DPP19-2019-000074

Abstract for an Invited Paper
for the DPP19 Meeting of
the American Physical Society

Observation of isotope separating and mixing states in isotope mixture plasmas in LHD

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Ion and electron density profiles are identical due to quasi-neutrality in single isotope plasmas. However, in mixed isotope plasmas, individual isotope density profiles can differ. Measurements of radial hydrogen (H) and deuterium (D) density profiles, using bulk charge exchange recombination spectroscopy, reveal two states of isotope particle transport in H-D in LHD plasmas[1]. One is isotope-separating (IS), where the source location impacts the density ratio profile and the other is isotope-mixing (IM) where the density ratio profile is flat regardless of the location of the H and D source. Gyrokinetic simulations predict an IM state in ITG turbulence regimes and an IS state in TEM regimes[2]. The IS state is observed in the low-density plasmas ($n_e \sim 1.5 \times 10^{19}\mathrm{m}^{-3}$, $dn_e/dr(0.8\rho) < 0$) where the beam fueling isotope species differ from the isotope species due to recycling. The H/(H+D) density profile is peaked for H beam fueling and D recycling wall conditions. A peaking of D/(H+D) density is observed for D beam fueling and H recycling wall conditions. When the wall recycling is equally mixed, (H/D $\sim$ 1), H/(H+D) dominates and D/(H+D) disappears. In contrast, the IM state is observed in higher density plasmas ($n_e \sim 3\times 10^{19}\mathrm{m}^{-3}$, dn_e/dr $(0.8\rho) > 0$) with shallow pellet injection. H and D pellets have been deposited at 0.9ρ in the plasmas with peaked H/(H+D) density profile. This results in the H/(H+D) profile becoming flat after the H and D pellets are injected, which clearly results in the IM state. These results demonstrate that either of two isotope states (IS or IM) can exist in mixed H and D plasmas depending on collisionality and density gradient and provides important insight into the control of isotope density ratio profiles needed for DT operations in tokamaks. [1] K. Ida, et. al., Nucl. Fusion 59 (2019) 056029. [2] C. Bourdelle et. al., Nucl. Fusion 58 (2018) 076028.