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LHDにおける粒子、熱輸送と乱流揺動の同位体効果
Isotope effects of particle, heat transport and turbulence in LHD

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The transport of different hydrogen isotopes is an important issue for predicting the performance of ITER and the future reactor operation. In a tokamak, improved transport character and lower H mode threshold power in D plasma than in H plasma were reported. Both tokamak scaling (ITER98y2) and helical scaling (ISS04) follow gyro-Bohm (GB) scaling with the exception of ion mass and ion charge number. While GB scaling predicts enhanced transport in D plasma, many experiments show better confinement in D plasma. In this paper, we report the result of systematic survey of isotope effects in energy and particle transport in ECRH plasma of LHD.

Figure 1 shows collisionality dependence of global energy confinement time (τ_E) and global particle confinement time (τ_P). In the dataset, the contamination of helium is less than 5% and the purity of the H and D are higher than 80%, respectively. The injection power was 0.6-3.9MW in D, 0.8-3.8MW in H, $n_{e\ bar}$ was 0.6-3.7x10^{19}m^{-3} in D, 0.3-3.8x10^{19}m^{-3} in H. The regression analysis was performed, then, the scaling $\tau_{E\ ECH} \propto A^{0.24\pm0.01} n_{e\ bar}^{0.58\pm0.01} P_{abs}^{-0.52\pm0.01}$ and $\tau_{p\ ECH} \propto A^{-0.33\pm0.02} n_{e\ bar}^{0.52\pm0.01} P_{abs}^{-0.69\pm0.02}$ were obtained, where A is ion mass (1 for H, 2 for D), $n_{e\ bar}$ is the line averaged density, and P_{abs} is absorption power. Positive mass dependence of τ_E and negative mass dependence of τ_p were found. This indicates that isotope effects are different in energy and particle channel.

Figure 2 shows comparison of profiles for almost identical $n_{e\ bar}$ and P_{abs} in H and D plasma. As shown in Fig.2 (a), n_e profiles are clearly different. In D plasma, n_e profile is clearly hollow, while it is flat in H plasma. Since neutral penetration of H and D are almost identical, the difference of n_e profile is due to the difference of transport. T_e is clearly higher in D plasma at r_{eff}/a_{99}<1.0, while ECH power deposition profiles are almost identical. In H plasma, logarithmic gradient (L_{Te}^{-1}) of T_e is constant at r_{eff}/a_{99}=0.2~0.9, while in D plasma, L_{Te}^{-1} varies depending on the location. Stronger stiffness is found in H plasma. Figure 2 (d) shows comparison of ion scale ($k\rho_i$~0.2) turbulence level measured by two dimensional phase contrast imaging [1]. The edge turbulence level at r_{eff}/a_{99}>0.9 are almost identical both in H and D plasma, while, core turbulence level at r_{eff}/a_{99}<0.9 in H plasma is clearly higher than those in D plasma. This suggests core particle transport is reduced in D plasma. On the other hands, global particle transport, which is close to the characteristics of edge particle transport, is enhanced in D plasma as shown by regression analysis. Thus, isotope effect of particle transport is likely to be different in core and edge region. Gyrokinetic study shows stabilization effects of hollowed density profile (positive density gradient) [2]. This supports experimental observations.

[1] K. Tanaka et al, Rev. Sci. Instrum.79, 10E702,(2008)

[2] M. Nakata et al, Plasma Phys. Ctrl. Phys. in press

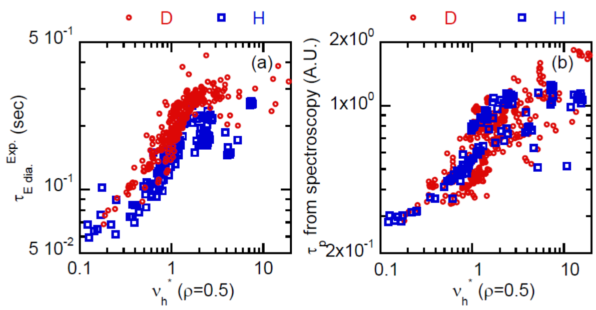

Fig.1 Collisionality dependence of (a) τ_E and (b) τ_P

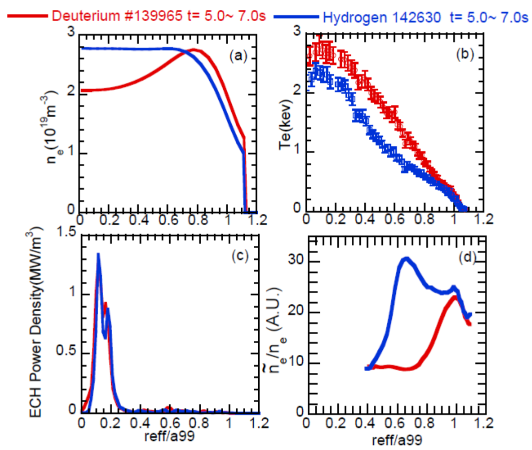

Fig.2 Comparison of profiles in D and H plasmas (a) n_e, (b) T_e, (c) ECH deposition profile and (d) turbulence level