficient for extrapolating with confidence to D-T plasmas in JET and challenge transport models currently used for the preparation of fusion plasmas in ITER.