Isotope effect of the H-mode pedestal in JET-ILW hydrogen and deuterium plasmas

L. Horvath[1], C.F. Maggi[2], A. Chankin[3], S. Saarelma[2], E. Belonohy[2], E.G. Delabie[4], A. R. Field[2], J. Flanagan[2], L. Frassinetti[5], C. Giroud[2], D. Keeling[2], D. King[2], M. Maslov[2], G.F. Matthews[2], S. Menmuir[2], S.A. Silburn[2], A.C.C Sips[6,7], H. Weisen[8], K.J. Gibson[1] and JET Contributors*

*EUROfusion Consortium, JET, Culham Science Centre, Abingdon OX14 3DB, UK, [1]University of York, UK, [2]Culham Centre for Fusion Energy, UK, [3]Max-Planck-Institut für Plasmaphysik, Germany, [4]Oak Ridge National Laboratory, US, [5]KTH Royal Institute of Technology, Sweden, [6]JET Exploitation Unit, UK, [7]European Commission, Belgium, [8]EPFL, Switzerland, *See the author list of "X. Litaudon et al 2017 Nucl. Fusion 57 102001"*

Unravelling the isotope dependence of plasma confinement and transport would improve our understanding of plasma turbulent transport and our ability to predict accurately the performance of burning plasmas. The positive scaling of energy confinement time with isotope mass observed in experiments is not yet fully understood theoretically. Experiments in Hydrogen (H) and Deuterium (D) have been executed on JET with the Be/W wall (JET-ILW) in preparation for the upcoming D-T campaign, providing data for stringent tests of plasma transport models [1]. In H-mode, a strong, favourable isotope effect has been found, originating at the pedestal and propagating through the plasma core due to the constant critical temperature gradient in conditions where ions and electrons are collisionally coupled and electron and/or ion transport are stiff [1].

Type I ELMy H-modes in H at the same input power and gas fuelling rate have lower pedestal pressure than in D, primarily due to a lower pedestal and SOL density. The ELM frequency is higher in H, but the ELM energy loss is lower, thus the ELM power loss is similar in H and D H-modes at same P_{IN}, gas rate, I_p and B_t. Inter-ELM power balance analysis showed that for H and D pulses at similar pedestal pressure (achieved at higher P_{IN} in H), the inter-ELM separatrix loss power is more than 50 % higher in H.

The direct isotope effect on linear MHD pedestal stability becomes apparent when the diamagnetic frequency (ω_{dia}) is included in the stability criterion to account for its stabilisation effect in HELENA/ELITE. The linear growth rates of ideal MHD modes decrease with increasing isotope mass, but ω_{dia} has no isotope dependence, thus Peeling-Ballooning (P-B) modes are more stable in D than in H. However, this effect is small (~10 % in predicted pedestal pressure) and alone does not fully explain the higher pedestal pressure observed in D. Interpretative EDGE2D-EIRENE simulations indicate a higher ion and electron temperature and lower density at the separatrix in H than in D in a pair of type I ELMy H-modes with similar stored energy. This difference in boundary conditions at the separatrix translates into significant differences in the P-B stability boundary between H and D, with both ballooning and peeling boundaries shrinking for the H case as a result of the maximum edge pressure gradient being closer to the separatrix, which increases destabilization of P-B modes. This effect is consistent with type I ELMs being triggered at lower pedestal densities in the H case. However, the physics mechanism underlying the profile changes at the plasma edge when the isotope mass is varied is not yet understood and is being investigated with gyrokinetic computations.

Analysis of the pedestal structure of the H and D type I ELMy H-mode dataset shows that the pedestal width is typically narrower in H than in D. This is in contradiction with the neutral penetration model which assumes that the pedestal density is set by edge particle flux and the pedestal width is approximately equal to the neutral penetration length [2]. The EDGE2D/EIRENE interpretative simulations imply instead that differences in edge particle and heat transport and in wall recycling/pumping could be responsible for the observed differences between H and D pedestals. This hypothesis is supported by results of power balance analysis, which shows that significantly higher inter-ELM separatrix loss power is required to maintain the same pedestal top pressure in H than in D plasmas.

[1] C.F. Maggi et al., PPCF **60,** 014045 (2018) [2] R.J. Groebner et al., PoP **9,** 2134 (2002)