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Numerical investigation of isotope transport scaling and its relation to L2H power threshold

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The influence of hydrogen isotopes and He ions on the transport out of the confinement region in toroidal magnetically confined plasmas is investigated by applying the HESEL model. HESEL is a four-field drift-fluid model including generalized vorticity, density, electron, and ion pressure equations and using the Braginskii closure for collisions,[1]-[2]. The model is solved on a 2D domain at the outboard mid-plane of a Tokamak including both open and closed field lines. The simulations are performed with parameters from specific JET shots.

For L-mode hydrogen isotope plasma, it is found that the energy flux density across the last closed flux surface decreases with mass number, A, and scales like $A^{-0.8}$ for the hydrogen isotopes H (Hydrogen), D (Deuterium), and T (Tritium), see Figure 1. This is consistent with standard isotope scaling of the energy confinement time. Correspondingly, the threshold, P_{LH}, for the transition to a high confinement state with strongly suppressed transport - an L-H-like transition, Figure 2 - is found to decrease with mass number as $A^{-1.4}$, Figure 3. This follows the standard ITPA scaling trend [3] with PLH decreasing like ~1/A. We have applied an effective mass approach for mixtures of isotopes, which fits the scaling from H to T. For the energy density transport, the relative contributions of electrons and ions were considered - showing that the electron contribution dominates in the L-mode cases, while the ion and electron contributions are almost equal for the L2H transition phase. The collisional contributions are negligible for the hydrogen isotopes. Our results compare quantitatively to the L2H campaign at JET, but we have not been able to reproduce the non-power-law behavior on A observed experimentally, [4-5].

The confinement transition is also investigated for Helium, He, plasma - here the threshold for L2H is in the same range as the threshold for Deuterium plasma at similar parameters, however, the collisional transport now becomes significant and is comparable with the anomalous turbulent transport in the H-mode plasma. The edge transport barrier, set up by a sheared poloidal flow, is found to be very similar for all the cases considered - the hydrogen isotopes and the He plasma, which is consistent with the radial ion force balance being independent of ion charge and mass.

References

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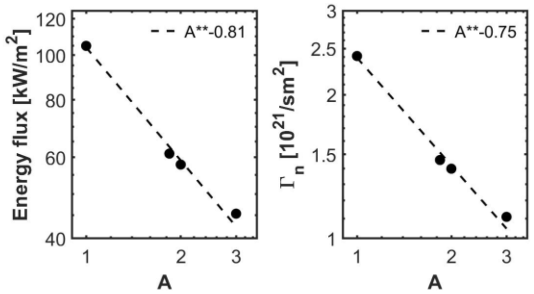

Figure 1 Energy flux density and particle flux density as a function of mass number A. Data points represent time average values from individual HESEL simulations for varying A and using plasma parameters from JET#90993, for a time when the plasma was in L-mode.

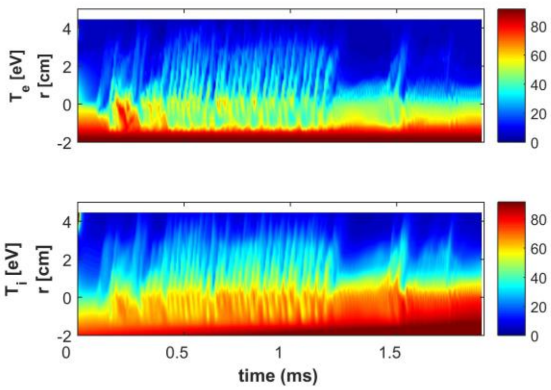

Figure 2 HESEL simulation using plasma parameters from JET#90993 just before L2H. Parameters are constant except for the edge ion temperature, which is increased linearly in time. At t=1.2s the plasma transforms from L- to H-mode.

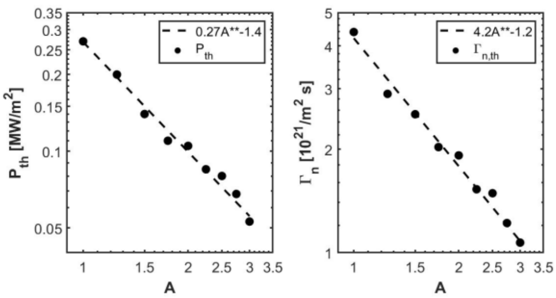

Figure 3 Energy flux density and particle flux density across the LCFS at L2H as a function of A. Plasma parameters from JET#90993, for a time just before