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Simulations of isotope effects on the formation of the edge transport barrier and the L2H-like transition in magnetically confined plasmas

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It is by now well established that the isotope composition plays an important role for the transition from the Low to High confinement mode (L2H) in magnetically confined plasmas. Generally, it is experimentally observed that the L2H power threshold, P_{L2H}, decreases with increasing isotope mass number, A, see e.g. [1], roughly like A^{-1}. This will have high importance for the ITER operation. In the initial phase ITER is planned to be operated with Hydrogen, implying a 2 times higher P_{L2H} than for Deuterium plasmas, which put severe demands on the available power input. On the other hand, one may expect that P_{L2H} for a mixture of Deuterium and Tritium will be lower than for pure Deuterium, which will facilitate the transition to H-mode operation.

We present numerical modelling of isotope effects on the formation of the edge transport barrier, ETB, and the ensuing L2H-like transition by using the HESEL model [2]. HESEL is a four-field drift-fluid model including generalized vorticity, density, electron and ion pressure equations and using the Braginskii closure for collisions. The model is solved on a 2D domain at the out-board mid-plane of a Tokamak including both open and closed field lines. The parallel dynamics is parameterized in the open field line region – the scape-off-layer - accounting consistently for the parallel losses. Previous HESEL results for D plasmas were found to be in quantitative agreement with observations from Medium Size Tokamaks (MST) like devices, as, e.g., EAST [2].

The results for pure isotopes; H, D, and T for plasma parameters of typical JET and MST-devices show a clear decrease of P_{L2H} for increasing mass number ~ $A^{-\gamma}$, with $\gamma \approx 1.5$. We observe that the energy density flux across the Last Closed Flux Surface (LCFS), is decreasing with increasing mass, and indeed the development of the shear flow - constituting the ETB - appears to be faster for the higher mass. However, in the quasi-steady phase after the transition the shear flow and the ETB appear almost independent of the mass.

We have attempted a simplified model of isotope mixtures, representing the mixture by an effective mass and charge number. Here we recover the ~ $A^{-\gamma}$ behaviour for the effective mass, for $1 \leq A_{eff} \leq 3$. However, recent JET experiments [3] have revealed a clear "nonlinear" behaviour for mixtures of H and D, where the main change of P_{L2H} appears near $A_{eff} = 1$ or $= 2$, while in between the threshold is rather weakly changing. This effect cannot be captured in a simple effective mass model and may call for a multi-isotope model. Such a model is under development.

[1] E. Righi et al., Nuclear Fusion, 39, 309 (1999); P. Gohil et al., ITR/P1-36, IAEA 2012; F. Ryter et al., Plasma Phys. Control. Fusion 58 (2016) 014007.
[2] A.H. Nielsen et al., Phys. Lett. A 79 (2015) 3097; J. Juul Rasmussen et al. Plasma Phys. Control. Fusion 58 (2016) 014031
[3] J. Hillesheim et al., 44th EPS Conf. Plasma Physics 2017; Belfast, UK. P5.162; E.R. Solano et al., 59th Annual Meeting, APS Division of Plasma Physics, 2017; Milwaukee, Wisconsin USA

Preference: ☐X Oral in session: *Effect of isotope mass on transport and confinement* - or - *L-H transition physics and plasma operation close to the threshold*