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Non-linear isotope and fast ions effects: routes for low turbulence in DT plasmas

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The isotope effect, i.e. the fact that heat and particle fluxes do not follow the expected Gyro-Bohm estimate for turbulent transport when the plasma mass is changed, is one of the main challenges in plasma theory. Of particular interest is the isotope exchange between the fusion of deuterium (DD) and deuterium-tritium (DT) nuclei as there are no clear indications of what kind of transport difference can be expected in burning plasmas. The GENE code [1] is therefore used for computing DD vs DT linear and nonlinear microturbulence characteristics in the core plasma region of a previously ITER hybrid scenario at high beta obtained in the framework of simplified integrated modelling. Scans on common turbulence related quantitates as external ExB flow shear, Parallel Velocity Gradient (PVG), plasma beta, colisionality or the number of ion species have been performed. Additionally, the role of energetic particles, known to reduce Ion Temperature Gradient (ITG) turbulence has been also addressed [2,3]. It is obtained that the ITER operational point will be close to threshold and in these conditions turbulence is dominated by ITG modes. A purely weak non-linear isotope effect, absent in linear scans, can be found when separately adding moderate ExB flow shear or electromagnetic effects, whereas collisionality just modulates the intensity. The isotope effect, on the other hand, becomes very strong in conditions with simultaneously moderate ExB flow shear, beta and low q profile with significant reductions of ion heat transport from DD to DT [3]. By analyzing the radial structure of the two point electrostatic potential correlation function it has been found that the inherent Gyro-Bohm scaling for plasma microturbulence, which increases the radial correlation length at short scales form DD to DT, is counteracted by the concomitant appearance of a complex nonlinear multiscale space interaction involving external ExB flow shear, zonal flow activity, magnetic geometry and electromagnetic effects. The number of ion species and the fast ion population is also found to play a role in this non-linear process whereas a symmetry breaking between D and T, with systematic reduced heat and particle transport for T, is always obtained. [1] F. Jenko, W. Dorland, M. Kotschenreuther and B.N. Rogers, Phys. Plasmas 7, 1904 (2000). [2] J. Citrin et al., Phys. Rev. Lett. 111, 155001 (2013). J. Garcia et al., Nucl. Fusion 55, 053007 (2015). [3] J. Garcia et al., Nucl. Fusion 57, 014007 (2017)