Isotope effect and multi-scale physics in fusion plasmas

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There is experimental evidence that at comparable plasma discharge parameters deuterium (D) discharges have improved confinement properties as compared with hydrogen (H) [1] with a degree of confinement improvement depending on plasma regimes. Interestingly the isotope effect seems to be weaker in stellarators than in tokamaks [1]. The mechanism governing the impact of the mass isotope on plasma confinement is still one of the main scientific conundrums facing the magnetic fusion community after more than thirty years of intense research.

We have investigated the properties of local turbulence and long-range correlations (LRC on the same flux surface) in Hydrogen and Deuterium plasmas in both the TEXTOR tokamak [2] and the TJ-II stellarator [3]. Experimental findings have shown a systematic increasing in the amplitude of LRC during the transition from H to D dominated plasmas in the TEXTOR tokamak but not in the TJ-II stellarator [3]. Meanwhile the local turbulence correlation lengths also increase from the Hydrogen-to Deuterium-majority plasmas at TEXTOR [2].

These results suggest the role of the ion mass on the amplitude of zonal flows, and thus, provide the first direct experimental evidence of the importance of multi-scale physics for unravelling the physics of the isotope effect on transport and confinement in fusion plasmas.