Experimental Investigations of the H-mode Access in Mixed Hydrogen-Deuterium Plasmas at ASDEX Upgrade

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A dependence of the H-mode power threshold (P_{LH}) on the main ion plasma species has been observed already in early isotope experiments [Righi NF 1999]. In hydrogen (H) plasmas P_{LH} is about two times larger than in deuterium (D) plasmas. In order to elucidate the underlying mechanism leading to a changed P_{LH}, L-H and H-L transition experiments were performed in ASDEX Upgrade, changing the relative hydrogen content ($f_H=n_H/(n_H+n_D)$) from 0 to 1 and employing different heating types (NBI and ECRH).

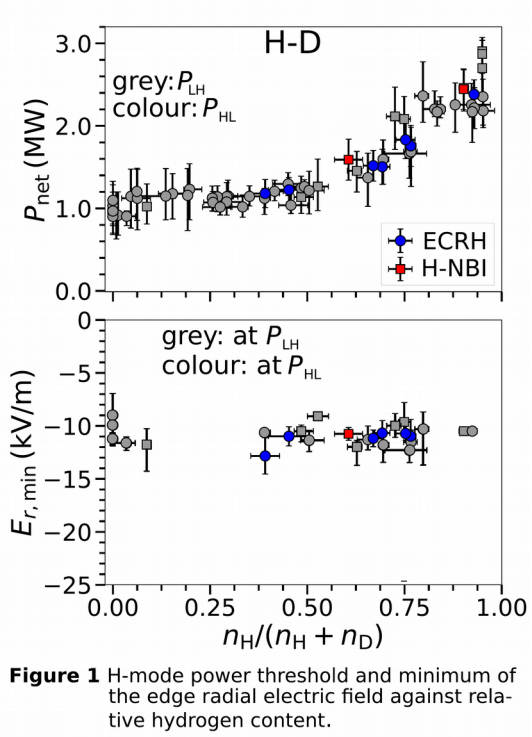

Figure 1 H-mode power threshold and minimum of the edge radial electric field against relative hydrogen content.

At high density P_{LH} and P_{HL} exhibit a non-linear dependence on f_H, whereas the minimum of the edge radial electric field ($E_{r,min}$) is constant, independent of f_H. Furthermore the same $E_{r,min}$ value is found at both, the L-H and the H-L transition (see Figure 1), indicating that similar E_r gradients are reached at both confinement transitions and for different hydrogen mixtures. Power balance calculations show that the ion heat diffusivity in H is about a factor of 2 higher than in D at the L-H transition, which is consistent with recent gyrokinetic simulations [Bonanomi PoP 2021]. These findings taken together could be a possible explanation for the increased P_{LH} in H compared to D plasmas.

In the same line, previous results show that in pure H plasmas P_{LH} is slightly higher in NBI than in ECRH heated plasmas, whereas the edge ion heat flux ($Q_{i,edge}$) is the same [Plank NF 2020]. This indicates that $Q_{i,edge}$ is an important quantity for the H-mode access. Edge measurements in these H plasmas show that also ∇p_i is comparable at the L-H transition, while the inner E_r gradient is steeper for NBI than for ECRH heated plasmas. This suggests that a contribution of the edge rotation to E_r is not negligible in these L-mode conditions.

In low density plasmas at high ECRH power and $f_H>0.6$ an I-mode-like confinement regime was discovered, which occurs in favourable drift configuration. It exhibits improved energy, but L-mode-like particle confinement and a weakly coherent mode. The existence of this regime indicates that a decoupling of energy and particle transport is possible as soon as P_{LH} is increased and not only if the plasma is in unfavourable drift configuration.