Isotope and Species Scaling in JET Deuterium, Tritium and Helium Plasmas

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The JET tokamak has the unique capability to perform experiments with Tritium. This paper reports the isotope mass scaling of transport and confinement between Deuterium and Tritium plasma, and furthermore, a comparison to transport scaling studies in corresponding recent Hydrogen and Helium plasmas is presented.

The dimensionless isotope mass scaling experiment between pure Deuterium and pure Tritium plasmas with matched ρ^*, ν^*, β_n, q and T_e/T_i in JET L-mode plasmas showed relatively strong isotope mass scaling as $\Omega_i\tau_{E,th} \sim A^{0.48\pm0.16}$ [1]. Local non-linear GENE simulation results indicated an isotope mass scaling effect in favour of Tritium at ρ_{tor}=0.6, but a significant part of the experimentally observed isotope scaling was not captured in the GENE and ASTRA-TGLF-SAT2 simulations by simply changing the isotope mass for the same input.

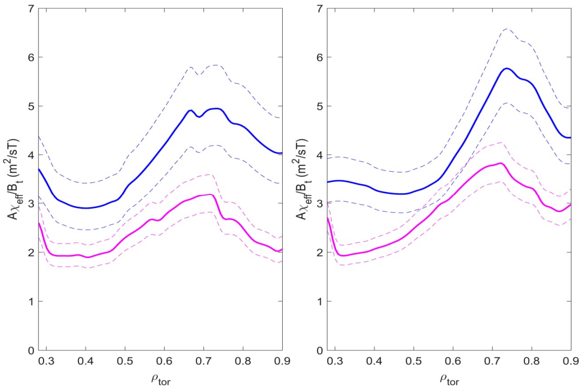

Figure 1. Scaled one-fluid effective diffusion coefficients for the Deuterium discharge (blue) and the Tritium discharge (magenta) at two different NBI power levels, P_{nbi} = 0.8/1.4MW (left panel, with 0.8MW for D and 1.4MW for T) and P_{nbi} = 1.8/3.4 MW (right panel, with 1.8MW for D and 3.4MW for T), with the larger NBI power level referring to the Tritium pulse and smaller one to the Deuterium pulse. The dashed lines indicate the error bars [1].

The confinement improvement in Tritium plasmas in favour of the Deuterium one in the dimensionally matched (same I_p, B_t, ne, P_{nbi}) pair is less than that in the matched dimensionless pair. The energy confinement time is 11-13% higher in T plasma than D plasma. This is also well seen in the one-fluid effective diffusion coefficients shown in figure 1. The confinement improvement is originating dominantly from the electron heat transport channel. Particle diffusion is similar for both dimensional and dimensionless matched pairs

Similar experiments comparing Hydrogen and Deuterium JET L-mode plasmas showed almost no isotope scaling [2]. In JET H-mode plasmas, the core confinement increases with pedestal pressure for all isotope masses due to profile stiffness and electro-magnetic turbulence stabilization [3]. By comparing the dimensionally matched Helium plasma with the Deuterium and Tritium ones, the following observations are made: the electron temperature is higher, and the electron density profile is more peaked in the He plasma than in the matching D and T plasmas. However, as the ion density in the He plasma is only half of the D or T ones, the plasma energy content is smaller and energy confinement worse in the He plasma.

The possible reasons for the observed relatively strong isotope scaling will be discussed, including gyro-kinetic and transport simulations.

[1] T. Tala et al., Nucl. Fusion **63**, (2023) 112012.
[2] C.F. Maggi et al., Nucl. Fusion **59**, (2019) 076028.
[3] P. Schneider et al., Nucl. Fusion **63**, (2023) 112010.